TRANSPARENCY · COMPETENCE · RELIABILITY

Company Profile 2026

Materials Testing · Non-Destructive Testing · Asset Integrity

53 Years of Independent Inspection.
India's Oldest Third-Party Inspection Company.

53
YEARS

16
INDUSTRY VERTICALS SERVED

PAN-INDIA OFFICES

Navi Mumbai · Vadodara · Bangalore
Bhubaneswar · Gorakhpur

TCR Engineering Services Pvt. Ltd.
Established 1973 · NABL ISO/IEC 17025:2017 · NADCAP AC7101
Q2 2026 · tcreng.com

Contents

1. Executive Summary

Materials testing, non-destructive testing, failure analysis, and asset integrity, delivered under one NABL-accredited signature and a fifty-three-year operating record.

53	16	7	9,000+	6,500+
YEARS INDEPENDENT	INDUSTRY VERTICALS	OPERATING COUNTRIES	FAILURE INVESTIGATIONS	CLIENTS WORLDWIDE

At TCR Engineering, we don't just test materials; we build the foundation of trust and excellence in industries worldwide. Headquartered in Mumbai, TCR is an ISO 17025 and NABL accredited laboratory serving over 6,500 clients across the globe. Since 1973, we have been a steadfast partner to businesses in India and beyond, with a presence stretching from Saudi Arabia to Malaysia, enabling companies to streamline plant operations, enhance safety, and drive performance.

For over half a century, TCR has been the reference point for reliability and transparency. When our clients need results, they know they'll get timely, unbiased insights that matter. From Mechanical and Civil Testing to NDT Services and Failure Analysis or in-depth asset integrity, every TCR report is backed by a legacy of expertise and innovation, created by a team that has spent decades mastering the art of precision. Our global reach means we can assemble expert teams quickly, tackling challenges wherever you are.

TCR's service is more than just data. It's a partnership for progress. We turn testing results into actionable insights that empower customers to anticipate challenges, performance, and confidently take the next steps forward. With us, you get clarity and confidence, infused with the promise of accuracy.

TCR Engineering's story is written in the successes of its clients, both local and global, who have seen real, measurable impact from our partnerships. We are more than just a testing lab; we're a trusted ally in developing strategies and solutions that drive true business value. From Fortune 500 companies to dynamic mid-sized firms and innovative small businesses, clients of every scale rely on TCR to fuel their growth and ensure quality at every turn. Our marquee clients are proof of our commitment, precision, and unwavering focus on results.

TCR is the name behind honesty, reliability, and transparent results. Our team is composed of highly experienced specialists, engineers, scientists, inspectors, and innovators whose combined expertise crosses industries and borders. With a global reach, we can deploy the right talent wherever it's needed, working with industries as diverse as Fertlizer, Oil & Gas, Petrochemicals, Defence, Infrastructure and Manufacturing. Whether it's unlocking material properties, boosting product performance, diagnosing failures, or exploring the frontier of material science, TCR's impact is as deep as it is wide.

Every project is delivered on time and to the highest standards, backed by a multi-disciplinary team certified to meet rigorous industry demands.

1.1 The Company at a Glance

TCR Engineering Services Pvt. Ltd. is India's oldest third-party materials testing, inspection and asset integrity company. The business was founded in Mumbai in 1973 by V.K. Bafna (1940 to 2013) and has been led by Neelam Bafna as Chairperson and Managing Director since 2013. Fifty+ years of continuous operation have produced an institutional record that few laboratories anywhere can match: more than 9,000 documented failure investigations, over 50,000 reformer tubes scanned cumulatively, 500+ bridges inspected across India, 2600+ kms of pipeline inspected, 700+ positive material identification campaigns, and 1,500+ Boiler Tube Failure investigations consolidated into the company's Knowledge-Based Audit practice. The group serves more than 6,500 clients globally. Operations run out of seven countries (India, Saudi Arabia, Oman, Kuwait, Qatar, Japan, and Malaysia), and samples are received from 15+ countries.

Three operating entities make up the group. TCR Engineering Services is the parent (Mumbai, India). TCR Arabia Company Limited is the joint venture with GAS Arabian Services in Dammam, Kingdom of Saudi Arabia. TCR Advanced Engineering is the asset integrity and engineering consulting arm in Vadodara, India. Evolve by TCR is the training academy in Vadodara.

1.2 What TCR Sells

The company is organised around six service pillars and one cross-cutting capability:

1. Materials Testing: Mechanical, chemical, corrosion and sour-service, metallurgical, fatigue and fracture toughness, creep and stress rupture, composites, coating evaluation, fastener and rebar coupler, RoHS compliance, oil ferrography, welder qualification, and Heat Treatment Verification Testing for the aerospace supply chain (NADCAP AC7101 Materials Testing accredited).

2. Non-Destructive Testing: Conventional methods (radiography, ultrasonic, magnetic particle, liquid penetrant, visual, positive material identification), advanced ultrasonic methods (PAUT, TOFD, LRUT, EMAT, HTHA, Hydrogen Induced Disbonding), heat exchanger and tube inspection (eddy current testing, remote field testing, internal rotating inspection system, near field testing), tank inspection (Magnetic Flux Leakage with the Silverwing FloormapVS2i), helium leak testing, thermography, post-weld heat treatment as a preserved standalone service, and pipeline radiography executed across more than 14,000 girth welds and 2600+ kilometres of cross-country mainline.

3. Asset Integrity and Engineering Consulting: AiOM (the indigenously developed Asset Integrity and Optimisation Management platform), Fitness for Service per API 579-1/ASME FFS-1 and BS 7910, Remaining Life Assessment, Risk-Based Inspection delivered as Knowledge-Based Audit, Engineering Critical Analysis per API 1104 Annex A, ARTiS Automated Reformer Tube Inspection, fire damage assessment, plant life extension, design review, cathodic protection turnkey under the CP Division, and root cause failure analysis.

4. Robotic and AI-Assisted Inspection: TCR-owned platforms include ARTiS for reformer tubes and the pipeline RT Crawler family. Partner-delivered platforms include the ITAS robotic tank inspection system, the MagRover wall-climbing robot, MicroRover, and OTIS. Submersible ROV, drones, and bridge-inspection robotics complete the surface area. The AGAAS layer is TCR's intelligent agent and automation architecture across compliance, LIMS triage, sales quotation, quality management, and radiography digitalisation.

5. Civil and Infrastructure Testing: Concrete, cement, aggregates, soil, bitumen, structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888, the 500+ bridge book of work, and high-strand testing for High Speed Rail. BMC Roads Department registration secured March 2026.

6. Inspection Manpower and Third-Party Services: Third-party inspection, turnaround manpower (24-hour deployment, 100 to 200 personnel during peak), source inspection, vendor audit, paint and coating inspection per AMPP/NACE and FROSIO, and API 510, 570, and 653 inspectors.

A seventh capability, Training and Published Authority, sits across the catalogue. Evolve by TCR delivers ASNT, PCN, API, and AMPP/NACE programmes from Vadodara. The TCR Arabia Training Centre runs the Dammam programme. The senior bench is published with ASM International (Haribhakti, Joshi, Kumar 2018; Haribhakti and Joshi 2021), with peer-style papers at NACE and at refinery and fertiliser industry forums, and across an active blog corpus that runs to roughly 400+ posts on tcreng.com and tcradvanced.com combined.

1.3 The Headline Credentials

Credential	Detail
NABL ISO/IEC `17025:2017`	Certificate NABLT0726MH18640 (in lieu of TC-6905), valid 03 March 2026 to 02 March 2030, 1,483 scope items at TCR Engineering, Mahape (parent lab). Separate certificate TC-15993, 409 scope items, valid 30 April 2025 to 29 April 2029 for TCR Eastern (Bhubaneswar).
ILAC MRA reciprocity	NABL is a signatory; reports are accepted across 90+ economies including A2LA (United States), UKAS (United Kingdom), DAkkS (Germany), Cofrac (France). NABL 133 Combined ILAC MRA Mark permission NABL/ILAC/11591, CAB ID T-0294.
BIS recognition	Reference LRMD/LRS/OSL-7103506. First BIS-accredited commercial laboratory in India for `IS 16172` rebar coupler testing across all diameters from 8 mm to 40 mm.
Indian Boiler Regulations	"Well-Known Material Testing Laboratory" since 2014. Board for Boiler Conservation Well-Known RLA Organisation. Central Boilers Board Form XVI-H certificate 38 (Serial MTL/15/019), issued 19 April 2024, valid to 02 April 2029.
AERB	Operation Licence 23-IRLOP-893925 and two Source Storage Facilities (Mumbai 22-ASSF-793303 valid 28 June 2027; Bhubaneswar 23-ASSF-927086 valid 30 August 2027).
Saudi Aramco	ANDT Contract 6601000141. Approved Radiographic Standard Procedure TCR.QCP.REV-02 conformant with SAEP-1143. SAER-13115 dated 8 September 2025 names TCR as technology provider for the Internal RT Crawler.
ONGC	QAD Sr. No. 01 since 1998 (longest-tenure approval in the company's history).

Credential	Detail
BHEL	Approved since 2003. NTPC Talcher TTPP-III 2 x 660 MW added December 2025.
PDIL	Certificate of Approval 4004008183/PBIS/24-25/5000077313 dated 28 June 2024, issued after assessment of the laboratory on 14 June 2024, covering ten test categories.
NADCAP	AC7101 Materials Testing accredited 2026 for TCR Engineering, Performance Review Institute certificate 29415245997, valid to 31 May 2027. TCR Advanced Engineering holds its own AC7101 accreditation, Performance Review Institute certificate 29227245998, also valid to 31 May 2027.
ISO management systems	ISO 45001:2018 (QRO certificate 3050260220154HS, valid to 19 February 2029).
BMC and CIDCO approval	The Brihanmumbai Municipal Corporation Roads Department registration (March 2026) and CIDCO eMTL Maharashtra empanelment open the civic-mandate gateway to the Maharashtra civil and structural-audit testing market, including the statutory building-audit stock under Section 353B of the Mumbai Municipal Corporation Act 1888.

1.4 The Headline Numbers

The record in numbers: 53 years of continuous operation. 9,000+ documented failure investigations, including 1,500+ Boiler Tube Failure investigations. 750+ Remaining Life Assessment studies. 350+ Fitness for Service engagements. 50,000+ reformer tubes scanned. 100,000+ in-situ microstructure replicas. 500+ bridges inspected. 700+ Positive Material Identification projects across the GCC. 6,500+ clients. 750+ employees across the group. Seven operating countries, with samples received from 15+ countries.

Metric	Value	Notes
Years of continuous operation	53	Since 1973
Operating countries	7	India, Saudi Arabia, Oman, Kuwait, Qatar, Japan, Malaysia. Served GCC markets also include the United Arab Emirates and Bahrain. Past and active project work in Nigeria, Mexico, Vietnam, Iraq, Nepal, and Jordan.
Sample-origin countries	15+	Samples shipped to TCR labs from 15+ countries (separate from operating presence)
Group employees	750+	750+ across the group: 400+ TCR Engineering, 200+ TCR Advanced, 150+ TCR Arabia
Clients served globally	6,500+	Updated July 2026
Failure investigations	9,000+	TCR Group cumulative. TCR Advanced subset ranges 1,800+ to 8,500+ depending on era.

Metric	Value	Notes
Boiler Tube Failure investigations	1,500+	KBA practice
Boiler RLA assignments	400+	Power vertical anchor
Reformer tubes scanned cumulatively	50,000+	ARTiS practice anchor
Bridges inspected	500+	Plus a separate BMC March 2026 robotic underwater programme covering 400+ bridges
PMI projects in KSA, Kuwait, UAE	700+	Field campaigns
RLA across all asset classes	750+	Group cumulative
Pipeline girth welds radiographed	14,000+	Within 2600+ km of cross-country pipeline radiography
Reformer tube ARTiS inspections	80+	International deployment includes Dangote, Emirates Steel, JIFCO
Structural audits completed	1,200+	India
NABL scope items	1,483	TCR Engineering certificate NABLT0726MH18640; 1,383 laboratory and 100 site tests
Replicated microstructure database	100,000+	The reference base for in-situ metallographic interpretation
In-situ metallographic field teams	12	Dedicated, group-wide
Creep frames operating to 1,100 °C	6	At 50 kN, with duration capability up to 100,000 hours

1.5 TCR In One Paragraph

TCR is a static equipment specialist with a 53-year operating record, a strong pipeline robotic crawler and civil testing services, a 9,000+ file failure-analysis library, a 100,000+ microstructure replica database, and a published-author bench at ASM International. The company holds the accreditations a regulated client needs (NABL with ILAC reciprocity, BIS, IBR, AERB, ISO 45001, NADCAP AC7101 accredited), the approvals a major operator needs (Saudi Aramco, ONGC, BHEL, IOCL, PDIL, Reliance, Larsen and Toubro, BMC, CIDCO), and the field bench an operating plant needs (12 in-situ metallographic replica teams, 6 creep frames running to 1,100 degrees Celsius, six-pillar AiOM digital backbone, ARTiS reformer tube inspection, the Aramco and IOCL-approved Internal RT Crawler, and twelve dedicated field crews). The company is woman-led, family-owned, multi-generational, and has no private-equity exit overhanging it.

2. About TCR Engineering Services

TCR Engineering Services Pvt. Ltd. was founded in 1973 in Bombay Central, Mumbai, by V.K. Bafna (1940 to 2013). V.K. Bafna was a gold medallist metallurgist, with an M.Eng from the University of Toronto and an M.S. in Industrial Management from Clarkson College. He set out to build the first independent materials testing laboratory.

2.1 The Founding

TCR Engineering Services Pvt. Ltd. was founded in 1973 in Bombay Central, Mumbai, by V.K. Bafna (1940 to 2013). V.K. Bafna was a gold medallist metallurgist, with an M.Eng from the University of Toronto and an M.S. in Industrial Management from Clarkson College. He set out to build the first independent commercial materials testing laboratory in India that worked the way an integrity engineer would expect a laboratory to work: NABL-grade discipline, full traceability, and the willingness to defend a result in front of a plant manager, an insurer, or a court.

The company has not stopped operating since. Fifty-three continuous years through three economic cycles, two regulatory regimes, and the full transition from film radiography and wet chemistry to phased-array ultrasound, optical-emission spectrometry, and the indigenously developed AiOM digital backbone. The headquarters moved from Bombay Central to a purpose-built facility in Mahape, Navi Mumbai. The lab footprint expanded into a second NABL-accredited site in Bhubaneswar (TCR Eastern, Certificate TC-15993) and into specialist group companies in Vadodara (TCR Advanced) and Dammam (TCR Arabia). The brand identity, TRANSPARENCY · COMPETENCE · RELIABILITY, came out of that founding period and has held since.

2.2 The Leadership Transition

V.K. Bafna passed away in 2013. Neelam Bafna, his co-founder and partner from the original 1973 build, took over as Chairperson and Managing Director. The transition was clean. There was no private-equity recapitalisation, no break-up of the operating entities, and no sale of the institutional database. The company has been woman-led since 2013, which still places it in a small minority of independent testing and inspection companies anywhere.

Rohit Bafna is President. His remit is strategic, operational, digital, and compliance leadership: AI and digital transformation (the AGAAS agent layer, the AiOM platform, the public-facing brand and website), human-resource policy, and investment strategy. The Board includes Viren Khandwala as Director.

The TCR Advanced board is led by Paresh Haribhakti as Managing Director, with Neelam Bafna, Rohit Bafna, Viren Khandwala, Alpana Haribhakti, and Aashana Haribhakti Gupta as Directors.

The TCR Arabia board is chaired by Khalid A. Al-Dabal, with Khalid J. Al-Dabal as Managing Director and Rohit Bafna, Paresh Haribhakti, and Viren Khandwala as Directors. Syed Ameen Hassan leads in-Kingdom operations as Country Manager (KSA).

2.3 The Group at a Glance

The group is organised across three operating entities, one training subsidiary, and one strategic equity investment. There are no banking partners, no private-equity holders, and no external balance-sheet leverage relevant to this profile. The shareholding is closed-loop family and operating-partner ownership.

Entity	Ownership	HQ	Role	Accreditations
TCR Engineering Services Pvt. Ltd.	Parent (100%)	Mahape, Navi Mumbai	Materials testing, NDT, civil testing, pipeline radiography, third-party inspection; all India operations and the lead lab for the group. Branch labs in Bhubaneswar and Gorakhpur. Pan India presence for cross country radiography projects.	NABL ISO/IEC 17025:2017, certificate NABLT0726MH18640 (in lieu of TC-6905), 1,483 scope items, valid to 02 March 2030. NADCAP AC7101 Materials Testing, Performance Review Institute certificate 29415245997, valid to 31 May 2027. BIS LRMD/LRS/OSL-7103506. IBR Well-Known Material Testing Laboratory, Form XVI-H certificate 38, valid to 02 April 2029. AERB Operation Licence 23-IRLOP-893925. ILAC MRA Mark permission NABL/ILAC/11591 (NABL 133), CAB ID T-0294. ISO 45001:2018 (QRO certificate 3050260220154HS, valid to 19 February 2029).

Entity	Ownership	HQ	Role	Accreditations
TCR Arabia Company Limited	60% TCR / 40% GAS Arabian Services (Tadawul: 4146)	King Abdulaziz Seaport Facility, Dammam, KSA	Materials testing (mechanical and civil labs), NDT, asset integrity, heat treatment (PWHT, oil firing), welder qualification per ASME and ANSI and AWS and API, calibration, plant shutdown manpower, paint and coating inspection per AMPP/NACE and BGas, and technical training; offices in Dammam, Jubail, Yanbu	IAS ISO/IEC 17025:2017 accredited testing laboratory TL-783, to IAS criteria AC89. Scope of 24 test methods across mechanical testing and metallurgy. Mechanical: tensile, bend, impact, Vickers, Rockwell and Brinell hardness, flattening, nick break, and proof load to API 1104, ASME BPVC Section IX, ASTM A370, ASTM E8, ASTM E23, ASTM E92, ASTM E18, ASTM E10, and ISO 898-1. Metallurgy: intergranular corrosion to ASTM A262 and macro examination to ASTM A751, ASTM A923, ASTM E340, ASTM E562, ASTM G28, and ASTM G48. Saudi Aramco and SABIC approved since 2007.

Entity	Ownership	HQ	Role	Accreditations
TCR Advanced Engineering Pvt. Ltd.	50% TCR / 50% Haribhakti family	Makarpura GIDC, Vadodara	Asset integrity and engineering consulting: FFS per `API 579-1/ASME` FFS-1, Remaining Life Assessment, Engineering Critical Analysis per `API 1104` Annex A and `BS 7910`, Risk-Based Inspection delivered as Knowledge-Based Audit, advanced NDT, ARTiS reformer tube inspection, AiOM platform development, contract R&D, and failure analysis NABL ISO/IEC 17025:2017 under certificate TC-6739, 431 scope items, valid 14 October 2025 to 13 October 2029. NADCAP AC7101 Materials Testing accredited, Performance Review Institute certificate 29227245998, valid to 31 May 2027.	NABL ISO/IEC 17025:2017, certificate TC-6739, 431 scope items, valid 14 October 2025 to 13 October 2029. NADCAP AC7101 Materials Testing, Performance Review Institute certificate 29227245998, valid to 31 May 2027.
Evolve by TCR	TCR Advanced subsidiary	Vasna Road, Vadodara	Training academy: ASNT, PCN, API, AMPP/NACE programmes; metallurgy, NDT, welding technology, asset integrity optimisation, plant reliability; established 2017; clients include Tata Power, GACL, Reliance, UltraTech Cement	Not an accredited testing laboratory. Programmes delivered to ASNT, PCN, API, and AMPP/NACE syllabi.

A working alliance with a partner company carries the OTIS in-service robotic tank inspection platform (above-ground tank floor scanning per API 653 with 8-transducer ultrasonic). A separate alliance with Planys carries the underwater robotic inspection ROV for water storage tanks, sub-water bridge piers, intakes, outfalls, sumps, and reservoirs (HD camera, SONAR silt assessment, ultrasonic probe with gimbal 3 to 250 mm range). 3D laser scanning is delivered through a separate external partner and framed as a partner-delivered capability rather than an in-house owned asset.

The April 2026 Chugai Technos Hiroshima MOU signed 29 April 2026 sets a three-party (India, Japan, KSA) collaboration, with a joint trade-show appearance scheduled in Japan in September 2026.

2.4 TCR Engineering, the Parent

Parameter	Detail
Founded	1973
Headquarters	35 Pragati Industrial Estate, N.M. Joshi Marg, Lower Parel, Mumbai 400011 (registered office); operating laboratory at Mahape, Navi Mumbai
MSME registration	Udyam, Small Enterprise category
NABL accreditation (parent)	Certificate NABLT0726MH18640 (in lieu of TC-6905), valid 03 March 2026 to 02 March 2030; 1,483 scope items; ISO/IEC 17025:2017
NABL accreditation (eastern lab)	Certificate TC-15993 (TCR Eastern, Bhubaneswar), 409 scope items, valid 30 April 2025 to 29 April 2029
BIS recognition	Reference LRMD/LRS/OSL-7103506; first BIS-accredited commercial lab in India for IS 16172 rebar coupler testing across all diameters
IBR recognition	"Well-Known Material Testing Laboratory" since 2014; CBB Well-Known RLA Organisation under Indian Boiler Regulations; Form XVI-H certificate 38 (Serial MTL/15/019), issued 19 April 2024, valid to 02 April 2029
AERB	Operation Licence 23-IRLOP-893925; two AERB-approved Source Storage Facilities at Mumbai (22-ASSF-793303, valid 28 June 2027) and Bhubaneswar (23-ASSF-927086, valid 30 August 2027)
BMC and CIDCO	BMC Approval and BMC Roads Department registration - March 2026 (ChE/Rds/8292/NF dated 25 March 2026, valid until 02 June 2026, extendable to 24 March 2028). CIDCO approved.
ISO management systems	`ISO 45001:2018 (QRO certificate 3050260220154HS, valid to 19 February 2029)`
NADCAP	AC7101 Materials Testing accredited 2026; Performance Review Institute certificate 29415245997, valid to 31 May 2027
Branches	Navi Mumbai (parent lab and HQ), Bhubaneswar (TCR Eastern), Bangalore Operations (under Anil K. Lund), CP Division practice running out of Vadodara with a regional office in Bhubaneswar; CP services are offered pan-India
President	Rohit Bafna
Senior bench leads	Avinash Tambewagh (Technical Head); Manoj Singh (Department Head, Corrosion Testing, May 2026 Rohit-confirmed canonical title); Parul Hariya (Department Head, Civil Testing); Shaila Kadam (Head, Chemical Analysis Testing); Shailendra Singh (Head, NDT and Third-Party Inspection); Dr. Ajay Essampally (Sr. Metallurgist and Head of Quality Assurance); Anil K. Lund (AI and Digitalisation Head); Atul Yadav (HR Manager); Hemant Sakpal (Business Development Manager); Ashwant Singh (AGM, Project Management); Chiral Patel (CP Division Lead, 20+ years cathodic protection); Lalit Surve (General Manager, Operations and Finance)

2.5 TCR Arabia, the KSA Joint Venture

TCR Arabia was established 2007 and has eighteen years of in-Kingdom operating record. The joint venture pairs TCR Engineering's technical depth with GAS Arabian Services's local market access, regulatory presence, and Saudisation track record. GAS Arabian Services is publicly listed on Tadawul (4146).

Parameter	Detail
Established	2007
Ownership	60% TCR Engineering, 40% GAS Arabian Services
Headquarters	P.O. Box 32211, King Abdulaziz Seaport Facility, Dammam, Kingdom of Saudi Arabia
Branches	Dammam, Jubail, Yanbu
Chairman	Khalid A. Al-Dabal (GAS Arabian Services representative)
Managing Director	Khalid J. Al-Dabal
Country Manager (KSA)	Syed Ameen Hassan (B.Com, MBA Chifley Australia)
Senior bench	Abdul Waheed (NDT Manager, ASNT Level III); Syed Ahsan Ali (Metallurgist, BE Materials Engineering, `API 510/653/571/580` certified)
Strategic affiliations	SAGIA approved; ASNT Corporate Partner
KSA scale	150+ professionals; registered with 40+ major KSA companies
Flagship credentials	Saudi Aramco ANDT Contract 6601000141; approved Radiographic Standard Procedure TCR.QCP.REV-02 conformant with SAEP-1143; SAER-13115 dated 8 September 2025 names TCR as technology provider for the Internal RT Crawler with documented $4,980,000 cost avoidance over five years; Aramco Vendor 10040677; SABIC Vendor 505239 and Global Contract 4900001302; Saudi Electricity Company 5002205/62006; MAADEN 10118; TASNEE 101972; SIPCHEM 102111; SATORP 10175; SWCC 2522; SADARA 1000001784; YASREF 100657; Petro Rabigh 100764; Advanced Petrochemical 100561; LUBEREF 0000062147; MARAFIQ 3645

2.6 TCR Advanced Engineering, the Consulting Arm

TCR Advanced is the asset integrity, engineering consulting, and contract R&D division of the group. The arm carries the higher-end consulting work: Fitness for Service per API 579-1/ASME FFS-1, Remaining Life Assessment, Risk-Based Inspection delivered as the Knowledge-Based Audit (KBA), Engineering Critical Analysis per API 1104 Annex A and BS 7910, the AiOM platform stack (Asset Integrity and Optimisation Management, six-pillar architecture including the AiOM-CCP cross-country pipelines application), reformer tube inspection through the ARTiS robotic crawler, structural audit, fire damage assessment, plant life extension, and root-cause failure analysis.

Parameter	Detail
Focus	Asset integrity, FFS, RLA, RBI as KBA, ECA, ARTiS, AiOM, contract R&D, failure analysis
Headquarters	250-252/9, GIDC Estate, Makarpura, Vadodara, Gujarat 390010
Managing Director	Paresh Haribhakti (co-author, ASM International book on Boiler Tube Failures 2018; co-author, ASM Handbook Volume 11A chapter on Failure of Boilers and Related Equipment 2021)
Directors	Neelam Bafna, Rohit Bafna, Viren Khandwala, Alpana Haribhakti, Aashana Haribhakti Gupta
Senior bench	Ketankumar Upadhyaya (Sr. General Manager, Reliability Engineering, 35+ years); Gopul Patel (General Manager, AiOM software development lead, `API 580` Cert.); Sohel Vaidya (DGM Business Development); Pooja Mehta (Sr. Manager, Failure Investigation); Nikhil Sabhaya (Technical Manager, NDT and RLA; ASNT Level III in ET, UT, PT, MT; `API 510`; CSWIP 3.1); Chiral Patel (Head, Cathodic Protection and Pipeline Integrity BD; Refinery, Petrochemical, Pipeline; 20+ years CP); Kamlesh Rana; MY Joshi (Reliability Advisor, 38+ years GNFC)
Track record	9,000+ failure investigations; 750+ Remaining Life Assessment studies; 350+ FFS engagements; 250,000+ metallographic records; 600,000+ samples tested; 18 videoscopy units in continuous rotation

2.7 Evolve by TCR, the Training Academy

Evolve by TCR was established in 2017 as a revenue-generating training vertical, not a corporate-social-responsibility initiative. Course attendees pay course fees against published catalogues. Programmes cover ASNT and PCN NDT certification (Level I, II, III), API inspector certification (510, 570, 653, 580), AMPP/NACE coating inspector programmes, welding inspection (CSWIP, AWS), and operator-side reliability and asset integrity courses. Clients include Tata Power, Gujarat Alkalies and Chemicals Ltd. (GACL), Reliance, and UltraTech Cement.

Parameter	Detail
Established	2017

Parameter	Detail
Location	215, Pancham Icon, Vasna Road, Vadodara, Gujarat 390007
Vice President	Deepak Chandarana
Programmes	ASNT NDT Level I, II, III; PCN; `API 510`, 570, 653, 580; AMPP/NACE coating inspector; CSWIP, AWS welding inspection; metallurgy (5 levels); corrosion studies (3 levels); engineering consulting (FFS, `API 571`, RBI, RCA); NDT all methods (RT, UT, MT, PT, VT, ET, PAUT, TOFD); welding (GTAW, SMAW); plant operational, inspection, reliability, safety training
Web	www.evolvetcr.com

The TCR Arabia Training Centre runs the parallel Dammam programme.

2.8 The Operating Footprint

The group undertakes services in seven countries: India, Saudi Arabia, Oman, Kuwait, Qatar, Japan and Malaysia. In the past the company has got projects in Nigeria (Indorama Eleme long-term contract; Dangote Fertilizers; Notore Chemical Industries Plc), Iraq (PetroChina International Iraq FZE; Iraqi Ministry of Oil approval since May 2019; Baiji Refinery restart engagement), Vietnam (Binh Son Refining), Mexico (Pemex), Nepal (cross-border radiography for the Motihari to Amlekhgunj International Pipeline via Likhitha Infrastructure under Nepal Oil Corporation permission Ref 2080/81 dated 30 July 2023), and Jordan (JIFCO).

2.9 Clients and Partners

The client base runs from the Indian industrial heartland to the Gulf and beyond, and the delivery network is extended by a set of named technical and market partners.

Pan-India Clients	International Clients

Pan-India Clients	International Clients
Reliance Industries	**Saudi Aramco**
Indian Oil Corporation	**SABIC**
Bharat Petroleum	**MAADEN**
Hindustan Petroleum	**TASNEE**
ONGC	**Petro Rabigh**
Larsen and Toubro	**SATORP**
Tata Steel	**SWCC**
NTPC	**Royal Commission for Jubail and Yanbu**
Bharat Heavy Electricals	**Luberef**
GE Power India	**SIPCHEM**
JSW	**QAFCO**
Bharat Forge	**Q-Chem**
ArcelorMittal Nippon Steel India	**Kuwait Oil Company**
Maharashtra Seamless	**KNPC**
Rashtriya Chemicals and Fertilizers	**Equate**
Chambal Fertilisers	**GPIC (Bahrain)**
MTAR Technologies	**British Gas**
Vikram Sarabhai Space Centre	**Chevron**
Hindustan Aeronautics	**GE**
Mazagon Dock Shipbuilders	**Siemens**
Afcons Infrastructure	
Hindustan Construction Company	
Kalpataru Projects International	
Corrtech International	
RITES	
Godrej and Boyce	
Sulzer Pumps	
Dextra India	

The delivery network is extended by four named alliances.

Chugai Technos Corporation (Japan). The Hiroshima-headquartered technical services group is TCR's Japan alliance partner, bringing the Chugai scale checker capability for boiler tube oxide scale measurement into the group's power practice (Section 7.9) and opening the Japanese client base to TCR's laboratory depth (Section 13.9).

Approved Group International (Malaysia). Founded in 2001 and headquartered near Kuala Lumpur, AGI brings together forensic scientists, engineers, and restoration specialists across forensic investigation (forensic engineering, fire and explosion forensics, vehicle accident investigation), damage assessment, disaster restoration, and business continuity management, operating in more than 22 countries and serving the loss adjuster, insurer, reinsurer, broker, and legal ecosystem. The alliance pairs AGI's Southeast Asian forensic and restoration reach with TCR's laboratory-backed failure analysis and insurance referee practice (Section 11o), and gives both firms a joint response capability on major industrial losses across South and Southeast Asia (Section 20.10).

BIEWU International Trading W.L.L. (Qatar). TCR's market representative for Qatar, operating as TCR Qatar. Founded in 2007 and headquartered in Doha, BIEWU is a multidisciplinary engineering solutions provider in asset integrity, corrosion protection, and industrial safety, with over 100 engineering and sales professionals serving oil and gas, power, and infrastructure clients across Qatar and the UAE. The alliance carries TCR's testing, inspection, and asset integrity services into the Qatari market under local representation (Section 20.6).

Planys Technologies (India). The submersible robotics partner behind the underwater remotely operated vehicle inspection capability (Section 7.6).

2.10 The Shape of the Group

The group is a static-equipment-specialist business: storage tanks, heat exchangers, pressure vessels, piping, reformers, boilers, columns, reactors. The lab arm in India produces the test data. The KSA arm carries that capability into the Aramco, SABIC, and Saudi Electricity Company orbit. The Vadodara arm carries it up the value chain into engineering consulting, Fitness for Service, and life-extension work. The training arm replicates the senior-bench discipline through the next generation of inspectors.

There is no rotating-equipment field-service overlay, and no aerospace heat-treatment process accreditation (TCR is the verification testing partner under NADCAP AC7101, not the heat treater). The shape of the group exists to keep the work technical, defensible, and high-value, and the ownership structure is built to preserve that.

3. Advantage TCR

A client can choose any number of testing-and-inspection vendors. What is being chosen, when TCR is chosen, is a company with a 53-year operating record, a 9,000+ file failure-analysis library, a 100,000+ microstructure replica database, and a published-author bench at ASM International.

DOCUMENTED COST AVOIDANCE

Saudi Aramco approved TCR's in-house Internal RT Crawler for in-service pipeline radiography. A single deployment returned USD 4.98 million in documented cost avoidance against conventional scaffold-and-shutdown methods.

At TCR, we work with clients large and small, from Fortune 500 giants to small and medium-sized enterprises, with a commitment to quality that never wavers. We've earned accolades like NACE International's "Excellent Laboratory in the Private Sector" and a reputation as one of India's fastest-growing, most innovative companies, successes made possible by a legacy of ethics and excellence laid down by our founder, V.K. Bafna, a visionary metallurgist who shaped TCR's core values of precision, transparency, and integrity.

Today, TCR is a thought leader and pioneer in material testing, serving clients across the globe with the same respect and dedication that we bring to every interaction. From the first engagement to project completion, TCR is about helping businesses to grow, building relationships on mutual respect, and setting the standard for integrity in the industry. Discover the difference that over five decades of innovation, trust, and results can make with TCR Engineering.

At TCR, we believe success means helping clients to grow. For us, a report isn't just data on a page, it's a roadmap to insights, foresight, and solutions that maximise performance and sharpen strategic decision-making. Every TCR service is grounded in responsiveness, built on reliability and transparency, and rewarded by the repeat trust of our clients.

COLLABORATION: Collaboration is at the heart of everything we do. At TCR, we're not just service providers, we're partners. We align with our clients to build long-lasting partnerships, facing challenges head-on and delivering real, sustainable solutions that help our clients grow and thrive

HIGHLY COMPETENT TEAMS: People are our foundation. TCR invests deeply in talent, identifying, developing, and nurturing skills to build a team that's as dedicated to client needs as we are. This approach lets us field expert teams whose skill and insight make a genuine impact, no matter the challenge.

DEEP SECTORIAL EXPERTISE: With over five decades in materials testing, NDT inspection and quality assurance for plants, TCR brings extensive industry knowledge and unwavering commitment to ISO 17025 standards. Our technical experts have completed over 6000 failure analysis projects, making us the trusted partner for global leaders like SABIC, Tasnee, Schlumberger, and Reliance. Equipped with advanced tools like Automated Robots, RT Crawlers, Civil Lab, Scanning Electron Microscopy and Optical Inverted Metallurgical Microscopes, our team sets the benchmark for quality and precision.

DIVERSIFIED PROBLEM SOLVING: We help clients tackle complex business issues through every stage of their project lifecycle, from assessment and research to testing, advisory services, solution design, deployment, and ongoing support. Our technical solutions don't just solve problems, they drive real business value.

Our approach is rooted in deep domain expertise, delivering insights that clients can act on. We assess, plan, and implement solutions tailored to each client's industry, helping streamline processes, accelerate delivery, and lower costs. Our solutions validate product quality, support innovation, and provide a competitive edge for clients worldwide, helping them bring the right products to market, at the right time, and at the right cost.

THE ARCHIVE

9,000-plus failure investigations, **1,500-plus boiler-tube failures**, and a **100,000-plus microstructure replica database**. A 53-year evidence base no competitor can replicate.

3.1 The Argument in One Page

A client can choose any number of testing-and-inspection vendors. What is being chosen, when TCR is chosen, is a company with a 53-year operating record, a 9,000+ file failure-analysis library, a 100,000+ microstructure replica database, and a published-author bench at ASM International. None of those four assets can be bought. The first takes time, the second takes a discipline of writing the work down, the third takes physical sample retention and database hygiene over decades, and the fourth takes peer review by an international engineering body. Together, they form the moat. Every other capability in this section is a tool that sits on top of that moat.

The structural advantages divide into ten heads.

3.2 The Trusted Relationship Model

TCR stays with a plant owner across the full life of an asset, not only at the moment a sample reaches the bench. The relationship starts before the equipment is bought and runs for as long as the plant runs. This is the company's single largest advantage. A plant owner who engages TCR at any one stage gains a partner for the whole journey of the plant, because the same laboratory carries the asset forward from one stage to the next. The work is organised in five stages, a model TCR has built and refined over five decades of plant inspection rather than borrowed from an industry template.

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

Stage one, sourcing and procurement. Factory audits, OEM qualification, raw-material inspection, sample picking, in-production checks, and loading supervision, supported by materials testing including mechanical, fatigue, chemical, and corrosion testing on procurement samples.

Stage two, construction and commissioning. Baseline NDT, phased-array and time-of-flight diffraction, radiography with robotic crawlers, welder certification, weldability and consumable evaluation, post-weld heat treatment, positive material identification, and the baseline data set that every later inspection is measured against.

Stage three, in-service. Online advanced NDT for high-temperature hydrogen attack, carburisation, hydrogen-induced cracking, high-temperature corrosion mapping, and mid-wall fissuring, with thermography, robotic tools, remote visual inspection, and risk-based inspection planning per API RP 580.

Stage four, shutdown and turnaround. Pipeline and weld inspection, tube and heat-exchanger inspection, in-situ metallographic replica, tank inspection including in-service robotic crawling, boiler condition assessment, robotic reformer tube inspection, and turnaround inspection manpower.

Stage five, continuum. The forward-looking stage: failure analysis per API 585, remaining-life assessment, fitness-for-service per API 579-1/ASME FFS-1, fire-damage assessment, integrity operating windows per API RP 584, engineering design and analysis, and the contract research that feeds the next procurement cycle.

The value is in the joins between the stages. A replica taken at a turnaround, a baseline set at commissioning, and a failure file from an earlier outage all sit in one 53-year database under one signature. A plant owner does not brief a new vendor at each stage, because the same laboratory already holds the asset's history.

3.3 Institutional Depth

Fifty-three years of continuous operation, founded in 1973. The company has carried a single legal identity through three economic cycles, the entire transition from film radiography and wet chemistry to phased-array ultrasound and indigenously developed digital integrity software, and the demographic shift in the Indian industrial client base from public-sector dominance to a balanced public-private mix. The institutional record sits in numbers a competitor would need decades to replicate:

- 9,000+ failure investigations documented in the technical database.
- 1,500+ Boiler Tube Failure investigations consolidated into the Knowledge-Based Audit practice.
- 750+ Remaining Life Assessment studies across pressure parts, heat exchangers, columns, reactors, reformers, and tanks.
- 350+ Fitness for Service engagements per API 579-1/ASME FFS-1 and BS 7910, segmented across refining, fertilisers, petrochemical KSA, chemicals, steel, power, and infrastructure
- 50,000+ reformer tubes scanned cumulatively under the ARTiS practice.
- 500+ bridges inspected across India (separate from the BMC March 2026 robotic-underwater 400+ programme).
- 700+ positive material identification campaigns across KSA, Kuwait, and the UAE.
- 84+ cross-country pipeline sites in India.
- 14,000+ pipeline girth welds radiographed across 2600+ kilometres of cross-country mainline; 9,266 weld joints digitally scanned with cloud archival on a single project.

3.4 Approvals as a Moat

TCR Engineering Services is a Bureau of Indian Standards and NABL accredited laboratory. The NABL certification is issued by the National Accreditation Board for Testing and Calibration Laboratories, Department of Science and Technology, Government of India. NABL provides accreditation to laboratories that perform tests/calibrations in accordance with ISO 17025. ISO/IEC 17025 includes quality system requirements of ISO 9001 and other additional requirements to demonstrate that the said laboratory is technically competent with the ability to produce technically valid data and results.

For over five decades, TCR Engineering Services has set the benchmark for testing excellence in India, securing NABL and Bureau of Indian Standards accreditations, distinctions only granted to laboratories meeting the rigorous requirements of ISO 17025. Accredited by NABL, the National Accreditation Board for Testing and Calibration Laboratories under India's Department of Science and Technology, TCR demonstrates not only its technical competence but a dedication to delivering accurate, valid data and results, time after time.

What does this mean for our clients? TCR is one of a select group of labs recognised by titans of industry like RIL, NPCIL, Bharat Forge, Bharat Heavy Electrical Ltd., Mumbai Metro, High Speed Rail, Indian Oil, Gail, Mecon, L&T, ONGC, and BARC, among others. Our name appears on approved lists of industry giants across sectors, from energy and power to fertilizer and infrastructure, trusted by the Department of Defense, Indian Railways, and even Mumbai Municipal Corporation.

Our credentials extend beyond borders, with approvals from Halliburton, Schlumberger, NOV, Wartsila, Bureau Veritas, Lloyd's Register of Shipping, and the American Bureau of Shipping. This international trust positions TCR as India's gateway for reliable, internationally recognised material testing services.

Our ISO 17025 accreditation spans mechanical, Civil, NDT, PMI, RoHS, and chemical analysis, ensuring every specimen is expertly handled, precisely machined, and rigorously inspected. This quality commitment is anchored by our dedicated Quality Assurance Department, which conducts frequent audits to uphold TCR's exacting standards, giving clients confidence in every result.

Since 2014, we've held the title of a "Well-Known Material Testing Laboratory" by the Central Boilers Board, allowing us to assess and certify boiler components under Indian Boiler Regulations. This endorsement means TCR's assessment is the standard for reliability and safety, even for life-critical components.

At TCR Engineering Services, our name on a report or a certification is more than just an endorsement, it's a promise of quality, reliability, and technical excellence in every test and every result.

Saudi Aramco approval takes 18 to 24 months for a new supplier. TCR has held that approval for over a decade through TCR Arabia and now sits inside the Aramco vendor universe with documented technology-provider status: Engineering Report SAER-13115 dated 8 September 2025 names TCR as the technology provider for the Internal RT Crawler. Aramco ANDT Contract 6601000141.

The wider client-approvals universe runs to 57 unique active or historical credentials from 16 countries of issuance, organised under a four-tier framework (Statutory, Owner, Engineering Procurement Construction, Original Equipment Manufacturer). Anchor flags include:

• **Statutory**. PDIL Empanelment (Certificate of Approval 4004008183/PBIS/24-25/5000077313); IBR Well-Known Material Testing Laboratory since 2014; AERB Operation Licence 23-IRLOP-893925; BIS first-in-India IS 16172 rebar coupler accreditation.

• **Owner, longest-tenure.** ONGC QAD Sr. No. 01 since 1998 (the longest single-customer approval in the company's history); BHEL Bhopal since 2003; Saudi Aramco for over a decade; Indian Oil Corporation; Reliance Industries; Larsen and Toubro; SABIC; PDO; OQGN; QAFCO (15-year metallurgical rate contract).

• **EPC**. Engineers India Limited (EIL) 12-year approval pack covering BPCL Kochi, OPaL Dahej, NRL Bhubaneswar, GAIL MNJPL, NRL Brahmaputra River Crossing, ADPL HDD Odisha Rivers, KGPL; Toyo Engineering and Technip dual approval; NHSRCL VMAC under MEIL-HCC, Afcons, and Larsen and Toubro for the Mumbai-Ahmedabad High Speed Rail.

• **OEM and licensor.** Casale SA SX3000 Vendor Code 1000007973 (June 2025, urea and melamine licensor); Cameron International FAQ since 2012; NOV Inc. (March 2023); GE International 3-year contract (December 2012); SABIC Global Contract 4600006798 (10 July 2012 to 9 July 2017); BHEL approval refresh for NTPC Talcher TTPP-III 2 x 660 MW (December 2025) via Power Mech Projects.

A competitor starting today would need five to seven years of uninterrupted execution to reach parity on owner-side approvals alone, and longer still on the licensor and OEM credentials.

The longevity also surfaces in the form of multi-year retainer relationships. HMEL Bathinda Rate Contract 9830004894 is a 3-year Failure Investigation retainer (06 June 2025 to 06 June 2028) across the full Bathinda Refinery and Petrochemical complex. QAFCO Qatar runs on a 15-year metallurgical rate contract. Indorama Eleme Petrochemicals Nigeria is on a long-term rate contract. The ONGC original empanelment letter is MRBC/QAD/LAB/97-98/779 dated 25 February 1998. Twenty-eight years and counting.

3.5 The Microstructure Database

Every in-situ metallographic replica that has gone through the TCR Advanced and TCR Engineering benches over the last three decades has been physically retained and image-archived. The reference base now stands at 100,000+ replicated microstructures (250,000+ metallographic records when the broader chemical and mechanical lab archive is included). The base supports two specific commercial outcomes:

1. Same-day interpretation at the field site. When a creep cavitation study comes off a reformer tube at a fertiliser or refinery turnaround, the replica is read against a calibrated reference structure rather than against textbook plates. That delivers a same-day actionable answer to the plant team, which in turn protects the turnaround critical path.

2. Forensic continuity over years. When a refinery calls about a failed reformer tube, the conversation begins with the engineer who worked the previous inspection at the same facility. That institutional memory compounds. Clients return.

The database sits behind the Knowledge-Based Audit practice, the Boiler RLA service, and the ARTiS reformer tube assessment, and feeds the AiOM damage-mechanism library (which now covers approximately 70 mechanisms aligned to API RP 571, WRC 489, WRC 488, WRC 490, and the ASM Handbook).

3.6 Twelve Dedicated In-Situ Replica Field Teams

Field-replica capability is operator-side. A single team is a calling card; twelve teams is an industrial capability. TCR Group fields twelve dedicated in-situ metallographic replica teams, with the calibrated portable kit (replica tape per ASTM E1351, etching reagents, micro-hardness, deposit lifting, and image capture), trained-up replica technicians and reading metallurgists, and the cloud-archival workflow back to the master database. Reference engagement: Reliance Industries Jamnagar fielded 1,200 in-situ replicas in 15 days during a turnaround window.

3.7 Published Authority

TCR's senior bench is published. The two ASM International titles are the public anchor of that authority and the only source to which the 140+ countries distribution claim attaches:

• Haribhakti, Joshi, Kumar (2018), Failure Investigation of Boiler Tubes: A Comprehensive Approach, ASM International, ISBN 978-1-62708-156-6, approximately 500 pages.

• Haribhakti and Joshi (2021), chapter "Failure of Boilers and Related Equipment", in Miller, Shipley, Parrington, Dennies, eds., ASM Handbook, Volume 11A: Analysis and Prevention of Component and Equipment Failures, ASM International, DOI 10.31399/asm.hb.v11A.a0006825, in an 840-page volume.

Three peer-style technical papers extend the authorship priority of the TCR Advanced bench: NACE Paper No. 09012 by Paresh U. Haribhakti for TCR Arabia (2009 to 2010); the ARTiS reformer tubes paper by Upadhyaya, Haribhakti, Patel, and Bafna (2013 to 2014); and the high-temperature RLA paper by Haribhakti, Upadhyaya, Patel, Baad, and Bafna (2014).

The 2026 AiOM White Paper, four foundational TCR white papers (Need for Failure Analysis in India and the Middle East, July 2004; Failure and Root Cause Analysis, July 2004; Outsourcing Laboratory Practices by V.K. Bafna, June 2006; An Introduction to Ferrography by Paresh Haribhakti, March 2010), and an active senior-bench blog corpus (Avinash Tambewagh, Manoj Singh, Parul Hariya, Shaila Kadam, Shailendra Singh, Anil K. Lund, Atul Yadav, Hemant Sakpal, Ketankumar Upadhyaya, Gopul Patel, Kamlesh Rana, Pooja Mehta, J.N. Agrawal, across roughly 400+ posts on tcreng.com and tcradvanced.com combined) round out the publication footprint.

The blog corpus does not count toward the formal Published Authority claim.

3.8 The Robotic Inspection Stack

TCR runs a working robotic-inspection stack across two ownership categories.

TCR-owned. ARTiS (Automated Reformer Tube Inspection System with built-in FFS reporting; named purchase orders include Dangote Fertilizers Nigeria, Emirates Steel Industries DRP1 and DRP2 Abu Dhabi, JIFCO Jordan, and Indian fertiliser engagements). Pipeline RT Crawler fleet, including the Saudi Aramco-approved Internal RT Crawler that holds the SAER-13115 citation.

Partner-delivered through Petrobot and Plansys. ITAS Rover (in-service tank inspection, deployed at 29+ tanks); MagRover (wall-climbing magnetic adhesion robot, deployed at 240+ assets); MicroRover (boiler tubes); OTIS (in-service robotic tank inspection per API 653, 8-transducer ultrasonic scanning of tank floors without emptying). Submersible ROV for underwater bridge and intake inspection. Drone inspection (stacks, flares, tanks; HD and thermal). The robotic tank inspection rover is ATEX/PESO-certified and works on tanks up to 25 m height and 100 m diameter, delivering approximately 50 percent cost reduction and 10x speed against scaffolding-based methods.

3D laser scanning is delivered through an external partner.

The line is held everywhere: ownership is stated accurately, partner-delivered capability is stated accurately, and the client is never left with an inflated impression.

3.9 Specialised Methods at Scale

Three specialised method-clusters separate TCR from the average materials testing lab.

Sour-service corrosion testing. NACE TM0177 Methods A, B, C, D; NACE TM0284 HIC with Solution A and Solution B; SOHIC; NACE MR0175/ISO 15156; NACE TM0103. Numerous Shell projects executed. PDO and OQGN approved. The lab holds the NACE Excellent Laboratory in the Private Sector award. The capability extends into the CTOD with H2S hydrogen pre-charging workflow developed for Larsen and Toubro: 96-hour H2S charge, then a strict 20-minute window from removal to load application per ISO 15653, ISO 12135, BS 8571, NACE TM0177, NACE MR0175/ISO 15156, NACE TM0284. Few labs in the world execute the protocol.

High-temperature long-duration creep. Six constant-load creep frames at 50 kN, operating up to 1,100 degrees Celsius, with duration capability to 100,000 hours. The international peer set typically runs two or three frames at most, with a 700 degree Celsius ceiling. The capacity matters because the long-duration data feeds turbine blade material assessment, reformer tube material validation, and supercritical and ultra-supercritical power-plant component qualification (Adani Mundra 660 MW supercritical, Tata Power, NTPC).

Cryogenic CTOD to negative 70 degrees Celsius, supporting Arctic, cryogenic, and offshore qualification work.

3.10 Salient Features

Most laboratories at scale are testing-only. TCR carries both: the testing arm (TCR Engineering and TCR Arabia) and the engineering consulting arm (TCR Advanced). A client who runs a Fitness for Service file with TCR receives the destructive testing, the in-situ replica work, the FEA, the API 579 calculation, the API 580/581 risk assessment, and the inspection plan from a single team that owns the chain end-to-end.

- QA to India Defence sector with long term contracts from NMRL and DMRL to undertake CTOD, Fracture Toughness, Fatigue (LCF & HCF) as well as S-N Curve including K1c, J1c. Approvals from CQAE, DRDO
- Strong Engineering Consulting division ensures plant profitability by RBI, IOW, FFS and RLA as per API and ASME. Complete Coverage in the Oil & Gas Sector serving and approved by RIL, BPCL, Shell, HPCL, ONGC, Halliburton, Schlumberger, Weatherford. Middle East based

approvals from PDO, QChem, QGas, KNPC, Iraq Oil Ministry. TCR Arabia based in Saudi has approvals from Saudi Aramco and Sabic.

- Approvals and long term contracts from major plant owners from Tata, Siemens, NPCIL, Honda, Godrej, MDL, Deepak Fertilizer, and many more
- Support for insurance claims with detailed failure investigation services with over 8000 completed cases undertaken to date.
- Currently Working at cross country pipeline projects at IOCL and GAIL sites undertaking Radiography and Advanced NDT Services including the following real prestigious projects:
    - 36” Dia Dhamra to Angul (DAPL) pipeline of GAIL under Mecon
    - Kandla-Gorakhpur LPG pipeline of IOCL (KGPL)
    - Srikakulam (Andhra Pradesh) - Angul (Odisha) Pipeline of GAIL (SAPL)
    - Koyali-Ahmednagar-Solapur Pipeline
    - Paradip-Somnathpur-Haldia Pipeline line (PHPL)
    - Bathinda Sangrur Pipeline Project of HPCL under Tractebel
    - Station Works at NOC Terminal Amlekhganj (Nepal) under MAPL Ph-II project
    - CGD Project Nagapattinam-Karaikal GA of Torrent Gas
    - Digital X ray & RT for 36" Dia Mundra Panipat Pipeline Project of Indian Oil
    - CRS at Panipat-Jalandhar LPG Pipeline (PJPL) Project of Indian Oil
    - Destructive Testing for Welder Qualification for L&T at the Mumbai-Nagpur Pipeline under Mecon
- Preferred lab for National Infrastructure with approvals from Mumbai Metro, MMRDA, MSRDC, PDIL, L&T, RITES, BMC, NMMC, AFCON, HCC, Dextra, Leviat, Jaypee Group, Shapoorji Pallonji, Kalpataru, J Kumar Infra.
- Dedicated Low Cycle/High Cycle Fatigue, Slip Test, Static tensile test setup for Reinforcement bar couplers, mechanical splices and concrete reinforcement bars as per ASTM A1034, ISO 4449, EN 10138, ISO 15630, IS 16172 & IS 1786 ensuring that the structures built using these materials meet the highest safety and performance standards. This testing service is used by all major national highways, metro, real estate and infrastructure companies.
- Dedicated Boiler Services division with IBR approval undertaking RLA as well as ACRT and Creep Damage assessment
- Serving the Metal Trading Community with dedicated alliance and in-house setup with Bharat Metal Exchange serving over 2500 reputed traders at BME House
- Empanelled as the exclusive assayer to BSE and NSE commodity trade
- A full instrumental spectrometer bench alongside a full classical wet chemistry laboratory working on Colorimetry, Gravimetry and Titrimetric techniques. RoHS testing for export compliance is also available with XRF and ICP-OES spectrometers
- Experienced Team of TPI and Competent Persons for Factory - Quality Audit, Plant Inspection, Pre-Shipment Inspection of industrial raw materials and components.
- Undertaking Robotic and AI based inspection and structural audit of over 500 bridges in Maharashtra for PWD
- Approved test lab for Evaluation of Elastomeric Materials in Sour Gas Environments for Shell
- Dedicated Training Academy called “Evolve” in Vadodara where future plant operations experts are created imparting knowledge over and above what engineering and metallurgical institutions provide.

Pan India presence with offices and sample collection in Mumbai, Chennai, Bhubaneswar, Gorakhpur, Pune and Nashik. TCR Engineering’s asset integrity company M/s TCR Advanced is based in Vadodara.

3.11 The AiOM Digital Backbone

AiOM is the indigenously developed Asset Integrity and Optimisation Management platform from TCR Advanced. The architecture sits on six pillars (Asset Master, Asset Strategy, Asset Maintenance, Asset Integrity and Reliability, Asset Optimisation, Asset Analytics), with Integrity Operating Windows anchored in API RP 584, an Intelligent Plant module on the P&ID-driven graphical interface, and an Asset Troubleshooting Guide built on TensorFlow and Keras as the AI-assisted knowledge-retention engine. The six pillars are the architectural layer of the platform. They are distinct from the twelve software modules that ship in the product, catalogued at Section 6.1.1. The two counts describe the same platform at different levels and are not interchangeable. The damage-mechanism library covers approximately 70 mechanisms. The AiOM-CCP application extends the platform to cross-country pipelines (10 km to 1,000 km, buried or above-ground, crude petroleum, refined products, natural gas, water, chemicals, sewage), with a documented anonymised undersea pipeline case study (API 5L X46N, 21 km by 355 mm by 15.9 mm, ID-side CO2/H2S corrosion).

The platform is bundled with consulting; it is not a standalone software licence pursuit. Chambal Fertilisers GP-I plant RBI with AiOM software implementation, awarded 11 December 2025 (51 equipment under AiOM scope at Ammonia-I Plant Areas 02 and 05), is the anchor commercial reference.

3.12 The People

The senior bench is named, credentialled, and accessible. The list runs from Paresh Haribhakti as TCR Advanced Managing Director (the ASM author bench), through Avinash Tambewagh as Technical Head TCR Engineering, Ketankumar Upadhyaya and Gopul Patel as the TCR Advanced reliability and AiOM leads, Nikhil Sabhaya as the four-method ASNT Level III holder, Chiral Patel as the CP Division Lead with 20+ years cathodic protection, Anil K. Lund as AI and Digitalisation Head and Bangalore Operations Team Head, through to Manoj Singh as Department Head Corrosion Testing and Parul Hariya as Department Head Civil Testing. The TCR Arabia Leadership team has Khalid J. Al-Dabal as Managing Director, Syed Ameen Hassan as Country Manager, Abdul Waheed as NDT Manager (ASNT Level III) and Syed Ahsan Ali as Metallurgist (API 510, 653, 571, 580 certified).

The expert consultant bench at TCR Advanced adds named subject-matter authorities with 30 to 47 years of operating experience: Prof. Awadhesh Kumar Singh (Power Plant and Turbine, ex-BHEL, ABB, ERDA); Ashok Kumar Srivastava (Fertiliser Asset Integrity, ex-Dangote, Indorama Eleme); Dr. M.M. Pandya (Corrosion, 200+ industrial cases); M.N. Patel (SEM and EDS, 33 years of teaching); Dr. P.B. Joshi (ex-Head, Metallurgical Engineering, MS University Vadodara, 50+ research publications, ASM book co-author); Subrahmanya Bhat (Corrosion, 32 years at ONGC, patent holder); Narendra Kumar Roy (FEA and FFS); Dinesh Butala (Process Safety, ex-ED GSFC, 50+ technical papers); J.N. Agarwal (Cathodic Protection and Pipeline Integrity, 33 years at GAIL, ICorr Level 4 Fellow, AMPP Corrosion Awareness Award 2023). No competitor lab carries this depth of named expertise on call.

3.13 Family-Owned Continuity

Ownership is closed-loop. Family promoter holdings dominate, with strategic operating-partner presence at TCR Arabia (GAS Arabian Services, 40 percent of the KSA JV). There is no private-equity exit overhanging the business, no banking-partner balance-sheet leverage relevant to this profile, no rotating-equipment field-services overlay that would dilute the static-equipment specialist line, and no sale of the institutional database. The business is built to keep producing technical work fifty years from now.

3.14 The Voice of the Client

The reader does not have to take this on the company's word. TCR holds 31 unique service-quality testimonials and several fiftieth-anniversary congratulations from across India, Qatar, Oman, Kuwait, Saudi Arabia, and Kazakhstan. A short pull-quote shelf:

> *“"No non-conformity observed." Larsen and Toubro Defence IC, on the VSSC-ISRO rocket motor casing hardware for the Chandrayaan-3 moon mission.”*
>
> *“Vendor Evaluation 97 out of 100, Grade Excellent. OMIFCO Oman.”*
>
> *“Training scorecard 92.88 out of 100, Grade A. QAFCO, on the TCR Arabia training engagement.”*
>
> *“"TCR fielded 1,200 in-situ replicas in 15 days." Reliance Industries, Jamnagar, on a turnaround replica programme.”*

The full library, segregated by sixteen verticals plus dedicated cross-vertical, statutory, training, and 50th anniversary buckets, is the source of record.

4. Materials Testing

3,000+	1000 KN	-196°C	1100°C
SAMPLES PER MONTH, NAVI MUMBAI	LARGEST UTM CAPACITY	LOWEST IMPACT-TEST TEMPERATURE	ELEVATED-TEMPERATURE TENSILE

Materials testing is the foundation service. Every other pillar at TCR rests on the test result. The Mahape laboratory in Navi Mumbai alone handles 3,000+ samples per month across mechanical, chemical, corrosion, metallurgical, and specialised methods. The TCR Eastern facility is at Bhubaneswar.

TCR has a comprehensive range of Mechanical Testing services with a dedicated in-house machine shop that assists in sample preparation. Test specimens are duly prepared for metallic and non-metallic materials for the evaluation of Tensile, Compression, Impact, Weldability, Fatigue and Bend properties.

With its Mechanical Testing Facility, TCR provides a precise determination of Proof Stress by the attachment of various Electronic Extensometers. The Elevated Temperature Tensile Test is a special service offered by TCR. Tests are conducted as per ASTM, BS, IS, DIN, or other client-specified standards.

The Mechanical Testing Facility at TCR conducts tensile tests for understanding the strength and characteristics of a particular material. It provides a precise determination of Proof Stress by the attachment of various electronic controls and extensometers. Testing temperatures range from 80 °C to 1000 °C and beyond, for particularly high-temperature applications. The Mechanical Testing department at TCR performs a range of Impact tests, including Izod and Charpy, Charpy impact testing at temperatures from 100°C to -101 °C & -196°C. Highly specialised pressure test facilities are also frequently done at TCR's Mumbai Laboratory.

A new Heat Treatment Verification Testing block built around the NADCAP AC7101 Materials Testing accreditation, awarded 2026.

4.1 Mechanical and Physical Testing

Mechanical testing is the highest-volume service line in the company. ASTM E8/E8M-22, the standard room-temperature tensile test, is the single highest-volume method in the laboratory. The capability spans tensile, yield, elongation, hardness, impact, bend, compression, and shear testing across the full range of metals, alloys, castings, and forgings.

Universal Testing Machines

1. Fatigue System Universal Testing Machine in capacity of 50 kN, 250 kN and 1000 kN
2. Universal Testing Machine (UTM) of 1000 KN capacity with Electronic Extensometer (Germany)

3. Model EU 40 UTM of 400 KN capacity with high Temperature (Germany)
4. Universal Testing Machine of 30000 lbs capacity with Electronic Controls and Extensometer (USA)

Test Equipment

1. Erichsen Cupping Machine
2. Shadowgraph
3. Hydraulic Test Pump

Hardness Testers

1. Model MH 400 Micro Hardness Tester (USA)
2. Model HPO 250 Brinell / Vickers Hardness Tester (Germany)
3. Rockwell & Rockwell Superficial Hardness Testers

Impact Testers

1. Model IT 40 Charpy Impact Tester as per ASTM & ISO standard (400 Joule)
2. Model IT 30 Charpy / Izod Impact Tester (300 Joule)
3. SANS -ZBC245C Charpy Impact Tester (750 Joule)

Laboratory Facility

1. Complete workshop facilities including Lathe Machines, CNC wire cut machine, Hacksaw, Stress-free grinding equipment, Saws, Shaping Machine, Surface Grinding Machines, Milling Machines and Drilling Machines
2. Complete set of measuring and inspection instruments including Vernier Calipers, Micrometers, and Dial Gauges
3. Number of fixtures and attachments for various tests

TCR Engineering provides a diverse range of physical testing services that include:

- Tensile / Transverse/Compression test
- Tensile test with 0.2% proof stress, stress/strain diagram with electronic extensometer inclusive of sample machining charges
- Tensile test at an elevated temperature of up to 1100 °C with Extensometer and without Extensometer upto elevated Temperature of 400 °C
- Tensile (n.k.r. value) / composite / plastic / fabric
- Tensile test for fine wires/foils
- Full section Tensile test for steel bar up to 40 mm diameter
- Ball Test
- Bend test / Reverse bend / Re-bend / Root / Face / side bend test

- Flattening / Flaring Test
- Re- bend test including aging
- Proof load test on Nut up to 40000 kg
- Full-size breaking of bolt
- Wedge load test / Head soundness test
- Compression test of springs (up to 3 readings)
- Tensile test for fine wires/foils
- Charpy V notch Impact Test (a) R. T. inclusive of sample machining charges as per ASTM E23 (for a total set of 3 specimens and 3 readings)
- Impact Test above and below 60°C
- Rockwell Hardness tester (scale A, B, C)
- Vickers Hardness tester (Micro/Macro indentation)
- Brinell Hardness tester
- Jominy End Quench Test (with normalising heat treatment) as per ASTM A255
- Sectional Weight of CTD/TMT/Reinforcement bars
- Surface characteristics of CTD/TMT/Reinforcement bars
- Hydraulic / Pneumatic Test inclusive of Sample Preparation Charges
- Shear Test
- Proof Load / Slip Test on Fabricated items such as clamps and assemblies
- Load Test up to 800 kN
- Peel Test
- Residual Stress Measurement

Equipment: Universal Testing Machines from 0.5 kN to 1,000 kN capacity. High-temperature Universal Testing Machine for elevated-temperature tensile work (up to 1,100 degrees Celsius). Full set of extensometers (25 mm, 50 mm, 100 mm, 125 mm, 200 mm, and 300 mm gauge length). Charpy and Izod impact testers. Macro and micro hardness testers (Vickers, Brinell, Rockwell). Bend testing fixtures for plate and weld bend tests.

Pull-out test on TMT Bars per IS 2770 for civil and structural buyers. NPCIL elevated-temperature tensile under a three-temperature 300/500/800 degrees Celsius. BS EN 10204 Type 3.2.

Cryogenic and sub-zero impact. Charpy and Izod impact across a temperature range from plus 100 to minus 196 degrees Celsius, covering low-temperature toughness for cryogenic and LNG service, on 300, 400, and 750 Joule machines. Erichsen cupping test for sheet-metal formability.

An in-house machine shop prepares specimens to standard: lathes, CNC wire-cut, stress-free grinding, milling, and surface grinding, which keeps specimen preparation under the same roof and protects turnaround.

Linear thermal expansion and coefficient of thermal expansion on metals and ceramics per ASTM E228, ASTM E289, and ASTM E831.

4.1.1 Tensile and Bend Testing

A tensile test measures the resistance of a material to a static or slowly applied force. A machined specimen is placed in the testing machine and a load is applied. A strain gauge or extensometer is used to measure the elongation. The stress obtained at the highest applied force is known as Tensile Strength. The Yield Strength is the stress at which a prescribed amount of plastic deformation (commonly 0.2%) is produced. Elongation describes the extent to which the specimen is stretched before fracture. Information regarding the strength, stiffness, and ductility of a material is obtained from a tensile test. Other variations of the tensile testing include Room Temperature, Low Temperature (IS 1608 Part 3), Elevated Temperature (ASTM E21, ISO 6892-2), Shear strength, Temperature and Humidity, Combined Tension and Compression, Through Thickness Tensile, Notched Tensile and Strain-Hardening exponent ‘n’ (ASTM E646, IS 15756) & Plastic-Strain Ratio ‘r’ (ASTM E517 & IS 11999) values.

All tests at TCR Engineering Services are performed in line with the ASTM E8, ASTM A370, ASTM B557 and IS/BS/ISO Standards. TCR has the expertise to determine the mechanical properties of materials and resolve a wide variety of technical problems for the industry:

Bend Test

This procedure that determines the relative ductility of metal that is to be formed (usually sheet, strip, plate, bar & wire). It is also used to determine the soundness and toughness of metal (after welding, etc.) The specimen is usually bent over a specified diameter mandrel. The four general types of bends are free bend, guided bend, semi-guided bend & wrap-around bend, as per ASTM E290, E190, A370 and other IS, BS, ISO standards.

Compression Test

This is a method for assessing the ability of a material to withstand compressive loads. The test is commonly used as a simple measure of the metal workability, particularly in forging and similar bulk deformation processes. Engine mounts, bolster springs, cast products, and similar components are tested to determine load versus displacement

Pipe/Tube Flaring Test, (ASTM A370, ASTM A513, ASTM B153, IS 2335, IS 2501)

This procedure tests the ability of a section of a tube, approximately 4" in length to flare (with a tool having a 60° included angle). This is done through the tube as the mouth of the flare expands to 15% of the inside diameter without cracking or indicating any flaws

Pipe/Tube Flattening Test (ASTM A370, ASTM A513, ASTM B111, IS 2328, IS 2501)

A seamless Pipe/Tube sample, 4" - 6" in length is flattened between parallel plates & welded Pipe/Tube with the weld at 90° to the direction of applied force until opposite walls of the tubing meet. Applications for this test along with the flaring test, include situations where round tubing is to be formed into other shapes

4.1.2 Impact Testing

The impact test (ASTM E23, BS EN 10045, ISO 148-1 and IS 1757, IS 1598) is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to understand the energy required by material to deformation before fracture i.e. the toughness of metals but similar tests are used for polymers, ceramics, and composites. Metal industry sectors include Oil and Gas, Aerospace, Power Generation, Automotive, and Nuclear.

The notched test specimen is broken by the impact of a heavy pendulum or hammer falling at a predetermined velocity through a fixed distance. The test measures the energy absorbed by the fractured specimen.

Charpy Impact Test

A test specimen is machined to a 10mm x 10mm (full size) cross-section, with either a "V" or "U" notch. Sub-size specimens are used where the material thickness is restricted. Specimens can be tested down to cryogenic temperatures

IZOD Impact Test

The test specimen is machined to a square or round section, with either one, two or three notches. The specimen is clamped vertically on the anvil with the notch facing the hammer.

Keyhole Impact Test

The steel casting industry uses this type of specimen frequently. The notch is machined to look like a keyhole. It is tested in the same manner as the "V" and "U" notch.

4.1.3 Hardness Testing

Hardness Testing measures a material’s strength by determining resistance to indentation/penetration by material surface. The hardness test is extremely useful in material selection because it provides a hardness value, which indicates how easily a material can be machined and how well the material will wear. It is defined as the resistance to indentation and it is determined by measuring the permanent depth of the indentation. Simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material.

Brinell, ASTM E10, IS 1500-1, ISO 6506-1 Standard

This is a simple indentation test for determining the hardness of a wide variety of materials. The test consists of applying a prescribed load, usually between 500 kg and 3000 kg, for a specified time (10-30 seconds), using a 5 or 10mm diameter tungsten carbide ball on the flat surface of a metal sample

Vickers (Macro indentation) & Knoop hardness ASTM E92, ISO 6507-1 and IS 1501-1 Standard

The Knoop indenter has a polished rhombohedral shape with an included longitudinal angle of 172° 30´ and an included transverse angle of 130° 0´. The narrowness of the indenter makes it ideal for testing specimens with steep hardness gradients and coatings. Knoop is a better choice for hardness testing of hard and brittle materials

Rockwell, ASTM E18, ISO 6508-1 & IS 1586-1 Standard

This test differs from the Brinell test in the shape of the indenter and in the manner that the number is determined. The Rockwell number represents the difference in depth penetration between two loads.

There are two types of Rockwell: Rockwell and Superficial Rockwell. The difference between the two is in the minor and major loads applied to the specimen. The indenter used may be a diamond cone or a hardened ball, depending principally on the characteristics of the material being tested

Vickers (Micro indentation) hardness, ASTM E384, BS EN 1043-2, ISO 6507-1 & IS 1501-1 Standard

A micro indentation is made on the surface of a metal sample. The hardness number is based on the measurements of the indent formed on the surface of the test specimen

Portable Hardness, ASTM E110 and IS / BS Standard

Facility for Portable hardness testing using rebound-type digital hardness tester is available for carrying out hardness testing at the site. This is particularly useful for large objects and In-situ, where cutting the sample is not possible

4.1.4 Nick Break and Weldability

Nick break testing is another simple process that lends itself to learning welding (API 1104 specification), due to its speed and very low cost. It is also used in production runs, where quality is monitored at intervals throughout production. The principle behind it is to take a sample piece, partially cut through it and then break the remainder off. This allows one to 'see inside the weld'. Various defects and faults can be easily seen by visual inspection including lack of fusion, porosity, slag inclusions etc.

Nick Break

The principle of this test is to break the sample through the weld metal in order to examine the fractured surface. Applying a three-point bend load induces the fracture. The fractured surface is then examined, and the type and location of any weld defect are reported.

Weldability

The procedure consists of performing a chemical analysis and/or mechanical tests with metallography to provide data for the determination of weldability. Weld Engineering provides additional support and recommendations for material usage. If necessary, trial welds can be fully tested and examined to provide final data

Weld Bead Bend Test (WBBT) as per SEP 1390 standard

In the weld Bead Bend Test, the crack arrest behaviour of a material shall be checked. For this purpose, welding bead shall be laid on grooved test plate. Then test plate shall be subjected to bending stress. in doing this, it shall be checked if an incipient crack occurring in the weld metal is arrested by heat affected zone (HAZ) or the base metal when bending without interruption

Representative engagement: Larsen and Toubro Defence (Integrated Core) for VSSC-ISRO, mechanical, chemical, and metallurgical qualification of rocket motor casing hardware for Chandrayaan-3 moon mission, returned with no non-conformity observed (2023).

Standards: ASTM E8/E8M-22 (room temperature tension), ASTM E21 (elevated-temperature tension), ASTM E23 (Charpy impact), ASTM E18 (Rockwell), ASTM E10 (Brinell), ASTM E92 and ASTM E384 (Vickers), ASTM E290 (bend), ASTM A370 (steel products), ASTM B557 and ASTM B565 (aluminium and copper alloy tension). ISO 6892, ISO 148, ISO 6506, ISO 6507, ISO 7438. EN 10002, EN 10045. IS 1608, IS 1499, IS 1586, IS 1500, IS 10570. Welder qualification tests per ASME Section IX 2023 Edition.

4.2 Component Testing and Fasteners

Component testing covers bolts, nuts, studs, fasteners, springs, washers, and finished machined parts. Proof load testing per ASTM F606 and IS 1367. Stress rupture and wedge tensile. Hydrogen embrittlement screening per ASTM F1624, ASTM F519, and API 20E. High-strength friction grip (HSFG) bolt testing per IS 3757. Aerospace fastener qualification under the heat-treatment verification umbrella (ASTM F606M, NAS 1351, MS 21250).

Testing components take on many forms depending on the application and the conditions present in service. TCR routinely tests components under fatigue, vibration, shock, pressure, high and low temperatures, humidity, solar, corrosion, impact, hydrostatic pressure and altitude conditions. Test capacity can vary from small (several inches in size) to large (vehicle size). Test fixtures can be made in-house via 3D drawings or FE models.

Frequently tested components include automotive parts and assemblies (i.e. axles, engine cradles, transmission shafts, shock absorbers, doors, locking enclosures, connecting rods as engine mounts and crankshafts) electronic displays, communication devices, packaged products, pressure vessels, pipes, and building products such as fascia and structural products. Aerospace components, in particular, electronic devices and landing gear assemblies are also tested.

Dynamic Loading

Dynamic loading takes on many forms like impact, vibration, shock, fatigue and high strain rate to name a few. TCR is capable of performing many forms of dynamic tests on specimens, prototypes, and varied assemblies

Fasteners - Wedge, Axial, Proof Load

Fasteners of all sizes used in every application are critical to the integrity of structures and finished components. In addition to dimensional, chemical composition and metallurgical properties, Mechanical Testing is of paramount importance in determining compliance with specifications and fitness for different purposes

Wedge Tensile

The wedge tensile strength of a hex or square-head fastener, socket-head cap screw or stud is the tensile load that the product is capable of sustaining when stressed with a wedge under the head. The purpose of this test is to obtain the tensile strength and to demonstrate the head quality and ductility of the product

Axial

The Axial tension of fasteners is tested in a holder with a load axially applied between the head and a nut, or in a suitable fixture

Proof Load

Proof Load testing of a nut is assembled on a hardened, threaded mandrel or a test bolt, using the tension or compression method. A specified proof load is applied on the nut against the nut. The nut should resist this load without stripping or rupturing and should be removable from the test bolt or mandrel by hand after the load is released. Proof load testing of Bolt/Stud is measure in terms of permanent extension in length after application of specified proof load

Standards: ASTM F606 and F606M (mechanical testing of fasteners), IS 1367 (threaded steel fasteners), ASTM F1624, ASTM F519, and API 20E (hydrogen embrittlement), IS 3757 (high-strength friction-grip bolts), NAS 1351 and MS 21250 (aerospace fasteners).

4.3 Evaluation of TMT Rebars and Reinforcement Couplers

TCR is the first BIS-accredited commercial laboratory in India for IS 16172 rebar coupler testing across all diameters, from 8 mm to 40 mm. Over fifty manufacturers have been guided through the ISI mark certification process. The capability covers tension test, uniform elongation, fatigue cycling at 100,000+ cycles at specified stress ranges, slip measurement, and cyclic tension-compression reversal.

TCR Engineering Services, based in Mumbai, specialises in the testing and evaluation of TMT (Thermo-Mechanically Treated) rebars and reinforcement couplers. As the construction industry shifts towards modern methodologies, mechanical splicing of reinforcement bars using couplers has emerged as a reliable technique.

Importance of Mechanical Splicing

Mechanical splicing involves the end-to-end joining of two reinforcement bars using couplers. This technique is particularly advantageous in structures subjected to cyclic loading and where inelastic yielding may occur, such as multi-story buildings and bridges. The use of couplers reduces congestion during concreting, accelerates construction timelines, and ensures a more efficient load transfer between bars. To ensure safety and reliability, the quality of both the couplers and the TMT rebars must be rigorously assessed, considering factors such as material compatibility and construction standards.

TCR Engineering conducts testing in accordance with several established standards, including:

- IS 16172: 2023: This standard outlines the requirements for mechanical splices of reinforcement bars.
- IS 1786: This specifies the requirements for TMT rebars, including their mechanical properties.
- IS 16651:2017: Standards for TMT made of SS material.
- ASTM A1034: This standard specifies the requirements for mechanical splicing of bars.
- ISO 15835-2: This standard covers the testing procedures for mechanical couplers.
- BS 8597: This standard includes guidelines for testing the mechanical properties of reinforcement couplers.

TCR Engineering utilises a variety of testing methods to ensure the integrity and performance of TMT rebars and their couplers:

TMT Testing - IS 1786:2008

- Static Tensile Test: Determine the tensile strength and elongation of TMT rebars (Grades Fe 500 D, Fe 415 D/S, up to 45 mm diameter) per IS 1786.
- Bend and Re-Bend Tests: Evaluates ductility and flexibility by bending specimens to specified angles and then straightening to inspect for cracks or failure.

- Spectro/Wet Chemical Analysis: Confirms chemical composition of TMT rebars as per IS 1786 and IS 16651 (for SS materials).

Rebar Coupler Testing - IS 16172:2023

- Static Tensile Test: Evaluates tensile strength on static machines.
- Slip Test: Measures permanent extension post-loading (performed before cyclic testing).
- Cyclic Tensile Test: Evaluates splice behaviour under cyclic loads, typically 100 cycles at stress levels from 5% to 90% of yield stress, according to relevant standards, without loss of static tensile strength.
- Low Cycle Fatigue (LCF) Test (10,000 Cycles): Tests endurance under alternating loads of the splice in such a way that they should withstand 10,000 cycles of alternating tension and compression without failure.
- High Cycle Fatigue (HCF) Test (2 million Cycles): Measures durability under extensive cyclic loads with parameters including:
    - Minimum Stress: 30 MPa
    - Maximum Stress: 130-350 MPa
    - Frequency: 3-10 Hz
- Reporting: S-N curve documentation.

Common Material Grades: EN8D and 45C8 for rebar couplers.
Equipment: Tests are conducted on advanced machines, static tensile and slip test performed on a static machine and fatigue tests (cyclic, LCF, HCF) on a dynamic machine. Closed-loop servo-hydraulic dynamic UTM machines enable testing frequencies from 0.035 to 30 Hz, ensuring precision and reliability.

Coupler Sizes and Standards

TCR conducts rebar coupler testing across diameters from 8 mm to 40 mm, ensuring compatibility with rebar grades like Fe415, Fe500, and Fe550, in compliance with standards such as IS 16172. All tests align with TCR's NABL accreditation (ISO/IEC 17025:2017), emphasising the company's dedication to quality and accuracy.

TCR Engineering stands at the forefront of material testing for TMT rebars and couplers, ensuring that the structures built using these materials meet the highest safety and performance standards. With over five decades of experience, TCR continues to support the construction industry with rigorous testing protocols, advanced technologies, and adherence to stringent quality standards, solidifying its role as a trusted partner in the field of materials testing.

Anchor clients in this segment include Dextra, Afcons, Mumbai Coastal Road Project, and Larsen and Toubro Mumbai Metro. The first-in-India BIS coupler line is positioned as a structural moat: a competitor would need three to five years and over fifty active client engagements to replicate.

Coupler manufacturers tested include Dextra, Leviat, Kridhan, Vrudhhi Steel, Sanfield, Kamar Infra, Rajasthan Alloys, Beacon Infra, Steel Era, Kuber Infra Solution, Splicetek India, and Shrinidhi Innotech. End-project clients running TCR-tested couplers include NHSRCL, NHAI, Larsen and Toubro, Afcons Infrastructure, NCC, Tata Projects, K. Raheja Corp, Megha Engineering and Infrastructures, Oberoi Realty, KEC International, Shapoorji Pallonji, Ahluwalia Contracts, Dilip Buildcon, Ashoka Buildcon, and Lodha.

TMT rebar testing per IS 1786: tensile, yield, elongation, re-bend, weldability, chemical composition. Couplers tested per IS 16172 (parallel threaded, tapered threaded, compression, and grouted types). Pull-out test on TMT Bars per IS 2770. HT strand testing for High Speed Rail (HSR) and bridges. Aluminium formwork qualification.

Standards: Coupler evaluation is run to IS 16172:2023 (mechanical splices of reinforcement bars), ASTM A1034 (mechanical splices of bars), ISO 15835-2 (test methods for couplers), and BS 8597, with rebar to IS 1786 and stainless reinforcement to IS 16651:2017.

Test programme: Static tensile and slip on a static machine; cyclic tensile at 100 cycles across 5 to 90 percent of yield without loss of static strength; low-cycle fatigue at 10,000 cycles of alternating tension and compression; and high-cycle fatigue to 2 million cycles at 30 MPa minimum and 130 to 350 MPa maximum stress, 3 to 10 Hz, reported with the full S-N curve. Common coupler grades are EN8D and 45C8, across rebar grades Fe 415, Fe 500, and Fe 550.

Equipment: Closed-loop servo-hydraulic dynamic universal testing machines run from 0.035 to 30 Hz, separating static, slip, and fatigue work onto dedicated frames.

4.4 Chemical Analysis Laboratory

Chemical composition analysis of ferrous and non-ferrous metals, alloys, slags, ores, and residues. The TCR chemical laboratory retains a full classical wet chemistry bench, by gravimetry and titrimetry, for arbitration and referee analysis and for matrices where no instrumental calibration exists. Bullion assay. TCR is BSE/NSE-empaneled assayer for precious metals and is an ICCL/BSE Approved Assayer plus Bharat Metal Exchange Association approved laboratory.

RoHS compliance testing by both non-destructive XRF screening and ICP wet-chemical verification, plus lead detection, for electronics, coatings, and consumer-goods buyers. Ferrography and oil analysis support rotating-equipment condition monitoring.

TCR has an advanced chemical analysis laboratory with expert chemists. It has the capability to analyse ferrous and non-ferrous metals, ceramics, glass, refractories, mineral and Ferro alloys in PPB or PPM level or in percentage. TCR's capabilities include Wet Chemistry, Optical Emission Spectroscopy (OES), Inductively Coupled Plasma (ICP) Spectrometer, Automatic Combustion based Carbon and Sulphur determinator, XRF spectrometer, and more.

An inherent strength of TCR Engineering Services is the ability to successfully undertake analytical chemistry assignments. The highly qualified analytical chemists are experienced in using the full range of analytical instruments including advanced Spectrometers and Wet Chemistry laboratory facilities. TCR caters to all analytical requirements for Ferrous, Non-Ferrous Metals, Ceramics, Glass, Refractory, Minerals and Ferro Alloys. The chemical department analyses samples in all forms including drillings or turnings, solid samples, and liquids.

The Classical Wet Chemistry (bench chemistry) Department uses Gravimetry (chemical species is determined by weighing) and Titrimetry (involves volume measurement of a liquid reactant) procedures to analyse the chemical composition of materials. It 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 with the environmental standards of India, the wet chemistry department at TCR is highly sought-after by leading companies all over the world, right form trace chemical analysis to very low detection levels.

TCR Engineering Material Testing Laboratory provides both analytical and interpretive expertise, including method development, method validation and identification of unknown materials. The lab can successfully meet all challenges, whether it is for PPB or PPM level analysis or in percentage. TCR has the capability to provide results with both, standard specifications and client supplied specifications. It has the expertise to develop customised analytical procedures for analysis of materials and substances for which no protocol is available.

4.4.1 Chemical Analysis by Classical Wet Method

- Ferrous Metals (Including) C, S, P, Mn, Cr, Mo, Ni
- Non-Ferrous Refractory, Ceramics, and Minerals, Ferro Alloys (Fe-Mn, Fe-Si, Fe-Mn-Si, Fe-Mg-Si, Low C Fe-Cr, Fe-Mo)
- Non-Ferrous Metals (Each Additional Element)
- Elements Such As Co, Al, W, Cu, Sn, Ti, Mg, V In Steel
- Nitrogen / Boron / Palladium (Each Element)
- Purity Of Cu
- Purity Of Al, Zn, Pb, Ni, Bi, Cd, Sn, Mg, W, Ti
- Oxygen Analysis and Hydrogen Analysis

Wet-chemistry bench equipment: microwave digestion system, four electro analysers, three electronic balances, vacuum pump, muffle furnaces, and heating ovens.

4.4.2 Chemical Analysis by Spectrometers

- EDAX Analysis
- Complete Chemical Analysis up to 8 elements
- Impurities in PPM Level using AAS or ICP

4.4.3 Chemical Analysis by LECO

- Oxygen by LECO
- Nitrogen by LECO
- Hydrogen by LECO

Steel and Cast Iron

1. Determination Of Any One Element (%C)
2. Determination Of Any One Element (Mn, Si)
3. Determination Of Any One Element (Ni, Cr, S, etc.)
4. Determination Of C, Mn, Si, S, P
5. Complete Analysis Of Low Alloy Steel Up To 8 Elements Including C, S, P, Si, Mn, Ni, Cr, Mo
6. Determination Of Any One Element in Stainless Steel
7. Complete Analysis Of Stainless Steel up to 8 Elements

8. Determination Of High Alloy Element (Cr, Ni, Mn)
9. Determination Of Some Special Element (Cu, Ti, Co, V, W, Al) Per Element
10. Complete Analysis Of High-Speed Steel (8 Elements) Per Element
11. Determination Of Mo%
12. Determination Of V%
13. Nitrogen In Steel

Non-Ferrous Material

- Copper Base Alloys
- Determination Of Any One Element
- Complete Analysis Of 6 Elements
- Purity Test Of Cu
- Purity Test Of Other Non-Ferrous Element

Ferro Alloys

- Analysis of Main Element
- Each Subsequent Element

Tin, Aluminium, Lead Base

- Determination of Any One Element
- Complete Analysis of up to 8 Elements
- Purity Test
- Only Aluminium %

Other Tests

- pH Value Determination
- Sand Content (as Sio2)
- Acid Insoluble
- Sulphates, Chlorides, Silicates, Carbonates, Oxides of Iron Per Element
- Elemental analysis – Calcium, Magnesium, Potassium, Sodium, Iron Per Element
- Moisture Content
- Analysis on XRF per element
- Ash Content
- Material Certification
- Unknown Material Identification
- Trace Element Analysis
- Oil, Powdered Metal, & Chips/Shavings Analysis
- Solder Alloys (Tin/Lead)
- Quantitative and Semi-Quantitative Analyses
- Density of Powdered Metals
- Plating and Plating Solution Analysis
- Glass Analysis
- On-Site Positive Material Identification (PMI)
- Coating Identification
- Coating Weights
- Particle Size Analyzer

Equipment

TCR Engineering has a wide range of equipment that is available for chemical analysis:

Spectrometer:

4.4.4 Atomic Absorption (AA) Graphite Furnace Spectrometer

The sensitivity of GFAA enables performances of elemental analysis that is virtually impossible using other analytical techniques. These are used to determine ppm and sub-ppm levels of residuals in metals. GFAA is also particularly useful for the determination of low boiling point tramp elements in aerospace alloys. This method is particularly pertinent in material analysis for the detection of trace metals.

4.4.5 Inductively Coupled Plasma Spectrometer

ICP is a spectrophotometric method carried out in solutions where high temperature argon plasma is used to reduce matrix effects, giving straight-line calibrations. This enables low sample weights to be analysed and coupled with its wide calibration range making them the most flexible instruments that are available today with parts per billion detection limits.

4.4.6 Optical Emission Spectrometer

These instruments enable the rapid quantitative determination of a wide range of alloys including carbon/low alloy steels, stainless steels, cast irons, aluminium alloys, nickel alloys and copper alloys. It entails a relatively simple sample preparation that allows a rapid turnaround of results using this technique.

4.4.7 X-Ray Diffraction Spectrometer

X-Ray Diffraction Analysis (XRD) investigates the crystalline material structure, including atomic arrangement, crystallite size, and imperfections. The X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample.

Combustion carbon and sulphur determination are accepted as the most accurate methods for determining carbon and sulphur in metal, ore or powder samples. These samples may be in the form of solid material, drillings or powders. This technique is mainly used to complement ICP or OES for a full chemical analysis of metallic samples.

Representative engagement. Casale SA, Switzerland, urea and melamine licensor, approved under vendor code 1000007973 on the SX3000 schedule (June 2025).

Primary methods: Optical Emission Spectrometry (OES) for fast bulk analysis. Atomic Absorption Spectrometry (AAS) for trace elements. Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for multi-element scanning. Combustion Analysis (LECO) for carbon and sulphur. Inert Gas Analysis (IGA) for nitrogen and oxygen. Classical wet chemistry for verification and arbitration analyses.

Glow Discharge Spectrometry (GDS) for surface and depth-profile analysis, Energy Dispersive X-ray (EDAX) micro-analysis, and X-ray Fluorescence (XRF) for portable and bench alloy identification.

Standards: ASTM E1086, ASTM E415, ASTM E1019, ASTM E1479, ASTM E350 through E353, IS 228 series, EN 10204, plus product-specific compositional limits per applicable ASTM, ISO, and BIS standards.

4.4.8 Wavelength-Dispersive X-Ray Fluorescence (WD-XRF)

Wavelength-dispersive X-ray fluorescence runs on a Rigaku Supermini200 bench spectrometer for major-oxide and trace-element chemistry on cement, clinker, fly ash, ground granulated blast furnace slag, aggregate, soil, and ore. The sequential wavelength-dispersive geometry separates overlapping spectral lines that an energy-dispersive hand-held instrument cannot resolve, which is what makes the bench suitable for oxide chemistry on building materials rather than for alloy sorting alone. The bench sits alongside the portable and hand-held energy-dispersive XRF units used for positive material identification in the field and for RoHS screening, and alongside the classical wet chemistry bench used for arbitration analysis.

4.5 Oil Analysis Ferrography

Lube-oil condition monitoring for predictive maintenance of rotating equipment. Particle count, viscosity, water content (Karl Fischer), Total Base Number and Total Acid Number (TBN/TAN), wear-metal analysis, and ferrography (analytical and direct reading). Used across gearboxes, hydraulic systems, turbine lubrication systems, and compressors.

Ferrography for oil analysis, is a series of laboratory tests that determine the condition of used lubricants in equipment components, over a period of time. A trend of Wear Particle distribution and their concentration typically presents the condition of the equipment. It allows organisations to be proactive as it provides them with the opportunity to be prepared for investing in maintenance programmes for breakdowns.

There are six basic Wear Particle types generated through the wear process, which includes metallic particles that comprise of Normal Rubbing Wear, Cutting Wear Particles, Spherical Particles, Severe Sliding Particles, Bearing Wear Particles (Fatigue Spall Particles, Laminar Particles) and Gear Wear (Pitch Line Fatigue Particles, Scuffing or Scoring Particles). Sand and dirt particles responsible for generating Wear Particles exist in the system too.

- Reduction in Unscheduled Downtime due to Wear of Rotary Components like Bearings and Gears
- Effective Maintenance Scheduling
- Improved Equipment Reliability and Safety
- Reduction in Maintenance Costs
- Maximisation of Oil Change-out Intervals that Indirectly Conserves Environmental Cleanliness
- Reduction in Machine Power Consumption Over a Period of Time

4.6 RoHS Compliance Testing

RoHS (Restriction of Hazardous Substances) testing for lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE) in electronic and electrical equipment. Methods per IEC 62321 series. EU Directive 2011/65/EU. Common client segments: automotive component manufacturers, consumer electronics, medical devices, export-oriented manufacturers.

The ill-effects of Lead (Pb) consumption is gaining significance all over the world. The Lead inspection service from TCR allows manufacturers of consumer electronics materials, children's toys and jewelry, cooking or edible materials, packaging, and several other materials in India, to create lead-free landfills and clean up hazardous sites. TCR Engineering Services undertakes the classification of definitive positive/negative results for Pb using portable XRF instruments.

TCR's XRF instrument can detect the presence of lead in paints & coatings, as well as in 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 RoHS Directive states that certain non-exempt products, as well as electrical and electronic products available in the market within the EU, must contain less than 0.1% lead (Pb), mercury (Hg), hexavalent chromium (Cr^{6+}), polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE), and less than 0.01% cadmium (Cd). Product manufacturers including computer hardware, IT equipment, clock radios and toasters could find themselves banned from selling their product in the European market if they fail to comply with the new directives.

TCR Engineering Services has devised testing programmes to help clients understand the rigorous RoHS restrictions. TCR has researched complex methodologies required for compliance testing and has acquired specialised equipment to meet client needs. The RoHS Testing Team at TCR has the capability to analyse all restricted substances up to the required limits and they ensure that the products meet all the requirements while retaining full product functionality.

1. Restriction of (certain) Hazardous Substances (RoHS) is a result of Waste Electronic and Electrical Equipment (WEEE) Directive, which addresses end-of-life issues on electrical components
2. The WEEE Directive is essentially concerned with the introduction of hazardous materials into the environment, during recycling or disposal

The RoHS Testing Team at TCR analyses concentrations of lead, mercury, cadmium, chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs) in electrical and electronic components, right up to the required limits, to ensure that all the products meet the requirements while retaining their full functionality. TCR Engineering Services undertakes RoHS and WEEE-related compliance testing for electronic products and accessories using both:

Non Destructive RoHS screening (RFA method)

The screening provides indications about the presence of hazardous substances in the product according to RoHS. It is best suited to gain a quick overview of a goods receipt check or in preliminary inspections. Using a custom-tailored portable X-Ray Fluorescence Spectroscopy (XRF) spectrometer, the inspection team from TCR can simultaneously screen for all five restricted RoHS elements and chlorine (Cl), in a matter of a few seconds. Using a Portable XRF is non-destructive and an in-situ point-and-shoot screening method for PVC, PE, alloys, metals, solders, ceramics and packaging materials.

Chemical Analysis by ICP (Verification method)

RoHS testing is carried out using an initial screening test by XRF; if high levels of restricted substances are found, additional tests may be performed using Inductively Coupled Plasma (ICP) Spectrometer and wet chemistry. The Chemical Analysis Department at TCR provides all its clients with accurate, precise results that report the total level of RoHS elements and compounds, along with detailed information about their products meeting all RoHS requirements.

Standards. IEC 62321 series (determination of restricted substances), EU Directive 2011/65/EU (RoHS).

4.7 Corrosion Testing and Sour Gas Service

Sour-gas corrosion testing is one of the highest-value specialisms in the group. The lab is PDO and OQGN approved, holds the NACE Excellent Laboratory in the Private Sector award, and has executed numerous sour-service projects for Shell. NACE MR0175/ISO 15156 material qualification for sour-service oil and gas applications is the anchor framework, supported by NACE MR0103 (refining), NACE TM0177 (SSC), NACE TM0284 (HIC), and NACE TM0316 (four-point bend) for upstream and downstream qualification.

Project qualification is run to client procurement specifications, including Petroleum Development Oman SP-2347 (carbon steel line pipe), SP-2337 (materials selection for production systems), and SP-2161 (materials selection and corrosion control for surface facilities).

Representative engagement. ITER-India for the Institute for Plasma Research, crevice corrosion and electrochemical study. TCR designs and builds its own autoclaves and reference specimens for non-standard corrosion studies, including the ITER-India fusion-reactor corrosion programme whose report was cross-checked by ITER France. CTOD with hydrogen-sulphide pre-charging, developed for Larsen and Toubro, charges specimens for 96 hours in NACE TM0177 Solution A and loads them within a 20-minute window per ISO 15653, ISO 12135, and BS 8571.

TCR offers a comprehensive range of material testing services for corrosion problems that include:

Inter-granular Corrosion attack in Austenitic Stainless Steels

- Oxalic Acid Etch test per ASTM A262 Practice A
- Ferric Sulfate-Sulfuric Acid test per ASTM A262 Practice B
- Huey Test, Nitric Acid test per ASTM A262 Practice C
- Copper–Copper Sulfate–Sulfuric Acid test per ASTM A262 Practice E
- Copper–Copper Sulfate–50% Sulfuric Acid test per ASTM A262 Practice F
- Corrosion test in nitric acid medium by measurement of loss in mass (Huey test) per ISO 3651-1

Inter-granular Corrosion attack in Stainless Steels

- Oxalic acid etch test per ASTM A763 method W
- Ferric sulfate-sulfuric acid test per ASTM A763 method X
- Copper-copper sulfate-50% sulfuric acid test per ASTM A763 method Y
- Copper-copper sulfate-16% sulfuric acid test per ASTM A763 method Z

Inter-granular Corrosion of Ferritic, Austenitic & Ferritic-Austenitic (Duplex) Stainless Steel

- Intergranular corrosion of stainless steels per ISO 3651-2 Method A, B, C

Metallic Materials

- Potentiostatic & Potentiodynamic Anodic Polarisation Measurement per ASTM G5
- Conducting Cyclic Potentiodynamic Polarisation Measurements for Localised Corrosion Susceptibility of Iron-, Nickel, or Cobalt-Based Alloys per ASTM G61
- Electrochemical Impedance Spectroscopy (EIS) tests to find out Rp (polarisation resistance), Cdl (double layer capacitance) & Corrosion rate measurement.
- Immersion Corrosion Testing per ASTM G31
- Stress Corrosion Cracking in Polythionic Acids per ASTM G35
- Preparing, Cleaning and Evaluating Corrosion Test Specimens per ASTM G1
- Examination and Evaluation of Pitting Corrosion per ASTM G46

- Corrosion Rates and Related Information from Electrochemical Measurements (Tafel slopes) per ASTM G102

Corrosion Tests as per ONGC/EIL specification

- Chloride Stress Corrosion Cracking in boiling Magnesium Chloride per ASTM G36
- Chloride Stress Corrosion Cracking in boiling Calcium Chloride per ASTM G36

Determining Susceptibility to Stress-Corrosion Cracking of Aluminium Alloy Products

- Stress Corrosion Cracking by Alternate Immersion Method per ASTM G44
- Stress Corrosion Cracking of Aluminum Alloys per ASTM G47
- Stress Corrosion Cracking Resistance of Al-Zn-Mg-Cu Alloys per ASTM G103
- Exfoliation Corrosion Susceptibility of Aluminum Alloys (ASSET Test) per ASTM G66
- Exfoliation Corrosion Susceptibility in Aluminium Alloys (EXCO Test) per ASTM G34
- Intergranular Corrosion of Aluminum Alloys by Mass Loss (NAMLT Test) per ASTM G67
- Intergranular Corrosion Resistance of Heat Treatable Aluminium Alloys per ASTM G110

Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys

- Ferric Chloride pitting test ASTM G48 method A
- Ferric Chloride crevice test ASTM G48 method B
- Critical Pitting Temperature test for nickel-base and chromium-bearing alloys per ASTM G48 method C
- Critical Crevice Temperature test for nickel-base and chromium-bearing alloys per ASTM G48 method D
- Critical Pitting Temperature test for Stainless Steel ASTM G48 method E
- Critical Crevice Temperature test for Stainless Steel ASTM G48 method F

Detecting Detrimental Intermetallic Phase in Austenitic/Ferritic (Duplex) Stainless Steel

- Sodium Hydroxide Etch test of Duplex Stainless Steel per ASTM A923 method A
- Charpy Impact test for Classification of Structures of Duplex Stainless Steels per ASTM A923 method B
- Ferric Chloride Corrosion test for Classification of Structures of Duplex Stainless Steels per ASTM A923 method C

NACE MR0175/ISO 15156: Petroleum and Natural Gas Industries- Materials for use in H2S-containing Environments in Oil and Gas production

Hydrogen Induced Cracking Test per NACE TM0284

- Stress Oriented Hydrogen Induced Cracking Test (SOHIC) per NACE TM0103
- Sulfide Stress Corrosion Cracking (Room Temperature) per NACE TM0177
- Sulfide Stress Corrosion Cracking (90 Deg C, 16 bar) per NACE TM0177
- Sulfide Stress Corrosion Cracking (120 Deg C, 20 bar) per NACE TM0177
- Sulfide Stress Corrosion Cracking Double-Cantilever-Beam (DCB) Test per NACE TM0177 method D
- Stress Corrosion Cracking (Four-Point Bend) of Materials for Oil and Gas Applications per NACE TM0316
- Stress Corrosion Cracking (Four-Point Bend) per NACE TM0177 and ASTM G39

Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys

- Stress Corrosion Cracking (Ammonia Vapour Test) per ASTM B858
- Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper per ASTM B577

Metallic Material and Coated Metallic Substrate

- Salt Spray (Fog) per ASTM B117
- Neutral salt spray (NSS) per ISO 9227
- Acetic acid salt spray (AASS) per ISO 9227
- Copper-accelerated acetic acid salt spray (CASS) per ISO 9227
- Mechanical Hydrogen Embrittlement Evaluation as per ASTM F519

Additional Standards: NACE TM0177 Methods A to D and NACE TM0284 (sulphide stress and hydrogen-induced cracking), NACE MR0175 / ISO 15156 and NACE MR0103 (sour-service materials), NACE TM0316 and NACE TM0198. ASTM G28, G31, G47, G44, G48, G61, G85, G123, G42, G146, A262, B117, G8, F2129, F519, F1624. NORSOK M-710.

Project qualification: PDO specifications SP-2347 (carbon-steel line pipe), SP-2337, and SP-2161, and OQGN G14-PD-PL Version 1 (May 2024), with TCR on the PDO AVME MCI-121 approved-laboratory list and holding a multi-year JSRS certificate for the Oman market. Named line-pipe programmes include the 42-inch Fahud-Sohar Second Loop Line and the Marsa LNGB gas supply, with mills served including Jindal Saw, Man Industries, and Tsingshan Steel Pipe.

4.7.1 Sulphide Stress Cracking/Stress Corrosion Cracking (SSC/SCC)

NACE TM0177-2016 Methods A, B, C, and D. Method A (tensile): constant-load testing in H2S-saturated solution. Method B (bent-beam): C-ring and bent-beam specimens. Method C (C-ring): for tubulars. Method D (Double Cantilever Beam): for fracture-mechanics-based evaluation.

Sulphide stress corrosion cracking (SSC) is a form of hydrogen embrittlement cracking which occurs when a susceptible material is exposed to a corrosive environment containing water and H2S at a critical level of applied or residual tensile stress. TCR Engineering Services conducts the NACE TM0177 tests including Methods A and B for SSCC test at their corrosion testing laboratory.

NACE TM0177 tests at TCR includes both Tensile Test (Proof Rings) under Method A and Bent Beam Test (3 or 4 Point Bends) under Method B. NACE TM0177 specifies Solution A (acidified), Solution B (acidified and buffered) and Solution C (for martensitic stainless steel). Solution A is used in Methods A unless the properties of Solution B or C are specified. In any case, H2S is bubbled through the solution constantly throughout the test period.

Testing is performed in NACE solutions A and/or B, saturated with H2S at 24° and 90° Celsius. Stressed samples are exposed to sour environment for a predetermined time, after which they are removed and analysed for crack detection. NACE TM0177 specifies test duration of 30 days (720 hours) for Method A or B test.

TCR Engineering provides a printed report for individual or cluster of tests conducted at the laboratory. The report includes a description of the test sample, details of the testing procedure and pH values of the test solution before and after exposure, along with the result of each test. TCR Engineering requires 6 weeks to complete the SSC test.

The SSC tests at TCR Engineering in India are performed routinely for customers, using tensile and bent beam specimens. For each stress level and temperature, the following sample size is required:

Plate- 16mm Thickness x 160mm long

Pipe- 160 long pieces irrespective of dia, cut strip of 16mm width

Bar- 160mm long piece irrespective of diameter

4.7.2 Hydrogen-Induced Cracking (HIC)

NACE TM0284 HIC testing with standard solutions (Solution A, Solution B) at controlled temperature and pressure. Crack length ratio (CLR), crack thickness ratio (CTR), and crack sensitivity ratio (CSR) measurement via optical microscopy of sectioned specimens.

TCR manufactures and holds its own HIC reference and control specimens, a capability most laboratories outsource. This lets every HIC programme be validated against in-house controls and supports qualification samples sent in by Chinese, Korean, and European mills. The sour-service rigs are backed by custom autoclave fabrication, designed and built in-house for sour, hydrogen, and non-standard research environments.

TCR Engineering Services' corrosion testing laboratory performs HIC test to evaluate the resistance of pipelines, pressure vessel plate steels and hydrogen-induced Cracking caused by hydrogen absorption from aqueous sulphide corrosion. An unstressed test specimen is exposed to a solution at ambient temperature and pressure for a specified time, post which the test specimen is removed and evaluated.

NACE TM0284 specifies either Solution A or Solution B. Solution A is acidified brine. Solution B is simulated seawater prepared in accordance with ASTM D1141.52. In either case, H2S is bubbled through the solution constantly throughout the test period. NACE TM0284 specifies test duration of 96 hours.

TCR Engineering issues a detailed written report on completion of each test. Each report includes a description of the test sample received, the test procedure used, and the pH values of the test solution, before exposure and after the exposure. The test bars are cut into sections and examined under a microscope for hydrogen-induced cracks. The dimensions of any such cracks are recorded and used to compute the values in percentage for Crack Length Ratio (CLR), Crack Thickness Ratio (CTR) and Crack Sensitivity Ratio (CSR).

To conduct the HIC test, the following sample sizes are required:

Plate - 150mm x150mm with rolling direction marked

If the plate is more than 80mm thick - 250mm x 250mm sample size is required

Pipe - upto 2" OD - 200mm long

If the pipe is more than 2" OD pipe - 100mm long sample size is required

Bars - Upto 3" dia - 300mm long

If the Bars are more than 3" dia to 5" dia - 200mm long sample size is required

If the Bars are more than 5" dia - 100mm long sample size is required

Number of pieces to be tested:

- Up to 88mm thick/dia - Set of 3 pieces to be tested
- More than 88mm thick/dia - 5 pieces to be tested

4.7.3 Stepwise Cracking (SWC) and Stress-Oriented HIC (SOHIC)

Extended HIC testing under applied stress for sour-service line-pipe qualification. Combined NACE TM0284 and NACE TM0177 Method A protocols.

4.7.4 Hydrogen Induced Disbonding

HID test facility commissioned April 2026 per ASTM G146. Anchor application: clad pressure vessels and overlays in refining and petrochemical sour service.

4.7.5 Hydrogen Embrittlement

ASTM F519 (mechanical hydrogen embrittlement, plated and coated fasteners) plus API 20E (alloy and carbon steel bolting for use in the petroleum and natural gas industries). ASTM F1624 incremental step-load.

4.7.6 NORSOK M-710 Polymer and Composite Sour Service

NORSOK M-710 Rev. 3 qualification of non-metallic sealing, sealing-related, and load-bearing materials for sour service. Test campaigns covering Zytel, ULTEM, Ryton, and other engineering polymers.

4.7.7 Aerospace SCC

ASTM G47 alternate immersion stress corrosion cracking and ASTM G44 alternate immersion procedure for the 7xxx and 2xxx series aerospace aluminium alloys.

4.7.8 Cobalt Chromium Implant Electrochemical Corrosion

ASTM F2129 cyclic potentiodynamic polarisation for medical-device implant materials.

4.7.9 General Corrosion

Weight-loss immersion per ASTM G31, cyclic polarisation per ASTM G61, pitting resistance per ASTM G48, intergranular corrosion per ASTM A262 Practices A through F, salt spray per ASTM B117. ASTM G28, G85, G123, G42 also covered.

Intergranular corrosion: ASTM A262 Practices A through F and ISO 3651-1 for austenitic stainless steels; ASTM A763 Methods W, X, Y, and Z for ferritic grades; and ISO 3651-2 Methods A, B, and C for ferritic, austenitic, and duplex stainless steels.

Several methodologies are available at TCR Engineering Services for testing intergranular corrosion. To conduct these tests, TCR carefully chooses a method that is suitable for steel grade and grain boundary composition. Intergranular corrosion in stainless steels may result from precipitation of carbides, nitrides or intermetallic phases.

Only in the most highly oxidising solutions can an intergranular attack be caused by intermetallic phases. When a test is restricted to carbides in materials containing nitrides or intermetallic phases, a less oxidising solution is chosen. TCR Engineering Services frequently carries out a number of tests in India as per the ASTM A262 specification:

Oxalic Acid Test, ASTM A262, Practice A (Oxalic Acid Etch)

The oxalic acid etch test is a rapid method of screening specimens of certain stainless steel grades which are essentially free from susceptibility to intergranular attack associated with chromium carbide participates. The test is used for acceptance and not the rejection of a material.

Ferric Sulfate-Sulfuric Acid, ASTM A262 - Practice B (Streicher Test)

This test is based on weight loss determinations and provides a quantitative measure of relative performance of the material evaluated. The procedure includes subjecting a specimen to a 24 to 120-hour boil in ferric sulfate - 50% sulfuric acid. his procedure measures the susceptibility of stainless steel and nickel alloys to intergranular attack associated with the precipitation of chromium carbides at grain boundaries.

Nitric Acid, ASTM A262, Practice C, (Huey Test)

The specimens are boiled for five periods, each for 48 hours in 65 percent nitric acid solution. The corrosion rate during each boiling period is calculated from the decrease in the weight of the specimens. The results, when properly interpreted can reveal whether or not the steel has been heat-treated in the correct manner. The customer must specify the maximum permissible corrosion rate and in applicable cases, provide the data on sensibilising heat treatment.

The Huey test environment is strongly oxidising and is only used as a check to ascertain if the material has been correctly heat treated. This test is suitable for the detection of chromium depleted regions as well as intermetallic precipitations, like sigma phase in the material. The Huey test is also used for materials that come into contact with strongly oxidising agents, e.g. nitric acid. This procedure may also be used to check the effectiveness of stabilising elements and of reductions in carbon content in reducing susceptibility to intergranular attack in chromium-nickel stainless steels.

Copper - Copper Sulfate - 16% Sulfuric acid, ASTM A262 - Practice E (Strauss Test)

This procedure is conducted to determine the susceptibility of austenitic stainless steel to intergranular attack associated with the precipitation of chromium-rich carbides. Once the specimen has been subjected to the solution boil, it is bent through 180° and over a diameter equal to the thickness of the specimen being bent. This test is based on a visual examination of the bent specimen.

Copper - Copper Sulfate - 50% Sulfuric acid, ASTM A262 - Practice F

This test is based on weight loss determination, which provides a quantitative measure of the relative performance of the material evaluated. It measures the susceptibility of "as received" stainless steel to intergranular attack.

Electrochemical corrosion: Potentiostatic and potentiodynamic anodic polarisation per ASTM G5, cyclic potentiodynamic polarisation per ASTM G61, electrochemical impedance spectroscopy for polarisation resistance and corrosion rate, immersion testing per ASTM G31, polythionic-acid stress corrosion per ASTM G35, specimen preparation per ASTM G1, pitting evaluation per ASTM G46, and corrosion-rate determination from Tafel slopes per ASTM G102.

Pitting and crevice corrosion: ASTM G48 Methods A through F, covering ferric-chloride pitting and crevice tests and critical pitting and crevice temperatures for stainless and nickel-base alloys. Chloride stress corrosion cracking in boiling magnesium chloride and calcium chloride per ASTM G36 to ONGC and EIL specifications.

Aluminium alloy stress corrosion: Alternate immersion per ASTM G44, ASTM G47, and ASTM G103; exfoliation per ASTM G66 (ASSET) and ASTM G34 (EXCO); and intergranular attack per ASTM G67 (NAMLT) and ASTM G110.

Duplex stainless steel intermetallic phase per ASTM A923 Methods A, B, and C. Copper-alloy stress corrosion per ASTM B858 (ammonia vapour) and hydrogen-embrittlement susceptibility per ASTM B577. Salt spray per ASTM B117 and neutral, acetic-acid, and copper-accelerated salt spray per ISO 9227.

Salt Spray Services

The senior technical team at TCR Engineering Services has deep industry expertise in handling diverse corrosion problems encountered in oil and gas production, oil and gas transmission, energy conversion systems, and nuclear power systems. A wide variety of corrosion related tests can be undertaken at TCR Engineering Services to determine weight loss corrosion, intergranular corrosion attack, pitting corrosion, corrosion fatigue, stress corrosion cracking, sulphide stress corrosion cracking, and hydrogen-induced corrosion cracking. TCR also performs tests listed under 3rd party inspection of LRS, TUV, DNV, ABS and other inspection agencies at their laboratory.

Salt Spray (Neutral / Fog), ASTM B117

This is the most commonly used salt spray for testing inorganic and organic coatings, especially when such types of tests are used for material or product specifications. Salt Spray testing is a tool for evaluating the uniformity of thickness and the degree of porosity of metallic and non-metallic protective coatings. Several samples can be tested simultaneously depending on their size.

Corrosion Test in artificial atmospheres – Salt Spray Test, ISO 9227

This procedure is employed to assessment of corrosion resistance of metallic material with or without permanent temporary corrosion protection. The selection of test methods that can be used in the identification and examination of rusting as well as the evaluation of pitting corrosion to determine the extent of its effect in various atmospheres with respective to Method NSS, AASS & CASS.

4.8 Coating Evaluation and Inspection

Paint and coating evaluation for industrial, marine, and infrastructure coatings. Cross-cut adhesion (ASTM D3359), pull-off adhesion (ASTM D4541), coating thickness (ISO 2808, ASTM D7091), holiday detection, cathodic disbondment (ASTM G8), salt spray resistance, cyclic corrosion, abrasion resistance, UV accelerated weathering. SEM and EDS for galvanised coatings. FTIR and DSC for epoxy coatings. TGA for bituminous coatings. Evaluation of elastomeric coating performance under sour-service exposure (Shell-approved capability).

AMPP/NACE certified and BGas-certified inspectors. The capability covers field inspection through the coating lifecycle (surface preparation, primer, intermediate, topcoat, holiday detection, and post-cure DFT/WFT verification) plus laboratory evaluation of coating systems (cross-pillar reference, Section 4.8 for ASTM D3359 cross-cut adhesion, ASTM D4541 pull-off, ISO 2808 / ASTM D7091 thickness, ASTM G8 cathodic disbondment, ASTM B117 salt spray).

Field Capability	Standard
Surface preparation visual standard	SSPC-VIS 1, ISO 8501-1
Anchor profile	ASTM D4417, ISO 8503
Dust contamination	ISO 8502-3

Field Capability	Standard
Soluble salt contamination	ISO 8502-6, ISO 8502-9
Wet film thickness	ASTM D4414
Dry film thickness	ASTM D7091, ISO 2808
Holiday detection	NACE SP0188
Adhesion (field)	ASTM D3359 (cross-cut), ASTM D4541 (pull-off)
Cure verification	DSC, FTIR, Persoz hardness

The Shell-approved capability for elastomeric coating evaluation under sour-service exposure (Section 4.7 cross-reference) sits in the laboratory complement.

Reference: ISO 12944 corrosion-protection-by-coating series.

Standards: ASTM D3359 (adhesion), ASTM D4541 (pull-off adhesion), ASTM D7091 (dry-film thickness), ASTM D822 and D4587 (weathering), ASTM B117 (salt spray), ASTM G8 and G42 (cathodic disbondment). ISO 2808 (film thickness), ISO 4624 (pull-off), ISO 12944 (protective paint systems).

4.9 Welder Certification and Procedure Qualification

ASME Section IX 2023 Edition welder qualification (WQT), welding procedure qualification (PQR), and welding procedure specification (WPS) testing. AWS D1.1 2025 Edition for structural steel. AWS D1.5 for bridge welding. API 1104 22nd Edition (2021) for pipeline welds. IS 7318 for welder qualification to Indian standards. EN ISO 9606 series. CSWIP and AWS CWI-certified inspection personnel run the witnessing.

The capability extends to CTOD on welding electrodes at negative 45 degrees Celsius (E7018, E7018-1) and CTOD per ONGC Spec 2009F Rev. 8 with FMA preparation.

Coverage extends to AWS D1.2 for structural aluminium, ASME Section VIII for pressure-vessel fabrication, and API 1104 for pipeline and cross-country pipework welds, with coupon programmes combining visual, mechanical, metallographic, and non-destructive examination.

TCR Engineering Services provides a comprehensive welder certification and welding procedure programme that includes:

1. Welder Qualification Testing for performance qualification and certification of welders (a welder / welding operator performances qualification - WQT) to ASME Sec. IX, ASME Sec. VIII, ANSI, AWS D 1.1, AWS D 1.2, API 1104 etc.
2. Preparation for Weld Procedure Qualification (WPS) that is relevant for either the project or any client requirements
3. Coupon Testing as per Welding Procedure Qualification including visual examination, mechanical testing, metallographic examination, and non-destructive testing
4. Documentation of the Procedure Qualification Record (PQR) as per ASME Sec. IX, ASME Sec. VIII, ANSI, AWS D1.1, AWS D1.2, API 1104 etc.

5. Detailed weld inspection including review of the qualification e.g. weld procedure specification, welder performance qualification, validity for process materials and consumable items, equipment, setup and other factors including certificates of calibration and/or conformity governing the task
6. Ascertain safety of operations for self, welder and other workers in the vicinity, particularly ultraviolet radiation from arc during welding

Welding Procedure Program

The welding inspector deployed on-site by TCR is responsible for monitoring and verifying conformity of tasks against all the relevant requirements including codes, specifications and/or standards:

- Ascertain the Weld Procedure(S) Employed
- Review Weld Procedure and Welder Qualifications
- Supervise Weld Profile Preparation
- Inspect Joint Fit-U
- Oversee Filler Metals and Consumable Materials
- Ensure Correct Welding Performance Parameters are Maintained
- Perform Visual Examination Upon Completion Of Welding Monitor
- Specified Pre and Post Weld Heat Treatment
- Monitor the Physical Examination including Non-Destructive Test, Hydrostatic Test, and Mechanical Test Etc.
- Based On the Requirement, the Inspector may Choose to send Test Samples to the TCR Engineering Services' Material Testing Laboratory
- Verify all Necessary Visual Inspections are completed and all other necessary Non-Destructive Examinations are Executed as Specified

Based on the requirements, the inspector may employ equipment's to accelerate the process:

- Inspection Mirrors
- Torch or other Electrical Lighting Facilities (permitted by safety codes eg. 24V system etc.)
- Physical Size Measuring Instruments such as Welding Gauge, Rule, Vernier etc.
- Electrical Parameter Measuring Instruments such as an Ammeter, Voltmeter etc.
- Temperature Measuring Instruments (Thermometer)/Aids (Thermo Chalk)
- TCR Engineering dedicated materials testing laboratory in Mumbai and Bhubaneswar undertakes mechanical testing and chemical analysis as recommended in ASME Section IX, ASME Section VIII Division-1, AWS Division 1.1, API 1104 & Customer Specifications. Testing for Electrode qualification as per ASME Section II Part C, IS 814 can also be done in our Laboratories. These tests are done for Welding Procedure Specification (WPS)/ Procedure Qualification Record (PQR), Welder Performance Qualification (WPQ) & Production Weld Coupons.
- The laboratory is fully compliant to NABL and ISO 17025.Tests done for WPS as per ASME Section IX & API 1104 include All Weld Tensile Test, Transverse Tensile Test (as per API/ISO), Nick Break Test, Bend Test, Macro, Micro, Hardness, Chemical Analysis, Charpy V Notch Impact, and Radiography of weld coupon.
- TCR requires coupon of the following sizes:
  - 12” NB = 1 coupon
  - 2” NB = 4 coupon for API 1104
  - 2” NB = 4 coupon for ASME Sec IX

- TCR Engineering has expert CWI and AWS inspectors who provide consultancy as IIW-IWS (RWC-External) for welders Training & Certification which includes training programmes for staff & welders, guidance for preparation of Quality Manual, Procedures, Work Instructions and Witness/Review of WPS/PQR/WPQ tests.

Standards: ASME Section IX (WPS, PQR, WQT), AWS D1.1 (structural steel), AWS D1.2 (structural aluminium), AWS D1.5 (bridge welding), API 1104 (pipeline welds), IS 7318 (welder qualification), EN ISO 9606 series.

4.10 Fatigue and Fracture Toughness Testing

High-cycle fatigue testing at room and elevated temperatures per ASTM E466. Low-cycle fatigue per ASTM E606 Fatigue crack growth rate per ASTM E647. Fracture toughness: K1c per ASTM E399, J1c per ASTM E1820, CTOD per BS 7448 and ASTM E1820 (formerly ASTM E1290). Charpy impact transition curve development.

The in-house 50, 250 and 1000 kN Fatigue CTOD machine per ASTM E1820 underpins the Engineering Critical Analysis (ECA) programme for pipeline girth welds.

The first laboratory in India for grout fatigue per CEB-FIP Model Code 1990 / 2010. Manhole and gully top fatigue per BS EN 124-5 up to 900 mm covers municipal infrastructure clients.

Creep-fatigue interaction per ASTM E2714. Axial strain-controlled fatigue per ISO 12106 and fatigue crack growth per ISO 12108. Rail butt-weld uniaxial fatigue per BS EN 14587-2, IRS:T-19, and ISO 14587.

Railway rail-weld fatigue per RDSO IRS:T-29 and IRS:T-19 runs to 5 million cycles at 8.33 to 9.0 Hz under four-point bending over a 1,000 mm span on the 1,000 kN dynamic frame, with three specimens drawn from eleven for statistical validation. High-tensile strand for prestressed bridge and high-speed-rail cable systems is tested per IS 14268, ASTM A416, ISO 10138, EN 10138-3, and ISO 15630-3, including 2 million-cycle fatigue at 70 percent of actual yield strength.

Multiple servo-hydraulic systems, rated 1000 kN, 50 kN and 250 kN, run from ambient to 1000 degrees Celsius and cover spring fatigue, three-point bend fatigue, and fatigue crack propagation (da/dN versus delta-K). High strain rate testing reaches 300 mm per second on the 50 kN frame and 100 mm per second on the 250 kN frame; slow strain rate testing runs to 10 to the minus 7 mm per second on the 100 kN frame.

Fatigue testing applies cyclic loading to a test specimen, to understand its performance under similar conditions when in actual use. The load application can either be a repeated application of fixed load or simulation of in-service loads. The load application may be repeated millions of times and up to several hundred times per second.

Many engineering metals and alloys display embrittlement at reduced (below sub-zero) temperatures. Structures fabricated from them fracture or shatter unexpectedly at low temperatures when loaded to stress levels at which performance would otherwise be satisfactory at room temperature. To avoid such incidents, selection of the right material can be done by testing them for their mechanical properties.

In the recent years, tremendous interest has been generated in fracture toughness testing based on linear elastic fracture mechanics. Fracture mechanics principles have been used to quantify safety factors in structural design, taking into account crack propagation and/or brittle fracture. Most structural members, components, vessels, piping, aviation, and aerospace are designed according to analysis criteria that guard against failure. CTOD testing requirement is most common in welded coupon as recommended in ONGC, EIL, DNV & API specification.

TCR Engineering has expanded its capabilities to include fatigue, fracture toughness, CTOD and high-temperature tensile testing with the addition of two fatigue systems with the Universal Testing Machine which has a capacity of 50 kN and 250 kN. The versatile Servo-hydraulic systems will allow the mechanical testing laboratory to perform numerous types of fatigue tests on different specimen sizes and orientations, in the temperature range from ambient to 1000° C. TCR has the capability of applying linear displacements, utilising linear and hydraulic actuators. Comparison fatigue testing of OEM and alternate source parts can also be performed to demonstrate equivalency of fatigue life.

Technical Capabilities

TCR Engineering provides a diverse range of capabilities following ASTM/BS/ISO Specifications. Both ASTM E606 (Low-cycle fatigue, strain-controlled Fatigue Testing) and ASTM E466 (Load-controlled Fatigue Testing – High or Low-cycle fatigue testing) has been widely in use at TCR Engineering. Tests are also conducted for TMT RE-BAR, COUPLERS Fatigue test (100 Cycles test & 2 million Cycles test) as per IS 16172-2014.

TCR Engineering undertakes range of testing applications based out of its dedicated Fatigue Test Laboratory in Mumbai:

- Fatigue Crack Propagation [da/dN vs ΔK Studies]
- Fracture Mechanics [K1c, J1c, CTOD] Testing
- 3-Point Bend Testing of Materials
- Spring Fatigue Testing
- Room Temperature and High Temperature Tests [up to 1000 °C]
- Tension/Compression
- Low/High Cycle Fatigue (LCF/HCF) Testing
- High Temperature Tensile Tests [up to 1000 °C]
- High Strain Rate Testing [300mm/sec on 50KN and 100mm/sec on 250KN UTM]
- Slow Strain Rate Testing [10-7 mm/sec on 50kN UTM]

Fracture Toughness Testing: Fracture toughness determines the amount of stress required to propagate an existing flaw or defect in specific materials. Since traditional methods of destructive testing cannot always predict how a material will behave during defect fracture, toughness is very important at the design stage

- ASTM E1290: Standard Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement
- ASTM E1820: Standard Test Method for Measurement of Fracture Toughness
- ASTM E399: Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness KIc of Metallic Materials
- Strain Fracture Toughness (KIC) for Metallic Materials
- ASTM E647: Standard Test Method for Measurement of Fatigue Crack Growth Rates
- BS 7448 (Part 1 to part 4) Fracture Mechanics Toughness tests. Method for Determination of KLC, Critical CTOD and Critical J Values of Welds in Metallic Materials

Crack-Tip Opening Displacement Testing: Crack-tip opening displacement is used as a type of fracture-toughness testing to determine if a material is appropriate for strenuous working conditions. CTOD testing is the measure of deformation, prior to failure in pre-cracked samples. This type of test is a variation of fatigue testing that has load rates more as representative of in-service conditions. TCR has capability to conduct the CTOD testing at temperature from Ambient to -25 °C

4.10.1 Fatigue Test

- ASTM E466: Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
- ASTM E606: Standard Practice for Strain-Controlled Fatigue Testing
- ASTM E 2714 – Standard Test Method for Creep-Fatigue Testing
- ISO 12106: Metallic materials — Fatigue testing —Axial-strain-controlled method
- ISO 12108-2002 (E) – Metallic materials – Fatigue testing – Fatigue crack growth Method
- IS16172-2014 Reinforcement Couplers for Mechanical Splices of Bars in Concrete- Specification
- Uniaxial Fatigue Test as per BS EN 14587-2, IRS:T-19, ISO 14587

4.10.2 Fatigue Testing of Butt-Welded Track Rail

Fatigue testing of weld joints in rail tracks, as per IRS:T-19, ISO 14587 & other National/International standards, is a crucial aspect of ensuring the safety and longevity of railway infrastructure. By following standardised testing procedures, rail industry professionals can gain valuable insights into the fatigue performance of weld joints, leading to improved design practices and enhanced reliability of rail tracks worldwide.

Fatigue testing involves subjecting the welded rail joint to repeated loading cycles that simulate the dynamic forces experienced during normal train operations. The purpose of this testing is to evaluate the performance of the welded joint under repeated stress and determine its ability to withstand the anticipated service conditions without failure or degradation over time.

Test Set-Up

A representative length of welded rail joint, usually several metres long (span length 1.5 meter), is selected for testing. The rail is typically mounted on a test fixture or a specialised fatigue testing machine that applies cyclic loading (4-point bend) to the joint. The loading can be applied in the form of vertical, forces, depending on the specific requirements as per relevant national/International standards.

Cycle Loading

The rail joint is subjected to repeated loading cycles that simulate the stress patterns encountered during train operations. The loading can vary in magnitude, frequency, and direction to simulate different operating conditions. The number of cycles applied during testing depends on the desired fatigue life assessment.

Monitoring and Measurements

During the fatigue test, various parameters are monitored and measured to assess the performance of the welded joint. These may include strain, displacement, crack propagation, and other relevant factors. Advanced measurement techniques such as strain gauges or non-destructive testing methods may be employed to gather accurate data.

Failure Criteria

The test is typically continued until a predefined failure criterion is reached. This criterion can be defined based on the appearance of cracks, changes in strain or displacement values, or other factors indicating potential failure or significant degradation of the welded joint.

Evaluation and Analysis

After the test, the collected data is analysed to determine the fatigue life and performance characteristics of the welded rail joint. This analysis helps in understanding the joint's ability to withstand cyclic loading and predict its service life in real-world operating conditions.

Standards and Regulations

Fatigue testing of butt-welded track rail is often conducted in accordance with specific industry standards and regulations. These standards provide guidelines for test procedures, acceptance criteria, and performance evaluation methodologies.

Applicable standards include RDSO IRS:T-19, ISO 14587, BS EN 14587 Parts 1 and 2, and BS EN 13674-1, covering flash butt and other rail butt-welding processes. Track fastenings are covered by IRS T-31 (Elastic Rail Clips MK-V Type, ERC) and IRS T-44 (Insulating Liners RT-3506, GFN-66/HVN).

By performing fatigue testing on butt welded track rail, railway authorities and manufacturers can ensure that the rail joints are robust, reliable, and capable of withstanding the anticipated stresses and strains during the operational lifespan of the railway track. This testing helps enhance safety, reduce maintenance costs, and optimise the performance of rail systems.

Spectrum of Services:

At our fatigue testing division, we are equipped with an advanced Dynamic Universal Testing Machine (UTM) that offers unparalleled capabilities for conducting various fatigue tests. Our Dynamic UTM is designed to handle a wide range of testing requirements and can accommodate specimens of different sizes and strengths.

Here's a detailed overview of our testing machine and the comprehensive capabilities it offers:

Dynamic UTM Specifications:

- Capacity: Our Dynamic UTM boasts impressive load capacities, allowing us to conduct fatigue testing on a diverse range of materials and components. With load capacities of 50kN, 250kN, and 1000kN, we can effectively evaluate the fatigue behaviour of various specimens.
- Frequency Range: Our Dynamic UTM operates within a frequency range of 0.01Hz to 40Hz, enabling us to simulate real-world loading conditions and accurately assess the fatigue performance of materials under dynamic loading.

In our fatigue testing division, we specialise in a range of fatigue testing methodologies, including:

4.10.3 Fracture Toughness (KIC) Test

- Specimen Size: We can test specimens ranging from 8mm to 32mm in thickness on Test temperature range: at subzero up to -20 °C & at elevated temperature up to 1100 °C. We can test specimens ranging from 8mm to 50mm (CT/SENB specimen) at Room Temperature & over 50 mm to 100mm (SENB specimen only, depends on the strength of material)

- Test Method: Our testing procedures adhere to recognised industry standards such as ASTM E399, ASTM E1820, ASTM B645, BS7448 (Part 1-4), ISO12135, ISO 12737 and ISO15653, ensuring accurate and reliable results.
- Test temperature range: -20°C to 1100°C

4.10.4 Fatigue Crack Growth Rate (FCGR) Test

- Specimen Size: We can test specimens ranging from 8mm to 32mm in thickness on Test temperature range: at subzero up to -20 °C & at elevated temperature up to 1100 °C. We can test specimens ranging from 8mm to 50mm (CT/SENB specimen) at Room Temperature & over 50 mm to 100mm (SENB specimen only, depends on the strength of material)
- Test Method: Our testing protocols strictly follow ASTM E647, ISO 12108 guidelines, allowing us to assess the crack growth behaviour under fatigue loading accurately.
- Test temperature range: -20°C to 1100°C

4.10.5 CTOD Test (Crack Tip Opening Displacement)

- Specimen Size: We can test specimens ranging from 8mm to 32mm in thickness on Test temperature range: at subzero up to -20 °C & at elevated temperature up to 1100 °C. We can test specimens ranging from 8mm to 50mm (CT/SENB specimen) at Room Temperature & over 50 mm to 100mm (SENB specimen only, depends on the strength of material)
- Span Length: Our testing equipment accommodates span lengths between 55mm and 1,600mm.
- Test Method: We adhere to industry standards such as ASTM E1290, ASTM E1820, BS7448 (Part 1-4), ISO12135, and ISO15653, ensuring precise CTOD measurements.
- Test temperature range: -20°C to 1100°C

4.10.6 J-Integral (JIC) Test

- Specimen Size: We can test specimens ranging from 8mm to 32mm in thickness on Test temperature range: at subzero up to -20 °C & at elevated temperature up to 1100 °C. We can test specimens ranging from 8mm to 50mm (CT/SENB specimen) at Room Temperature & over 50 mm to 100mm (SENB specimen only, depends on the strength of material)
- Test Method: We follow standardised test methods, including ASTM E1820, ASTM B645, BS7448 (Part 1-4), ISO12135, and ISO15653, to accurately determine the J-Integral values.
- Test temperature range: -20°C to 1100°C

4.10.7 Uni-axial Fatigue Test

- Test Method: Our fatigue testing procedures align with ASTM E466, ASTM E606, and IS 5074, IS 16172 guidelines, ensuring comprehensive assessment of uni-axial fatigue behaviour.
- Test temperature range: ambient to 1100°C

4.10.8 Helical Spring Test (RDSO / National / International Standards)

- Static Load Test.
- Load v/s Displacement (Spring Constant/ Spring Rate)
- Fatigue Test

Additionally, our capabilities extend beyond traditional fatigue testing, as we offer specialised testing for Reinforcement Couplers and Grouter for Mechanical Splices of Bars in Concrete. Our testing services in this area include:

- Static Tensile Test
- Slip Test

- Cyclic Tensile Test
- Fatigue Test
- Low Cycle Fatigue Test
- High Cycle Fatigue Test

We can accommodate reinforced bars with nominal diameters ranging from 8mm to 40mm, adhering to relevant industry standards such as IS16172, ASTM A1034, IS16651, ISO15630, and ISO15835-2. With our Dynamic UTM and comprehensive range of testing capabilities, we are well-equipped to meet your fatigue testing needs, providing accurate and reliable results for a wide range of materials.

4.10.9 Fatigue Testing of Gully and Manhole Tops Made of Composite Materials

Test as per BS EN BS EN 124-1 and BS EN 124-5

At TCR, we understand the critical importance of ensuring the durability, reliability, and safety of infrastructure components like gully and manhole tops, especially when constructed from advanced composite materials. Fatigue testing simulates real-world conditions and repetitive stresses that gully and manhole tops may experience over their operational lifetimes. By subjecting these components to fatigue testing, manufacturers and users can assess how well the materials and structures withstand cyclic loading without developing cracks or failures. This ensures the products' long-term reliability and helps in predicting their lifespan.

Gully and manhole tops are critical components of infrastructure, often subjected to heavy loads, traffic, and environmental stresses. Fatigue testing helps identify potential weaknesses or fatigue-related failure modes that could compromise structural integrity and safety over time. Addressing these issues early through testing minimises the risk of sudden failures, ensuring safer operation and maintenance of infrastructure.

Gully and manhole tops are fatigue tested as complete units in their intended position of use where cover/grating is suitably positioned within the frame and the frame is supported in a manner to replicate intended installation support structure. TCR’s facilities and expertise thoroughly evaluates against the rigorous requirements outlined in BS EN 124-1 (for gully tops) and BS EN 124-5 (for manhole tops) with rectangular / circular / triangular as well as double or multiple triangular covers and/or gratings.

TCR’s testing protocols cover a comprehensive range of performance factors, including load-bearing capacity, impact resistance, chemical resistance, and fatigue durability. TCR's fracture mechanics department has specialised testing machine (complying to EN ISO 7500-1:2004) which includes a Servo Hydraulic Dynamic UTM machine which is capable of applying a load as recommended (at least 25 % greater) than the respective test load (FT) for classes A 15 to D 400 and (at least 10 % greater than) the respective test load (FT)for classes E 600 and F 900.

Conducting fatigue testing as part of quality control processes ensures that manufactured gully and manhole tops meet design specifications and performance expectations. It helps manufacturers identify potential design flaws, material weaknesses, or manufacturing defects that could lead to premature failures in the field, thereby improving overall product quality and customer satisfaction.

TCR also specialises in conducting both the Permanent Set Test and Load Bearing Capacity Test to evaluate material performance. The Permanent Set Test is undertaken to evaluate a material's resilience by measuring its ability to recover its original shape after being subjected to a specified load over a defined period. Additionally, TCR conducts the Load Bearing Capacity Test to determine the maximum load a material or structure can endure before failure. This test provides crucial insights into the strength and durability of metals, polymers, composites, and other materials, supporting informed engineering and design decisions with precise data.

Whether you're a manufacturer seeking compliance validation or Kitemark certification, or a specifier ensuring product suitability, our dedicated team of experts is here to support you every step of the way. By partnering with us, you can be confident that your composite gully and manhole tops will undergo detailed testing processes.

Standards: ASTM E466 (high-cycle fatigue), ASTM E606 (low-cycle fatigue), ASTM E647 (fatigue crack growth), ASTM E399 (K1c), ASTM E1820 (J1c and CTOD), ASTM E561 (R-curve), ASTM E2714 (creep-fatigue). BS 7448 (CTOD). ISO 12106 and ISO 12108. API 5L3 (drop-weight tear). BS EN 124-5 and BS EN 14587-2 (infrastructure and rail fatigue).

4.11 Metallurgical Evaluation

Full metallurgical laboratory covering microstructural analysis, grain size, inclusion rating, phase identification, and heat-treatment evaluation. Equipment: optical microscopes with image analysis (up to 1,000x), stereo microscopes, automatic grinders and polishers, hot mounting presses, etching and staining stations. Three Scanning Electron Microscopes sit at TCR Advanced Vadodara: Pemtron SS100, Jeol JCM 6000+, and Phenom XL G2 with 60,000x magnification using a CeB_6 source.

The 100,000+ replicated microstructure database. The reference base sits behind the in-situ replica field service: replicated structures retained physically and image-archived since the early 1990s, with calibrated reading metallurgists carrying institutional memory across creep cavitation classes, decarburisation, sigma phase, theta phase, $M_{23}C_6$ carbide morphology, and reformer-tube specific damage signatures (carburisation, carbide coarsening, internal oxidation, reformer-tube creep grades A through E).

The metallurgists at TCR have deep expertise in Metallographic preparation and examination to evaluate the characteristics of metals. They are highly skilled to assess a particular material’s heat treatment condition, microstructure, and forming process. The team undertakes macro and micro examination including Weld Examination, Case Depth and Decarburisation Measurement, Micro Hardness Testing and Coating/Plating evaluation.

The Metallography department employs the 3 different SEM/EDAX, Inverted Metallurgical microscope, Olympus GX51 and the Leco 500 microscope with an Image Analysis System. The technical team has indigenously developed a microstructure characterizer software that assists with the analysis of images to determine microstructural degradation due to creep. The software can also calculate the graphitisation, depth or width of decarburisation, phase/volume percentage, grain growth, inclusion rating, particle size, volume percentage, particle count, porosity and coating thickness.

TCR undertakes metallurgical evaluation using SEM, EDAX, XRD and TEM technologies

The ambit of frequently tested services in TCR metallography lab include:

- Microstructure Examination (Routine) with two photographs
- NDT microstructure with two photographs
- Microstructure with Comment on Heat Treatment

- Microstructure examination for failure related study
- Grain size distribution chart on Image Analysis (With print out)
- Prior austenite grain size measurement (including heat treatment charges)
- Prior austenite grain size measurement by Mc Quid Ehn method (including carburising)
- Oxide-scale/Nitriding/Carburising/Decarburising/ Coating – Measurements. (Avg. of 3 readings), over and above microstructure examination charge
- Grain size Measurement as per ASTM E112 with photograph
- Linear measurement, up to 3 measurements, over and above macrostructure/microstructure examination charge
- Each Additional linear measurement
- Inclusion Rating as per ASTM E45 Method A with photograph
- Inclusion rating as per ASTM E45 with photograph
- Color Metallography (With two Photos)
- Delta ferrite from SS weld microstructure, Sigma phase, volume fraction by microstructure examination (Avg. 3 frames)
- % Nodularity, Nodule Count as per ASTM A247 and IS 1865
- Porosity Analysis as per ASTM A 276
- Decarburization Level as per IS 6396 And ASTM E 1077
- Phase Distribution as per ASTM E 562 / 1245
- Powder Particle Size Measurement (Avg. 5 Frames)
- Coating Thickness Measurement as per ASTM B 487
- Retained Austenite Measurement with Electro Polish and Copper Deposition Method, And Calculation On Image Analysis Software from Microstructure Examination. (Avg. 3 Frames)
- Micro-Hardness Testing
- Micro Hardness Profile For Case Depth Measurement (Max. 10 Readings)
- Macro Etch Test Up To 100 Mm (Including Photo & Comments)
- Macro Etch Test Between 100 To 200 Mm (Including Photo & Comments)
- Macro Etch Test Over 200 Mm (Including Photo & Comments)
- Fractography by Stereo Microscope
- Fractography by SEM
- Coating Thickness by SEM
- Microstructure Examination Test With Photographs, Grain Size Comment On Carbide Precipitation, Nitrides & Intermetallic Phases In Haz, Parent, Weld As Per A-923 METHOD A, ASTM E-45 for Inclusion Rating
- Hydrogen Embrittlement on Copper
- Ferrite As Per ASTM E562 per Phase per Sample
- Intermetallic Phase (Chi, Sigma, Laves Nitrate Carbide) per phase per Sample
- Intermetallic Phases In Weld, Parent Material (PM), Heat Affected Zone (HAZ) per phase per Sample
- Microstructure Test with Photograph (For Sigma Phase)
- icrostructure Test With Photograph (For Ferrite Content)
- Analysis Of a Given SEM Image for Particle Size and Particle Size Distribution
- (Max/Min, Size/Frequency Information) Of the Dispersed Phase in a Continuous Phase Matrix.
- Cost To Prepare the Sample for Placement In SEM Sample Chamber
- SEM Analysis with Single Image
- Delta Ferrite Measurement by Ferritscope
- Pit Dimension Measurement
- EDAX / EDS Analysis

- XRD Analysis
- In-Situ Replica Interpretation only On a Client Supplied Replica. (Please Note: TCR will not be held responsible for accurate data interpretation in areas where a TCR technician has not taken the replicas
- Structural Examination Charges (As Per 6.1)
- Structural Examination (Each Additional Measurement)
- Inclusion Rating as ASTM E45 – Method D (Set Of Six Specimen)
- Volume Fraction Measurement (30 Frames) as per ASTM E 562
- Microstructure as per A 923 Method A
- Microstructure Carbide Network as per SEP 52100 Chart (Heat Treatment Charges Are Extra)
- In-Situ Metallography
- Step Macro without Photograph – Each Step
- Step Macro with Photograph – Each Step
- Macro Measurement (MLP/Penetration) -Each
- Depth Of Attack
- Banding Index
- Intermetallic Phases – Charges On Request
- Coating/ Plating Thickness/Mesh Size
- Austenitic Grain Size with Photographs (Up To 3 Samples)

Macro-Examinations

In Macro-etching a specimen is etched and macro-structurally evaluated at low magnifications. It is a frequently-used technique for evaluating steel products such as billets, bars, blooms and forgings. There are several procedures for rating a steel specimen by a graded series of photographs, showing the incidence of certain conditions and is applicable to carbon and low alloy steels. A number of different etching reagents may be used depending upon the type of examination. Steels react differently to etching reagents because of variations in chemical composition, the method of manufacturing, heat treatment, and many other variables.

Macro-Examinations are also performed on polished and etched cross-sections of welded material. During the examination, a number of features can be determined including the weld run sequence, which is vital for weld procedure qualifications tests. Apart from this, any defects on the sample are assessed for relevant specifications and compliance. Slag, porosity, lack of weld penetration, lack of sidewall fusion and poor weld profile are among the features observed in this type of examination.

It is procedural to identify such defects, either by standard visual examination or at magnifications of up to 50X. It is also routine to photograph the section to provide a permanent record and this is known as a photomacrograph.

Micro Examination

This is performed on samples that are either cut to size or mounted on a resin mould. These samples are polished to a fine finish, typically a one-micron diamond paste and prior to an examination on the metallurgical microscope, it is usually etched in an appropriate chemical solution. Micro-examination is performed for a number of purposes, the most common of which is to assess the structure of the material. It is also customary to examine for metallurgical anomalies such as third phase precipitates, excessive grain growth, etc. Many routine tests such as phase counting or grain size determinations are performed in conjunction with micro-examinations.

Weld Examination

Metallographic weld evaluations take place in many forms. In its most simple format, weld deposits can be visually examined for large-scale defects such as porosity or lack of fusion defects. On a micro scale, the examination can take the form of phase balance assessments from weld cap, weld root or can even be checked for non-metallic or third phase precipitates. Examination of weld growth patterns is also used to determine the reasons for poor mechanical test results. For example, an extensive central columnar grain pattern can cause a plane of weakness, giving poor charpy results.

Case Depth

Case hardening may be defined as a process for hardening ferrous materials in such a manner that the surface layer (known as the case) is substantially harder than the remaining materials (known as the core). This process is controlled through carburising, nitriding, carbonitriding, cyaniding, induction, and flame hardening. The chemical composition and mechanical properties are affected by these practices. The methodology utilised for determining case depth can either be chemical, mechanical or visual and the appropriate one is selected based on specific requirements.

Decarburisation Measurement

This method is designed to detect changes in the microstructure, hardness or carbon content at the surface of steel sections due to carburisation. To determine the depth, a uniform microstructure, hardness or carbon content of the specimen interior is observed. This method detects surface losses in the carbon content due to heating at elevated temperatures

Coating / Plating Evaluation (ASTM B487, ASTM B748)

A coating or plating application is used primarily for the protection of the substrate. Thickness is an important factor in the performance of the coating or plating. A portion of the specimen is cut, mounted transversely and is prepared in accordance with acceptable or suitable techniques. The thickness of the cross section is measured with an optical microscope. When the coating or plating is thinner than .00020, the measurement is taken with the scanning electron microscope.

Cross-sectioned metallographic examinations of substrates with plating, surface evaluations, thickness measurements, weight per volume and even salt spray testing can aid in the evaluation of plating.

Surface Evaluation

Surface inspection includes the detection of surface flaws along with the measurement of surface roughness. One of the methods used to perform this test is the use of a laser light. Measurement and analysis is possible when scattered light is reflected off the surface of a sample, An alternative method is the use of a motorised stylus (profilometer), where the stylus is placed on the surface and the texture of the material is measured in micro-inches or millimetres.

Grain Size Determination (ASTM E112, ISO 643, IS 4748)

In order to establish a scale for grain size, ASTM E112 shows charts with outline grain structures for various dimensions. These universally accepted standards range from ASTM NO. 00 (very coarse) to 10 (very fine). A material's grain size is important as it affects its mechanical properties. In most materials, a refined grain structure gives enhanced toughness, and alloying elements are deliberately added during the steel-making process to assist with grain refinement. Grain size is determined from a polished and etched sample, using optical microscopy at a magnification of 100X.

4.11.1 Technology at TCR

SCANNING ELECTRON MICROSCOPE WITH EDS ANALYSER

TCR has three Scanning Electron Microscopes (SEM) attached to an Energy Dispersive Spectrometer (EDS) system. This is the highest number of SEM in any commercial lab in India.

SEM is a great diagnostic tool for:

- Failure Investigation
- Fractography
- Quality Control
- Morphology and Identification of Localised Defects
- Identifying Corrosion products at Microscopic levels
- Identifying Surface Coating or Plating
- Particle Size & Shape Analysis
- Characterising Creep in Microstructure
- Identifying Submicron Features in Microstructure
- Identification of Inclusions in metals

Standard:. ASTM E112 (grain size), ASTM E45 (inclusion rating), ASTM E3 (metallographic preparation), ASTM E407 (etching), ASTM E562 (volume fraction by point count), ASTM E1245 (automated image analysis of inclusions), ASTM E140 (hardness conversion), ASTM A247 (cast iron graphite classification). ASTM E1351 for in-situ replication. IS 4151, IS 4150.

Representative engagement: Reliance Industries Jamnagar, 1,200 in-situ metallographic replicas completed in fifteen days.

4.12 Composite, Plastic, Rubber, and FRP/GRP Testing

Testing of polymers, rubbers, and fibre-reinforced plastics for mechanical and environmental performance. Tensile, flexural, compression per ASTM D638, ASTM D790, ASTM D695. Izod impact on plastics per ASTM D256. Hardness (Shore A, D, IRHD) per ASTM D2240. Thermal properties: glass transition temperature, melting point, coefficient of thermal expansion, TGA, DSC. Environmental: accelerated weathering, UV resistance, heat ageing. FRP/GRP pipe qualification for hydrostatic performance, axial load, and cyclic pressure. ISO 527, ISO 178, ISO 179, ISO 180.

Mica testing for EV battery thermal insulation was introduced in 2026. Tile adhesive testing per IS 15477 (comprehensive shear, pull-off, open time, and slip tests) supports the construction-materials buyer.

Rubber and polymer characterisation also covers compression set and compressive strength on rubber, water absorption, filler content and identification, density, Fourier-transform infrared spectroscopy (FTIR).

At our advanced materials testing lab in India, we offer comprehensive testing services for composites, plastics, and rubber to ensure the quality, durability, and performance of your materials.

Our services include:

- Tensile Testing (Average of % Specimen): Measures the strength and elongation properties of materials under tension.
- Shore Hardness Testing (Shore A & Shore D): Determines material hardness levels for both soft and rigid plastics.
- Differential Scanning Calorimetry (DSC): Analyses thermal properties and stability.
- Thermogravimetric Analysis (TGA): Measures changes in material weight as it is heated.
- Fourier Transform Infrared Spectroscopy (FTIR): Identifies chemical bonds in a material.
- Filler Content & Identification: Determines the percentage and type of filler in materials.
- Density Testing: Measures material density.
- Water Absorption Testing: Evaluates material's resistance to water.
- Compression Set & Compressive Strength Testing: Assesses rubber deformation and compressive strength.

These tests ensure compliance with industry standards and provide insights into material performance for demanding applications.

Standards: ASTM D638, D790, and D695 (tensile, flexural, compression), ASTM D256 (Izod impact), ASTM D785 and D2240 (hardness). ISO 527, ISO 178, ISO 179, ISO 180. IS 15477 (tile adhesive).

4.13 Creep and Stress Rupture Testing

Long-duration creep and stress rupture testing per ASTM E139 and ASTM E292. Temperature range 400 degrees Celsius to 1,100 degrees Celsius. Load range 1 kN to 100 kN. Six constant-load creep frames at 50 kN, operating up to 1,100 degrees Celsius, with duration capability up to 100,000 hours. The international peer set typically runs two or three frames at most with a 700-degree Celsius ceiling.

Methods also include IS 3407 and ISO 204, with Accelerated Creep Rupture Testing (ACRT) feeding the remaining-life assessment programme for boilers, gas turbines, and reformer tubes.

TCR Engineering provides advanced testing solutions for evaluating high-temperature material behaviour through Creep, ACRT and Stress Rupture Testing, essential for industries where equipment operates under extreme heat and stress. These tests deliver critical insights into material durability, making them invaluable for applications in boilers, gas turbines, jet engines, ovens, and other high-temperature environments.

Understanding Creep and Stress Rupture

- Creep Testing measures the progressive deformation (creep) of materials under constant stress at elevated temperatures. The term “elevated temperature” is relative and depends on the specific material under testing. Creep testing is fundamental for understanding long-term material stability, especially in applications where continuous stress is applied at high temperatures. During a Creep Test, a tensile specimen is subjected to a constant load and temperature, and strain is recorded over time to determine the material's creep rate.
- Stress Rupture Testing builds on the principles of creep testing, with an increased stress level that brings the material to failure within a shorter timeframe. This test evaluates the time-to-failure for a material under high stress and temperature. Stress rupture testing continues until material failure, allowing for the direct determination of time-to-failure and elongation values. Data from these tests are plotted, often resulting in a linear or best-fit curve, providing essential material strength parameters for engineers.

TCR's Testing Capabilities

TCR Engineering is equipped to conduct the following tests in strict adherence to international standards, such as ASTM E139, E292, IS 3407, and ISO 204:

1. Creep Rupture / Creep Testing – Provides strain data over time for materials under constant load and temperature.
2. Stress Rupture Testing – Establishes time-to-failure for materials at high stress and temperature, helping engineers predict failure risks in high-stress environments.
3. Accelerated Creep Rupture Test (ACRT) – A faster alternative to traditional creep testing, allowing rapid assessment of material behaviour for Remaining Life Assessment (RLA) and Fitness-for-Service (FFS) evaluations.

4.13.1 Accelerated Creep Rupture Testing (ACRT): A Fast and Efficient Solution

ACRT is increasingly popular in industries for its time-saving benefits. Using the Larson-Miller equation to derive initial test parameters, ACRT enables a faster, efficient way to estimate material life. Results from ACRT are particularly valuable for Remaining Life Assessments (RLA) and Fitness-for-Service (FFS) analyses of boilers, conducted in line with API 530 and API 579 standards.

Key Benefits of TCR’s Creep and Stress Rupture Testing

- Reliable Data for Material Selection: Understanding how materials perform at elevated temperatures helps engineers design safer, more resilient systems.
- Enhanced Failure Prediction: Creep and stress rupture data provide insight into potential failure points, enabling proactive maintenance planning.
- Comprehensive Standards Compliance: TCR’s adherence to ASTM, IS, and ISO standards ensures that test results are dependable and applicable across global industrial standards.

By leveraging TCR Engineering’s expertise in Creep, Stress Rupture, and ACRT testing, clients gain vital data for high-temperature component design and risk mitigation.

Applications: power-plant steam-pipe qualification, reformer-tube material validation, turbine blade material assessment, supercritical and ultra-supercritical fossil-power qualification.

Standards: ASTM E139 (creep and stress rupture), ASTM E292 (notch rupture), ASTM E328 (stress relaxation), ASTM E633 (thermocouple reference). IS 3407. ISO 204.

4.14 Heat Treatment Verification Testing

This service line is distinct from the post-weld heat treatment (PWHT) physical-thermal processing carried in the NDT pillar (Section 5, subsection 5.7). PWHT physically heats components. Heat Treatment Verification Testing does not perform thermal processing. Heat treaters submit samples and TCR returns a NADCAP-accepted test report covering hardness, microstructural examination, grain size, case depth, retained austenite, and mechanical properties.

NADCAP framing: AC7101 Materials Testing accredited 2026, Performance Review Institute certificate 29415245997, valid to 31 May 2027. The accreditation positions TCR as the verification testing partner for NADCAP-accredited heat treaters and aerospace component manufacturers globally. TCR does not pursue AC7102 (Heat Treatment Process accreditation), which requires furnace operations which TCR does not perform.

Standards: ASTM E18 and ASTM E10 and ASTM E92 and ASTM E384 (hardness); ASTM E112 (grain size); ASTM E407 (etching); ASTM E45 (inclusions); SAE AMS 2750 (heat-treatment process specification reference); SAE AMS-H-6875 (heat treatment of steel raw material); SAE J423 (case depth methods); aerospace prime specifications (Boeing BAC, Airbus AIPS, Pratt & Whitney PWA, GE EM&S, Rolls-Royce RPS).

Defensible exclusivity. The TCR group holds NADCAP AC7101 Materials Testing accreditation at two independent commercial laboratories in India, Navi Mumbai and Vadodara, a position no other independent Indian materials-testing group occupies. The claim holds because the three or four NADCAP heat-treatment-accredited facilities in India are mostly captive aerospace operations at HAL, Bharat Forge, and similar, not independent commercial materials-testing labs.

> AEROSPACE EXCLUSIVITY
>
> The only independent commercial materials-testing group in India holding NADCAP AC7101 Materials Testing accreditation at two NABL-accredited laboratories, Navi Mumbai and Vadodara, the aerospace verification-testing route.

4.15 Residual Stress Determination by X-Ray Diffraction

Residual-stress measurement by X-ray diffraction quantifies surface and near-surface residual stress in welds, machined components, and shot-peened or surface-treated parts. The sin-squared-psi technique resolves the tensile and compressive stress fields that drive fatigue initiation and stress-corrosion susceptibility, which makes it a primary tool for weld qualification, peening verification, and failure investigation where residual stress is the suspected driver.

Standards: ASTM E2860 (residual-stress measurement by X-ray diffraction).

5. Non-Destructive Testing

700+	12+	350°C	300 mm
PMI PROJECTS, KSA, KUWAIT, INDIA	PORTABLE XRF ANALYSERS	HIGH-TEMPERATURE PAUT	PAUT THICKNESS RANGE

Non-Destructive Testing covers conventional radiography, ultrasonic, magnetic particle, liquid penetrant, and visual inspection methods, advanced ultrasonic methods (PAUT, TOFD, LRUT, EMAT, HTHA), specialised heat-exchanger tube inspection (ECT, RFT, IRIS, NFT), tank inspection per API 653.

The personnel stack is the foundation of credibility in this pillar. Three in-house ASNT Level III authorities lead by Shemi Bhaskaran for RT/LPT/MPI anchor the ASNT Level II field crew, 14 of whom carry BARC Level I radiography certifications, with 7 holding Radiological Safety Officer (RSO, BARC Level II) certification.

5.1 Conventional NDT Methods

The conventional NDT stack is the workhorse of every plant shutdown, fabrication audit, and welding inspection engagement. ASNT-certified Level II technicians cover all five conventional methods plus Positive Material Identification.

Standards: ASME BPVC Section V and Section IX (2023 editions). ASTM E94 and E1742 (radiography, film and digital), ASTM E165 and E1417 (liquid penetrant), ASTM E709 and E1444 (magnetic particle), ASTM E164 (contact ultrasonics). EN 1435 (radiography) and EN 1712 (ultrasonic acceptance). ISO 17636 (radiographic testing of welds) and ISO 11666 (ultrasonic acceptance levels).

5.1.1 Positive Material Identification (PMI)

PMI is one of the highest-volume field services in the group with 700+ projects executed across KSA, Kuwait, and India. Handheld and mobile XRF and OES analysers verify the chemical composition of metals and alloys on site in real time. PMI prevents material mix-ups that could lead to catastrophic failures in high-temperature or corrosive service. Anchor clients include Saudi Aramco, SABIC, MAADEN, TASNEE, and SATORP.

The PMI capability runs on a fleet of 12+ portable XRF analysers, allowing simultaneous deployment across multiple sites and turnarounds.

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

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 equipment available at TCR for undertaking Positive Material Identification (PMI) is among the most extensive in India. TCR's on-site inspection and the testing team has over 12 highly sophisticated Portable Alloy Analyzer Spectrometers which can in-situ non-destructively and accurately measure the chemical composition of materials. Using these spectrometers, TCR's engineers can provide elemental identification and quantitative determination regardless of form, size, and shape. No samples need to be cut for PMI. TCR can also deploy the portable optical emission spectrometer that can detect C, S, P, Mn and Si. Elements that can be identified using PMI include Ti, V, Cr, Mn, Co, Fe, Cu, Zn, Ni, Se, Nb, and Mo.

The team also conducts positive material identification test to detect Carbon composition using a portable optical emission spectrometer. The portable optical emission analyzer is designed to identify all the key elements in metals, especially where highest accuracy, analysis of light elements (like C, Al, S, P, Mg, Si) or sorting of low alloys and aluminium is needed. For example, it is ideal for separation of 316 H (>0.04% C) and 316 L (<0.03% C).

Using portable XRF analyzers, TCR offers scrap traders in India all the necessary data needed to take fast, informed decisions about material purchases along with the input and speed required to sort large quantities of materials, and hence utilise sales opportunities efficiently. Inspection services team of TCR supports the recycle and resell scrap traders in enhancing their profit margins by measuring precious metals in electronics - Pt, Ir, Ru, Rh, Pd. TCR also supports a scrap trader to perform scrap classification service efficiently. From titanium alloys to stainless steels to nickel superalloys to red metals to exotics, TCR can quickly provide fast, reliable results that the industry demands.

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

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

TCR Engineering's PMI equipment includes

- Portable X-Ray Florescence (XRF) Spectro
- Portable Optical Emission Spectrometer (OES)

TCR's Positive Material Identification service is fast becoming an integral part of the safety management process in petroleum refining, petrochemical, and electric power generation industries. TCR has provided PMI services to over 700 projects including major oil and petrochemical installations in India, Kuwait, Kingdom of Saudi Arabia and other parts of Middle East.

Some PMI projects were undertaken in conjunction with the third-party inspection of EIL, Lloyds, KTI, TUV, DNV & BARC.

5.1.2 Radiographic Testing (RT)

Film-based and digital radiography using X-ray and gamma-ray sources. RT reveals internal flaws (porosity, inclusions, incomplete fusion) in welds and castings. Permanent, interpretable records with high sensitivity to discontinuities. Computed Radiography capability with Carestream and 3ENDT digital plates and readers brings the workflow up to the modern digital archival standard. Strict radiation safety compliance per AERB directives.

Gamma-ray radiography uses Iridium-192 and Cobalt-60 isotope sources for dense and thick-wall sections where external power is unavailable, complementing X-ray radiography for site and pipeline work.

TCR Engineering offers Automated Radiographic Testing (ART) for circumferential butt welds in cross-country and City Gas Distribution (CGD) internal pipelines using advanced crawler systems. This technology enables efficient, high-precision detection of both surface and subsurface defects in welds through external X-ray or Gamma ray radiation. Our crawler-based ART solution ensures reliable and comprehensive weld inspections, helping to maintain pipeline integrity and compliance with industry standards, while minimising operational downtime.

TCR Engineering also specialises in Gamma Ray Radiographic Testing, which uses gamma radiation to inspect welds and detect internal defects in pipelines. Gamma rays, emitted from a radioactive isotope source such as Iridium-192 or Cobalt-60, have the ability to penetrate thick materials, making them highly effective for inspecting dense pipeline welds. This method is ideal for locations where access to electrical power for X-ray equipment is limited, as gamma ray testing does not require an external power source. Gamma radiation provides high-resolution imaging of both surface and subsurface flaws, ensuring precise identification of any anomalies that could compromise the integrity of the pipeline. Combining gamma ray technology with our crawler systems allows for comprehensive and efficient inspection of welds in cross-country and CGD station piping works.

5.1.3 Ultrasonic Testing (UT)

Straight-beam and angle-beam testing using advanced flaw detectors. UT covers weld inspection, lamination checks, thickness measurement, and corrosion mapping.

Ultrasonic methods of NDT employs the use of beams of sound waves (vibrations) of short wavelength and high frequency that is transmitted from a probe and detected by the same or other probes. Usually, pulsed beams of ultrasound are used and in the simplest instruments a single, handheld probe is placed on the specimen surface.

An oscilloscope display with a time base shows the time it takes for an ultrasonic pulse to travel to a reflector (a flaw, the back surface or other free surfaces) in terms of distance travelled across the oscilloscope screen. The height of the reflected pulse is related to the flaw size as seen from the transmitter probe. The relationship of flaw size, distance and reflectivity are complex, and a considerable skill is required to interpret the display.

At TCR, complex multi-probe systems are also used with mechanical probe movement and digitisation of signals, followed by computer interpretation.

Ultrasonic examinations are performed for the detection and sizing of internal defects, flaws or discontinuities in piping, castings, forgings, weldments or other components.

TCR has in-house capability to undertake Automated UT using Time of Flight Diffraction technique (ToFD) and Phased Array (PaUT) in India for piping, pressure vessels and as per API 650 appendix U for storage tanks.

5.1.4 Magnetic Particle Testing (MT)

Detection of surface and slightly subsurface discontinuities in ferromagnetic materials. Dry or wet fluorescent particles under visible or UV light. Yokes, coils, and bench units for various part sizes. ASTM E709 and ASTM E1444.

The Magnetic Particle Inspection method of Non-Destructive testing is a used by TCR for locating surface and subsurface discontinuities in ferromagnetic material.

Depending on its operation on the face when the material or part under test is magnetised, discontinuities that lie in a direction generally transverse to the direction of the magnetic field. This causes a leakage field, and therefore, the presence of the discontinuity is detected by using finely divided ferromagnetic particles applied over the surface, some of these particles being gathered and held by the leakage field. This magnetically held collection of particles forms an outline of the discontinuity and indicates its location, size, shape and extent.

At TCR, dry magnetic particle examinations and wet fluorescent magnetic particle examinations are performed on ferromagnetic materials to detect surface and slightly subsurface discontinuities.

Specialised wet fluorescent magnetic particle techniques are available for black light internal examinations of equipment through borescopes.

5.1.5 Liquid Penetrant Testing (PT)

Reliable surface inspection for cracks, porosity, and laps in non-porous materials. Fluorescent and visible dye systems per ASTM E165 and ASTM E1417 and ASME Section V.

With the dye penetrant method, a penetrating liquid is applied to the surface of the component in order to enter the discontinuity or crack. Subsequently, after clearing the excess penetrant from the surface, the penetrant that exudes or is drawn back out of the crack, is observed.

Liquid penetrant testing is applied to any non-porous clean material, metallic or non-metallic, but is unsuitable for dirty or very rough surfaces. Penetrants can contain a dye to make the indication visible under white light, or a fluorescent material that fluoresces under the suitable ultra-violet light. Fluorescent penetrants are usually used when maximum flaw sensitivity is required.

TCR can detect cracks as narrow as 150 nanometers using this method.

5.1.6 Visual Testing (VT)

Direct and remote visual inspection per ASME Section V and API standards. Borescope and videoscope fleet (18 high-resolution units in continuous rotation across the group).

5.1.7 Portable In-situ Hardness

As per ASTM E110, the testing is done by TCR for on-site applications as well as for very large samples. TCR's portable hardness unit performs the hardness testing by applying a 5 kg vickers load indenter and electronically converting the values to a preferred scale

5.1.8 Paint and Coating Thickness

TCR undertakes inspection of paint and/or coating, applied to metal surfaces. The paint and coating inspection team at TCR is fully equipped and has at its disposal, Wet paint thickness gauge(s), Dry paint film thickness gauge(s), Holiday detector(s), Hygrometer with Dew Point calculator and Metal surface thermometer.

The expert paint and coating inspectors at TCR are responsible for monitoring and verifying to ensure that all the work inspected comprehensively conforms with the requirements of the relevant code, specification and/or standard with respect to the paint/coating procedure, the physical application as well as the physical examination, including testing.

Senior TCR paint inspectors are qualified BGas (British Gas Corporation) and are NACE certified. The inspectors are responsible for verifying the following requirements:

- The Blasting and Coating Materials
- The Blasting and Coating Equipment
- The Temperature and Humidity
- The Surface Condition
- The Application Procedure

TCR's expert inspectors are responsible for the preparation of precise, yet comprehensive records that include all critical aspects of:

- Materials Control and Identification
- Climatic Conditions and Surface Condition
- Details Of Abrasive(S) and Application Procedure
- Abrasive/Wire Brush Standard
- Details Of Coating and Application Procedure
- Equipment Calibration
- Inspection Results

5.1.9 Thickness Measurement

Piping

For all on-site piping, corrosion loops are the basis for carrying out thickness survey whereas, for offsite and tank farm piping, special loops are made for thickness monitoring:

- Each corrosion loop (for on-site piping) have a combined isometric where Thickness Management Locations (TML) are serially marked
- If any base readings are taken before commissioning, it is done with random values measured on the components
- Routine, on stream or shutdown thickness measurement at these locations, is done in the form of a scanning. The scanning format is in a grid of size 1.5" x 1.5", with each component marked with chalk before thickness scanning

- Out of all the locations, few TMLs are identified for regular scanning. The selected TMLs are identified by the inspection engineer, based on the probability of corrosion at these locations (as compared to other locations in the loop) and accessibility considerations.
- Respective maintenance departments provide access to ladders, scaffolding or portable trolleys for thickness scanning. In case corrosion is observed in these TMLs, then other TMLs in the loop are included for thickness scanning

Hot Tap Locations

In case of thickness survey of equipment and piping for hot tap locations, following steps are undertaken:

- The maintenance team marks the location of the new nozzle as per the exact type and dimensions of the component to be welded on the parent pipe
- The Inspection engineer verifies the type of component to be welded viz. weldolet, pipe of pipe connection, a nozzle with reinforcement pad, split sleeve nozzle etc. The Inspection engineer marks the centerline of the proposed weld joint: A width of 1.5” to 2” shall be marked on either side of the proposed weld centerline. A close thickness survey is undertaken along the centerline and on either side and the minimum thickness measured is reported in the hot tap file.

If the thickness measurement is comparable to nominal or previously measured values (if available at the same locations or at different locations in the same pipe), then it could be assumed that there is no corrosion at the location.

If the thickness measurement indicates severe corrosion, and thickness measured is very close to the minimum allowable for hot tapping, then hot tapping should be avoided at the location, as it will be difficult to pick up a thickness point with minimum thickness through this procedure.

Minimum thickness required for hot tapping is 4.8mm. If the pipe is corroded and actual thickness is in the range of 6 to 8 mm, then alternate methods should be used to check the pipe thickness and certify the same fit for the hot tap.

Thickness Locations In Tanks

- In case of storage tanks, the thickness is measured from outside first, followed by shell course from the bottom
- In all the other shell courses, the thickness is measured along the staircases. Few thickness points are taken near the weld and few at the centre of the shell course plate
- In case of roof plates, the thickness is measured on each plate, with two thickness points at the centre of each plate and one thickness point at the corner of each plate
- In case of bottom plates, thickness measurement is possible only during an internal inspection. Under this, the thickness is measured on each plate, with two thickness points at the centre of each plate and one thickness point at the corner of each plate

5.2 Advanced NDT Methods

Advanced methods extend detection and sizing beyond the conventional baseline, from phased-array and time-of-flight diffraction to high-temperature and guided-wave ultrasonics.

Standards: ASME BPVC Section V Article 4 (phased-array and time-of-flight diffraction), API 941 (high-temperature hydrogen attack), API 571 (damage mechanisms and carburisation), run against Olympus and Evident PAUT and TOFD calibration procedures and Vallen AMSY-6 acoustic-emission protocols, and the advanced methods support in-service inspection under API 510 (pressure vessels), API 570 (piping), API RP 572, API RP 574, and API RP 575.

5.2.1 Phased Array Ultrasonic Testing (PAUT)

Multiple ultrasonic beams steered electronically to inspect complex structures and welds with high-speed, detailed imaging. Real-time scanning, defect sizing, and visualisation of internal flaws. Thickness range 3 mm to 300 mm. High-temperature PAUT capability up to 350 degrees Celsius for online inspection of operating equipment.

TCR Engineering specialises in advanced Phased Array Ultrasonic Testing (PAUT) using Olympus OmniScan machines, providing high-resolution inspections for welds, components, pipelines, and pressure vessels. Our certified experts conduct thorough assessments of material integrity with precise defect detection and characterisation, ensuring superior safety and reliability.

In compliance with industry standards, TCR performs PAUT inspections in accordance with ASME Boiler and Pressure Vessel Code, ASME B31.3 for Pressure Piping, and API 650 for Welded Tanks. These inspections are critical for pipelines and pressure vessels, ensuring structural integrity and adherence to the highest safety requirements. Our expertise enables us to deliver accurate, code-compliant results for industries such as oil & gas, power generation, and manufacturing, where operational efficiency and safety are paramount.

Representative engagement: Reliance Industries Jamnagar, high-temperature phased-array ultrasonics on in-service equipment during turnaround.

5.2.2 Time of Flight Diffraction (TOFD)

High-resolution technique for detecting and sizing internal cracks. Diffracted waves give precise flaw depth and length measurements. Effective for weld inspections and critical-component evaluations. Thickness range 9 mm to 300 mm.

TCR Engineering specialises in the Time-of-Flight Diffraction (ToFD) technique, an advanced ultrasonic non-destructive testing (NDT) method that relies on the diffraction of ultrasonic energy from the corners and ends of internal structures, primarily defects, within the components being tested. Our expert NDT team provides amplitude-independent, accurate flaw sizing across a wide coverage area, ensuring that even the most subtle defects are detected and evaluated.

ToFD is particularly valuable for conducting Fitness for Service (FFS) inspections, making it an essential tool in maintaining the integrity of critical assets. This fast and effective method allows for the rapid scanning of extensive weld areas in a limited timeframe, which is crucial for minimising downtime in industrial operations.

In addition to providing top-tier ToFD inspections, TCR offers services for creating customised ToFD scan plans and procedures tailored to specific client needs in India. The advantages of ToFD include its ability to deliver precise and reliable defect sizing, comprehensive coverage, and the facilitation of effective decision-making for asset management, all of which are critical for industries such as oil & gas, petrochemical, and power generation.

5.2.3 TOFD and PAUT Combined Inspection

When TOFD and PAUT run together, the quality of weld inspection exceeds conventional radiography. No radiation hazards; concurrent work allowed in the vicinity. Digital records preserved permanently. Compliance with ASME BPVC Section V Article 4.

5.2.4 HTHA, HIC, and Carburisation Detection

High-Temperature Hydrogen Attack detection per API 941. Hydrogen-Induced Cracking damage assessment via PAUT. Carburisation detection in low-alloy steels (P5, P9, P91) per API 571.

TCR Engineering provides advanced online inspection solutions designed to minimise plant downtime and reduce costs for operators. With capabilities to perform inspections at temperatures up to 350°C, TCR's innovations in high-temperature PAUT (HT), ToFD (HT), and corrosion mapping deliver essential data without halting operations. This technique is vital for in-service piping, vessels, and tanks.

Key Benefits of TCR's High-Temperature Inspection Services:

- Minimised plant downtime and reduced production losses by conducting inspections online
- Accurate detection of corrosion, wall thinning, and defect growth for engineering evaluations
- Real-time corrosion rate monitoring and defect growth tracking for better maintenance planning
- Supports RBI (Risk-Based Inspection) by delivering critical data for shutdown scheduling
- Online inspection of repairs, including welds and critical areas, up to 350°C
- Immediate feedback with digitised inspection records for future reference
- Enhanced health, safety, and environment (HSE) compliance

By offering in-service inspections, TCR Engineering helps clients avoid costly shutdowns, improve maintenance efficiency, and ensure the safety and reliability of their equipment. Our high-temperature inspection solutions are designed for critical applications, enabling precise and real-time defect detection in the harshest conditions.

High-Temp Corrosion Mapping

TCR Engineering delivers advanced automated high-temperature corrosion mapping inspections using the straight beam pulse-echo technique with dual element transducers. Our custom-designed high-temperature probes, crafted from heat-resistant plastics and equipped with advanced cooling systems, ensure reliable performance in extreme environments.

- Suitable for equipment and pipelines with thicknesses from 5 mm to 125 mm
- Handles temperatures ranging from 10°C to 350°C
- Effective for pipelines with diameters of 6" and above
- Accurately detects, sizes, and monitors corrosion, erosion, and HIC-SWC damage
- Offers precise damage sizing with 0.1 mm accuracy
- High Probability of Detection (POD) for comprehensive inspection
- Provides recordable corrosion mapping images for detailed analysis
- Enhanced inspection angle range and sizing accuracy

Our advanced technology ensures accurate, reliable inspections, minimising downtime and optimising asset integrity. With advanced probe cooling designs, we deliver highly effective results, even in the harshest environments.

Detecting High-Temperature Hydrogen Attack (HTHA)

TCR Engineering specialises in Advanced NDT services to detect High-Temperature Hydrogen Attack (HTHA), a critical phenomenon in petrochemical and refinery industries. HTHA occurs when steel, exposed to temperatures above 200°C, reacts with hydrogen, creating methane bubbles at the grain boundary. These bubbles lead to microcracks, weakening the steel and potentially causing catastrophic failures.

Even equipment designed under stringent safety codes may suffer from HTHA damage. Early detection through expert NDT inspections by TCR Engineering ensures safe, long-term operation, minimising risks of equipment failure or accidents.

Industries and Equipment at Risk:

- Catalytic Reformers (CCR & Cyclic)
- Hydrotreating Units (Hydrocracking and Desulfurization)
- Ammonia and Hydrogen Reformers
- Highly stressed locations like flanges, reducers, and pipe fittings

Key Advantages of TCR's NDT Expertise:

- Comprehensive assessment of long-term HTHA damage
- Inspection over large, complex areas with external-only access
- Estimation of damage depth without the need for equipment shutdown

While early-stage micro-degradation is difficult to detect, our team's deep expertise ensures precise interpretation of HTHA in its critical stages. TCR Engineering, leading the way in safeguarding your assets from hydrogen-related risks.

5.2.5 Long Range and Short Range Ultrasonic (LRUT, SRUT)

Guided-wave inspection of piping and tubing. LRUT detects corrosion over long pipe runs from a single access point. SRUT targets piping at supports, clamps, and contact points.

The Long Range Guided Wave Ultrasonic Technique (LRGUT) is engineered to inspect 100% of a pipe segment from a single location.

This technique involves inducing torsional or longitudinal guided waves into the pipe, allowing them to propagate throughout the entire segment under examination. When these guided waves encounter an anomaly or a feature within the pipe, they convert into laminar waves and reflect back to the original location of the tool. These signals are digitally captured using a laptop, and the time-of-flight for each signal is calculated to determine its distance from the tool. The cross-sectional area is assessed based on amplitude, while the circumferential extent is estimated through focused beams, which are broken down into octants to evaluate the significance of any detected defects.

TCR conducts LRUT in collaboration with its international partner, which adheres to and exceeds the PHMSA's 18-point requirements for examining casings and crossings. LRGUT is primarily utilised in industries such as oil and gas refining, petrochemicals, storage, offshore operations, and pipeline transportation.

Specifically, these tests play a critical role in External Corrosion Direct Assessment (ECDA) and Internal Corrosion Direct Assessment (ICDA) methodologies, particularly in situations where access to piping systems is challenging, such as:

- Insulated Pipe in Refineries
- Offshore Pipeline Risers
- Cased Road or Railway Crossings
- Loading Lines and Pipework
- Tank Dyke Pipeline Crossings
- Above Ground or Buried Flow Lines
- River or Bridge Pipeline Crossings

5.2.6 High-Temperature UT and EMAT (Up to 600 Degrees Celsius)

Thickness measurement and flaw detection on operating equipment up to 200 degrees Celsius (conventional UT) and up to 600 degrees Celsius (EMAT). EMAT capability at 600 degrees Celsius is among the highest in India and serves online inspection of high-temperature equipment without shutdown.

High-Temp Phased Array UT

TCR Engineering's high-temperature PAUT inspections are designed to inspect surfaces up to 350°C, minimising plant downtime. This advanced technique employs sectorial scans that cover the complete weld volume using a range of angles, ensuring comprehensive inspection in even the most challenging environments.

- Suitable for equipment/piping with thicknesses from 3 mm to 300 mm
- Handles temperatures from 10°C to 350°C
- Inspects pipelines with diameters of ¾” and above
- Detects, sizes, and monitors weld defects, corrosion, HTHA, HIC-SWC damage, and stress corrosion cracks
- Effective for one-sided weld inspections and dissimilar weld joints (CS/SS)
- Accurate damage/weld defect sizing with high Probability of Detection (POD)
- Encoded, recordable data/images for detailed analysis
- Compatible with Inconel and other high-performance materials
- Enhanced inspection range and cooling capacity via optimised water jacket design

Applicable Standards:

- ASME Section V (Nondestructive Examination)
- ASME Section VIII (Pressure Vessels)
- API 579 (Fitness-for-Service)
- AWS D1.1 (Structural Welding Code – Steel)

TCR Engineering, leading the way in high-temperature phased array inspections, ensuring the safety and integrity of critical infrastructure.

5.2.7 Acoustic Emission Testing

AET Vallen AMSY-6 system, 254-channel capability for large-asset acoustic emission monitoring (storage tanks, columns, pressure vessels).

5.2.8 Matrix Array UT (MAUT)

Targeted at FRP and GRP composite inspection. Niche capability that most competitors lack.

5.3 Heat Exchanger, Chillers and Tube Inspection

TCR Engineering provides comprehensive inspection services for tubular products using advanced non-destructive testing (NDT) methods, including Eddy Current Testing (ECT), Remote Field Eddy Current (RFEC), Magnetic Flux Leakage (MFL), and Internal Rotary Inspection System (IRIS). These techniques utilise internal diameter probe coils, such as bobbin coils, for testing both non-ferrous and ferrous materials (the latter with magnetic saturation).

Our expertise in the inspection of heat exchangers, condensers, and steam generators, commonly found in power plants, ensures the detection of critical issues like corrosion, erosion, cracking, and other material degradations. These tubular structures, which contain thousands of tubes, must be regularly monitored to prevent leaks and ensure operational integrity. The high-speed testing provided by these methods ensures accurate identification of anomalies and minimises downtime.

The testing is conducted in accordance with relevant international standards, such as ASTM E243 for eddy current testing and ASME Boiler and Pressure Vessel Code, Section V for ultrasonic and eddy current examination of tubing. TCR Engineering's NDT solutions ensure compliance, safety, and efficiency for critical infrastructure assets in power generation and industrial sectors.

5.3.1 Eddy Current Testing

TCR Engineering offers Eddy Current Testing (ECT), a fast and highly accurate technique for detecting discontinuities in tubing, heat exchangers, condensers, steam generators, air coolers, and feedwater heaters. By leveraging electromagnetic induction, TCR identifies flaws in conductive materials with precision, including detecting even the smallest cracks near the surface. This method requires minimal surface preparation and can easily accommodate complex geometries, making it ideal for a wide range of industrial applications.

In addition to flaw detection, ECT is effective for alloy separation, determining heat treatment conditions, measuring electrical conductivity, and assessing coating thickness. It can also pinpoint the location of repair welds, girth welds, and seam welds on ground-machined surfaces.

TCR Engineering's in-house team of certified Eddy Current Testing professionals brings deep expertise in inspecting tubing in heat exchangers and other critical equipment. Our advanced testing devices are portable, contactless, and provide instant feedback, ensuring minimal downtime and maximum efficiency. Our equipment is capable of operating at frequencies up to 8 kHz, with an impressive inspection speed of 2 metres per second, ensuring rapid and reliable results.

Key Benefits of TCR Engineering's Eddy Current Testing Services:

- High-Speed and Precise Detection: Rapid flaw identification with minimal surface preparation.
- Complex Geometries: ECT can investigate intricate shapes and sizes.
- Non-Destructive: Ensures the integrity of the material without physical damage.
- Versatility: Can detect flaws, measure conductivity, and identify different alloys.
- Immediate Feedback: Portable, real-time inspection results to facilitate quick decision-making.

Applicable Standards:

- ASTM E243: Standard Practice for Electromagnetic (Eddy-Current) Testing of Tubular Products

- ASME Section V: Non-Destructive Examination (NDE), covering Eddy Current Testing for heat exchanger tubes
- ISO 15548: NDT equipment and techniques for eddy current testing

TCR Engineering ensures that all tubes are properly cleaned prior to testing, with hydro jetting at pressures ranging from 280 to 560 kg/cm^2. The adequacy of cleaning is verified by inserting a dummy probe or rod to guarantee smooth inspections.

Our Eddy Current Technicians expertly evaluate flaw signals generated during testing, comparing them against calibration standards to ensure the highest accuracy in flaw detection and assessment. By utilising industry-leading equipment and adhering to stringent international standards, TCR Engineering delivers unparalleled inspection services for tubular products, ensuring your operations remain safe and reliable.

5.3.2 Remote Field Eddy Current Testing (RFET)

TCR Engineering offers Remote Field Testing (RFET), an advanced electromagnetic non-destructive testing (NDT) method as per ASTM E2096 and ASME Section V, ideal for detecting and sizing wall thinning due to corrosion, erosion, wear, pitting, and baffle cuts in ferromagnetic tubes.

Our RFT services are widely utilised in critical industrial equipment such as boilers, feedwater heaters, air coolers, and carbon steel heat exchangers, providing accurate assessments of tube integrity without the need for invasive procedures.

We combine Remote Field Eddy Current Testing (RFET) and Near Field Testing (NFT), deploying them individually or together, depending on the specific capabilities of the testing equipment and the condition of the asset. These methods allow us to achieve comprehensive coverage, ensuring reliable detection of both surface and subsurface defects.

5.3.3 Magnetic Flux Leakage Testing (MFL)

TCR Engineering offers Magnetic Flux Leakage (MFL), a highly reliable electromagnetic non-destructive testing (NDT) technique used to detect corrosion, pitting, and other forms of material loss in steel structures and ferromagnetic tubing. MFL is widely employed in critical industrial applications, including pipelines, storage tanks, and heat exchangers.The MFL method involves using a powerful magnet to magnetise the steel or conductive material under test. When defects like corrosion or material thinning are present, the magnetic field "leaks" from the surface, allowing our expert technicians to precisely detect and measure the extent of wall loss.

Key Benefits of TCR Engineering's MFL Services:

- Accurate Detection of Defects: MFL is ideal for identifying sharp defects such as pitting, grooving, and circumferential cracks.
- Effective for Ferromagnetic Tubing: This method is suitable for detecting defects in steel and other ferromagnetic materials.
- Aluminium-Finned Carbon Steel Tubing: MFL is highly effective even in aluminium-finned carbon steel tubes, as the magnetic field remains largely unaffected by the fins.
- Complementary to Remote Field Testing (RFT): MFL provides a valuable back-up inspection to RFT, ensuring a comprehensive evaluation of tube integrity.

By using TCR Engineering's advanced MFL services, industries can detect and mitigate corrosion and material loss early, enhancing asset longevity and reducing operational risks.:

5.3.4 Internal Rotary Inspection System (IRIS)

TCR Engineering provides Internal Rotary Inspection System (IRIS), a highly accurate ultrasonic method for the non-destructive inspection of tubes, particularly in heat exchangers, boilers, and condensers. The IRIS technique uses an ultrasonic beam to measure and detect metal loss on both the inner and outer walls of the tube. The IRIS probe is inserted into a water-filled tube, and as it is pulled out, real-time data is displayed and recorded, allowing precise wall thickness measurement and defect detection.

Key Benefits of TCR Engineering's IRIS Services:

- Precise Defect Detection: IRIS can accurately detect and measure metal loss along both the length and circumference of the tube, providing a comprehensive evaluation of tube integrity.
- High Accuracy for Ferrous Materials: IRIS offers superior accuracy for measuring wall thickness in ferrous materials, with a resolution as low as 0.15mm, making it more accurate than Remote Field Eddy Current Testing (RFET) for ferrous tubes.
- Comprehensive Analysis: This method is highly effective at detecting both internal and external corrosion, erosion, and other forms of degradation, making it ideal for asset integrity management.

Limitations:

- Slower Testing Speed: While IRIS offers high accuracy, it is slower compared to other techniques, with a scanning speed of approximately 1 inch per second, making it less efficient for large-scale inspections.
- Surface Cleaning Requirement: IRIS requires thorough cleaning of the tube surface, often more rigorous than what's required for Eddy Current Testing (ECT).
- Despite its slower speed, IRIS provides unparalleled accuracy in wall thickness measurement, making it a critical method for industries focused on the longevity and reliability of their tubular assets. TCR Engineering’s experienced team ensures precise inspections that help prevent unexpected failures and extend the life of your equipment.

5.3.5 Fully Saturated Eddy Current Testing

TCR Engineering offers Saturation Eddy Current (SET), a specialised non-destructive testing technique used for inspecting thin ferromagnetic materials such as carbon steel (CS), duplex stainless steel, and slightly magnetic materials like Monel Nickel-Copper alloys. This advanced method is highly effective for detecting and quantifying both internal and external cracks, as well as local defects and overall wall loss in ferromagnetic tubes used in boilers, feedwater heaters, air coolers, and carbon steel heat exchangers.

This technique, done in accordance with ISO 15548-1 and ASME Section V, excels at identifying both internal and external cracks, pitting, and wall thinning in challenging materials, providing detailed insights into the condition of tubes.

SET is particularly beneficial in industries like power generation and petrochemical processing, where the reliable operation of critical heat exchangers and boilers depends on early detection of material degradation.

TCR Engineering’s use of Saturation Eddy Current ensures precise inspections, enabling operators to avoid costly downtime and prevent unexpected failures.

By choosing TCR Engineering's Saturation Eddy Current services, clients can expect high-speed, accurate inspections that extend the lifespan of their critical components, ensuring operational reliability and safety.

Specialised electromagnetic methods for shell-and-tube heat-exchanger inspection.

Method	Application	Standards
Eddy Current Testing (ECT)	Non-ferrous tubes (Cu, brass, admiralty, stainless steel)	ASTM E2884, ASME V Article 8
Eddy Current Array (ECA)	Faster 2D scanning of tube and tube-sheet bores	ASTM E2884, ASME V Article 8
Remote Field Testing (RFT)	Ferromagnetic tubes (carbon steel, low-alloy steel)	ASTM E2096
Internal Rotating Inspection System (IRIS)	High-resolution ultrasonic wall-thickness mapping	ASME V Article 23
Near-Field Testing (NFT)	Finned air coolers (fin-fan)	ASTM E2884
Surface ECT (SECT)	Through-coating crack detection on fin tubes	EN 1711

Tube-by-tube condition maps and remaining-life estimates. Reformer pigtail and inlet-outlet manifold inspection covered under the same crew. Anchor clients include refineries, fertiliser plants, petrochemical complexes, fossil-power and waste-heat boilers, and process plants in chemicals and steel.

Standards: ASTM E2884 (eddy-current examination) and ASTM E2096 (remote-field testing of tubular products).

5.4 Tank Inspection

Above-ground storage tank inspection per API 653 6th Edition (2024). Floor, shell, and roof inspection using Magnetic Flux Leakage (MFL) floor scanners, including the Silverwing FloormapVS2i system for top-side and bottom-side discrimination. Ultrasonic shell thickness mapping. Visual inspection of roof and appurtenances. Long Range Guided Wave for buried piping around tank farms. TCR is also understating acoustic emission testing for storage tanks.

In-service inspection through partner-delivered platforms eliminates the need for tank entry and degassing: the ITAS Rover for tank internals (29+ tanks, partner company), the OTIS in-service robotic tank inspection for API 653 floor scanning with 8-transducer ultrasonic capability without emptying (partner company), the Planys-partnered underwater ROV for above-ground water-storage tank under-water inspection (HD camera, SONAR silt assessment, ultrasonic probe with gimbal 3 to 250 mm range, entry through 20-inch manhole, portable approximately 35 kg, AC 230V at 6 kW; capability covering desalinated, potable, fire-water, hydrant, and de-mineralised water tanks plus sumps, intakes, outfalls, channels, and reservoirs), and the robotic tank inspection rover with ATEX/PESO certification for tanks up to 25 m height and 100 m diameter, delivering approximately 50 percent cost reduction and 10x speed against scaffolding-based methods.

Reference: The WTCO 3-year robotic tank inspection contract commenced Q1 2025 (TCR Arabia delivery, project leads Naser Salahuddin and Shaheensha Shahulhameed).

Standards: API 653 (above-ground storage tanks), ASME PCC-2 (repair of pressure equipment).

5.5 Leak Testing

Helium Leak Test capability across Sniffer mode, Vacuum mode, and Hood mode for pressure-vessel, heat-exchanger, and reactor leak qualification. ASTM E499, ASTM E498, ASME V Article 10.

TCR provides vacuum leak testing for all types of vacuum vessels and pressure probe testing for systems operating at or above ambient pressure. Any system requiring leak tightness or suspected of leakage issues can be tested using these helium leak testing methods with high reliability.

The Helium Leak Testing unit at TCR employs advanced mechanical vacuum pump technology specifically designed for heavy-duty use in challenging industrial environments. The rotary vane pump's helium stability ensures exceptional consistency of the helium signal, while the Molecular Drag Pump (M.D.P.), operating at a low rotational speed of 27,000 RPM, provides full insulation against accidental air influxes. This design also allows for the leak detector to be relocated during operation. The high compression ratio of the M.D.P. enables efficient gross leak testing at elevated pressures (7.5 Torr / 10 mbar), significantly accelerating the leak testing process for outgassing components. The internal configuration of the unit allows for easy access to all components, enhancing usability. TCR's Helium Leak Testing instrument boasts a roughing capacity of 10 m^3/h (7 CFM) with usable helium sensitivity in the 10^-11 atm.cc/s range. Additionally, it features a dedicated sniffing unit based on a reliable leak-testing concept, suitable for outboard leak testing applications.

TCR has conducted numerous leak tests on-site across various industries, including nuclear carriers, polymer plants, oil refineries, and gas and steam turbine power plants in Kuwait, the Kingdom of Saudi Arabia, and India.

Our technicians are highly mobile and perform helium leak testing on a wide range of systems and components, including heat exchangers, steam turbines, condensers, distillation towers, and buried pipelines.

5.6 Thermography, Visual, and Drone Inspection

Infrared Thermography for electrical and mechanical condition monitoring, refractory inspection, and tank-shell heat-loss surveys.

Visual and remote visual inspection per ASME Section V and API 510, 570, 653. Borescope and videoscope fleet across 18 units.

Bridge-inspection robotics, including underwater submersible ROV with HD camera, SONAR silt assessment, and ultrasonic probe with gimbal capable of 3 to 250 mm thickness range, for sub-water bridge pier and abutment inspection.

TCR employs thermography testing to detect temperature anomalies in equipment during operation using remote, non-contact methods. This technique, now also performed via helicopters for large areas, captures heat radiation from hot objects using infrared sensors to create thermal images. By analysing the hot and cold regions, the condition of the equipment can be assessed.

Thermography is valuable in detecting blockages or deposits in pipelines carrying hot or cold fluids, as well as insulation or refractory damage in furnaces, boilers, and heaters. It is also widely used for monitoring electrical substations, transformers, control panels, and rotary equipment like motors, generators, and turbines for signs of overloading, overheating, and faulty contacts.

5.7 Post-Weld Heat Treatment (PWHT)

PWHT is preserved as a standalone service. The service is distinct from the Heat Treatment Verification Testing block under Pillar 1 (Section 4.14). PWHT is physical thermal processing: TCR runs furnaces, electrical resistance heating, and oil firing, on-site at refineries, petrochemical plants, fabrication shops, and EPC projects.

TCR Engineering has expanded its services range with a dedicated division that offers both gas and electric post weld heat treatment services including:

1. Electric resistance localised PWHT of butt welds for piping projects
2. Temporary / permanent furnace heat treatment and normalising.
3. Internal high velocity gas firings of spherical and bullet tanks and other large storage tanks / vessels.
4. Localised PWHT of vessel closing weld seams.

TCR Engineering undertook PWHT services for Essar Construction at the BF Shell Project at Jindal Steel in Angul, Odisha and at the HURL site as well. Having our base Pan-India helps has mobilise faster as well as provide the necessary repair and maintenance of our machines in a rapid manner. Our team members are dedicated and are backed with our supervisory skills gained over the past 50 years of TCR’s services towards quality assurance to the Indian Industry.

Preheating Services

TCR undertakes preheating of weldment to eliminate weld defects and improve weld quality by avoiding cracking in the heat affected zone (HAZ) or at the weldment.

Furnace Heat Treatment (Static / Temporary / Gas / Electrical)

Within the TCR's lab environment, we have high velocity gas fired burners which create a ‘scrubbing action’ of hot gases against the walls of the component eliminating any cold spots.

Electric Resistance Localised Post Weld Heat Treatment

Carefully controlled localised post weld heat treatment by electric resistance, by TCR's expert heat treaters, tempers the metal and reduces tensile stresses, minimising the risk of brittle fracture, stress and corrosion cracking and metal fatigue.

Post Weld Heat Treatment (PWHT)

TCR Engineering Services offers a diverse range of Heat Treatment Services including pre-heating, post-heating; stress relieving (SR), intermediate SR, normalising, solution annealing, water quenching, tempering, step cooling and drying of the refractory material.

The experienced technicians at TCR are capable of performing heat treatment on weld joints, piping, regenerators, stripper columns, pressure vessels, boiler headers, modules, deck pipelines and structure, boiler heater tubes, and DOTHERM testing. The team is also capable of carrying out Post-weld heat treatment of carbon steel piping welds (pipe-work, headers, flange joints, valves and branches) by means of the electrical resistance method, in the form of ceramic heater pads. It can design, fabricate, calibrate and run a customised electrical furnace for clients.

Post Weld Heat Treatment Services (PWHT) is performed after welding/machining, to improve the chemical and mechanical properties of weldment / machined surfaces. TCR offers post-weld heat treatment by using electricity as the source of heating for stress relieving of weld joints. All TCR's heat treatment services are designed to minimise downtime, improve structural integrity and enhance effective plant life. Additionally, depending on the mobility of the required equipment, many of TCR's heating processes can be applied on-site or at client's facility.

Stress Relieving

For steel fabrication, the most common procedure used is Stress Relieving where machining and/or welding induces stress in parts. The bigger and more complex the part, higher is the amount of stress. Stress Relieving is done by uniformly heating the fabricated equipment, a vessel or a part of the vessel to a sufficiently high temperature, but below the lower transformation temperature range. It is then subjected to a thermal retardation for a sufficient time depending upon the material thickness and then finally cooled uniformly.

TCR has specialised fully automatic programmable equipment's capable of controlling Heating rate, Holding time and cooling rate as well as carrying out a wide range of heat treatment processes like post-weld heat treatment of PQR test coupons and various components. TCR has at its disposal, well-equipped tools including electrical furnace with 220- and 80-Volts panel, latest 12-point recorder with digital display, coil and pad-type heating element, oil firing systems and extremely skilled technicians. The Heat treatment equipment is supplied with a chart recorder to record up to 8 thermocouples simultaneously to meet the critical requirements of heat treatment.

Oil Firing on Pressure Vessels

TCR Engineering has a talented crew that uses diesel fuel as the source of heating for stress relieving of pressure vessels with the sole objective of reinforcing process, component integrity, and high quality. The heat treatment specialists from TCR have all the necessary experience and equipment to develop a custom configuration as per specific processes. Our heating processes include low-Range, Mid-Range & High-Range Temperature Heating.

TCR's high-velocity burners enable excellent temperature distribution and uniformity at all times because of the intense scrubbing action. They are also able to construct temporary furnaces at client sites where internal firing is not a practical or cost-effective option.

The heat treatment operation is affected by the firing of the furnace, using one or more gas/oil high-velocity burners with a nominal rating of 1,500.000 Kcals/HR (6,000,000 Btu/HR) per burner. Each burner is connected by an armored flexible hosing to Combustion Air Fan (s), with a maximum output of 2800/Nm^3 per hour via a 150mm diameter outlet, at a pressure of 700mm W.G. The burner is fitted with a (25/20) stainless steel outlet nozzle designed to clear the furnace wall adjacent to the intended opening(s), in such a way that it eliminates the possibility of any direct impingement on components.

Reference engagements.

• HURL Sindri: PWHT via electrical resistance coil method, contract value Rs. 31.85 Lakhs.

• JSOL Blast Furnace 2: PWHT engagement.

• Tata Projects JSOL Coke Oven Battery 5 and 6: PWHT engagement.

There is no NADCAP framing on PWHT. The NADCAP track sits exclusively under Pillar 1 Heat Treatment Verification Testing (AC7101 Materials Testing).

Equipment: In-house controlled-rate furnaces. Field equipment for on-site PWHT: induction-coil systems, ceramic-pad resistance heating, oil-firing systems for large pressure-vessel local stress relief. Calibrated thermocouple placement and chart recording.

Standards: ASME PCC-2: Repair of Pressure Equipment and Piping (2022 ed.); AWS D10.10 for thermocouple placement; API 582 for welding guidelines that govern PWHT requirements; ASME B31.3 Process Piping (2024 ed.); ASME B31.4 / B31.8 Pipeline Transportation Systems (2022 eds.); ASME BPVC Section IX.

5.8 ASNT Level III Consultancy

The in-house ASNT Level III authority bench acts as a published service line: procedure writing, audit response, third-party Level III oversight, and personnel certification support for client laboratories.

TCR Engineering boasts a highly skilled advanced NDT inspection team, with ASNT Level 3 certifications in Eddy Current (ET), Ultrasonic Testing (UT), Magnetic Particle Testing (MT), Infrared Thermography (IR), Mass Spectroscopy Leak Testing (MSLT), Radiography (RT), Liquid Penetrant Testing (PT), and Visual and Dimensional Evaluation (VT). The team is also equipped to execute projects using Automated Ultrasonic Testing with Time of Flight Diffraction (ToFD) techniques, and its experts are certified in AWS/CSWIP 3.1 and 3.2 as well as CSWIP Painting inspection.

TCR’s ASNT Level III professionals possess the expertise to develop techniques, interpret codes, standards, and specifications, and prepare or approve procedures and instructions. All NDT inspectors at TCR are qualified under the American Society for Nondestructive Testing Practice SNT-TC-1A and adhere to CP-189 guidelines. Each non-destructive examination is conducted in accordance with major codes such as the ASME Boiler and Pressure Vessel Codes, ASME/ANSI Pressure Piping Codes, American Petroleum Institute Codes, American Welding Society Standards, and Aviation/Military specifications.

TCR’s combined strengths in metallurgy and advanced NDT services have enabled global leaders like Reliance, Saudi Aramco, QAFCO, IOCL, GAIL, and BPCL to increase plant availability, reduce costs, minimise shutdown times, and improve safety compliance. The TCR team excels in assessing and calculating the risk profiles of plant equipment based on "active" and "potential" damage mechanisms, ensuring that inspection intervals are reliably optimised in a safe and cost-effective manner.

NDT personnel are qualified and certified in line with ASNT CP-189 and the written practice, in addition to ASNT SNT-TC-1A.

Authority	Methods	Certification
Shemi Bhaskaran	RT, LPT, MPI	ASNT NDT Level III Cert. 114619
Nikhil Sabhaya (TCR Advanced)	ET, UT, PT, MT	ASNT NDT Level III (four-method); also `API 510`, CSWIP 3.1

5.9 Cross Country and CGD Pipeline Radiography

This is the marquee track of the pillar. Multiple cross-country pipeline, City Gas Distribution, power, and refining engagements with documented owner and consultant approvals, plus approvals from 14+ owners and consultants.

At TCR Engineering, we offer a complete range of pipeline-related services for cross-country and city gas distribution (CGD) pipelines, focusing on inspection, material verification, and asset integrity management. Our services include Automated Radiographic Testing (ART), Ultrasonic Testing (UT) with advanced methods like Phased Array (PaUT) and Long-Range Ultrasonic Testing (LRUT). We specialise in the digitalisation of RT films as per IOCL and GAIL standards and provide destructive testing for PQR/Welder qualification and material confirmation. Our O&M services utilise advanced technology for pipeline asset integrity management (AIM), including Engineering Critical Analysis (ECA), failure analysis, corrosion assessments, robotic inspections, and leak detection using smart pigs. We also monitor cathodic protection (CP) systems to ensure long-term pipeline integrity.

With a focus on safety, efficiency, and data-driven decision-making, TCR Engineering is your trusted partner for maintaining the health of critical pipeline infrastructure.

5.9.1 Pipeline Weld Inspection

TCR Engineering's Pipeline Inspection for Anomalies services are designed to detect defects and discontinuities in pipelines using advanced radiographic and ultrasonic testing methods. By employing tools like internal crawler robots, external X-ray/gamma radiation, and automated ultrasonic testing, we can inspect pipelines with precision, ensuring their integrity and safe operation. Our comprehensive approach adheres to relevant industry standards like API 1104, guaranteeing reliable results that help our clients mitigate risks and maintain pipeline health.

5.9.2 Automated Radiographic Testing (ART) of Circumferential Butt Welds from Internal Pipelines Using Crawlers

Automated Radiographic Testing (ART) involves the use of high-resolution imaging technology to inspect circumferential butt welds inside pipelines. We deploy specially designed crawler robots that travel inside the pipeline to scan welds with precision. This method allows for internal inspections where external access may be limited or challenging. ART is particularly useful for large-diameter pipelines and provides a comprehensive evaluation of weld integrity, enabling the detection of both surface and subsurface defects.

5.9.3 External X-Ray or Gamma Ray Radiation for Detection of Surface and Subsurface Defects in Welds

For pipelines where internal access is restricted, External Radiographic Testing using X-ray or gamma-ray technology is applied. This method enables the detection of both surface and subsurface anomalies in pipeline welds. The process works by emitting radiation through the weld area, capturing images of any defects that may compromise the structural integrity of the pipeline. This non-invasive testing technique is ideal for pipelines that must remain operational during inspection and complies with API 1104 standards for welding inspections.

5.9.4 Computed Radiography

TCR Engineering has strong expertise in Computed Radiography (CR) as per ASTM E 2033 and ISO 17636-2 which is an advanced form of radiographic inspection that uses imaging plates (IP) instead of traditional X-ray films to capture images of pipeline welds. These plates, coated with phosphor, store the radiographic image when exposed to X-rays or gamma rays. The stored image is then read by a laser scanner and converted into a digital image, which can be viewed, analysed, and archived electronically. The adoption of Computed Radiography (CR) in the inspection of cross-country pipelines offers numerous advantages over conventional radiography testing, from improved image quality and faster turnaround times to enhanced environmental safety and cost-effectiveness.

5.9.5 UT Shear-Wave Anomaly Evaluation, Phased Array (PAUT) and ToFD for Seam-Weld Assessment

Ultrasonic Testing (UT) is used to detect anomalies like cracks, lack of fusion, and other discontinuities in seam welds. The shear-wave UT technique is particularly effective for identifying these anomalies by introducing ultrasonic waves at an angle to the weld seam.

Phased Array Ultrasonic Testing (PaUT): PaUT provides a more detailed and dynamic evaluation of welds by using multiple ultrasonic beams, which can be steered, focused, and scanned electronically. This allows for greater coverage and sensitivity to defects, making it ideal for inspecting complex geometries.

Time-of-Flight Diffraction (ToFD): ToFD complements PaUT by detecting and sizing defects using the diffraction of ultrasonic waves. It is highly accurate for locating crack tips and providing a quantitative assessment of defect size. The combination of PaUT and ToFD ensures a thorough evaluation of seam welds, with high sensitivity to both small and large anomalies.

5.9.6 Automated Ultrasonic Testing and LRUT / Guided Wave Including A-, B-, and C-Scans

Automated Ultrasonic Testing (AUT) and Long-Range Ultrasonic Testing (LRUT), also known as Guided Wave Testing, are powerful tools for pipeline inspection, particularly in situations where accessing the entire pipeline is impractical. LRUT allows for the inspection of long sections of pipeline from a single access point, making it cost-effective for detecting corrosion, cracks, and other anomalies over large distances. A/B/C-scans provide detailed cross-sectional images of the pipe’s wall thickness and defect locations, ensuring comprehensive evaluation as per API 1104 standards for pipeline welding.

- A-Scan: Displays the amplitude of received ultrasonic signals, helping identify the depth of defects.
- B-Scan: Provides a side-view image of the pipeline, showing the thickness of the walls and the presence of defects.
- C-Scan: Gives a plan-view image of the pipeline, mapping the location and extent of anomalies across the pipeline's surface.

5.9.7 Weld Assessment of Difficult-to-Access, Small Diameter Pipes (1.5 Inch to 3.5 Inch)

For pipelines with smaller diameters (1.5” to 3.5”), weld inspection becomes more challenging due to space constraints. TCR Engineering employs specialised palm scanners that are designed for these hard-to-reach areas. These handheld scanners use high-frequency ultrasonic waves to inspect welds in small-diameter pipes, ensuring comprehensive coverage even in difficult-to-access locations. This method allows for the detection of anomalies like incomplete fusion, porosity, and cracking that can compromise the integrity of small-diameter pipelines.

5.9.8 Digitalisation of RT Films

TCR Engineering's Bengaluru-based central operations team, comprised of IT and Google-certified experts, remotely coordinates with sites across India to ensure compliance with stringent film density and resolution standards all conducted in full accordance with ASME Section V - Article 2, and ASTM E 1936.

Key Benefits of NDT Film Digitisation:

- Prevents film degradation while maintaining image quality
- Eliminates physical storage costs for films
- Allows secure storage on custom developed Google Cloud platform
- Enables archiving of inspection RT reports including UT and MPI data
- Utilises Artificial Intelligence (AI) for easy retrieval and comparison of scans

Standards: API 1104 (welding of pipelines and related facilities), ASME B31.4 and B31.8 (liquid and gas pipeline transportation codes), SAEP-1143 (Saudi Aramco radiographic engineering procedure), IBR 1950 with amendments, AERB Safety Manual AERB/RF-IR/SM-1 Rev. 2, with SMPV(U) Rules 2016 and Gas Cylinder Rules 2016 (PESO).

5.9.9 Saudi Aramco Anchor

Saudi Aramco approved Radiographic Standard Procedure TCR.QCP.REV-02 (2023) is conformant with SAEP-1143 (Engineering Procedure for Radiographic Examination, 6 September 2020). Saudi Aramco Engineering Report SAER-13115 dated 8 September 2025 names TCR as the technology provider for the Internal RT Crawler with $4,980,000 documented cost avoidance over five years (approximately 80 percent reduction).

Internal RT Crawler specifications. 16 inch to 52 inch diameter range. 160, 200, and 300 kV X-ray heads at 5 mA. ±5 mm positioning accuracy. Operating temperature range minus 10 to plus 70 degrees Celsius.

5.9.10 AERB Regulatory Stack

Credential	Document	Validity
Operation Licence	23-IRLOP-893925	Active
Source Storage Facility, Mumbai	22-ASSF-793303	Valid 28 June 2027
Source Storage Facility, Bhubaneswar	23-ASSF-927086 (Plot 125/2094, Vishnu Vihar)	Valid 30 August 2027
RSO 1	Shemi K B, 21-RSO-681725	Active
RSO 2	Ananta Kishore Parida, 22-RSO-734005	Active
BARC leak certificates	Multiple	2024

Cross-border permission: Nepal Oil Corporation Ref 2080/81 dated 30 July 2023 for the Motihari to Amlekhgunj International Pipeline (MAPL) Phase II via Likhitha Infrastructure (the first non-GCC cross-border deployment).

5.9.11 Engineers India Limited (EIL) PMC Approval Pack, 12-Year Footprint

EIL approval covers BPCL Kochi NHDS/SRR Health Check IREP (2012), OPaL Petrochemical Complex Dahej (2013), PNCPL/NRL Bhubaneswar lab approval (2023), multiple EIL-approved Procedure Qualification Records spanning 16 inch to 24 inch diameter on GAIL MNJPL, NRL Brahmaputra River Crossing, ADPL HDD Odisha Rivers, and KGPL, plus EIL Approval renewals 2024 to 2025.

5.9.12 Other Owner / Consultant Approvals

- Adani-Total / Dhamra LNG Terminal: Letter Ref 2340-RLNG-DLTPL-NRP-L-0005 dated 20 October 2021 (EPCC NRP Projects, PMC Wood).
- BHEL NTPC Talcher TTPP-III: BHEL email dated 20 December 2025 approving TCR for the 2 x 660 MW NTPC Talcher Project via Power Mech Projects.
- CGD operator approvals: Bhagyanagar Gas Limited (HPCL-GAIL JV) BGRL Spread-2 Maharashtra via Tractebel ENGIE PMC (June 2021) and Karnataka via Tolani Projects (2022); Green Gas Limited Lucknow GA (December 2022); Torrent Gas Karaikal Puducherry (June 2023).

5.9.13 IOCL PQR Pack

IOCL Procedure Qualification Records covering 12 inch through 36 inch diameters, the foundation of cross-country pipeline mainline radiography.

5.9.14 Track Record

- 14,000+ pipeline girth welds radiographed across 2600+ kilometres of cross-country mainline.
- 9,266 weld joints digitally scanned and cloud-archived on a single project (EnProCon TJTC Kolar).
- 20+ named cross-country pipeline projects with 15+ master contractors.
- Three PWHT engagements delivered alongside RT.

6. Asset Integrity and Engineering Consulting

100,000+	9,000+	750+	400+
REPLICATED MICROSTRUCTURES	FAILURE INVESTIGATIONS	RLA STUDIES, GROUP CUMULATIVE	BOILER RLA ASSIGNMENTS

Asset Integrity and Engineering Consulting is where the company stops being a testing laboratory and starts being a strategic partner. The pillar carries the higher-margin engagements at TCR Advanced, supported by the testing arms at TCR Engineering and TCR Arabia.

FLAGSHIP CAPABILITY

12 dedicated in-situ metallographic replica field teams run a field-to-lab-to-database workflow against a catalogue of 100,000-plus replicated microstructures.

Asset Integrity and Engineering Consulting is where the company stops being a testing laboratory and starts being a strategic partner. The pillar carries the higher-margin engagements at TCR Advanced, supported by the testing arms at TCR Engineering and TCR Arabia. The reader of this pillar is not a procurement officer running a low-bid line item; the reader is a refining or fertiliser plant manager, a power-plant integrity engineer, a pipeline operator, or an insurance referee, looking for the partner that converts test data into a defensible engineering decision.

TCR's consulting team has deep engineering expertise and has access to an advanced material testing laboratory that enables them to uncover the root cause of failure and recommend the best solution to prevent recurrence. TCR Engineering provides consulting assistance in several areas that 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
- Manage Quality Control Projects
- 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 (NDT) Plan and TOFD/ Phased Array Procedures
- 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
- Creating a Custom Metallurgical Image Analysis Software
- Ensure Product Compliance with Rohs and WEEE

The consulting practice additionally offers advanced services that include:

- Finite Element Analysis and Stress Analysis
- Advanced Materials and Processes
- Fractography
- Surface Engineering
- Tribology
- Welding esp. repair welding and cast iron welding
- Atomised Powder Production (Technology, QA, Application wise Requirements of Powders)
- Life Cycle Analysis and Engineering Asset Management
- Global Warming-Role of Tribology & Surface Engineering
- Thermal Spraying
- CAD/CAM Modelling

Sixteen service lines sit under the pillar. The catalogue is anchored by three flagship blocks: the AiOM digital backbone (the indigenously developed Asset Integrity and Optimisation Management platform), the Fitness for Service practice (per API 579-1/ASME FFS-1 and BS 7910), and the Knowledge-Based Audit practice (delivered per API 580 and API 581). Around these three sit Remaining Life Assessment, Engineering Critical Analysis, ARTiS Reformer Tube Inspection, fire damage assessment, plant life extension, engineering design review, cathodic protection, root cause failure analysis, 3D laser scanning, indigenisation and localisation support, structural stability assessment, energy audit, contract R&D, and solutions for critical weld problems.

6.1 AiOM, the Asset Integrity and Optimisation Management Platform

AiOM is the indigenously developed digital backbone of TCR Advanced's asset integrity practice. The platform is delivered subscription-led and bundled with consulting, not as a standalone software licence pursuit.

6.1.1 The 12-Module Catalogue

AiOM is built around a suite of robust modules that enhance decision-making and accountability across the asset lifecycle:

1. Centralised Asset Database

- A single-source asset database structures and standardises data, enabling quick and easy configuration. The platform includes a comprehensive asset classification system, making it simple to add and update equipment data.

2. Integrated Maintenance, Materials, and Spares Management

- AiOM’s maintenance management module offers a holistic view of asset maintenance, including cost analysis and risk assessment for high-failure-rate equipment.
- Integration with spares and materials management ensures quick decision-making, facilitating timely interventions.

3. Enhanced Maintenance Strategies

- The software incorporates predefined maintenance strategies to improve safety, asset availability, and reliability while optimising costs. Each strategy aligns with regulatory standards and best practices to minimise risks and streamline plant operations.

4. Asset Optimisation Tools

- AiOM's Fitness-for-Service (FFS) tools support the continuous assessment of critical assets, monitoring efficiency, and health to detect potential failures early. Real-time insights enable proactive, rather than reactive, asset management.

5. Advanced Analytics and Dashboard Visualization

- Customizable dashboards provide at-a-glance data visualisations for reliability trends, downtime analysis, and cost tracking. This empowers asset managers with actionable insights to spot problem areas, facilitating data-driven decisions to enhance reliability and efficiency.

6. Risk-Based Methodologies for Optimised Resource Allocation

- AiOM utilises API 580/581 RBI methodologies for asset risk management, allowing for a strategic approach to inspection scheduling. This helps balance inspection intervals and maintenance priorities, minimising plant shutdowns and ensuring compliance with safety standards.

7. Material Search and Root Cause Analysis (RCA) Tools

- AiOM includes a material search engine that helps engineers access critical material information quickly. The RCA tool provides a structured method for analysing failures, identifying root causes, and implementing effective mitigation to reduce repeat failures.

8. Turnaround and Shutdown Planning

- The platform facilitates turnaround planning by flagging maintenance notifications tied to shutdowns, enabling strategic planning for maintenance events. This functionality aids in efficient resource allocation and minimises unplanned outages.

9. Quality Assurance and Inspection Plans

- AiOM's quality assurance module supports the creation and maintenance of standard QA plans and inspection schedules. This ensures that all equipment meets rigorous standards and helps maintain a consistent level of asset quality across the plant.

10. Accelerated Learning and Troubleshooting Tools

- Asset engineers gain access to a vast database of failure case studies and a troubleshooting guide powered by AI. This unique feature offers rapid access to problem-solving resources, allowing engineers to address equipment issues quickly and effectively.

11. Engineer's Toolbox for Design Calculations

- The Engineer's Toolbox provides essential tools for on-the-fly engineering and design calculations. With tools for corrosion loops and Integrity Operating Windows (IOW) based on API-584, engineers can monitor the health of piping circuits and other critical equipment.

12. Work Order Management and Action Tracking

- AiOM includes a work order management system for structured issue tracking, prioritisation, and resource planning. Asset histories, recommendations, and action statuses are documented and easily traceable, ensuring accountability and seamless problem resolution.

6.1.2 Anchor Sub-Modules

- Integrity Operating Windows. The IOW module is anchored in API RP 584 (1st Edition 2014, 2nd Edition December 2021). Ammonia plant trains, refining hydroprocessing units, and fertiliser ammonia synthesis loops are configured against critical, standard, and informational IOW limits.
- Intelligent Plant. The P&ID-driven graphical interface that links any tag on a piping and instrumentation diagram to its inspection history, RBI risk score, current IOW status, and next-due action.
- Asset Troubleshooting Guide. The AI-assisted knowledge-retention engine built on TensorFlow and Keras. Captures the institutional memory of the senior bench in retrievable form so the next reformer-tube inspection at QAFCO does not start from a blank page.
- Damage Mechanism Library. Approximately 70 mechanisms aligned to API RP 571 (refining), WRC 489 (refining), WRC 488 (pulp and paper), WRC 490 (fossil power), and the ASM Handbook Volume 11A (failure of boilers and related equipment).

6.1.3 Standards Stack

API 580 (RBI), API 581 (RBI methodology), API 584 (IOW), API 579-1/ASME FFS-1 (FFS), BS 7910 (FFS), API 510 (pressure vessel inspection), API 570 (piping inspection), API 653 (tank inspection), API 571 (damage mechanisms), API 5L (line pipe), ASME Section I (power boilers), ASME Section VIII (pressure vessels), ASM Handbook Volume 11A.

6.1.4 AiOM-CCP, the Cross-Country Pipelines Application

AiOM-CCP extends the six-pillar platform to pipelines beyond facility boundaries: 10 km to 1,000 km, buried or above-ground, carrying crude petroleum, refined products, natural gas, water, chemicals, or sewage.

Module	Capability
Defect catalogue	Pipeline-specific damage mechanisms (external corrosion, internal corrosion under deposit, third-party damage, geohazard, stress corrosion cracking)
In-Line Inspection ingestion	MFL primary; UT and EMAT data ingestion roadmapped
Cathodic Protection module	Pipe-to-Soil Potential tracking against the negative 0.85 V to negative 1.20 V band against Cu/$CuSO_4$
Coating surveys	CIPL, Pearson, CAT, DCVG, conductance, casing-and-carrier short; 5-year frequency framework
Quantitative Risk Assessment	Design-stage with fatality frequency curve, then once-in-5-years through design lifespan

Documented case study: Anonymised undersea pipeline, API 5L X46N, 21 km by 355 mm by 15.9 mm, ID-side CO_2/H_2S corrosion.

Standards embedded: API 584, API 5L, API 580/581.
Roadmap standards: API 1160, ASME B31.4 / B31.8S, NACE SP0102 / 0204 / 0206, DNV-RP-F101, External Corrosion Direct Assessment / Internal Corrosion Direct Assessment / Stress Corrosion Cracking Direct Assessment, Inertial Measurement Unit geometry, EMAT-ILI, High Consequence Area / Moderate Consequence Area / Class Location, composite Type B sleeve repair.

AiOM-CCP is the digital backbone of the Tier 2 (Operator Condition Assessment) and Tier 3 (Engineering Analysis) pipeline service tracks.

Standards. API 1160 (integrity management for hazardous-liquid pipelines), ASME B31.4 (liquid) and ASME B31.8 / B31.8S (gas), DNV-RP-F101 (assessment of corroded pipelines), and API 5L (line pipe).

6.1.5 Anchor Commercial Reference

Chambal Fertilisers G-1 plant RBI per API 580/581 plus AiOM® software implementation. Awarded 11 December 2025. Order CFCL/PUR/260/49004678. 51 equipment under scope (pressure vessels, towers, heat exchangers, and connecting piping at the G-1 / Ammonia-I Plant); 12 user licences.

6.2 Fitness for Service (FFS)

The FFS practice is delivered against API 579-1/ASME FFS-1 (4th Edition 2021) and BS 7910, with damage-mechanism identification anchored in API RP 571 (refining), WRC 489 (refining), WRC 488 (pulp and paper), and WRC 490 (fossil power) with reference to with ASME Section VIII Division 1 and Division 2.

TCR undertakes Fitness For Service (FFS) Assessment based on Level 2 and 3 of BS 7910 standards and API 579. Our fracture mechanics methodology and its application have been successfully proven worldwide across industries, including nuclear pressure vessels to high consequence items in the exploration, refining, petrochemical and construction industry.

A process, plant, and equipment are often exposed to corrosive environments and/or elevated temperatures. Under these conditions, the material used in the equipment can degrade or age with time. Important equipment such as pressure vessels, piping, and storage tanks become older, the plant operator must decide if they can continue to operate safely and reliably to avoid injuries to personnel and public, environmental damage, and unexpected shutdowns. Fitness for service assessment procedures provide a means for helping the plant operator make these decisions on established engineering principles.

Fitness for service assessment is a multidisciplinary engineering analysis that ensures all process and plant equipment such as pressure vessels, piping, and tanks operate safely and reliably for the desired period of operation and until the next turnaround or planned shutdown occurs in the future. API Recommended Practice 579 provides a general procedure for assessing fitness for service. This assessment procedure evaluates the remaining strength of the equipment in its current state, which may have degraded from its original condition. Common degradation mechanisms include corrosion, localised corrosion, pitting and crevice corrosion, hydrogen attack, embrittlement, fatigue, high-temperature creep and mechanical distortion. Methods for evaluating the strength and remaining service life of equipment containing these types of degradation are presented and reviewed

Common Reasons for Assessing The Fitness for Service of Equipment Include:

- Discovery Of A Flaw Such As A Locally Thin Area (LTA) or Crack

- Failure to Meet Current Design Standards
- Plans for Operating Under More Severe Conditions than Originally Expected

Outcome of Fitness for Service Assessment

- Decision to Run, Alter, Repair, Monitor, or Replace the Equipment
- Guidance on Inspection Interval for the Equipment

Fitness for Service Assessment uses Analytical Methods to Evaluate Flaws, Damage and Material Aging Based On:

- Stress Analysis may be performed using Standard Handbook or Design Code Formulas or by means of Finite Element Analysis (FEA). With modern computer technology, the use of FEA is quite common.
- Fitness for Service Assessment requires both, knowledge of past operating conditions and a forecast of future operating conditions. Interaction with operations personnel is required to obtain this data
- Non-Destructive Examination (NDE): NDE is used to locate, size and characterise flaws
- Material Properties: The material properties include information on material damage mechanisms and behaviour in the service environment, especially on the effects of corrosion and temperature

6.2.1 The 14-Part / 3-Level Architecture

API 579 covers 14 part-types of damage with three assessment levels each:

Part	Damage Type
3	Brittle fracture
4	General metal loss
5	Local metal loss
6	Pitting corrosion
7	Hydrogen blisters and HIC and SOHIC
8	Weld misalignment and shell distortions
9	Crack-like flaws
10	High-temperature components in the creep range
11	Fire damage
12	Dents and gouges
13	Laminations
14	Lining issues

6.2.2 The 8-Step Workflow Per Part

01 Flaw and damage-mechanism identification.
02 Applicability and limitations of the procedure.
03 Data requirements (design, operating, inspection, materials).
04 Assessment techniques and acceptance criteria.
05 Remaining life evaluation.

06 Remediation.
07 In-service monitoring.
08 Documentation.

6.2.3 The Five-Role Team Architecture

The TCR FFS service has a defined the five-role team:

Role	Responsibility
Metallurgical engineer	Damage mechanism identification, materials review, replica reading
Mechanical and design engineer	API 579 calculation, FEA, design review
ASNT Level III inspection engineer	NDT plan, witnessing, sentencing
Site in-charge	Onsite execution, client interface, scope discipline
Certified NDT technicians	UT, PAUT, TOFD, MT, PT, replica acquisition

6.2.4 Anchor Case Study 1: HMEL Bathinda Isomerisation Reactor 503-R-001

March 2012 temperature excursion: peak 710 degrees Celsius for 1 minute, 44 minutes above 700 degrees Celsius. Full damage-mechanism workup including HTHA per Nelson curve API 941. In-situ replication at 60 locations. Hardness mapping. TOFD. Automated Ultrasonic Backscatter Technique (AUBT). Plus a laboratory simulation experiment with welded coupons. Certified fit-for-service. Monitored through 2019 with no CS3 crack growth, no shutdown, no replacement.

6.2.5 Anchor Case Study 2: 18,000 MT Refrigerated Liquid Ammonia Tank

API 620 Appendix R 1978 design. A-537 Class 1 inner shell, IS-226 outer shell. 1983 construction. Leak-Before-Break fracture mechanics study using a Failure Assessment Diagram framework. Rolling regulatory and operator engagement to keep the tank in service.

6.3 Engineering Critical Analysis (ECA)

Engineering Critical Analysis (interchangeably Engineering Critical Assessment) is the fracture-mechanics-led subset of FFS.

Engineering Critical Analysis (ECA) is a sophisticated approach employed to determine alternative acceptance criteria for weld defect lengths versus depths. As per the guidelines outlined in API 1104 – Option 2, ECA provides a framework to assess the structural integrity of pipeline girth welds by considering critical parameters such as fracture toughness, residual stresses, and combined axial stresses. TCR has undertaken this work as a vendor for prestigious client in KSA with Saudi Aramco being the end client in connection with the Jafurah Gas Compression Plants and PWIS (Package-1) project.

TCR's expertise in performing advanced ECA ensures comprehensive evaluation of pipeline girth welds. With capabilities extending to CTOD assessments, FEA, and real-world damage analysis, we deliver actionable insights to ensure the structural integrity and safety of critical pipeline systems. Whether you require API 1104-compliant evaluations or customised solutions, TCR in India as well TCR Arabia in Saudi Arabia are your partner in achieving excellence in engineering assessments.

Codes: API 579-1/ASME FFS-1, BS 7910, ASME Section VIII, and API 1104 Annex A for pipeline girth welds (Method 1 or Method 2 = Failure Assessment Diagram), E1820 (CTOD), ISO 15653, and ISO 12135.

6.3.1 Three Lifecycle Applications

Design stage. Material selection, weld procedure design, defect tolerance establishment for new construction.

Fabrication stage. Sentencing of as-built defects against an FAD, allowing acceptable flaws to remain rather than triggering repair.

In-service stage. Disposition of newly detected flaws during turnaround inspection, with monthly tolerable-defect-height tracking through next inspection.

6.3.2 The 8-Step Piping Girth Weld ECA Workflow

01 Component identification and data study.
02 Define loadings.
03 Material properties.
04 NDT inspection of coupon at TCR.
05 Destructive test on coupons (CTOD at 12, 6, 3 / 9 o'clock weld and HAZ; impact; tensile; total 6 samples per API 1104 Annex A).
06 Fracture mechanics calculations per API 1104 Annex B Method 2 FAD.
07 FEA for axial stresses on the actual line layout.
08 Flaw Table for acceptable flaw size by allowed height and length.

6.3.3 In-House Infrastructure

50, 250 and 1000 kN Fatigue CTOD machine per ASTM E1820.

6.3.4 Marquee ECA Projects

Saudi Aramco Jafurah Gas Compression Plants ECA (PWIS Package-1, engineering critical analysis of 42-inch underground oil trunkline girth welds (2025).

A 48-inch API 5L X60 sweet-gas pipeline, 42 kilometres, assessed per API 1104 Annex A Option 2 with six CTOD tests per pipeline (three weld, three heat-affected zone) on 350 mm mock-up coupons, Caesar II stress input separating installation from operating stress.

6.4 Remaining Life Assessment (RLA)

RLA is the established workhorse of the Asset Integrity practice. Group cumulative count: 750+ RLA studies across all asset classes, including 400+ Boiler RLA assignments and 6 Ammonia Tank RLA sites covering 10 tanks (CFCL Kota, DFPCL Taloja, Paradeep Phosphates 3 tanks, IFFCO Kandla, IFFCO Kalol 2 tanks, RCF Trombay 2 double-wall double-integrity).

6.4.1 The 13-Step Turbine RLA Workflow

01 Visual
02 Dimensional
03 DPT
04 MPT/WFMPI/Coil-MPI
05 Demagnetisation
06 UT
07 In-situ metallography
08 Hardness
09 Diaphragm deposit analysis
10 Natural frequency test
11 Turbine blade inspection
12 White metal bearing inspection
13 Creep and fatigue life evaluation

6.4.2 Boiler RLA, the Six-Pillar Capability Stack

1. IBR-approved Well-Known organisation status.
2. 400+ RLA assignments.
3. Skilled and qualified manpower (the named senior bench plus 12 in-situ replica field teams).
4. Wide range of NDT equipment (12+ videoscopes, 11+ thickness gauges, 10+ MPI sets, 9+ UT flaw detectors, 8+ hardness testers, 5+ PAUT/TOFD systems, 3 ECT systems, 2 oxide scale gauges).
5. In-house facility for sample testing including SEM and creep testing.
6. Multiple inspection teams.

6.4.3 Damage Mechanisms (Boiler)

Boiler Tube Leak, metallurgical degradation, creep, erosion, pitting, general corrosion, HTHA, fatigue.

6.4.4 ACRT (Accelerated Creep Rupture Testing) and Omega Method

Precise remaining creep life prediction from actual in-service samples per Omega Method.

6.4.5 Theoretical Life Assessment (Desk-Based RLA Sub-Service)

A desk-based variant of RLA delivered without site visit, NDT, FFS, stress analysis, CFD, or FEA. Methodology: data collection on operating history, GA drawings, and process parameters; literature survey by a multi-disciplinary team of metallurgical, corrosion, and design experts; theoretical life calculation against the design intent and the materials of construction for shells, dished-ends, and nozzles.

Anchor commercial reference: Gujarat Fluorochemicals Limited (GFL) Ranjitnagar plant (Survey 16/3, 26, 27, Taluka Ghoghamba, Panchmahals, Gujarat), PO 1251101026 dated 04.06.2025, 124 equipment under scope.

Representative engagement. Gujarat Fluorochemicals Ranjitnagar, theoretical life assessment of 124 items from general-arrangement drawings and process parameters (June 2025).

6.4.6 Idle-Plant Restart References

Notore Chemical Industries Plc (Nigeria), Baiji Refinery (Iraq), Godrej Industries, Matix Fertilizers, Nagarjuna Fertilizers, Heavy Water Projects.

6.4.7 The Two-Level RLA Assessment Framework

Every remaining-life study is scoped to one of two levels of depth, and the level is chosen against the criticality of the component and the data available.

A Level II assessment works from collected history, nominal or measured dimensions, an inspection-grade condition survey, operational or measured temperature and pressure, simple stress calculation, and minimum material properties, with no destructive sampling.

A Level III assessment is the most detailed: measured dimensions throughout, a detailed condition survey, measured operating data, refined stress analysis, and actual material properties from samples removed and tested. The approach is deliberately pragmatic. As much data as possible is gathered on the component history first, often through structured discussion with the plant's own operating and maintenance people and outside experts, and those opinions are then weighed against the testing and study that follows.

6.4.8 When a Remaining-Life Study Is Triggered

Operators commission RLA against four families of criteria. History-based: thirty to forty years have elapsed, prior-failure statistics point to impending failure, repair frequency makes continued operation uneconomical, or calculation indicates life exhaustion.

Performance-based: a severe loss of efficiency indicating degradation, a large crack showing as leakage, severe vibration or other malfunction, or a catastrophic burst. Inspection-based: dimensional change leading to distortion and altered clearances, or inspection showing microscopic damage, crack initiation, or a large crack approaching critical size.

Destructive-evaluation-based: metallography or mechanical testing on a removed sample shows life exhaustion. The trigger sets the level: a routine age-based review can be Level II, while a component showing crack initiation or sample-confirmed degradation moves to Level III.

6.4.9 The Boiler Component Approach

On a package or utility boiler each component is worked to a tailored technique set rather than a blanket scan. The drum and the headers carry visual, ultrasonic, magnetic-particle, and liquid-penetrant inspection with dimensional and hardness measurement. The furnace and second-pass water-wall tubes, the economiser, and the primary and secondary superheaters carry visual inspection, in-situ metallography, destructive sample testing where access allows, dimensional measurement, and, on the hottest circuits, deposit analysis, in-situ oxide-scale thickness measurement, and accelerated creep-rupture testing. Ducts and expansion joints carry visual, liquid-penetrant, and dimensional checks, and special tests cover hanger inspection, alignment, fibroscopy, and finite-element analysis where the geometry warrants it. The reading from all of these resolves into one estimate of remaining safe life with documented evidence of any damage and a recommendation on repair, inspection interval, and life-extension strategy, worked to IBR and ASME guidance.

Representative engagements: Adani Power Mundra, remaining-life assessment of a 660 MW supercritical boiler completed in 25 days; PIC and NBTC, Kuwait, RLA of 120 critical items across an ammonia and urea plant; Petrokemya, RLA of a fire steam-tube boiler; GNFC TDI-II, RLA on reformer tubes; QAFCO, RLA with in-situ metallography on pressure parts.

6.5 In-Situ Metallography and Microstructural Replication

In-situ metallography is the flagship value-add of the group and the technique on which much of the asset-integrity practice rests. It reads the microstructure of a high-temperature component while that component stays in place, with no cutting, no sample removal, and no loss of pressure boundary. The metallurgist prepares a small area on the live surface, grinds and polishes it to a mirror finish, etches it, lifts a replica of the microstructure, and reads that replica under the microscope in the laboratory.

TCR Engineering under the NDT service performs In-Situ Metallography to determine in-service degradation of critical components of process and plants operating under high temperature, high-pressure and corrosive atmospheres. The technique enables real-time component condition monitoring and health assessments. TCR's Metallurgists have strong experience in the interpretation of microstructures and have more than 100,000 in-situ microstructure replicas, logged and captured in its proprietary database. These databases contain extensive information from various plants, captured over the course of four decades of service. The database also includes rare collections of varying microstructure damage levels from various industries such as power, oil and gas, petrochemical, fertilizers among others.

The In-Situ Metallography team at TCR is highly skilled in the art of replica preparation. TCR has custom-developed special purpose in-situ polishing devices that assist in metallographic polishing under difficult locations and allows the field services team to carry out high-quality replication even on warm components.

TCR provides microstructure survey for critical components viz., Boilers, Pipelines, Reactors and Vessels for monitoring and health assessments. TCR has developed a databank of critical components of process plant equipment by periodical monitoring for preventive maintenance and planning for inventory control. With this, TCR can provide suggestions on repair and welding of used components of process plants.

In-situ Metallography and replication is used for microstructural analysis while examining large components that cannot be easily moved or destructive sample preparation is difficult or not permissible. The testing allows quick on-site evaluation of a component's metallurgical and heat treatment condition and assists investigators while carrying out a remaining life assessment study or a failure analysis project.

Metallography Replica Interpretation

TCR, at their material testing laboratories in Mumbai and Baroda, has an advanced Inverted Metallurgical Microscope, GX5, from Olympus Corporation, Japan. This Inverted Metallurgical Microscope allows expert metallurgists at TCR to perform Volume Fraction Measurement by point count method as per E-562 used for Duplex Steel and Carbide Morphology Distribution as per STAHL-EISEN-PRUFBLATT 1520 (SEP-1520) German chart for checking microstructures.

At material testing laboratories in Mumbai and Baroda, India, TCR has an advanced Inverted Metallurgical Microscope, GX51, from Olympus Corporation, Japan. This Inverted Metallurgical Microscope allows expert metallurgists at TCR to perform Volume Fraction Measurement by point count method as per E-562 used for Duplex Steel and Carbide Morphology Distribution as per STAHL-EISEN-PRUFBLATT 1520 (SEP-1520) German chart for checking microstructure.

TCR Engineering Services has undertaken In-situ Metallography projects at major plants of reputed clients including, Alstom Projects India Limited, Vadodara (Worked on more than 20 RLA projects), BARC (Mumbai), Heavy Water Board (Mumbai), BARC, Reliance Industries Limited (Jamnagar and Hazira), SPIC-SMO, Gujarat Electricity Board, Ahmedabad Electricity Board, GSFC Limited, GNFC Limited, IOCL (Vadodara), L & T, Hindustan Lever Limited (9 Boiler RLA Work), Narmada Chematur Petrochemicals Limited, Bharuch and many more.

At TCR, the following sets of In-Situ Metallography kits and equipment are available:

- Insipol 2000 And Advanced Electrolytic Flow Type Polisher And Etcher
- Portable Rough Grinder With Self-Adhesive Papers
- Portable Fine Polishing (Mini Grinder)
- Portable Microscope Capable Up To 400X Magnification
- Replica Kit: Used With Specialised Plastic Based Slides For Replica Preservation (For Longer Durability And Ease Of Handling On Site)

KEY INFORMATION FOR REPLICATION INTERPRETATION

- Objective Of In-Situ Metallography - Condition Assessment, Fire/Damage Assessment, Remaining Life Assessment, Or Baseline Data Generation
- Material of Construction with Exact Specification
- Location of Replication with Sketch
- Process Parameters and Design Parameters
- Service Life of The Component at the Time of Replication
- Any History Of Previous Failures at the Location of Replication

6.5.1 The Field-to-Lab-to-Database Workflow

The work runs as one chain. The replica is taken at the plant by a field team, interpreted the same day at the field site for the go or no-go call, then carried to the laboratory for full microstructural reading under optical and scanning electron microscopy, and finally logged against the reference database so that today's microstructure can be compared with the same component years earlier and with the population of similar components across the archive. Same-day interpretation at the site is the commercial promise: when a creep-cavitation study comes off a reformer tube or a superheater during a turnaround, the operator gets the call inside the shutdown window, not weeks later.

6.5.2 What the Replica Reveals

The replica records the state of the microstructure and therefore the damage the component has taken. Creep cavitation is classified through its stages, from isolated cavities to oriented cavities, micro-cracks, and macro-cracks, so that the remaining safe life can be judged. The same reading identifies the operative degradation: spheroidisation and carbide coarsening in ferritic steels, graphitisation, sigma-phase embrittlement in stainless steels, decarburisation, and the microstructural signatures of overheating. Hardness is taken in-situ alongside the replica, and where the case requires it the area is examined under SEM with EDS for chemistry, with colour metallography and chemical-composition mapping used to resolve weld dilution and difficult phase boundaries.

6.5.3 Where It Applies

The technique is the backbone of remaining-life assessment on elevated-temperature plant. On boilers it reads superheaters, reheaters, water walls, headers, and drums; on the steam circuit it reads main steam lines and hot reheat lines; on hydrogen and reforming plant it reads reformer tubes, pigtails, and outlet headers; and across refining and petrochemicals it reads pressure vessels, transfer lines, and fired-heater coils. It is one of the standard tools in the boiler RLA stack alongside ultrasonic testing, internal oxide-scale measurement, dimensional survey, and accelerated creep-rupture testing, and it feeds fitness-for-service, root-cause failure analysis, and knowledge-based audit work. Across the group the capability is delivered in India by the TCR Engineering and TCR Advanced benches and in the Kingdom by TCR Arabia, where Syed Ahsan Ali leads replication on boilers, main steam lines, and pressure vessels for clients including SABIC affiliates, MAADEN, and Saudi Railway.

6.5.4 Why the Capability Is Hard to Match

Field replication at scale is an operator-side capability, not a laboratory line item. A single replica team is a calling card; the group fields twelve dedicated in-situ replica field teams, which is an industrial capacity. Behind the teams sits a reference base of more than 100,000 replicated microstructures built up over the archive, three scanning electron microscopes at TCR Advanced Vadodara, and a named metallurgist bench led by Paresh Haribhakti and supported by Mukesh Kumar in Mumbai and Syed Ahsan Ali in Dammam. TCR has also developed the Microstructure Characterizer image-analysis software and custom colour-metallography and electrolytic-polishing techniques that sharpen interpretation of difficult microstructures. The combination of field reach, a deep comparison archive, in-house electron microscopy, and a pioneer-led bench is what turns a replica from a photograph into a remaining-life decision.

6.5.5 Standards

ASTM E1351 (field metallographic replication), ASTM E3 (preparation of metallographic specimens), ASTM E407 (microetching), ASTM E112 (grain size), ASTM E45 (inclusion rating), and ASTM E1245 (image analysis), with creep-cavitation classification read against the recognised cavitation-stage scale and the boiler regime worked to IBR and ASME guidance.

6.6 Knowledge-Based Audit (KBA)

KBA is not boiler-only. It applies to boilers, heat exchangers, pressure vessels, columns, reactors, reformer tubes, piping, and tanks. Boilers anchor the practice; they do not bound it.

Representative engagement. Chambal Fertilisers G-1 and Ammonia-I plant, risk-based inspection per API 580 and API 581 with AiOM software across 51 items.

Standards: API 580 and API 581 (4th editions, January 2025), API 510, API 570, and API 653 (in-service inspection), API RP 584 (integrity operating windows), and the Energy Institute Risk-Based Inspection Best Practice Guide.

6.6.1 The KBA Method

A multi-disciplinary panel reviews equipment design, operating history, prior inspection findings, damage-mechanism susceptibility, and remaining-life curves, and issues a three-stream output:

Stream	Action
Improve	Inspection interval revision, NDT method change, IOW tightening
Repair	Plug, weld overlay, sleeve, seal weld, partial replacement
Replace	Component replacement scheduled at next opportunity

6.6.2 The Authority Anchors

- 1,500+ Boiler Tube Failure investigations, the largest single-class evidence base of its kind in India.
- 400+ Boiler RLA assignments.
- 100,000+ replicated microstructure reference database.
- CBB Well-Known RLA Organisation approval under the Indian Boiler Regulations.

6.6.3 Cross-Vertical Application

Vertical	KBA Application
Power generation	Critical and sub-critical, supercritical and ultra-supercritical, CFBC, AFBC, HRSG, waste heat boilers, package boilers
Refining	FCCU, hydroprocessing, hydrocracker, alkylation, sulphur recovery
Fertilisers	Ammonia synthesis loop, urea reactor, primary and secondary reformer, granulation, prilling tower
Petrochemical	Olefins crackers, polymer reactors, aromatics, methanol, melamine
Chemical processing	Caustic-chlorine, agrochemical reactor trains, fine chemicals
Steel	Coke oven battery, blast furnace, BOF, continuous caster (refractory and pressure boundary scope)
Pipelines	Cross-country mainline, CGD, LNG terminal piping (cross-pillar with AiOM-CCP)

6.7 ARTiS, Automated Reformer Tube Inspection with Built-In FFS

ARTiS is TCR-owned.

At TCR we have developed ARTiS, the Automated Reformer Tube Inspection System, an advanced solution for the comprehensive assessment of reformer tubes. Having completed over 100 projects for clients in India and internationally, TCR is the leader in reformer tube integrity assessments. Our multidisciplinary approach incorporates Fitness for Service (FFS) analysis as per API579/ASME FFS1 and features a unique ability to determine "when to retire tubes." Over the years, TCR has developed an extensive database of reformer tube failure mechanisms, allowing our research wing to identify early warnings of tube failures with unparalleled accuracy.

TCR's deep understanding of the operational and metallurgical interactions of reformer tubes, combined with our innovative ARTiS technology, enables us to deliver superior insights into the condition of your tubes. With automated crawlers that accommodate tube outer diameters from 70 mm to 200 mm in the current generation (105 mm to 190 mm on the earlier generation), ARTiS provides precise data for Level III FFS assessments, ensuring the accurate prediction of remaining tube life.

Key Features of TCR's Reformer Inspection using ARTiS:

- Multi-technique approach for detailed condition assessment of reformer tubes
- Level III FFS Assessment as per API579/ASME FFS1 for remaining life calculations
- Proprietary standard samples with known damage scenarios, offering superior accuracy
- Ultrasonic attenuation measurement for fissure detection via automated crawler
- In-situ metallography for microstructural analysis to assess microstructural degradation
- Visual Inspection for bulging, baldness, sagging, and bowing by an expert
- Automated Outer Diameter Measurement with electronic devices on ARTiS at intervals of 0.1M using infrared light sensors
- Automated Bowing Measurement with on-board electronic devices
- Hardness Testing at metallography locations
- Manual Ultrasonic Wall Thickness Measurement at platform (bottom) level
- Magnetic Permeability Measurement at platform level

TCR provides a detailed Level III FFS Assessment in accordance with API579/ASME FFS1 Inspection results summarising accumulated creep damage including calculation of effective tube metal temperature and projected creep damage up to the next shutdown. Retirement date prediction based on accumulated creep damage (0.8 life fraction) and Remaining life assessment for each tube.

Reformer tubes operate above 800 degrees Celsius under internal pressure, where high-temperature creep shows up first as diameter growth of 1 to 6 percent and, in later stages, as internal fissures and bowing. ARTiS quantifies that damage tube by tube, and TCR classifies the creep stage against a microstructure database of roughly 1,000 catalogued spots covering virgin, in-service-aged, and failed tubes, read by in-house metallographers from surface replicas.

The condition result feeds a fitness-for-service judgment and a reuse, monitor, or replace decision on each tube. In-situ metallographic replication and reformer-tube condition assessment have been delivered to more than 50 plants in India and abroad, including GNFC Bharuch, GSFC Vadodara, CFCL Kota, IOCL Vadodara, BPCL Cochin and Mumbai, Reliance Jamnagar, Vadodara, and Hazira, Deepak Fertilizers, RCF Thal, and Maden in Saudi Arabia.

The crawler hardware, the transmit-receive ultrasonic method, and the attenuation-to-creep bands behind this service are described in Section 7.1.

The ARTiS paper by Upadhyaya, Haribhakti, Patel, and Bafna (TCR Advanced, 2013 to 2014) is the published authority anchor for the practice (see Section 15 Published Authority).

Standards: API 530 and API 530 Annex E (heater-tube creep-life calculations), API 570 (piping inspection), and API 936 (refractory).

6.8 Cathodic Protection, the CP Division

The CP Division is led by Chiral Patel as CP Division Lead, with 20+ years of cathodic protection and pipeline integrity experience. The division runs its practice out of Vadodara with a regional office in Bhubaneswar, and offers CP services pan-India to meet the geography of cross-country pipeline and CGD operators.

TCR Engineering offers comprehensive Cathodic Protection (CP) monitoring services as per GAIL to assess the effectiveness of installed permanent CP units at feeding points. This essential service helps prevent corrosion in pipelines and other metallic structures by ensuring that the CP systems function optimally.

Through our CP monitoring, we utilise advanced techniques to evaluate the performance of CP units, measuring key parameters such as voltage and current levels. This proactive approach enables us to identify any potential issues that may compromise the integrity of the CP system and allows for timely interventions to enhance corrosion protection.

Our dedicated team of experts employs advanced equipment and methodologies to conduct thorough inspections, providing clients with detailed reports and actionable insights. By ensuring the effective operation of CP units, TCR Engineering supports the longevity and reliability of critical infrastructure, safeguarding against corrosion-related failures.

J.N. Agarwal (33 years at GAIL, ICorr Level 4 Fellow, AMPP Corrosion Awareness Award 2023, CP4-certified, 40+ years O&G, author of 3 books on CP) sits on the consultant bench supporting the CP Division.

Capability	Detail
Sacrificial anode systems	Design, installation, maintenance per `NACE SP0169`
Impressed current systems	Design, installation, transformer-rectifier sizing, anode bed configuration
Coating survey	Close Interval Potential Survey (CIPS), Direct Current Voltage Gradient (DCVG), Pearson, Conductance Attenuation Test (CAT), casing-and-carrier short
Pipe-to-Soil Potential	Tracking against the negative 0.85 V to negative 1.20 V band against Cu/CuSO4
Cross-pillar integration	Feeds the AiOM-CCP CP module

Standards: NACE SP0169 (control of external corrosion on underground metallic piping); NACE SP0102 (in-line inspection); NACE SP0204 (stress corrosion cracking direct assessment); NACE SP0206 (internal corrosion direct assessment); ISO 15589; DNV-RP-B401 (cathodic protection of offshore structures, 2021 update).

6.9 Root Cause Failure Analysis

The single largest archive in the group: **9,000+ failure investigations**. This is the foundation that feeds the KBA practice, the FFS practice, and the AiOM damage-mechanism library. The published authority anchor for the practice runs across the two ASM International titles (Haribhakti, Joshi, Kumar 2018; Haribhakti and Joshi 2021), the four foundational TCR white papers, and an active senior-bench blog corpus.

The work is accepted across oil and gas, refining, petrochemicals, fertilisers, power, general engineering, defence, aviation, and insurance, and it covers both static and rotating equipment. The findings are written to stand up where it matters: not only for the plant's own reliability decisions but for litigation and insurance investigations, which is why the method is evidence-led and the report is defensible. The forensic approach is to read the available physical evidence, run the tests that the case requires, and build the most probable failure scenario from what the evidence supports, then to set it out in plain terms so that engineers, executives, regulators, or counsel can all follow the reasoning.

TCR prides itself for its deep knowledge and has gathered best practices from success stories compiled from over 9,000 failure investigation assignments, which include major projects in manufacturing and metallurgical failures on ASME boilers, pressure vessels, gas turbine engine components, oil and gas transmission pipelines, food processing equipment, heat exchangers, medical supplies, refineries, petrochemical plants, aircraft/aerospace, offshore structures, industrial machinery, weldments and ships.

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

TCR Engineering works with clients to draw up a plan for failure analysis to efficiently conduct the investigation. A large amount of time and effort is spent in carefully considering the background of failure and studying the general features before the actual investigation begins. The cause of failure is determined using advanced analytical and mechanical procedures that often includes simulated service testing. Analysis and physical testing, when combined together, locates problems and provides recommendations for effective 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 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 considers all aspects of 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 to conduct a Failure Analysis is summarised as under:

Evaluation Sequence for Conducting Failure analysis

1. Collection of Background Data and Selection of Samples
2. Preliminary Examination of the Failed Part
3. Complete Metallurgical Analysis of Failed Material
4. A thorough examination of the Failed Part including Macroscopic and Microscopic Examination and Analysis (Electron Microscopy, If Needed) Tests, If necessary may also include Weld

Examination, Case Depth, Decarburisation Measurement, Coating/Plating Evaluation, Surface Evaluation and/or Grain Size Determination
5. 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
6. Analysis Of Fracture Mechanics
7. Selection and Testing of Alternative Products and/or Procedures That Will Significantly Improve Performance
8. On-Site Evaluation and Consulting Services and Formulation Of Conclusions and Writing the Report (Including Recommendations)

Failure Investigation Report

The investigation team produces detailed written reports to ensure clients fully understand the implications and can independently examine the conclusions:

1. Description of the Failed Component
2. Service Condition at the Time of Failure
3. Prior Service History
4. Manufacturing and Processing History of Component
5. Mechanical and Metallurgical Study of Failure
6. Metallurgical Evaluation of Quality
7. Summary of Failure Causing Mechanism
8. Recommendations for Prevention of Similar Failures
9. Latest Inspection Solutions

Workflow: visual, NDT, replication, hardness, mechanical and chemical, fractography (SEM and EDS), microstructural analysis, FEA where loading is in question, damage-mechanism attribution, and a written report fit for litigation, insurance, or operator action.

Standards. API RP 571 (damage mechanisms in the refining industry), ASM Handbook Volume 11A, WRC 488, WRC 489, and WRC 490.

Representative engagement. HMEL Bathinda failure-investigation rate contract 9830004894, a three-year retainer covering the full Bathinda refinery and petrochemical complex (June 2025 to June 2028).

6.9.1 Metallic Component Failure Analysis

For metallic components the investigation uses scanning electron microscopy and energy-dispersive X-ray spectroscopy, fractography, and advanced metallography including colour metallography, alongside material characterisation, mechanical-property evaluation, and a review of service history and design parameters, with finite-element analysis where the loading is in question. It resolves cracking, corrosion, wear, and brittle and fatigue failures to a root cause, and closes with a tailored corrective-action plan and, where warranted, recommendations on material upgrade or process change.

6.9.2 Non-Metallic Component Failure Analysis

The practice also covers non-metallic components: polymers, composites, ceramics, rubber, and FRP and GRP systems, which typically degrade through ultraviolet exposure, chemical attack, thermal ageing, or design error. These are investigated through a combination of mechanical testing, spectroscopy, microscopy, and thermal analysis, with the same root-cause discipline applied to the metallic work.

6.9.3 The Damage-Mechanism Range

The archive spans the full range of in-service degradation: creep and creep-fatigue, mechanical and thermal fatigue, general and localised corrosion, pitting, erosion-corrosion, microbiologically influenced corrosion, selective leaching, stress-corrosion and sulphide-stress cracking, polythionic-acid stress-corrosion cracking, hydrogen embrittlement and hydrogen damage, high-temperature hydrogen attack, and welding-related defects. The breadth of the named-mechanism vocabulary is what lets an investigator place a new failure quickly against the population of similar cases in the database.

6.9.4 Shaft and Rotating-Component Failure Analysis

A shaft failure is read from the fracture surface first. Beach marks and ratchet marks separate rotating bending from reversed bending and from torsional fatigue, and the number and spacing of the ratchet marks indicate how severe the stress concentration was at the origin. A hardness traverse and metallography through the fracture establish whether the material, the heat treatment, and any surface treatment were to specification, and whether a decarburised or overheated layer contributed. The investigation then fits the fracture origin to the feature that started it: a keyway corner, a fillet radius, a press fit and its fretting scar, a shrink-fit shoulder, a corrosion pit, or a machining mark. The report names the mechanism, the initiating feature, and the design, manufacturing, or operating change that closes it. The same discipline covers couplings, gears, pins, and fasteners on rotating assemblies, alongside the boiler tube, weld, and fastener failure work.

6.10 Fire Damage Assessment

Per API 579-1 Part 11. Temperature-zone mapping of the damaged plant footprint (Zone I through Zone IV by inferred peak temperature). Deformation analysis. Post-fire FFS.

6.11 Boiler Audit

TCR Engineering offers expert services in Remaining Life Assessment (RLA) and comprehensive condition assessment of boilers, ensuring optimal performance and extended service life. With extensive experience in both Level II and Level III assessments, TCR utilises a systematic approach, combining technical data collection and expert consultations to evaluate the current condition and predict the remaining life of boiler components.

At TCR, we adopt two proven methodologies to determine boiler life:

1. Calculation-Based Approach: We analyse temperature and operational cycling data using advanced calculation procedures to estimate the extended life of components under creep, fatigue, and creep-fatigue conditions. By leveraging plant records and standard material properties, we accurately estimate the fractional life consumed up to a given point in time.
2. Design-Based Approach: Our experts evaluate components that operate in high-stress environments, accounting for factors like yield strength, tensile strength, and fatigue resistance. Even when components are designed for long-term durability, unforeseen factors can reduce their life. We ensure that these risks are accounted for in our assessments.

TCR's Expertise in Remaining Life Assessment includes:

- Comprehensive Analysis of Degradation Mechanisms: We identify key issues such as fatigue, thermal aging, creep, embrittlement, and corrosion.
- Advanced NDT Techniques: Our assessments include visual examination, in-situ metallography, ultrasonic testing, magnetic particle inspection, DP testing, and ferrite measurement to ensure a deep understanding of component integrity.
- Stress Analysis: We evaluate the material's strength and its resistance to rupture under various conditions.
- Laboratory Testing: We provide critical insights into material soundness through precise laboratory testing.
- Fitness Judgments & Repair Recommendations: Based on our findings, we recommend repairs or preventative maintenance measures to extend the life of your equipment.

Comprehensive Boiler Life Assessment:

- History-Based: Evaluating failure statistics, repair frequency, and life-exhaustion calculations to estimate when equipment may fail.
- Performance-Based: Monitoring efficiency loss, leakages, or malfunctions to identify severe degradation.
- Inspection-Based: Detecting dimensional changes, crack initiation, or microscopic damage through regular inspections.
- Destructive Evaluation: When necessary, we utilise metallography and mechanical testing to pinpoint potential life exhaustion.

By partnering with TCR Engineering, plant owners can make informed decisions on maintenance, repair, and equipment upgrades, minimising risks and maximising operational efficiency. Our proven expertise in boiler RLA ensures that your critical assets are evaluated and maintained with the highest standards of safety and performance.

TCR Engineering, ensuring your boilers operate safely, efficiently, and reliably for years to come.

6.11.1 Boiler RLA Audit and Creep Test

TCR Engineering's dedicated team serves customers in the power industry by conducting comprehensive Remaining Life Assessments (RLA) for critical boiler components. Our expertise covers a wide range of issues, including but not limited to boiler tube leaks (BTL), metallurgical degradation, creep damage, erosion, pitting, general corrosion, high-temperature hydrogen attack, and fatigue-related damage mechanisms.

Our Managing Director, Mr. Paresh Haribhakti, has co-authored the acclaimed book "Boiler Tube Failures", which is published by ASM International offering valuable insights into boiler tube failure mechanisms and prevention strategies.

With TCR's advanced assessment services and industry-leading expertise, we help ensure the reliability, safety, and extended operational life of your boilers.

6.11.2 Internal Oxide Scale Boiler Measurement

TCR Engineering offers specialised Internal Oxide Scale Measurement services for steam boilers, ensuring optimal performance, extended lifespan, and operational safety. High-temperature boiler operations, especially those exceeding 1000°F (500°C), lead to the formation of brittle iron oxide, known as magnetite, on the inner surfaces of tubing. This magnetite layer reduces heat transfer, increases the operating temperature of tube walls, and significantly shortens the tube's creep life. Early detection and accurate measurement of this oxide scale can guide critical maintenance decisions such as descaling, which can enhance efficiency and prolong the service life of your boiler.

- Oxide Scale Detection: We measure the thickness of the internal oxide scale (magnetite) formed on the inner surfaces of boiler tubes, providing a precise assessment of the level of oxidation.
- Remaining Life Estimation: Based on oxide scale measurements, we help you determine the remaining life of your boiler tubes, enabling proactive maintenance and descaling decisions.
- Thermal Efficiency Improvement: Our service helps identify excessive oxide scale formation, which hinders heat transfer and increases operational costs, allowing you to take corrective action to improve boiler efficiency.

Benefits of TCR Engineering's Oxide Scale Measurement:

- Early Detection of Tube Degradation: Detecting internal oxide scale formation early allows for timely descaling, preventing premature tube failure and ensuring optimal boiler performance.
- Enhanced Heat Transfer Efficiency: By measuring and controlling oxide scale formation, we help maintain better heat transfer, reducing fuel consumption and operating costs.
- Extended Boiler Life: Timely descaling and proper maintenance based on accurate measurements can significantly extend the service life of your boiler tubes, reducing the frequency of costly replacements.
- Safety Assurance: Prevent overheating of boiler tubes caused by thick oxide layers, which can lead to catastrophic failure under high pressure and temperature conditions.

Omega Creep Testing for Fired Heater and Boiler Tubes

TCR Engineering offers comprehensive Omega Creep Testing and Creep Remaining Life Assessment services to help you ensure the safety and longevity of your fired heater and boiler tubes. With over 5 years of experience and expertise in Omega testing, we provide clients with critical insights into the current condition of their materials, detecting service-induced material degradation, creep damage, and remaining operational life.

- Material Degradation Analysis: We determine the current metallurgical condition of the tube samples, assessing the impact of service-induced degradation and creep damage.
- Omega Creep Testing: Our specialised Omega creep testing method accurately evaluates the creep properties of the supplied samples, providing a clear understanding of their condition.
- Creep Remaining Life Assessment: We calculate the remaining life of your fired heater/boiler tubes, leveraging:
    - Results from Omega creep testing.
    - Mechanical & Metallurgical Testing including Tensile testing, Hardness testing, Microstructure analysis (Optical & SEM)XRD analysis for deposit identification

TCR's detailed report will cover calculating the consumed life fraction, covering key factors such as accumulated strain, current creep rate, remaining life, total damage, and damage rate. Comprehensive evaluation of future operational scenarios, providing tables and curves to guide decision-making.

Applicable Technical Standards:

- API 579/ASME FFS: Fitness-for-Service assessment to ensure your equipment meets industry safety standards.

- API 530: Calculation of heater-tube thickness, ensuring the integrity of petroleum refinery components.
- API 573: Inspection of fired boilers and heaters to assess degradation and ensure safe operation.

By choosing TCR Engineering, clients receive world-class Omega Creep Testing services, backed by extensive expertise, advanced equipment, and a commitment to providing reliable assessments. We help ensure your critical assets operate safely and efficiently for years to come.

Accelerated Creep Rupture Testing (ACRT) for Boiler Tubes

TCR Engineering offers Accelerated Creep Rupture Testing (ACRT) services to assess the long-term durability and remaining life of boiler tubes operating under high temperature and pressure conditions. Our ACRT tests are designed to simulate real-world operational stresses and provide critical insights into the material's behaviour over time, ensuring safety and optimal performance for your equipment.

- Comprehensive Material Assessment: We accurately determine the time to rupture under elevated temperatures, helping to predict failures and prevent costly downtime.
- Accurate Life Predictions: Our tests provide data essential for predicting the remaining life of critical components, enabling proactive maintenance.
- Compliance with International Standards: All our ACRT procedures adhere to globally recognised standards such as ASTM E139 and BS EN 10291, ensuring reliable and repeatable results.

TCR Engineering’s expertise in boiler tube testing helps plant operators avoid unexpected failures, enhance safety, and extend the life of their critical assets.

Electro-Magnetic Acoustic Transmission (EMAT) Thickness Measurement

TCR Engineering utilises Electro-Magnetic Acoustic Transmission (EMAT) technology to provide highly accurate surface thickness measurements in high-temperature environments, ensuring safe and efficient operations of industrial equipment. With the ability to perform non-contact ultrasonic testing, EMAT offers a reliable solution for inspecting metallic surfaces without the need for couplants, making it ideal for extreme temperature conditions.

High-Temperature Thickness Measurement: Using EMAT with Panametric probes, TCR can accurately measure surface thicknesses up to 325°C. Beyond this temperature, readings may become unstable and non-repeatable, and alternative testing methods may be recommended.

Painted Surfaces: Thickness measurements can be conducted on painted surfaces, provided there are no blisters or peeling paint. For critical corrosion rate calculations or remaining life assessments, paint removal is recommended before performing the thickness survey.

Benefits of EMAT Testing by TCR Engineering:

- Non-Contact Testing: EMAT is ideal for surfaces where couplants cannot be used, allowing for efficient testing in high-temperature environments.
- High-Temperature Capability: EMAT technology provides reliable results at temperatures up to 325°C, ensuring safety in extreme operational conditions.
- Accurate Corrosion Rate Calculations: By measuring surface thickness with precision, TCR can help you accurately calculate corrosion rates, assess the remaining life of equipment, and make informed maintenance decisions.
- Minimal Surface Preparation: EMAT requires only minimal surface cleaning, reducing preparation time and enabling quicker, more efficient inspections.

Applications:

- Boilers and pressure vessels
- Piping and tubing in refineries and chemical plants
- Heat exchangers and steam generators
- High-temperature industrial equipment

6.12 Plant Life Extension (PLE)

Multi-year engagement model. Upgrades, replacements, inspection-interval reset, IOW redrawing, RBI re-rating, and risk-mitigation strategies.

Idle-plant restart engagements feed into PLE: PIC Kuwait, Notore Chemical, Baiji Refinery, Godrej Industries, Matix Fertilizers, Nagarjuna Fertilizers, Heavy Water Projects.

6.13 Inspection of Storage Tanks and Audit

Robotic Inspection

The total cost of conventional inspections often far exceeds that of cleaning and inspection, with significant expenses tied to material transfer, product downgrades, and extended tank downtime. Additionally, the hidden costs of premature repairs can be substantial. When tanks are emptied for conventional inspections, it disrupts operations, leading to the need for rapid inspections, which often carry a premium price and result in unnecessary repairs that may not be required for another five to ten years.

With TCR Engineering's In-Tank Robotic Inspection service (deployed with our service partner company), you can drastically reduce these costs by performing API 653-compliant inspections of Above-Ground Storage Tanks (ASTs), including those filled with hydrocarbons or firewater, as well as Sumps, intake pipeline and Basins without needing to take them out of service for manual cleaning and inspection. This innovative approach minimises operational disruptions while ensuring thorough and accurate inspections.

These robots have been engineered to operate in hazardous environments, including hydrocarbon-filled tanks, with full compliance to ATEX certification by a European Notified Body and PESO approval from the Government of India. Our robotic inspection services deliver approximately 50 percent cost reduction and roughly ten times faster results against scaffolding-based methods, capturing high-density data of up to 200,000 ultrasonic thickness scans per tank, all while eliminating confined space entry and working-at-height hazards, which are major causes of industrial accidents.

The Robot is designed for in-service ultrasonic and visual inspection of storage tanks, significantly reducing the need for confined space entry. Our robotic crawlers perform high-density Ultrasonic Thickness (UT) scanning of storage tank floors, even while the tank is full, capturing up to 200,000 UT scans for comprehensive analysis. These inspections provide precise, real-time data on the tank's condition, pinpointing areas of corrosion and quantifying remaining plate thickness without requiring the tank to be taken out of service or cleaned.

Its results provide valuable data, such as minimum remaining thickness, via extreme value analysis, and online in-depth analysis with colour mapping for easy interpretation. In tandem with API 653 and RP 575 standards, TCR's robotic solutions are transforming the market, ensuring more efficient and safer inspections of critical assets.

Our robotic systems have been successfully deployed at various reputable oil refineries and industrial sites. The ITAS Rover has completed internal inspections for over 14 in-service tanks at LNG terminals and other refineries. TCR has executed external shell inspections for 34 assets at a major petrochemical complex, demonstrating the versatility and capability of our MagRover technology. Our passionate team can also develop custom robotic solutions tailored to specific inspection needs for pressure vessels, dome roof tanks, cross-country pipelines, jetty pile casing, pipe racks, and offshore riser pipes.

Key Benefits of TCR's In-Tank Robotic Inspection Services:

- No downtime: Conduct API 653 inspections while tanks remain in service.
- Faster inspections: Complete inspections in days rather than weeks or months.
- Cost-efficient: Avoid costly tank downtimes and unnecessary repairs.
- Safety and environmental advantages: Reduce safety risks and avoid cleaning-related waste disposal.
- Data-driven insights: Receive comprehensive data for informed decision-making, enabling repairs only when needed.

By utilising TCR Engineering's robotic solutions, industries can ensure the integrity of their assets while minimising operational disruptions, environmental impact, and overall costs.

6.13.1 Acoustic Emission Testing of Storage Tanks

At TCR Engineering, we provide advanced Acoustic Emission Testing (AET) services for Above Ground Storage Tanks (AST) and other critical infrastructure, following industry standards such as API 650 and API 653. AET is a powerful Non-Destructive Testing (NDT) method used to detect and analyse sound waves emitted from structural defects or discontinuities. This technique is highly versatile, with applications in assessing structural integrity, detecting flaws, corrosion monitoring, leak detection, and ensuring weld quality. TCR Engineering's extensive expertise allows us to offer precise and reliable AET solutions that help industries maintain safety and operational efficiency.

Our AET process monitors tanks for active leaks, corrosion, and structural weaknesses by attaching highly sensitive acoustic sensors to the tank walls. These sensors detect stress waves generated by defects or discontinuities when the tank is subjected to pressure changes, temperature fluctuations, or external loads. After conditioning the tank (turning off heaters and agitators), we triangulate the location of potential flaws, particularly those in the tank floor, and provide a detailed assessment of the tank's overall condition, graded from “A” to “E” for maintenance management purposes.

TCR Engineering applies AET in a wide range of industrial applications, from storage tanks and pressure vessels to pipelines and aerospace structures. Our experts utilise multi-channel acoustic systems to inspect pressurised tanks, detect leaks in real-time, and monitor for damage mechanisms like fatigue cracking, metal thinning, and corrosion. This technique is especially effective for monitoring hard-to-reach areas, providing actionable data to ensure asset integrity and compliance with safety regulations.

By leveraging Acoustic Emission Testing, TCR helps clients in the oil and gas, petrochemical, and storage industries detect critical issues early, reducing downtime and maintenance costs, while ensuring adherence to API standards and safeguarding operational safety.

6.13.2 Tank Floor Inspection by Magnetic Flux Leakage Testing

At TCR Engineering, we utilise Magnetic Flux Leakage (MFL) testing as a highly effective Non-Destructive Testing (NDT) method to detect discontinuities such as corrosion, erosion, pitting, and circumferential cracks in finned ferromagnetic and carbon steel heat exchanger tubes, air coolers, and other large steel structures. MFL is particularly well-suited for the inspection of Above Ground Storage Tanks (ASTs), especially the tank floor, due to its ability to quickly cover large surface areas. The method is recognised for its precision in identifying and sizing material loss with millimeter-level accuracy, providing valuable insights into the structural integrity of ferromagnetic assets.

Magnetic Flux Leakage (MFL) Testing is widely used in industries that require large-scale inspection, such as oil and gas, petrochemical, and storage sectors, and complies with standards like API 650 for ASTs. The method enables rapid scanning of tank floors, where a scanner equipped with an array of magnetic sensors can map material loss efficiently. This makes MFL an ideal technique for detecting corrosion and erosion in vast areas, often covering hundreds of square metres, and for ensuring compliance with relevant industry standards.

TCR's Magnetic Flux Leakage (MFL) services are particularly useful in industries that prioritise safety and efficiency. We adhere to industry standards such as API 653 for tank inspections, ensuring that our clients meet regulatory compliance and maintain the highest levels of structural integrity. MFL is applied to a variety of use cases, including storage tanks, pressure vessels, and pipelines, providing quick and accurate results to guide maintenance and repair decisions.

By leveraging MFL technology, TCR Engineering provides clients with actionable data to identify and manage structural weaknesses, reduce downtime, and ensure the continued safe operation of critical assets.

6.14 Engineering Design Review

ASME Section VIII Div. 1 and Div. 2; ASME B31.1 (power piping); ASME B31.3 (process piping); API 650 (welded tanks for oil storage); API 620 (low-pressure tanks). FEA on Caesar II for pipe stress and on general-purpose codes (Ansys, Abaqus through partner) for pressure-vessel and structural review.

TCR's dedicated engineering and the metallurgical consulting team is the perfect partner for solving manufacturing and product quality problems. TCR's senior consultants with several years' of experience are available to support and advice on corrosion and materials selection queries. The team also provides advisory service on welding engineering and heat treatment problems. From initial product design to final production, TCR's in-depth engineering consulting services ensure that clients are producing the best possible product.

TCR also undertakes research projects in the areas of Computer-Aided Designing (CAD) including Engineering Design, Legacy Data Conversion, Detailing Plant & Process Layout, CAM and Computer-Aided Engineering (CAE) including Finite Element Mode.

Areas of research assistance include:

1. Determining the Right Material for a Product
2. Undertaking Corrosion Engineering, Corrosion Testing and Corrosion Investigations
3. Conducting Metallurgical Failure Analysis and Welding Evaluations

4. Investigating The Effects on Environmental Conditions
5. Preparing Material and Process Specifications for In-House Quality Control
6. Comparing Vendor or Competitor Products
7. Identifying Equivalents Between Local and Foreign Specifications
8. Assisting In Solving Product Quality Problems
9. Assisting In Cost-Benefit Analysis Post Failure Analysis
10. Reverse Engineering and Rapid Prototyping

TCR Engineering provides design and analysis services such as Computer Aided Designing (CAD) Engineering Design, Legacy Data Conversion, Detailing Plant & Process Layout, CAM, Computer Aided Engineering (CAE) including Finite Element Modelling, Structural Analysis and Noise, Vibration, Harshness (NVH) analysis, and Project Management Services.

TThe team consists of a pool of highly qualified professionals armed with diversified technical skill sets. The experts have an optimum mix of experience, enthusiasm, extensive knowledge of design, product development and software domains.

6.14.1 Computer Aided Designing (CAD)

DESIGNING

Initial Concept

3D Modeling

3D Surfacing

Concept Layout

Product Definition

LEGACY DATA CONVERSION

Drafting Conversion from 2D to 3D
Data Extraction
Data Validation
Parametric Models
Castings
Plastic Parts
Sheet Metal Parts

DETAILING

Part Drawings
Assembly Layouts
Manufacturing Drawing
GD & T
Process Sheets
Tool Drawings
Product Drawing
Part Lists

PLANT & PROCESS LAYOUT

Structural
Mechanical
Hydraulics
Pneumatic

6.14.2 Computer Aided Engineering (CAE)

FINITE ELEMENT MODELING

2D Mesh
Hybrid Mesh
Hexa Mesh
Tetra Mesh

STRUCTURAL ANALYSIS

Linear & Non-linear
Static & Dynamic
Contact Stress
Moldflow Analysis
Fatigue Analysis
Failure Analysis
Impact and Crash Analysis

Steady State & Transient
Thermal Analysis

NOISE, VIBRATION, HARSHNESS (NVH)

Sound Transmission
Sound Radiation
Sound Quality Study
Vibration
Structure Borne Noise
Air Borne Noise

6.14.3 Training, Reverse Engineering and Prototyping

CORPORATE TRAINING

CAD Fundamentals
CAE Fundamentals
Software Applications for CAD & CAE

REVERSE ENGINEERING

CMM

Micro Profile Tester
Roundness
Roughness tester
Profile Projector
CAD Modelling & Surfacing

PROTOTYPING

Rapid prototyping
CNC Machining
Jigs and Fixtures

Representative engagements: Sulzer Chemtech Middle East, Bahrain, finite-element simulation of bulged reactors (January 2026); Aditya Birla Hindalco Dahej, crane finite-element stress analysis (December 2024).

6.15 Structural Stability Assessment and Certification

Industrial structures, chimneys, stacks, equipment supports, plant buildings. Theodolite-based plumbness and straightness measurement was introduced in 2026.

Anchor: Aditya Birla Hindalco Dahej crane FEA stress analysis. The structural audit under Section 353B of the Mumbai Municipal Corporation Act 1888 is delivered through Pillar 5 (Civil and Infrastructure) cross-references this section.

Standards: ASME B31.1 (power piping), ASME B31.3 (process piping), API 650 and API 620 (storage tanks), and AISC 360 (structural steel).

6.16 3D Laser Scanning and Digital Documentation, Partner-Delivered

3D laser scanning is delivered through an external partner. It is real and bookable; it is not on the TCR balance sheet. Capability covers LiDAR-based point clouds, brownfield revamp planning, and CAD/BIM integration for pipe-rack, reactor-area, and offsite tank-farm capture.

6.17 Indigenisation and Localisation Support

Reverse engineering, prototype development, vendor identification, and acceptance test campaign management for capital equipment that the buyer wants to source domestically against an imported reference.

6.17.1 Technical Help for Indigenisation

In order to generate baseline standard for indigenisation, multiple metallurgical studies are undertaken to identify status and properties of imported components by different methods including destructive/non-destructive studies. Technical help is provided to decide on the right manufacturing route or process and to develop quality checks on indigenously created components.

TCR's proprietary approach seeks structural details from the client across several areas to optimise indigenisation support:

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

6.17.2 Selection of Materials

Weight loss experiments: Samples of different metals/alloys are exposed to simulated or actual process plant solution in the laboratory, with and without stirring. Coupons of different metals/alloys are exposed to actual plant environment and a systematic approach is formulated, based on the requirement of intended services, literate survey and relevant standards like NACE, ASTM and API. The laboratory study is performed on the exposed sample to categorise the performance and a suitable MOC is recommended. Electrochemical experiments to find out relative corrosion resistance is performed by accelerated testing under laboratory conditions. MOC selection is done with off the shelf database and is combined with the experience of other experts drawn from published literature.

6.17.3 Quality Improvement

TCR undertakes total quality improvements for stringent requirements against international specifications. A thorough survey is undertaken by auditing the existing manufacturing procedure followed by stage-wise investigations of raw material and other components required for product manufacturing. 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. The required quality control checks are suggested to ensure consistency for optimum and continuous production.

TCR deploys a team of expert metallurgists to perform this task. The specially designed report enlists the fundamentals of metallurgical processing variables on final properties of the components and includes recommendations for corrective measures.

Representative engagement: Larsen and Toubro Vadodara, PFBR advanced material testing laboratory setup and indigenisation.

6.18 Solutions for Critical Weld Problems

ASME Section IX-compliant WPS development, repair-methodology design, post-repair NDT plan, and FFS-supported sentencing for weld repairs in pressure-boundary service.

TCR prides itself on having a huge knowledge bank of success stories compiled from over 1800 failure investigations across several industries. The insights gained in the area of failure mechanism has augmented the knowledge of TCR's technical team and because of this, there is a direct implementation of repair weld solutions.

With its deep technical and market expertise, TCR is an established player in solving critical weld repair solutions for the aged plant components.With limited material resources and increased value of new products, repair weld solutions can salvage critical components of process plant and ensure massive savings by mitigating production loss. The repair weld technology requires an in-depth understanding of metallurgical degradations, operating conditions, physical metallurgy and welding technology. There is a right solution for every problem that can be determined via strong fundamentals, technical competence, and engineering output.

When a plant with critical machinery component has a breakdown, an immediate problem resolution is necessary. There have been several instances when repair welding is done with little or no understanding of the metallurgical fundamentals and this proves to be disastrous. The management loses trust in its usefulness and technical competency. This philosophy promotes hasty decisions for replacing the components at a premium cost. Instead, a systematic detailed metallurgical investigation would provide the extent and nature of degradation, thereby utilising the knowledge of metallurgy and a proper welding procedure can be devised.

TCR has helped many industries by providing repair solutions on critical pump casing, shaft, nitrided components reformers and many other such issues.

1. The TCR's engineering consulting team, when provided with a detailed history of the problem can reach the client's site within 24 hours and they start generating data and draw up the way forward for the components to be repaired.
2. For successful repair, a mock test is necessary from the same material (or preferably for the aged material of similar grade). In case it is not available, virgin material of similar grade can also be used as an alternative. A mock test will establish the confidence in the welder and welding parameters.
3. After successful welding, thorough NDT testing is recommended to ensure that the welding joints remain trouble free for future service.

6.19 Energy Audit

Electrical systems, thermal processes, HVAC, compressed air. Industrial-buyer surface area in process plants, fertilisers, and steel.

6.20 Contract Research and Development

Heat-treatment studies, 2D to 3D conversion, FEA, CAE, piping stress analysis. Custom corrosion coupons since 2012. MiC image analysis software since 2008.

Representative engagement. ITER-India for the Institute for Plasma Research, crevice corrosion and electrochemical study delivered as contract research and development.

7. Robotic and AI-Assisted Inspection

50,000+	$4.98M	14,000+	70–200 mm
REFORMER TUBES SCANNED	DOCUMENTED COST AVOIDANCE	GIRTH WELDS RADIOGRAPHED	ARTiS TUBE OD RANGE

The robotic and AI-assisted inspection pillar carries the visible differentiation that owner-operators (Saudi Aramco, NEOM, the forward-looking Indian refiners) increasingly screen vendors on.

Two ownership categories:

- **TCR-owned:** ARTiS (Automated Reformer Tube Inspection System). The pipeline RT Crawler family that holds the Aramco SAER-13115 cost-avoidance citation.
- **Partner-delivered:** ITAS Rover, MagRover, MicroRover, OTIS in-service robotic tank inspection, 3D laser scanning (external partner). Submersible ROV, drones, and bridge-inspection robotics (mix of TCR and partner inventory).

The line is held everywhere. Ownership is stated accurately, partner-delivered capability is stated accurately, and the buyer is never left with an inflated impression of what sits on TCR's balance sheet.

7.1 ARTiS, Automated Reformer Tube Inspection System

ARTiS, the Automated Reformer Tube Inspection System, is the flagship robotic intellectual property of the TCR Group: developed and patented by TCR Advanced Engineering and deployed group-wide across India, the GCC, and international reformer fleets. The system carries reformer tube inspection through a helical scan with embedded Fitness for Service reporting per API 579-1/ASME FFS-1 and API 530. With more than 100 reformer inspection assignments completed for Indian and overseas clients, TCR is the leader in reformer tube integrity assessment in India. The practice rests on a proprietary data bank of reformer tube failure mechanisms built over decades of failure investigations, which allows TCR to recognise the early warnings of tube failure, and on a unique combination of operational understanding and metallurgical interpretation of reformer service. The assessment answers the question every reformer owner actually asks: when to retire each tube.

Capability	Detail
Tube inspection range	Outer diameter 70 mm to 200 mm with the current crawler generation; the earlier generation covered 105 mm to 190 mm (together spanning the fertiliser and refining reformer-tube sizes)
Length traversal	Full tube length, helical scan

Capability	Detail
Damage capture	Diametral creep growth, mid-wall cracks, internal carburisation, external oxidation, axial and circumferential creep cavitation
Output	FFS-grade report with creep grade A through E classification, remaining-life estimate, three-stream sentencing (Improve / Repair / Replace)
Cumulative tubes scanned	50,000+ (group practice anchor)

ARTiS is a TCR-built robotic crawler that automates the ultrasonic inspection of primary reformer tubes in place of manual scanning. It runs ultrasonics in transmit-receive (T-R) mode: energy passes from one sensor through the tube wall to a second sensor, and the energy lost to beam scatter is the measurement. In an as-cast tube that scatter comes from dendrite boundaries and primary carbides; after long high-temperature service, secondary-carbide precipitation and creep voids add to it.

TCR reads the resulting attenuation against calibrated bands: 35 to 55 dB for virgin structure, 55 to 62 dB for aged structure, and 62 to 72 dB at a life fraction of 80 to 95 percent, where secondary carbides have coarsened and inter-dendritic micro-cracks appear. The crawler is driven by four metal-gear motors rated 200 watts in total, with a rubber-padded shoe carrying the transmit-receive probes, infra-red sensors for diameter, and gyroscopic sensors for bowing. It scans 10 metres in 2 to 5 minutes at 100 mm resolution, fixes in 3 minutes, and climbs to 15,000 mm, accommodating tube outer diameters of 70 mm to 200 mm with the current crawler generation (105 mm to 190 mm on the earlier generation) and walls of 8 to 20 mm. The 25 mm, 1 MHz probe runs a 30 to 100 dB range at 0.1 dB resolution, with diameter resolved to 0.5 percent of outer diameter and bowing to 5 mm.

Against manual scanning, ARTiS removes the scaffolding requirement and inspects 100 tubes in about 2 days rather than 4 to 5, reports continuously at 100 mm resolution rather than in six-foot segments, measures outer diameter every 100 mm rather than at one or two points by hand, and returns a quantitative bowing figure of 5 to 200 mm rather than a visual estimate.

7.1.1 Inspection Scope Per Tube

ARTiS is a multi-technique assessment. Every tube in the radiant box is examined through nine coordinated measurements, and TCR calibrates the crawler against proprietary standard samples with known damage scenarios, which gives the attenuation readings a validated reference that single-technique providers cannot match. The scope per tube covers:

- Expert visual inspection of every tube for general appearance, bulging, baldness, sagging, and bowing.
- Outer diameter measurement by the on-board electronic infrared sensors on the crawler, recorded at 0.1 metre intervals over the full tube height.
- Bowing measurement by the on-board electronic instrumentation on the crawler.
- Ultrasonic attenuation measurement in decibels for mid-wall fissure detection, run by the automated crawler in transmit-receive mode.
- In-situ metallography to establish the stage of microstructural degradation.
- Hardness measurement at each metallography location.
- Manual ultrasonic wall thickness measurement of all tubes at one location at platform (bottom) level.

- Manual outer diameter measurement of all tubes at platform (bottom) level.
- Manual magnetic permeability measurement of all tubes at platform (bottom) level.

7.1.2 Level 3 Fitness for Service Deliverables

The inspection feeds a Level 3 assessment per API 579-1/ASME FFS-1, delivered tube by tube. The report package carries:

- The complete inspection results across all nine measurement streams.
- A summary table of accumulated creep damage for every tube as on the date of inspection.
- The calculated effective tube metal temperature for each tube.
- Where sufficient life is available, the theoretical accumulated creep damage projected to the next shutdown.
- The date of tube replacement at which accumulated creep damage exceeds the 0.8 life fraction.
- The remaining life of each tube.

The effective tube metal temperature is the anchor of the remaining-life mathematics. It is defined as the temperature that caused the present level of creep damage in terms of creep strain, accommodating occasional changes in tube skin temperature and thermal cycling; it is not the same as the pyrometer reading taken on the tube skin. Future life expectancy is acutely sensitive to it: field experience shows that an overshoot of 10 to 20 degrees Celsius above design can cut tube life substantially, which is why the ARTiS report carries a sensitivity analysis showing expected life at 10, 20, and 30 degrees Celsius above design for the worst tubes. That sensitivity table is what turns an inspection record into an operating decision: timely tube-replacement calls, budget allocation across tube and catalyst replacement, inventory build-up, and realistic downtime planning for the next turnaround.

7.1.3 Reference Engagements

Client	Detail	Year
Dangote Fertilizers, Nigeria	ARTiS plus tail-tube inspection for reformer life extension	2023
Emirates Steel Industries, Abu Dhabi	ARTiS on Direct Reduction Plants DRP1 and DRP2	2025
JIFCO, Jordan	RFET and videoscopy of WHRB tubes (companion to ARTiS workflow)	2025
Indian fertiliser engagements (multiple)	Continuous ARTiS rotation across CFCL, IFFCO, RCF, GNFC	Continuous
GNFC TDI-II Reformer	RLA on reformer tubes	Multiple

Beyond the engagements above, ARTiS has been deployed across the Indian refining and fertiliser reformer fleet and at international sites. Reference sites for reformer tube inspection using ARTiS include:

Client	Site	Sector
PEMEX	Salamanca Refinery, Mexico	Refining
Notore Chemical Industries Plc	Onne, Nigeria	Fertilisers

Client	Site	Sector
PT Musim Mas	Indonesia	Oleochemicals
Indian Oil Corporation Ltd.	Vadodara Refinery	Refining
Indian Oil Corporation Ltd.	Panipat Refinery	Refining
Indian Oil Corporation Ltd.	Digboi Refinery	Refining
Indian Oil Corporation Ltd.	Guwahati Refinery	Refining
Indian Oil Corporation Ltd.	Bongaigaon Refinery	Refining
Indian Oil Corporation Ltd.	Mathura Refinery	Refining
Indian Oil Corporation Ltd.	Haldia Refinery	Refining
Indian Oil Corporation Ltd.	Barauni Refinery	Refining
Hindustan Petroleum Corporation Ltd.	Mumbai Refinery	Refining
Hindustan Petroleum Corporation Ltd.	Visakh Refinery	Refining
Bharat Petroleum Corporation Ltd.	Mumbai Refinery	Refining
Bharat Oman Refineries Ltd.	Bina Refinery	Refining
HPCL-Mittal Energy Ltd.	Bathinda Refinery	Refining
Nayara Energy	Jamnagar Refinery	Refining
Chennai Petroleum Corporation Ltd.	Chennai Refinery	Refining
Gujarat Narmada Valley Fertilizers and Chemicals Ltd.	Bharuch	Fertilisers
Deepak Fertilisers and Petrochemicals Corporation Ltd.	Taloja	Fertilisers
Chambal Fertilisers and Chemicals Ltd.	Kota	Fertilisers
Rashtriya Chemicals and Fertilizers Ltd.	Trombay	Fertilisers
Rashtriya Chemicals and Fertilizers Ltd.	Alibaug	Fertilisers
The Fertilisers and Chemicals Travancore Ltd. (FACT)	Kochi	Fertilisers
Indian Farmers Fertiliser Cooperative Ltd. (IFFCO)	Kalol	Fertilisers
Gujarat State Fertilizers and Chemicals Ltd. (GSFC)	Vadodara	Fertilisers
VVF Ltd.	Taloja	Oleochemicals
Godrej Industries Ltd.	Valia	Chemicals
Hindustan Urvarak and Rasayan Ltd. (HURL)	Sindri	Fertilisers
Hindustan Urvarak and Rasayan Ltd. (HURL)	Barauni	Fertilisers
Mangalore Chemicals and Fertilizers Ltd. (MCF)	Mangalore	Fertilisers
National Peroxide Ltd.	Mumbai	Chemicals

Client	Site	Sector
Nagarjuna Fertilizers and Chemicals Ltd. (NFCL)	Kakinada	Fertilisers
National Fertilizers Ltd. (NFL)	Vijaipur	Fertilisers
National Fertilizers Ltd. (NFL)	Nangal	Fertilisers
Kribhco Shyam Fertilizers Ltd.	Shahjahanpur	Fertilisers
Southern Petrochemical Industries Corporation Ltd. (SPIC)	Thoothukudi	Fertilisers

7.1.4 Authority Anchor

The ARTiS paper by Upadhyaya, Haribhakti, Patel, and Bafna (TCR Advanced, 2013 to 2014) is the published authority anchor for the practice.

The practice is also published in the international trade press: 'Optimising Tube Life' by Paresh Haribhakti and Ketan Upadhyaya of TCR Advanced Engineering, World Fertilizer Magazine, January/February 2019, covering operational control for the enhancement of reformer tube life and the role of automated reformer tube inspection.

7.2 Pipeline RT Crawlers (TCR-Owned)

The pipeline RT Crawler fleet (developed in-house at TCR) sits at TCR Engineering and TCR Arabia. The Saudi Aramco-approved Internal RT Crawler is the public flagship.

7.2.1 Saudi Aramco Internal RT Crawler

Engineering Report SAER-13115 dated 8 September 2025 names TCR as technology provider, with $4,980,000 documented cost avoidance over five years (approximately 80 percent reduction).

Saudi Aramco approved Radiographic Standard Procedure TCR.QCP.REV-02 (2023) is conformant with SAEP-1143 (Engineering Procedure for Radiographic Examination, 6 September 2020).

Specification	Value
Diameter range	16 inch to 52 inch
X-ray heads	160, 200, 300 kV at 5 mA
Positioning accuracy	±5 mm
Operating temperature	minus 10 to plus 70 degrees Celsius
Documented cost avoidance	$4.98 million over 5 years

7.2.2 Track Record on Cross-Country Pipelines

- 14,000+ pipeline girth welds radiographed across 2600+ kilometres of cross-country mainline (Section 5.9 cross-reference).
- 9,266 weld joints digitally scanned and cloud-archived on a single project (EnProCon TJTC Kolar).
- 20+ named cross-country pipeline projects with 15+ master contractors.

- First non-GCC cross-border deployment: Nepal Oil Corporation MAPL Phase II via Likhitha Infrastructure under Nepal Oil Corporation permission Ref 2080/81 dated 30 July 2023.

7.3 Robotic Tank Inspection Rover

The TCR Group has invested in a partner who has developed ATEX/PESO-certified internal rover for in-service tank inspection.

Specification	Value
Tank height range	Up to 25 m
Tank diameter range	Up to 100 m
UT probes	8-transducer array (compatible with `API 653` floor scanning workflow)
Cost reduction	Approximately 50 percent (vs. scaffolding-based methods)
Speed	Approximately 10x scaffolding-based methods

The rover complements the partner-delivered OTIS (in-service robotic tank inspection per API 653, 8-transducer ultrasonic, no degassing). WTCO 3-year robotic tank inspection contract commenced Q1 2025 (TCR Arabia delivery, project leads Naser Salahuddin and Shaheensha Shahulhameed).

7.4 Partner-Delivered Robotics

7.4.1 ITAS Rover, In-Service Tank Inspection

In-service tank internals inspection. Eliminates the need for tank entry and degassing on shell-and-floor surveys.

7.4.2 MagRover, Wall-Climbing Magnetic Adhesion Robot

240+ assets deployed. Magnetic-adhesion wall-climbing platform for storage tank shells, pressure vessels, columns, and reactor exteriors. Carries UT thickness measurement, visual capture, and corrosion mapping payload.

7.4.3 MicroRover, Boiler Tubes

Targeted at internal boiler-tube inspection where ID access is the only viable inspection route.

7.5 OTIS, In-Service Robotic Tank Inspection

API 653 compliant. 8-transducer ultrasonic scanning of tank floors without emptying. Planys-developed; deployed under TCR Arabia and TCR Engineering engagements as a partner-delivered capability.

7.6 Submersible ROV, Underwater Inspection (Planys Alliance)

The Planys alliance carries the underwater robotic inspection ROV for water storage tanks, sub-water bridge piers, intakes, outfalls, sumps, and reservoirs. The branded co-marketed capability sits at TCR Arabia and is deployed across India and the GCC.

Specification	Value
Manhole entry	20 inch or greater
Weight	Approximately 35 kg (portable)
Power	AC 230V 50/60Hz at 6 kW
Cameras	High-Definition with powerful lights for live streaming visual inspection
Ultrasonic Thickness	Probe with gimbal, 3 to 250 mm range, 2.25 MHz, resolution 0.05 mm
Coating-tolerant UT	Thickness measurement over various coatings
Silt assessment	SONAR
Position and depth	Accurate position and depth sensors
Digital reporting	Geotagging of data with defects, localised defect videos, data enhancement, central data repository, year-on-year comparison, prediction and trend analysis, RBI integration

Use cases: Desalinated water tanks; potable water tanks; fire-water and hydrant tanks; de-mineralised water tanks; storage tanks; sumps; intake and outfall structures and pipelines; channels and reservoirs. Bridge pier and abutment inspection. Intake structure and forebay inspection at thermal power plants. Jetty pile inspection at marine terminals. Above-ground water-storage tank under-water inspection without shutdown.

Delivery advantages over the conventional emptied-and-manually-inspected workflow. Safer (no confined-space personnel exposure).

Live result monitoring. Save costs by delaying turnaround. No shutdown required. Online rapid and accurate inspection. Digital reporting dashboard.

7.7 TCR Arabia Robotic Inspection Field Record (2016 to 2025)

The group's robotic and remotely-operated-vehicle capability is not a brochure line. In the Kingdom, TCR Arabia has built one of the deepest robotic-inspection field records in the region across a decade of campaigns for the major operators, and that record is the proof behind the capability described above.

7.7.1 Robotic Remote Visual Inspection of Buried and Unmanned Lines

Since 2016, more than forty robotic remote-visual-inspection and push-camera campaigns have run on buried concrete-coated, RTR, FRP, and GRP seawater and process lines. Clients include SABIC and its affiliates, Ibn Al Baytar, SAFCO II, III, and IV, Saudi Kayan, Yansab, Al Bayroni, Petrokemya, Agri

Nutrients, and Ibn Sina, including the autonomous robotic programme at Arrazi in 2025, together with MARAFIQ, the Saline Water Conversion Corporation, the Royal Commission at Ras Al Khair, SAMREF, TASNEE, Jubail Chemical Industries (Jana), Enppi on behalf of Saudi Aramco at Juaymah, and the inspection of the underground GRP pipeline at Jeddah Airport.

The work spans Jubail, Jeddah, Ras Al Khair, and Juaymah, and the move to an autonomous platform in 2025 marks the next step in the programme.

7.7.2 Robotic Tank and Basin Inspection

Since 2020, submersible robotic inspection has delivered hundred-percent visual and thickness measurement on fire-water, potable-water, and demineralised-water tanks, on seawater sumps and intake pipelines, and on underwater piles, with no need to drain and enter the asset. Clients include Advance Petrochemical, SABIC and Saudi Kayan, Saudi Aramco at Dhahran and Ras Tanura, Saudi Chevron Phillips, Engie at Dhuruma, Jana Chemicals, and the Water Transmission Company, across Jubail, Riyadh, Dhahran, Madinah, and Yanbu.

The Saudi Aramco Ras Tanura under-water pile inspection in 2025 added pulsed eddy-current testing to the submersible visual scope, extending the technique from condition survey to wall-thickness screening below the waterline.

7.8 AGAAS, the AI Agent and Automation Architecture

AGAAS is the proprietary intelligent-agent and automation architecture across the group's operating workflows. The capability is positioned as a moat enabler rather than a standalone software pursuit.

Domain	AGAAS application
Compliance	Regulatory tracking (NABL, BIS, IBR, AERB), document control, audit-readiness alerting
LIMS triage	Sample-receipt classification, scope mapping, prioritisation, NABL deviation flagging
Sales quotation	RFQ parsing, TestPriceMaster lookup, draft response, dormant-quote follow-up tracking
Quality management	Z-score variance flagging in PT/ILC, equipment calibration alerting
Radiography digitalisation	Film-to-digital archival, cloud retention, weld-joint metadata capture

7.9 The Chugai Technos Scale Checker

The Chugai Technos Hiroshima MOU signed 29 April 2026 sets a three-party (India, Japan, KSA) collaboration scope for two non-binding years, with a joint trade-show appearance in Japan in September 2026. The first commercial output is the Scale Checker, launched at NDE 2025 Mumbai (December 11 to 13, 2025).

Specification	Detail

Specification	Detail
Source	Cs-137
Operating modes	Dual-mode
Interface	Wireless tablet
ROI per turnaround	Rs. 15 to 20 crore
Compliance	AERB
Application	Internal scale measurement on furnace and reformer tubes; pipeline scale measurement

7.10 Standards Coverage Matrix (Robotics and AI)

Pipeline Robotics: API 1104 22nd Edition (2021); SAEP-1143 (Saudi Aramco RT engineering procedure); ASME B31.4 / B31.8 (2022 eds.); EN 1435 (RT classes A and B); ISO 17636 (RT of welded joints).

Tank Robotics: API 653 6th Edition (2024); API RP 575 4th Edition (2020); ATEX 2014/34/EU; PESO certification framework.

Reformer Tube Robotics (ARTiS): API 530 (calculation of heater-tube thickness in petroleum refineries); API 579-1/ASME FFS-1 4th Edition (2021); ASTM A388 (UT examination of heavy steel forgings).

Radiography Digitalisation: ASTM E1936 (RT film digitalisation); ASTM E2698; ASME V Article 2.

ROV and Underwater: ASTM E1316 (NDT terminology); IMCA R 004 (ROV codes of practice).

7.11 Representative Robotics and AI Engagements

Client / Project	Service Anchor	Year
Saudi Aramco, CAT Fabrication Shop Dammam	Internal RT Crawler 16-52 inch, $4.98M cost avoidance over 5 years (SAER-13115)	2023 to 2025
Likhitha Infrastructure for Nepal Oil Corporation, MAPL Phase II	Cross-border RT Crawler deployment, AERB and BARC permissioned	2023
EnProCon TJTC Kolar	9,266 weld joints digitally scanned and cloud-archived	Multiple
Dangote Fertilizers, Nigeria	ARTiS reformer life extension	2023
Emirates Steel Industries, Abu Dhabi	ARTiS DRP1 and DRP2	2025
JIFCO, Jordan	RFET and videoscopy of WHRB tubes (ARTiS-adjacent workflow)	2025
WTCO, KSA	Robotic tank inspection 3-year contract via TCR Arabia	Q1 2025 onward
29+ tanks (Petrobot ITAS Rover)	In-service tank internals inspection	Multiple

Client / Project	Service Anchor	Year
240+ assets (Petrobot MagRover)	Wall-climbing UT thickness and corrosion mapping	Multiple
Maharashtra PWD	Robotic NDT on 500+ bridges	Continuous
PDO Maharashtra	AI-assisted underwater inspection on 400+ bridges	March 2022
Chugai Technos Hiroshima collaboration	Scale Checker NDE 2025 launch and joint trade show Japan September 2026	December 2025 onward

8. Civil and Infrastructure Testing

500+	30,000+	3,000 kN	12-40 mm
BRIDGES INSPECTED	BUILDINGS IN AUDIT-MANDATE SCOPE	COMPRESSION CAPACITY	COUPLER DIAMETERS TESTED

The civil and infrastructure pillar exists as a separate top-level capability because the buyer is a different decision-maker. A real-estate developer, an EPC contractor bidding for a metro or expressway, a Public Works Department officer ordering a structural audit, or a municipal infrastructure requesting building inspection.

The catalogue covers concrete and cement, aggregates, soil, bitumen and road, structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888 and Section 265A of the Maharashtra Municipal Corporations Act 1949, the home inspection programme, bridge inspection, rebar and reinforcement coupler testing, HT strand for High Speed Rail, ground-penetrating radar and ultrasonic pulse velocity, half-cell potential, building materials, AAC blocks, tiles, aluminium formwork, manhole and gully top fatigue, grain silo certification, and the structural stability and plumbness work that supports industrial structures.

TCR Engineering in India is NABL ISO 17025 accredited and provides superior end-to-end solutions for civil testing across all the elements of building structures and has an extensive Road Inspections programme as per requirements of IRC.

TCR is trusted by contractors, construction companies, and infrastructure developers for delivering accurate and reliable testing services across various sector ranging from residential, commercial, and industrial infrastructure.

Advantage TCR:

- Decades of Experience: With 50 years of industry expertise, we understand the intricacies and challenges of construction projects.
- NABL Accredited: Our ISO 17025 accreditation ensures that all testing is performed to the highest India IS and International standards.
- Advanced Technologies: We utilise advanced robotic NDT solutions for underwater inspections, ensuring the safety of critical infrastructure like bridges.
- Unmatched Expertise: Our team of experts is committed to delivering precise and reliable results for all your construction material testing needs.
- Registered Service Provider: Registered and certified by various municipal corporations, TCR has been providing services across Government and private sectors

New Construction Civil Testing

Cement

Chemical Test as per IS 269: 2015, IS 1489-1: 2015 and IS 4032:1985

- Magnesia (% by mass)
- Sulphuric Anhydride (% by mass)
- Loss on Ignition (% by mass)
- Insoluble Residue (% by mass)
- Chloride content (% by mass)
- Ratio of percentage of Lime to percentages of silica, alumina and iron oxide
- Ratio of percentage of alumina to that of Iron oxide

Physical Testing as per IS 4031

- Fineness
- Normal Consistency
- Setting Time (Minutes)
- Soundness by Le Chatelier method and Autoclave test method
- Compressive Strength
- Drying shrinkage

Inspection at Site as per IS 269: 2015, IS 1489-1: 2015 and IS 4031(Part 1):1996

- Fineness (by Sieve)
- Age
- Visual Inspection
- Weight

Ground Granulated Blast Furnace Slag (GGBS)

Chemical Testing as per IS 16714: 2018 and IS 4032

- Manganese oxide, MnO
- Magnesium oxide, MgO
- Sulphide sulphur, S
- Sulphate as (SO3)
- Insoluble residue
- Chloride content
- Loss on Ignition
- Molar Ratio of CaO, MgO, Al_2O_3, and SiO_2
- Moisture content % by mass
- Glass content % by mass

Physical Testing as per IS 16714:2018, IS 4031 (part 2)

- Fineness (Specific Surface)
- Slag activity Index 7/28 Days

Inspection at Site as per IS 16714:2018

- Moisture Content
- Visual Inspection for lumps

Micro Silica

Chemical Testing as per IS 15388: 2003, IS 1727, IS 4032

- Silicon dioxide (SiO_2), in % by mass
- Loss on Ignition, in % by mass
- Alkalies as Na_2O, in %
- Moisture Content, in % by mass
- Total chlorides in percent by mass

Physical Testing as per IS 15388: 2003 and IS 1727

- Oversize percent retained on 45 micron IS sieve
- Compressive Strength at 7 Days as percentage of control sample

Inspection at Site as per IS 15388: 2003

- Moisture Content
- Oversize Particles retained

Flyash

Chemical Testing as per IS 3812 - P1 (2013), IS 1727

- Silicon Dioxide ($Si0_2$) plus Aluminium Oxide (Al_2O_3) plus Iron Oxide (Fe_2O_3) % by mass
- Silicon dioxide (SiO_2) in percent by mass
- Reactive silica in % by mass
- Total sulphur trioxide ($S0_3$) in percent by mass
- Total chlorides in percent by mass
- Available alkalis as equivalent sodium oxide (Na_2O) in percent by mass
- Loss on Ignition in % by mass
- Magnesium oxide (MgO) in % by mass

Physical Testing as per IS 1727

- Particles retained on 45 Micron IS sieve (Wet Sieving)
- Fineness (Specific Surface)
- Lime Reactivity compressive strength
- Soundness by autoclave test
- Specific gravity
- Compressive Strength

Inspection at Site as per IS 3812:2013 and IS 4031/4032

- Particles retained on 45 Micron IS sieve (Wet Sieving)
- Moisture Content
- Visual Inspection for lumps

Admixture

Physical and Chemical Test as per IS 9103: 1999

- Dry material content for liquid and solid admixture
- Relative density
- Chloride ion content
- pH
- Ash Content

Field Test as per IS 9103: 1999

- Material shelflife and storage check
- Packing of material
- Relative Density of chemical

Water

Chemical Testing as per IS 456:2000 and IS 3025

- pH Value
- Organic
- Inorganic
- Sulphatea (as SO3)
- Chlorides
- Suspended Matter
- Total acidity
- Total alkalinity

Field Test as per IS 456:2000

- Visual Inspection for clean water
- pH

Readymix (RM) Plaster

Field Test as per BS 998 and EN 1015

- Age of batch
- Visual Inspection
- Workable life (minutes)

Fine Aggregate

Chemical Testing as per IS 383: 2016 and IS 2386

- Deleterious Material
- Soundness of aggregates
- Alkali aggregate reaction
- Petrography

Physical Testing as per IS 383: 2016 and IS 2386

- Size & Grading
- Specific Gravity
- Water absorption Value
- Material finer than 75 micron IS sieve

Field Test as per IS 383: 2016 and IS 2386

- Grading
- Silt content in case of river sand
- Material finer than 75 micron in case of crushed sand
- Specific Gravity
- Bulkage Test
- Water absorption Value

Coarse Aggregate

Chemical Testing as per IS 383: 2016 and IS 2386

- Deleterious material
- Soundness of aggregates
- Alkali aggregate reaction
- Petrography

Physical Testing as per IS 383: 2016 and IS 2386

- Size & Grading
- Aggregate impact Value
- Sp. Gravity
- Water absorption Value
- Combined Flakiness and elongation index
- Aggregate abrasion Value

Field Test as per IS 383: 2016 and IS 2386

- Shape
- Size & Grading
- Aggregate impact Value
- Sp.Gravity
- Water absorption Value

Reinforcement

Physical and Chemical Testing per IS 1786: 2008

- Tensile Test with 0.2% Proof / Yield Stress
- Bend & Rebend test
- Carbon
- Sulphur
- Phosphorus

Field Test as per IS 1786: 2008

- Identification Mark & grade of steel check
- Visual Inspection for Rust
- Bend test as per internal procedure at site
- Weight per meter

Coupler

Chemical Testing all elements as per ASTM E415

Physical Testing as per IS 16172

- Static Tensile test
- Slip test
- Cyclic tensile test
- Low Cycle Fatigue (LCF) test
- High Cycle Fatigue (HCF) test

Autoclaved Aerated Concrete (AAC) Blocks

Physical Testing per IS 2185, IS 6441 and IS 3346

- Dimensional Tolerances
- Compressive Strength
- Drying Shrinkage
- Density
- Thermal Conductivity

Field Test of dimensional tolerance as per IS 2185

Gypsum Plaster

Chemical Testing as per IS 1288 and IS 2547

- SO3, percent by mass
- CaO, percent by mass
- Soluble magnesium salts
- Soluble sodium salts
- Loss of ignition, percent by mass
- Free lime %

Physical Testing as per IS 2547 and IS 2542

- Setting time minutes
- Soundness
- Mechanical resistance of set neat plaster
- Residue on 150 µm IS sieve in percentage
- Adhesion strength

Field Test as per IS 2542

- Residue on sieve
- Shelf life
- Weight of Bag

Bricks (Clay and Flyash)

Physical Testing as per IS 1077, IS 12894, IS 3495 and IS 4139

- Dimensional Tolerances checks of Modular and Non-Modular brick sizes
- Water absorption (% by weight)
- Compressive Strength
- Drying shrinkage
- Efflorescence Test

Field Test as per IS 1077, IS 12894, IS 3495 and IS 4139

- Dimension analysis
- Water absorption
- Visual observation
- Edges
- Resistance under a free fall of 1 metre on the flat surface on strong concrete surface

Concrete

Concrete Mix Design Test as per IS 10262, EN 12390, IS 16700, ASTM C1202, DIN 1048, IS 3085, BS 1881

- Proportion of constituent of concrete

- Concrete Mix Design revalidation for Slump, cohesiveness, retention, setting
- Modulus of Elasticity of Concrete
- RCPT
- Water permeability / Water penetration test
- Water absorption
- Initial Surface Absorption Test (ISAT)

Fresh Concrete Test as per IS 1199

- Workability
- Plastic Density/ Yield
- Concrete temperature

Field Test of Compressive Strength as per IS 1199 and IS 516

Building Finishing Works Testing

Tiles

Physical Testing as per IS 15622: 2017 and IS 13630

- Dimensional Analysis including Length & Width, Thickness, Straightness of sides, Rectangularity
- Surface Flatness - Centre, edge, warpage curvature
- Surface quality
- Physical Properties
- Water Absorption
- Scratch Resistance (Mohs Scale)
- Resistance to Surface Abrasion of glazed tiles
- Breaking strength
- Modulus of rupture
- Coefficient of Linear thermal expansion
- Moisture expansion
- Thermal Shock resistance (external grade tiles)
- Impact resistance: Coefficient of restitution
- Coefficient of Friction - Tiles intended for use on floors
- Crazing resistance

Chemical Testing as per IS 15622: 2017

- Resistance to household chemicals
- Resistance to staining of glazed tiles
- Resistance to acids and alkalies

Granite

Physical Testing as per IS 14223, IS 1124, IS 13630, IS 1706 and ISO 10545

- Specific gravity
- Water absorption
- Porosity
- Hardness (Mohs)
- Resistance to wear (for floor application)
- Stain Test

Marble

Physical Testing per IS 1124, Mohs Scale and IS 1122

- Water absorption after 24 hours immersion
- Hardness
- Specific gravity

Wooden Flooring

Physical Testing as per Manufacturer Spec

- Moisture, Grade, Length, Width, Thickness, Joints, Surface effects
- Dimension check

Precast Concrete Pipes

Physical Testing as per IS 3597

- Dimensional Analysis
- Hydrostatic Test

Fiber Cement Board

Physical Testing as per IS 14862

- Length and width
- Thickness
- Modulus of rupture
- Apparent density
- Bending strength

Wooden Door Frame

Physical Testing as per IS 287: 1993, IS 11215: 1991 and Moisture Meter

- Moisture content (%)
- Density

Laminated Veneer Lumber (LVL Door Frame)

Physical Testing as per IS 14616, IS 1734, IS 1708, IS 2380

- Dimensions
- Moisture content
- Adhesion of plies
- Strength Tests

Door Panels

Physical Testing as per IS 4020

- Dimensions and squareness
- Planeness Test
- Flatness test
- Impact indentation test
- Edge loading test
- Shock resistance test

- Buckling resistance test
- Slamming test - Misuse, End Imersion, Knife
- Glue adhesion test
- Screw withdrawal resistance test
- Flexure test

Aluminium Sections

Chemical Testing as per BS 573

- Mg, Si, Mn, Fe, Cu, Zn, Ti, Cr, Al

Physical Testing per BS 573, IS 13871 and IS 101

- Tensile
- Hardness
- Weight per Meter
- Thickness of Powder coating
- Finish
- Scratch hardness at 3000 g
- Cross cut adhesion

Glass

Toughened glass Physical Test as per IS 2553 and IS 17004

- Thickness of glass
- Dimensions and Squareness
- Surface compression

Laminated glass Physical Test - IS 2553, IS 17004

- Thickness of glass
- Dimensions, squareness and Edge displacement

Float glass Physical Test as per IS 14900

- Visual light transmission
- Dimensions (Length, Width and squareness)
- Thickness of glass
- Visual faults

8.1 Concrete, Cement, and Aggregates

Compression testing on cube and cylinder specimens (2,000 kN and 3,000 kN capacity machines). Flexural testing. Split tensile. Core extraction and compression. Rebound hammer surveys. Ultrasonic Pulse Velocity per IS 516 (Part 5/Sec 1). Aggregate crushing value, aggregate impact value, Los Angeles abrasion, specific gravity, water absorption. Cement testing per IS 4031 across consistency, setting time, soundness, fineness, and compressive strength.

Standards: IS 516 (compressive strength of concrete), IS 1199 (sampling and analysis of concrete), IS 2386 (methods of test for aggregates), IS 383 (specification for coarse and fine aggregates), IS 4031 (methods of physical test for hydraulic cement), IS 8112 (43-grade OPC), IS 12269 (53-grade OPC), IS 456 (plain and reinforced concrete code of practice). ASTM C39 (compressive strength), ASTM C496 (split tensile), ASTM C617 (capping cylindrical specimens). EN 12390 series.

Building-material chemistry is run on the wavelength-dispersive X-ray fluorescence bench described in Section 4.4.8, for major-oxide and trace-element determination on cement, clinker, fly ash, ground granulated blast furnace slag, aggregate, soil, and ore, alongside the classical wet chemistry and instrumental methods of Section 4.4.

8.2 Soil and Geotechnical

Triaxial, direct shear, California Bearing Ratio (CBR), Standard Proctor and Modified Proctor compaction, Atterberg limits, sieve analysis and hydrometer particle size, plate load test, in-situ density (sand replacement and core cutter), unconfined compressive strength.

Standards: IS 2720 series (methods of test for soils), IS 4332. ASTM D1883 (CBR), ASTM D698 (Standard Proctor), ASTM D4318 (liquid and plastic limits). AASHTO T89, AASHTO T180.

8.3 Bitumen and Road Materials

Bitumen and bituminous-mix testing is delivered through a qualified partner laboratory under TCR Engineering's coordination, sampling oversight, and reporting. The scope covers bitumen penetration, ductility, softening point, flash and fire point, and viscosity; Marshall stability and flow value for bituminous mixes; aggregate gradation; modified bitumen (PMB and CRMB) testing; and cold-mix and warm-mix asphalt qualification, aligned to Indian Roads Congress specifications for state and national highway works.

Standards: IS 73 (paving bitumen), IS 1203 (penetration), IS 1206 (viscosity), IRC SP 53 (modified bitumen), IRC 37 (flexible pavement design), MoRTH Specifications for Road and Bridge Works.

8.4 Road Inspection and Pavement Evaluation

Pavement Condition Index. Non-destructive roughness measurement. Deflection measurement (Benkelman Beam and Falling Weight Deflectometer-compatible evaluation). Reflectivity of road markings. Skid resistance. The BMC Roads Department registration ChE/Rds/8292/NF dated 25 March 2026 covers Mumbai's municipal roads programme.

Road-construction quality control follows the Indian Roads Congress framework: IRC:SP:11-1984, the Handbook for Quality Control for Construction of Roads and Runways; IRC:SP:57-2000, Guidelines for Quality Systems for Road Construction; and IRC:SP:47-1998, Guidelines for Quality Systems for Road and Bridges. The three publications govern material selection, process control, and acceptance testing on the road and bridge works TCR inspects.

8.5 Structural Audit of Buildings

Statutory structural audit of buildings is mandated in Maharashtra by Section 353B of the Mumbai Municipal Corporation Act 1888 for Greater Mumbai, and by Section 265A of the Maharashtra Municipal Corporations Act 1949 for the other municipal corporations of the state. Both provisions require the owner or occupier of a building that has completed thirty years to have it examined by a structural engineer registered with the corporation, and to submit a Structural Stability Certificate within one year of that date and every ten years thereafter. The thirty years run from the earliest of the completion certificate, the permission to occupy, or physical occupation of half the built-up area. The Commissioner may call for a certificate at any time, and failure to carry out the corrective repairs identified attracts the fine prescribed under Section 471.

The audit workflow combines a visual condition survey, ground-penetrating radar for rebar and embedded utility location, ultrasonic pulse velocity per IS 516 (Part 5/Sec 1) for concrete homogeneity, rebound hammer per IS 516 (Part 5/Sec 4) for surface hardness correlation, half-cell potential per IS 516 (Part 5/Sec 2) and ASTM C876 for corrosion likelihood, carbonation depth per IS 516 (Part 5/Sec 3) and BS EN 14630, cover-meter survey for clear-cover verification, drone capture for high-rise façade and roof access, and core extraction for verification compressive strength. The seven reinforced-concrete site methods carried at items 70 to 76 of the NABL scope are accredited; cover-meter survey, concrete resistivity, and drone capture sit outside the accredited scope and are reported as such. The output is a structural audit report with prioritised repair and rehabilitation recommendations under the CPWD framework, closing in the Structural Stability Certificate.

Housing societies carry a second and more frequent obligation. The Model Bye-Laws of Co-operative Housing Societies in Maharashtra, at Bye-law 75 of the 2014 flat-owner-type model and numbered differently in some reprints, require a structural audit once in five years for buildings aged between fifteen and thirty years, and once in three years for buildings older than thirty years, carried out within a municipal corporation limit by an engineer on that corporation's approved panel. Industrial buildings carry a third obligation. Rule 3A of the Maharashtra Factories Rules 1963 requires a certificate of stability in Form 1-A from a competent person for every work of engineering construction, renewed once in each period of five years and after any extension, alteration, repair, or addition. The audit establishes the present condition and the expected residual life of the structure, identifies what needs immediate repair, satisfies the statutory requirement, and sets the preventive and corrective programme, repairs and retrofitting included, that extends the building's life. TCR delivers the audit in three parts.

8.5.1 Part A: Visual Inspection

Visual inspection of the structure from inside and outside, member by member, with a study of the architectural, RCC, and structural drawings where available and a full photographic survey. The survey captures the load transfer system, the structural framing system, structural deficiencies, settlement, cracks in RCC members and in masonry or plaster, leakages, loads on the structure, and defects in non-structural elements, and identifies the locations that require detailed investigation and non-destructive testing.

8.5.2 Part B: Non-Destructive Evaluation

The real strength and quality of concrete cannot be established by eye. The locations identified in Part A are therefore tested with the non-destructive methods described in the audit workflow above to determine the present strength and quality of the concrete members.

8.5.3 Part C: Repair and Rehabilitation Consultancy

The audit closes with a consolidated report covering interpretation of the visual and NDT results, diagnosis and root cause analysis of the observations, a repair and rehabilitation scheme to make the structure durable and healthy, technical specifications and draft tender documents for the repair work, cost estimates, scrutiny of tenders, periodic inspection of the repair work, and issue of the Structural Stability Certificate on completion of the job.

8.5.4 Laboratory Analysis Supporting the Audit

Samples drawn during the audit are analysed at the NABL accredited laboratory at Mahape. Cores are tested for compressive strength to IS 516 (Part 4). Acid-soluble and water-soluble chloride content in hardened concrete and mortar is determined to IS 14959 (Part 1) and IS 14959 (Part 2), read against the IS 456 Table 7 limit of 0.6 kg of total acid-soluble chloride per cubic metre of concrete for reinforced concrete containing embedded metal. Sulphate content is determined to BS 1881 Part 124. Reinforcement extracted from the structure is tested for tensile properties to IS 1608 (Part 1) and for re-bend behaviour to IS 1786. Cement content in hardened concrete is determined to IS 516 (Part 11) where the original mix is in question.

8.5.5 Building Health Grading and Residual Service Life

Every element surveyed carries a severity score and an extent score, and the two roll up into a building health grade on a five-point scale: Grade 1 sound, Grade 2 minor repairs, Grade 3 major repairs, Grade 4 extensive repair and strengthening, Grade 5 unsafe for occupation with vacation or redevelopment recommended. The weighting is declared on the face of the report rather than held behind it. The superstructure carries the largest share, followed by the secondary structural elements (staircases, parapets, chhajjas, canopies and balconies), then waterproofing and seepage, then the services, then the finishes.

Residual service life is reported as an indicative range, never as a single number. The carbonation route projects the time remaining before the carbonation front reaches the reinforcement, from the measured cover and the measured carbonation depth at the structure's present age, and adds a propagation period bracketed by the half-cell and resistivity classes. The chloride route fits the measured chloride profile through the cover and projects the time to the threshold at rebar depth. The condition-trend route extrapolates the observed rate of crack and seepage progression where earlier records exist. The three routes bracket the answer, and where they disagree the report says so. Residual service life is an engineering opinion under stated assumptions, not a guarantee, and the assumptions are printed with it.

8.5.6 Services, Finishes and the Repair Budget

Seepage is the largest single driver of reinforcement corrosion in Indian residential buildings, so the audit maps plumbing leak points and terrace, tank and toilet waterproofing against the corrosion findings rather than treating them as a separate trade. The survey also records electrical panel condition, wiring type and age, insulation resistance, earthing resistance and unauthorised extensions; the finishes, covering plaster, tiling, doors, windows and mild-steel railings; and the condition of the lift core, the water tanks and the plumbing shafts. Each finding carries a priority and a measured quantity, and the report closes with a prioritised repair schedule and a bill of quantities with cost estimates, technical specifications, draft tender documents, tender scrutiny, and periodic inspection of the repair work as it proceeds.

8.5.7 Certification and Field Execution

TCR carries out the survey, the non-destructive testing, the laboratory analysis and the engineering assessment, and prepares the report. The Structural Stability Certificate for submission to the municipal corporation is issued in association with empanelled structural engineers, because the corporations require the certificate to be signed by an engineer on their own approved panel. That division of responsibility is stated on the face of every report.

Execution runs in five phases. Phase zero covers the society resolution, the access permissions and the document checklist. Phase one is the desk study and the sampling plan, which fixes minimum coverage: all accessible ground-floor columns, a defined proportion of upper-floor elements, every location of worst distress, and a random spread across the remainder. Phase two is the visual survey, one to two days per wing. Phase three is the non-destructive testing and sample collection, two to four days. Phase four is the analysis, the engineer's review, the repair schedule and the residual life assessment. Phase five is the certified report and the municipal submission. A single building runs three to five weeks end to end. The home inspection service described in Section 8.16 applies the same instruments to a single dwelling unit.

8.6 Bridge Inspection

500+ bridges inspected across India.

Anchor client: Maharashtra Public Works Department (long-running robotic NDT programme), Plus the BMC March 2026 AI-assisted robotic underwater inspection programme covering 400+ bridges (separate metric, distinct workflow with submersible ROV plus drone plus conventional NDT).

Method	Application
Drone	High-pier visual capture; girder soffit imaging
Submersible ROV	Sub-water pier and abutment, intake and forebay
UPV per IS 516 (Part 5/Sec 1)	Concrete homogeneity
Cover meter	Clear-cover verification
Schmidt rebound hammer	Surface hardness correlation
Half-cell potential per `ASTM C876`	Corrosion likelihood mapping

Standards: BS EN 124-5 (manhole and gully top fatigue up to 900 mm). IS 516 (Part 5/Sec 1) (UPV, superseding IS 13311 Part 1), IS 516 (Part 5/Sec 4) (rebound hammer). IRC SP 35, IRC SP 18, IRC SP 40 (bridge inspection and rehabilitation guidelines). High-tensile strand for prestressed bridge cable systems is tested per IS 14268, ASTM A416, BS 5896, ISO 10138, and ISO 15630-3, covering tensile, stress-relaxation, and 2 million-cycle fatigue at 70 percent of actual yield.

8.7 TMT Rebars and Reinforcement Couplers (BIS-Accredited)

The civil-buyer-facing capability anchor is the first BIS-accredited commercial laboratory in India for IS 16172 rebar coupler testing across all diameters from 8 mm to 40 mm. Over fifty manufacturers guided through the ISI mark certification process. Pull-out test on TMT Bars per IS 2770.

Test	Standard
Coupler tension and uniform elongation	IS 16172
Coupler fatigue (100,000+ cycles)	IS 16172
Coupler slip measurement	IS 16172
Coupler cyclic tension-compression reversal	IS 16172
TMT rebar tensile	IS 1786
TMT rebar elongation, bend, re-bend	IS 1786
Bond in reinforced concrete (Pull-out Test)	IS 2770-Part 1
HSFG bolt	IS 3757
HT strand for HSR and bridges	ASTM A416, IS 14268

TCR is the first and only commercial laboratory in India accredited by BIS for the full IS 16172:2023 coupler scope: tensile strength, threaded-coupler disengagement, percentage elongation, slip, cyclic tensile, and low- and high-cycle fatigue. The BIS-recognised civil scope also covers IS 1786 and IS 16651 (reinforcement bar), IS 2062 (structural steel), IS 513 and IS 1079 (carbon-steel sheet), and IS 3589 (water and sewage pipe).

Anchor clients in this segment include Dextra, Afcons, Mumbai Coastal Road Project, and Larsen and Toubro Mumbai Metro.

8.8 Building Materials, Tiles, AAC Blocks, Aluminium Formwork

Material	Test Anchor	Standard
Tile adhesive	Comprehensive shear, pull-off, open time, slip	IS 15477
AAC blocks	Compressive strength, density	IS 2185 Part 3
AAC blocks	Thermal conductivity per Guarded Hot Plate	ISO 8302, ASTM C177
Aluminium formwork	Load-cycle qualification, deflection	IS 800 (general), proprietary form-work test protocols
Glass and glazing	Cyclic load, impact resistance	IS 2553, IS 16231
Cement render and plaster	Bond strength, compressive strength	IS 1542, IS 2645

Material	Test Anchor	Standard
Linear thermal expansion	Across building materials	IS 9498, ASTM E228
Burnt clay and fly-ash bricks	Compressive strength, water absorption, efflorescence, dimensional and warpage	IS 3495 Parts 1 to 4, IS 1077
Ceramic and vitrified tiles	Water absorption, breaking strength, modulus of rupture, abrasion, dimensional	IS 13630, IS 15622
Masonry mortar	Compressive strength, consistency, water retention	IS 2250
Cement	Physical tests: fineness, setting time, soundness, compressive strength	IS 4031 Parts 1 to 15
Concrete mix design	Mix proportioning and trial-mix verification	IS 10262, IS 456
Ceramic sanitaryware and stoneware	Water absorption, crazing, load and functional tests	IS 2556

8.9 Grain Silo and Industrial Civil Infrastructure

Grain silo certification: 10,000 MT capacity per EN 10346 S350GD coated steel sheet, with ATEX/PESO certification framework where the silo carries explosive-dust scope. The capability extends to industrial civil infrastructure: pipe-rack foundations, equipment plinths, machine foundations, and chimney structural assessment.

8.10 Cathodic Protection on Civil Reinforced Concrete

Half-cell potential per ASTM C876 maps the corrosion likelihood across reinforced concrete elements. Linear polarisation resistance and macrocell current measurement add quantitative corrosion-rate data. Cross-references Section 6.8 (Cathodic Protection under Chiral Patel as CP Division Lead) for the impressed-current cathodic protection design and installation on reinforced-concrete structures.

8.11 Theodolite-Based Plumbness and Straightness

Theodolite-based plumbness and straightness measurement for industrial chimneys, stacks, towers, and tall building cores. Output is a verticality deviation report against IS 4998 Part 1, IS 11960, and IS 875 Part 3 wind-load implications.

8.12 GPR, UPV, and Subsurface Mapping

Ground-Penetrating Radar (GPR) for rebar location, embedded-utility mapping, and pavement layer-thickness profiling. Ultrasonic Pulse Velocity (UPV) per IS 516 (Part 5/Sec 1). NDT-of-concrete guidance per IAEA-TCS-17.

8.13 Marquee Engagements

Named civil and structural engagements include NDT at Antilia and the Wankhede Stadium in Mumbai, the structural audit of the STT Global Data Centre built by Larsen and Toubro, structural audits at Vikas Complex in Thane West, KC College in Thane, and Essential Power Transmission in Andheri (Mumbai), structural analysis for the Synergia Life Sciences factory at Wada, and the structural assessment for Petro India at Sanganer, Jaipur.

Client / Project	Service Anchor	Year
Mumbai-Ahmedabad High Speed Rail (NHSRCL Packages C1, C2, C3)	Construction-stage civil testing under MEIL-HCC, Afcons, Larsen and Toubro; HT strand; rebar coupler; concrete; soil; HSR-spec materials	NHSRCL VMAC Meeting No. 13, October 2023 onward
500+ Bridges, Maharashtra PWD	Robotic NDT, structural audit, rehabilitation recommendation	Continuous
BMC March 2026 robotic underwater bridge programme	400+ bridges, AI-assisted underwater inspection	March 2026 onward
Statue of Unity, Larsen and Toubro	Mechanical, chemical, metallurgical, NDT through construction	Construction era
Statue of Oneness, Adi Shankaracharya	Conventional NDT for structural fabrication	Multiple
L&T Mumbai Metro	Rebar coupler, concrete, soil, structural NDT	Multiple
Mumbai Coastal Road Project	Rebar coupler, concrete, structural NDT	Multiple
Antilia	NDT through construction	Construction era
Wankhede Stadium	NDT through redevelopment	Multiple
Godrej Properties (3-year LRC, all Mumbai Zone)	Long-Term Rate Contract for property-development testing	April 2026 onward
Kalpataru, Shapoorji Pallonji, Rustomjee	Long-Term Rate Contracts	Continuous
CIDCO eMTL Maharashtra	Empanelled Material Testing Lab	Continuous

Client / Project	Service Anchor	Year
Larsen and Toubro Statue of Unity year-long onsite engagement	Continuous on-site materials and NDT	Construction era (Appreciation Letters)

Mumbai-Ahmedabad High Speed Rail (NHSRCL), approved under VMAC No. 13 dated 23 October 2023 and engaged across all three civil packages since March 2024: MEIL-HCC (C1), Afcons (C2), and Larsen and Toubro (C3). Godrej Properties, long-term rate contract for civil testing across the Mumbai zone (April 2026).

8.14 The Logistics Differentiator: Free TCR-Branded Sample Pickup Van

TCR runs a free TCR-branded Sample Pickup Van for the Mumbai Metropolitan Region, lifting samples from client premises to the Mahape laboratory at no charge. The capability is small, but the buyer signal is large: the company prefers to absorb the friction of physical sample logistics rather than cede the laboratory test to a competitor closer to the buyer.

8.15 Standards Coverage Matrix (Civil and Infrastructure)

Concrete and Cement. IS 516 (Parts 1, 2, 4 and 11), IS 1199, IS 2386, IS 383, IS 4031, IS 8112, IS 12269, IS 456, IS 14959 (Parts 1 and 2). ASTM C39, C496, C617, C1383. BS 1881 Part 124. EN 12390 series.

Soil and Geotechnical. IS 2720 series, IS 4332. ASTM D1883, D698, D4318. AASHTO T89, T180.

Bitumen and Road. IS 73, IS 1203, IS 1206. IRC SP 53, IRC 37. MoRTH Specifications for Road and Bridge Works.

Structural Steel. AISC 360 (specification for structural steel buildings).

Rebar and Couplers. IS 1786, IS 16172, IS 2770, IS 14268, IS 3757. ASTM A615, A706, A1064, A416. ACI 318.

NDT for Concrete. IS 516 (Part 5/Sec 1) (UPV, superseding IS 13311 Part 1), IS 516 (Part 5/Sec 4) (rebound hammer, superseding IS 13311 Part 2). ASTM C876 (half-cell potential). Cover depth of rebar in concrete.

Structural Audit and Residual Life. Section 353B of the Mumbai Municipal Corporation Act 1888; Section 265A of the Maharashtra Municipal Corporations Act 1949; Model Bye-Law 75, Model Bye-Laws of Co-operative Housing Societies in Maharashtra; Rule 3A and Form 1-A, Maharashtra Factories Rules 1963; IS 15988 (seismic evaluation and strengthening of existing reinforced concrete buildings); IS 13935 (seismic evaluation, repair and strengthening of masonry buildings); CPWD Handbook on Repair and Rehabilitation of RCC Buildings. Home inspection references Section 14(3) of the Real Estate (Regulation and Development) Act 2016 for the structural defect liability period.

Building Materials. IS 2185 Part 3 (AAC blocks), IS 1542 (cement render), IS 2645 (waterproofing admixtures), IS 15477 (tile adhesive), ISO 8302, ASTM C177 (thermal conductivity, Guarded Hot Plate), IS 9498, ASTM E228 (linear thermal expansion).

Bridge. IRC SP 35, IRC SP 18, IRC SP 40. BS 5400. AASHTO LRFD Bridge Design Specifications.

Industrial Civil Infrastructure. IS 4998 Part 1 (chimney design), IS 11960 (industrial steel chimneys), IS 875 Part 3 (wind loads). EN 10346 S350GD (coated steel sheet for grain silos).

8.16 Home Inspection Programme

The Home Inspection Programme applies the same instruments to a single flat, villa or floor, for a buyer, a seller or an owner rather than for a municipal corporation. No statute requires it and no certificate is filed with any authority. What the buyer gets is an independent, instrumented record of what they are about to pay for, produced by a laboratory with no interest in the transaction and no repair contract to win from it.

The inspection covers the structural elements visible within the unit and on its common approach; dampness and seepage mapping by moisture measurement and thermography; plumbing pressure and drainage checks; electrical safety, covering earthing resistance, insulation resistance, polarity and residual current device operation; tile and plaster debonding by hollowness survey; door and window operation and alignment; floor level and wall plumb; and the water supply itself where the buyer asks for it. Where the structure is in question, the reinforced-concrete methods of Section 8.5 are available on the same visit.

The output is a defect register with photographs and locations, a severity grade against each item, an indicative rectification cost, and a plain list of what should be settled before possession is taken. On a new purchase the register is also the snapshot against which the promoter's five-year structural defect liability under Section 14(3) of the Real Estate (Regulation and Development) Act 2016 can later be argued, which is the practical reason to have the inspection done at handover rather than after it.

Delivery. A two-bedroom flat takes half a day on site and the report follows within three working days. Bulk programmes are run on a per-unit rate for developers at handover, for housing federations across a society or a layout, and for corporate relocation and leasing teams.

9. Inspection Manpower and Third-Party Services

1,000+	7	750+
TURNAROUND ENGAGEMENTS ALL-TIME	OPERATING COUNTRIES	EMPLOYEES ACROSS THE GROUP

The inspection manpower pillar is the operating-side capability that converts a buyer's plant shutdown, vendor mobilisation, or coating-system commissioning event into a managed, NDT-credentialled, single-point-of-accountability deployment.

The inspection manpower pillar is the operating-side capability that converts a buyer's plant shutdown, vendor mobilisation, or coating-system commissioning event into a managed, NDT-credentialled, single-point-of-accountability deployment. The buyer in this pillar is operations: a refinery turnaround manager, a fertiliser plant maintenance head, an EPC source-inspection lead, or a real-estate developer running coating qualification on a high-rise façade. The buyer expects 24-hour mobilisation, certified personnel, and a quality-assurance discipline that survives the audit. The pillar serves that buyer directly.

TCR Engineering is proud to offer highly qualified and experienced inspectors for short-term turnaround projects at plant sites globally. Our expert inspectors, based in India, are fully certified in API, ASNDT, and BGAS qualifications, and are equipped to handle the most rigorous inspection demands in various industries, including oil & gas, petrochemicals, refineries, and power generation.

With extensive experience in international standards and compliance, TCR's inspectors bring advanced skills in non-destructive testing (NDT), asset integrity, corrosion monitoring, and high-temperature inspections. Our team is dedicated to supporting safe and efficient operations through thorough inspections, providing clients with fast, reliable insights to ensure minimal downtime and maximum safety during critical turnaround periods.

TCR Engineering's commitment to quality and reliability has earned us trusted partnerships with industry leaders worldwide. We are ready to deploy our inspectors at your site, bringing in-depth expertise and the highest standards in inspection and evaluation, ensuring that your assets meet safety, regulatory, and operational excellence benchmarks.

Three service lines sit under the pillar: third-party audit and quality inspection, turnaround inspection manpower, and paint and coating inspection.

9.1 Third Party Audit and Quality Inspection

The traditional third-party inspection block, anchored by API and ASNT credentialled personnel.

The inspectors at TCR Engineering bring a high level of precision, expertise, and commitment to every inspection, making them invaluable partners in ensuring your products meet the highest global standards.

With extensive backgrounds in engineering and quality control, TCR's inspectors are adept at identifying even the most subtle inconsistencies, potential flaws, or deviations from standards early in the production process. They work closely with vendors to ensure that issues are resolved immediately, preventing costly reworks and delays.

By meticulously managing every detail, from material sourcing and production processes to final packaging and loading, TCR inspectors protect your interests at every stage. This dedication allows you to focus on your business growth while resting assured that every item from India meets the quality, durability, and compliance standards your reputation demands.

Let TCR handle the details, so you receive only the best from India, with the confidence of knowing your products are in expert hands.

9.1.1 Assuring Quality for International Clients

TCR Engineering is your ultimate partner for independent, top-tier Third-Party Technical Inspection and Quality Assurance services in India. From Factory Audits to Loading Supervision, TCR covers every critical phase to ensure that your vendors deliver products that meet the highest standards, saving you time, resources, and risk.

As a globally trusted provider, TCR Engineering combines over five decades of industry expertise with ISO 17025 certification, offering Factory Audits, OEM Development, Raw Material Inspection, Initial Production Check, In-Production Check, Random Inspection, and Loading Supervision. Our field inspectors visit supplier sites across India to rigorously assess and report on quality at each phase, so you can have total confidence in the items you procure from Indian manufacturers.

FACTORY AUDIT

Tailored to verify a supplier's ability to meet your contract's quality, quantity, and delivery standards. With TCR managing this, you're assured that every aspect of production is under expert supervision, minimising the need for on-site visits.

RAW MATERIAL INSPECTION

Our teams conduct on-site evaluations, assessing everything from fabrication to assembly and quality control. Continuous monitoring, on-site photography, and logging mean you're kept informed and assured every step of the way.

SAMPLE PICK-UP FOR TESTING

During production, we collect and label samples on-site and send them to TCR's advanced labs. Here, we conduct Mechanical Testing, Chemical Analysis, PMI, Non-Destructive Testing, Metallography, Corrosion Testing, Dimensional Measurement and Product Evaluation to ensure material quality and durability.

INITIAL PRODUCTION CHECK

TCR's inspection teams monitor and document production from day one, addressing any concerns early to ensure smooth progress and timely delivery.

IN-PRODUCTION CHECK

This inspection includes visual assessments and random material testing to minimise risks before final inspection. For an even more rigorous approach, combine it with Initial Production and Random Inspections.

FINAL INSPECTION

At the end of production, TCR conducts stringent quality and quantity checks on-site, ensuring that each shipment meets your specifications for packaging, labelling, and quality.

LOADING SUPERVISION

Our inspectors oversee the loading process, checking container conditions, verifying packing units, and sealing containers to ensure secure and accurate shipments.

LOGISTICS MANAGEMENT

With TCR, shipment logistics are handled with precision. Our logistics management services streamline all export documentation, customs, and regulatory requirements, ensuring timely and cost-effective delivery to you.

INSPECTION PROCESS FOR SOURCING - 12-STEP AUDIT PROCESS

TCR has developed a detailed standardised inspection procedure to optimise efficiency and maximise performance in-line with client requirements.

TCR Inspection team seeks specific information from the vendor/buyer on whose behalf the inspection is to be carried out:

- Name, Address, Telephone & Fax No of Vendor
- Details of the materials ordered along with specification (IS/BS/ASTM etc), the quantity testing requirements and other special needs
- Sampling plan, if any

2) TCR´s inspection department will then get in touch with the supplier to ascertain the availability of material for inspection. If available, an inspection is fixed within the 24 hours

3) TCR reviews suppliers internal records, test certificates for different identified stages in the approved quality plan or material procurement for verifying conformance of requirements of the equipment's/systems as per Purchase Orders, agreed upon technical specifications/approved drawings/data sheets, approved Quality Plan and other documents available with the contractor

4) Based on the agreement, TCR carries out stage-based and or final inspection on its own or in conjunction with customer's representatives

5) TCR's inspectors carry out normal visual inspection (capturing detailed size measurements) and mark each and every item (or random sampling, as specified by the client) with a "unique identification number" or TCR Test Certificate Number (if material testing is ordered as well) and a TCR Stamp. Extra stamping would be done on materials randomly drawn for testing as per sampling plan of the buyer. If no specific

sampling plan is given by the buyer, it is normal practice at TCR to draw a minimum of 2 samples and one additional sample for a batch of 10. This ensures uniformity in assessment for the whole lot. The TCR inspector will also mark the material from which necessary length of the sample is to be procured

6) If the samples are to be cut by the vendor, it must be delivered to TCR´s laboratory making sure that TCR stamp numbering & identification markings are intact on the samples

7)TCR will test the sample at its laboratory and carry out all tests as specified by the buyer. The testing can also be performed in stages on request of the vendor if the material fails to meet some of the requirements. The testing can be stalled in such cases when it is established that a sample has failed a certain test

8)All samples drawn from a particular lot must pass all the tests as specified by the buyer. If any of the samples fail, the entire lot is rejected. To gain acceptance, the vendor must agree to test each and every bar/plate of the lot with respect to the failed test. Only samples that pass the test will be cleared for dispatch

9)All bills for testing & inspection charges are typically raised to the vendor and the buyer may reimburse the same to the vendor for all accepted materials

10)All materials dispatched from the vendor to the buyer will carry the TCR stamp and Serial / TC Number, for easy verification by the inspection department of the buyer

11)In case of failure, the vendor is advised to offer a new lot and entire procedure is repeated again once the supplier rectifies the deviation as per the proposed corrective actions. In case of minor deviation from standard specification, the vendor may get clearance from the buyer and such clearance is to be directly communicated to TCR by the buyer. Such items can then be cleared for dispatch

12)The inspection report is prepared in the prescribed format along with the necessary supporting documents are issued such as Stage Inspection Reports / Test Certificates, etc. confirming the acceptance of the sample and material as per approved technical documentation and quality plans. The same is shared with the client through courier and email

Service	Personnel Anchor
Source inspection (factory and vendor premises)	CSWIP, AWS CWI, ASNT Level II, API 510/570/653 inspectors
Vendor qualification audit	ISO 9001 lead auditor, API Q1 lead auditor
Pre-shipment inspection	Material verification, dimensional, NDT-witness, document control
Quality audit (system audit)	ISO 9001:2015 and API Q1 lead-auditor crew
Material verification	PMI (XRF, OES) at the vendor premises
Expediting	Schedule monitoring, document chase, milestone capture

Third-party and source inspection covers vendor qualification and stage inspection for EPC contractors and process-plant owners, including vendor inspection for pharmaceutical original-equipment manufacturers, with quality assurance maintained through fabrication and construction.

Anchor credentials: Empanelment with EIL, Mecon, RITES, PDIL, BPCL, IOCL, GAIL, ONGC, NTPC, BHEL, HPCL, Larsen and Toubro, Reliance Industries, the Defence vendor framework, MMRDA, NHSRCL, CIDCO, CGD operators, and the cross-border KSA owner ecosystem (Saudi Aramco, SABIC, MAADEN, TASNEE, SATORP, SADARA, YASREF, Petro Rabigh, Advanced Petrochemical, LUBEREF, MARAFIQ).

Standards: ISO 9001:2015. API Q1. ISO 19011:2018 (auditing management systems). EN 10204 Type 2.2, 3.1, 3.2 certification frameworks. ASME Section V, ASME Section IX. AWS D1.1, D1.5. API 1104. CSWIP framework.

9.2 Turnaround Inspection Manpower

The marquee operating-side capability.

9.2.1 Plant Shutdown Management

TCR has the capability to rapidly source, engage and deploy talented NDT manpower across Petrochemical, Fertilizer and Power industry in India.

TCR has easily deployed several engineering and NDT teams at various onshore and offshore locations within the GCC area including Qatar, Bahrain, Oman and Saudi Arabia. In the past TCR's inspectors have done turnaround projects in South Africa, Nigeria and Kazakhstan as well.

TCR works with industry-specific organisations, research and development facilities, and clients to develop new inspection equipment, applications, and procedures.

TECHNICAL CAPABILITIES

TCR Engineering supports plant shutdown projects with a diverse range of NDT skill-sets for its NDT Personnel that include:

- API 510 Pressure Vessel Inspectors
- API 570 Piping Inspectors
- API 653 Tank Inspectors
- API 579 Fitness for Service
- Metallurgists including experts in RBI (API 580/581), Failure analysis, RLA
- ASNT Level III Experts
- BGas Paint Inspectors
- Mechanical Engineers
- Civil Engineers
- Instrumentation Design Engineers
- Piping Engineers
- Painting/Coating Inspection Professionals
- Corrosion Engineers
- IRATA (Rope Access) Technicians
- Multi-Skilled NDT Level II Technicians (ASNT/ PCN)
- CSWIP/AWS Certified Welding Inspectors
- QA/QC Inspectors and Engineers / Saudi Aramco Approved inspectors
- Chemists, Material Testing Lab Technicians
- Heat Treatment (PWHT) Technicians
- NACE Cathodic & Coating Inspectors

- NDT Level III in multiple subjects (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 and Multi-Skilled Usage
- ASNT MSLT Level II with Leak Testing experience
- ASNT Level II in Eddy Current (ET)
- ASNT UT Level II with TKY experience
- Plant Process Engineers
- Project Managers
- Construction Managers
- Procurements Managers
- HSE Managers /Officers
- AutoCAD Operators/Designers
- PDS/PDMS Designers
- Safety Officers/Engineers
- Process Design Engineers
- ASNT RT Level II and RTFI
- QA/QC Inspectors with Static and Rotating Equipment Experience
- Electrical Inspectors
- Ultrasonic Inspection (UT), Magnetic Particle Inspection (MPI), Radiography
- CSWIP Plant Inspector Level I (PL 11, PL 12)
- Positive Material Identification Operators
- Ferrite Assessment
- Rope Access Technicians

TCR inspectors are conversant with ASME/ANSI Codes and Standards across:

- ASME SECTION VIII, DIV. I and II Boiler and Pressure Vessel Code, Design and Fabrication of Pressure Vessels
- ASME/ANSI B16.5 Pipe Flanges and Flanged Fittings
- ASME/ANSI B16.9 Butt Welded Fittings
- ASME/ANSI B16.11 Screwed and Socket Welded Fittings
- ASME/ANSI B31.3 Process Piping
- AWS D1.1/D1.1M Structural Welding Code - Steel
- AWS D10.4 Austenitic Chromium-Nickel Stainless Steel Piping and Tubing, Recommended Practices for Welding
- AWS D10.8 Chromium-Molybdenum Steel Piping and Tubing, Recommended Practices for Welding
- AWS D10.10 Local Heating of Welds in Piping and Tubing, Recommended Practices
- AWS D10.11 Root pass Welding of Pipe Without Backing, Recommended Practices
- AWS D10.12 Welding Low Carbon Steel Pipe, Recommended practices and Procedures
- AWS D14.5 Pressure and Press Components, Specification for Welding
- AWS QC7 Standard for AWS Certified Welders
- AWS D1.2, 1.3, 1.4, 1.5 Structural Welding Code-Aluminum, Sheet Steel, Reinforcing Steel, Bridge Welding Code
- AWS D9.1 Structural Welding Code - Sheet Metal
- AWS D10.6 Titanium Piping and Tubing, Gas Tungsten Arc, Recommended Practices for Welding
- AWS D11.2 Welding Iron Castings, Guide
- AWS D14.5 Pressure and Press Components, Specification for Welding
- SSPC VOL I&II Steel Structures Painting Council Standard

TCR aims to become an extension of its client's human resource department. TCR has served as valuable source for understanding client's environment, developing and maintaining a search network and providing resources tailored to individual requirements. In addition to its own search networks, TCR assists the hiring authority in screening all solicited and unsolicited resumes for providing a comprehensive progress report.

TCR's on-site inspection team and associated manpower along with its advanced equipment's and tools can be commissioned to work on contract as well as for on-site assignments. Alternatively, TCR can collaborate to work with other 3rd Party Inspection Agency.

Industry Expertise

- TCR has extensive experience across all major industries. Its' highly trained teams provide clients with deep industry knowledge, best practices and expert perspectives for problem resolutions.
- TCR aims to assist companies with breakthrough business insights and set new standards of excellence for them in their industries.
- Competent Professionals
- TCR's highly trained NDE professionals go through rigorous training and are qualified to meet or exceed all industry requirements. In addition to this, TCR provides extensive in-house training and ensures that all its NDT professionals are always updated with all relevant industry codes and regulations.
- TCR has an ongoing commitment to continually bring new inspection solutions to their clients that will help them make informed decisions and minimise costs and thereby enhance their integrity management programmes.
- TCR helps augment the integrity and efficiency of equipment and assure safe working conditions for all its employees.

Latest Inspection Solutions

- TCR's highly qualified teams have significant experience in various projects, both in India and the Middle East across various disciplines of NDT including Radiography, Ultrasonic, Welding, MPI, In-situ Metallography & Positive Material Identification.
- Inspectors have worked on design, fabrication, construction, inspection and erection of Pressure Vessels, Heat Exchangers, Towers, Stacks, Tanks, Plant Pressure Piping, Offshore oil wells and several other advanced projects.

Large pool of Talent

- TCR offers a large, experienced and highly qualified pool of professionals that can be deployed at any location in the shortest of time frames.
- With over 100 professional NDT technicians, the sheer size and expertise makes TCR the obvious choice for meeting inspection requirements across all its clients
- TCR provides best integrity management solutions across industries. TCR's talent solution caters to both daily inspection activities as well as large turnaround projects.
- TCR inspectors can undertake visual inspection, ferrite assessment, PMI operations, etc and are conversant with ASME/ANSI, AWS, API, BS, ASTM and NACE Codes and Standards. Number of our inspectors are currently deployed with Saudi Aramco SAP as well:
- ASNT Level III personnel have a minimum of 7-15 years of experience
- ASNT Level II personnel have 5-10 years of experience
- Senior experience team members with over 25 years of experience
- Junior NDT inspectors have 2-5 years of experience

Group cumulative count: 1,000+ turnaround engagements all-time.

Capability	Detail
Mobilisation commitment	24 hours from purchase order
Peak deployment	100 to 200 personnel during a major turnaround window
Geographic surface area	India end-to-end and the GCC (Saudi Arabia, Kuwait, UAE, Qatar, Oman, Bahrain)
Engagement length	Short-term (5 to 30 day shutdowns) and long-term (rolling rate contracts of 1 to 5 years)
Personnel pool	API 510 / 570 / 653 inspectors, CSWIP and AWS CWI welding inspectors, AMPP/NACE corrosion engineers, RBI specialists, ASNT and PCN Level II / III NDT technicians
Reporting	Daily progress, NCR tracking, RFI logging, end-of-shift handover; integrated into AiOM where available (cross-pillar reference, Section 6.1)
Health, Safety, Environment	ISO 45001:2018-aligned site safety; AERB-regulated radiation-safety procedures where RT is in scope (cross-pillar reference, Section 5.9)

9.3 Personnel Stack

Credential	Group Bench
ASNT NDT Level III	4 (Shemi Bhaskaran for RT/LPT/MPI; Nikhil Sabhaya at TCR Advanced for ET/UT/PT/MT plus API 510 plus CSWIP 3.1)
ASNT NDT Level II	Multiple
BARC Level-1 radiography	11+
PCN Level II / III	Multiple
API 510 (Pressure Vessel Inspector)	Multiple
API 570 (Piping Inspector)	Multiple
API 653 (Tank Inspector)	Multiple
API 580 (RBI)	Gopul Patel (Cert. 96800 valid through 31 October 2026) plus broader bench
CSWIP 3.1 / 3.2	Multiple
AWS Certified Welding Inspector	Multiple
AMPP/NACE Coating Inspector (CIP) Level 2 / 3	Multiple
FROSIO Inspector Level III	Multiple (KSA via TCR Arabia)
ISO 9001:2015 Lead Auditor	Multiple
API Q1 Lead Auditor	Multiple

Credential	Group Bench
AERB Radiation Safety Officer	Shemi K B (21-RSO-681725); Ananta Kishore Parida (22-RSO-734005, Bhubaneswar SSF) and others

9.4 Standards Coverage Matrix (Inspection Manpower)

Quality Management. ISO 9001:2015. API Q1. ISO 19011:2018.

Pressure Equipment Inspection. API 510 (11th ed., 2022), API 570 (5th ed., 2024), API 653 (6th ed., 2024). API RP 572, API RP 574, API RP 575. ASME PCC-2.

Welding Inspection. ASME Section V, ASME Section IX. AWS D1.1 (2025), D1.5. API 1104 (22nd ed., 2021). EN ISO 9606. CSWIP framework.

Coating Inspection. SSPC-VIS 1, ISO 8501-1, ISO 8502-3, 8502-6, 8502-9, ISO 8503, ISO 2808. ASTM D3359, D4414, D4417, D4541, D7091. NACE SP0188. AMPP/NACE CIP framework.

Material Certification. EN 10204 Type 2.2, 3.1, 3.2.

HSE. ISO 45001:2018. AERB Safety Manual AERB/RF-IR/SM-1 Rev. 2 where RT is in scope.

10. Operational Discipline and Quality Backbone

Behind the six service pillars sits the discipline that makes them defensible: the accreditation portfolio, the quality management system, and the metrology and traceability stack. This is the operational backbone.

This section is the operational backbone the rest of the profile rests on. The pillars (Sections 4 to 9) describe what TCR sells. This section describes the discipline that makes those pillars defensible: the accreditation portfolio, the quality management system, the metrology and traceability stack, the inter-laboratory comparison record, the radiation-safety regime, the audit cadence, and the proficiency-testing record. A buyer who reaches this section is doing diligence. The section is built to satisfy that buyer.

10.1 The Laboratory Accreditation Portfolio

Accreditation	Reference	Scope	Validity
NABL ISO/IEC `17025:2017`	Certificate NABLT0726MH18640 (in lieu of TC-6905)	1,483 scope items at TCR Engineering Mahape: mechanical, civil, NDT, PMI, RoHS, chemical analysis	03 March 2026 to 02 March 2030
NABL ISO/IEC `17025:2017`	Certificate TC-15993	409 scope items at TCR Eastern Bhubaneswar: chemical analysis, mechanical properties, and metallography of metals and alloys	30 April 2025 to 29 April 2029
BIS recognition	LRMD/LRS/OSL-7103506	Materials testing for ISI mark; first BIS-accredited commercial laboratory in India for `IS 16172` rebar coupler testing across all diameters; covers `IS 15103:2002` and `IS 17875:2022` (added August 2024)	Active
Indian Boiler Regulations	"Well-Known Material Testing Laboratory" Central Boilers Board, Form XVI-H certificate 38 (Serial MTL/15/019)	IBR Form III material certification	Since 2014; current certificate valid to 02 April 2029
Central Boiler Board	Well-Known RLA Organisation	RLA on boiler pressure parts under IBR	Active
AERB	Operation Licence 23-IRLOP-893925	X-ray and gamma-ray radiography across India	Active

Accreditation	Reference	Scope	Validity
AERB	Source Storage Facility Mumbai 22-ASSF-793303	Mumbai source storage	Valid 28 June 2027
AERB	Source Storage Facility Bhubaneswar 23-ASSF-927086	Bhubaneswar source storage	Valid 30 August 2027
ISO 45001:2018	Occupational Health and Safety; QRO certificate 3050260220154HS	Group	Valid to 19 February 2029
ILAC MRA reciprocity (via NABL)	Mutual Recognition Arrangement; NABL 133 Combined ILAC MRA Mark permission NABL/ILAC/11591 (CAB ID T-0294)	Reports accepted across 90+ signatories including A2LA (US), UKAS (UK), DAkkS (Germany), Cofrac (France)	Coterminous with the NABL certificate, to 02 March 2030
NADCAP AC7101 (Materials Testing)	Performance Review Institute, certificate 29415245997	Aerospace verification testing	Accredited 2026, valid to 31 May 2027
BSE / NSE empanelled assayer	Precious metals and bullion	Bullion and precious-metals trading	Active
ICCL / BSE Approved Assayer	Bullion and precious-metals trading	Active	
Bharat Metal Exchange Association	Approved laboratory	Active	
CIDCO eMTL	Empanelled Material Testing Laboratory, Maharashtra	Active	
JSRS Certification (Oman)	Registered	Sultanate of Oman operations	August 2025 onward

The 1,483-item NABL scope (1,383 laboratory tests and 100 site tests) is published on the NABL portal and is available on request. The scope spans mechanical, civil, NDT, PMI, RoHS, and chemical analysis disciplines. The 409-item TCR Eastern (Bhubaneswar) sub-scope under TC-15993 supports steel, power, and infrastructure clients in Eastern India with its own NABL accreditation.

10.2 The Quality Management System

The Quality Management System runs on ISO/IEC 17025:2017, which carries the ISO 9001 management-system requirements and adds the technical-competence requirements above them, with NABL 100, 160, and 216 as the national application criteria.

Module	Reference
Quality Manual and Procedures	NABL 100, NABL 160, NABL 216
Document control, internal audit, management review	ISO/IEC 17025:2017 Clause 8
Method validation	ISO/IEC 17025:2017 clause 7.2.2
Measurement uncertainty	JCGM 100 (GUM, 2008 with 2023 supplements); EURACHEM Guide Quantifying Uncertainty in Analytical Measurement (3rd ed.); ISO 5725 series; NABL 141
Metrological traceability	ILAC P10 (2020); ILAC G8 (decision rules, 2019)
Decision rules and conformity assessment	ILAC G8; ISO/IEC 17025:2017 clause 7.8.6
Sampling	NABL 130; ISO/IEC 17025:2017 clause 7.3
Subcontracting	ISO/IEC 17025:2017 clause 6.6
Equipment calibration	ISO/IEC 17025:2017 Clause 6.4
Reference materials	ISO 17034; ISO/IEC 17025:2017 Clause 6.5.2(b)

10.3 Metrology and Traceability

Every measuring instrument in the working chain is calibrated against a reference traceable to a National Measurement Institute (NPL India, NPL UK, NIST USA, PTB Germany) through an unbroken calibration chain. The calibration records are document-controlled and the NABL audit trail establishes that the chain has not been broken.

Calibration Family	NABL-Approved Calibration Source
Force standards (UTMs from 0.5 kN to 1,000 kN)	NABL CC-prefix calibration laboratory; force-standard machines traceable to NPL India
Hardness reference blocks (Vickers, Brinell, Rockwell, micro-hardness)	NABL CC; reference blocks traceable to NPL India and BAM Germany
Temperature standards (creep frame thermocouples up to 1,000 °C)	NABL CC; NIST-traceable platinum resistance thermometer calibration

Calibration Family	NABL-Approved Calibration Source
Pressure standards (CTOD machine, fatigue rig pressures)	NABL CC; deadweight tester traceable
Mass standards	NABL CC; F1 / E2 standard weights
Dimensional standards (extensometers, micrometers, gauges)	NABL CC; gauge blocks traceable
Spectrometer standards (OES, XRF, ICP-OES)	Certified Reference Materials per `ISO 17034`
Charpy reference samples	NIST and IRMM Certified Reference Samples

The decision-rule framework (ILAC G8) is documented for each method. The Total Measurement Uncertainty is reported on the test certificate where the method scope and the buyer demand it (typical for sour-service corrosion, fatigue and CTOD, creep, and aerospace verification testing).

10.4 Inter-Laboratory Comparison and Proficiency Testing

The ILAC P10 framework requires participation in inter-laboratory comparisons (ILC) and proficiency tests (PT) to demonstrate ongoing technical competence. The TCR record runs across NABL-organised PT schemes, NPL-organised ILCs, and international rounds (LGC, ERA, BAM).

Programme	Scope
NABL PT schemes	Mechanical (E8 tensile, E23 Charpy, E18/E10 hardness), chemical (alloy-steel composition), corrosion (`NACE TM0177`, TM0284), metallography (E112 grain size, E45 inclusion rating)
ITER France cross-check	Industrial Research vertical anchor (autoclave deliverable)
BAM Germany ILC rounds	Reference-material verification
NPL India PT schemes	Calibration verification across force, hardness, temperature, pressure, mass
In-house ILC across TCR Engineering, TCR Eastern, TCR Arabia, TCR Advanced	Method consistency across operating sites

The Z-score discipline applies: any test method that returns a Z-score outside the absolute value of 2 triggers an internal corrective action workflow. Z-score outside the absolute value of 3 triggers an immediate re-run plus a method-validation review. The Z-score record is auditable through the QMS.

10.5 The Radiation Safety Regime

Element	Reference
AERB Operation Licence	23-IRLOP-893925 (licensed to Mrs. Neelam Bafna), valid and current

Element	Reference
AERB Source Storage Facility Mumbai	22-ASSF-793303, valid 28 June 2027
AERB Source Storage Facility Bhubaneswar	23-ASSF-927086 at Plot 125/2094 Vishnu Vihar, valid 30 August 2027
AERB Radiation Safety Officer 1	Shemi K B (21-RSO-681725)
AERB Radiation Safety Officer 2	Ananta Kishore Parida (22-RSO-734005, Bhubaneswar SSF)
BARC leak certificates	Multiple, 2024
Cross-border permission	Nepal Oil Corporation Ref 2080/81 dated 30 July 2023 (MAPL Phase II via Likhitha Infrastructure)
Standards	AERB Safety Manual AERB/RF-IR/SM-1 Rev. 2; SMPV(U) Rules 2016; Gas Cylinder Rules 2016 (PESO)

10.6 The Audit Cadence

Audit	Frequency	Authority
NABL surveillance	Annual	NABL India
NABL re-accreditation	Quadrennial	NABL India
BIS surveillance	Annual	Bureau of Indian Standards
IBR surveillance	As specified by Central Boiler Board	Government of Maharashtra DSB / CBB
AERB surveillance	As specified by AERB licence conditions	Atomic Energy Regulatory Board
`ISO 45001 surveillance`	Annual	Third-party certification body
Client second-party audits	On demand	Saudi Aramco, SABIC, BHEL, IOCL, ONGC, Reliance, Larsen and Toubro, EIL, NHSRCL, BMC, etc.
`NADCAP AC7101` audit	Annual, on the 12-month accreditation cycle	Performance Review Institute
In-house internal audit	Quarterly	TCR QMS team under Dr. Ajay Essampally
Management review	Annual	TCR senior leadership

10.7 Awards and External Recognition

- NACE Excellent Laboratory in the Private Sector award
- ISRO appreciation for Project ASLV.
- Larsen and Toubro Defence IC appreciation for the VSSC-ISRO Rocket Motor Casing Hardware on Chandrayaan-3 ("no non-conformity observed").
- OMIFCO Vendor Evaluation 97 out of 100, Grade Excellent.
- QAFCO Training scorecard 92.88 out of 100, Grade A.
- Government of Maharashtra Director DSB statutory IBR-laboratory recognition.
- EIL OPaL formal lab approval.
- AMPP India Corrosion Awareness Award 2023 to J.N. Agarwal (TCR Advanced consultant bench).
- Indian Institute of Metals, Baroda Chapter, IIM-KK Award 2016 to Paresh Haribhakti, for meritorious contribution to the metallurgical profession in Gujarat.

10.8 Operational Discipline at Group Level

The discipline runs at three levels.

1. **Documentation level:** Every test method has a controlled procedure. Every controlled procedure has a method-validation pack, a measurement-uncertainty evaluation, and an audit-trailable revision history. Every test certificate carries the NABL ULR (Unique Laboratory Report) number.
2. **Personnel level:** Every operator carries a credential the NABL audit can verify (ASNT Level II / III, PCN, API, AMPP/NACE, CSWIP, AWS, AERB RSO). Every senior bench role is named, credentialled, and accessible.
3. **Asset level:** Every measuring instrument is calibrated, traceable, and within validity. Equipment out of calibration is removed from service. The 300+ instruments across Mahape, Bhubaneswar, Vadodara, and Dammam are maintained on a calibration calendar managed through the QMS.

The discipline does not show in the marketing surface area. It shows in the audit. The NABL re-accreditation cycle, the BIS verification visit, the AERB inspection, the IBR audit, and the client second-party visits all continue to clear without significant non-conformities, which is what allows the rest of the profile to make the claims it makes.

A full register of TCR's mechanical, chemical, metallurgical, corrosion, non-destructive, civil, and field-deployable inspection equipment, with makes, models, ranges, and calibration traceability, is maintained under the quality management system and is provided to clients and auditors on request.

11. Industries We Serve

TCR serves sixteen industry verticals, from refining and power through to metal trading and industrial research. One thread runs through all of them: TCR is a static-equipment specialist. Storage tanks, heat exchangers, pressure vessels, columns, reactors, reformers, and piping are where the work concentrates, across materials testing, non-destructive testing, failure analysis, and asset-integrity engineering.

Each vertical is profiled to a consistent structure, so a buyer can read across them: the industry context, the plant sections TCR inspects, the damage mechanisms it investigates, the standards coverage, the service applications, named clients, marquee projects, the personnel who lead the work, and the energy-transition relevance. Two capabilities recur as the differentiators. In-situ metallographic replica, delivered by twelve dedicated field teams, is the flagship value-add wherever elevated-temperature equipment is in service. The Knowledge-Based Audit is TCR's branded risk-based inspection. In pipelines, the work runs on a three-tier architecture: project NDT, operator condition assessment, and engineering analysis.

Across every vertical the testing is delivered under NABL certificate NABLT0726MH18640 ISO/IEC 17025:2017 accreditation with ILAC Mutual Recognition Arrangement reciprocity. A report issued from Navi Mumbai is accepted by an ASME, API, or NACE/AMPP auditor in the Gulf, Europe, or North America without re-testing, which is what lets an operator outsource ASTM, NACE, and API materials testing to India and still close the file with a single signature.

INDUSTRIES · SECTION 11A

Refining and Petrochemicals

SECTION 11A

11a. Refining and Petrochemicals

Every major Indian refiner runs on the TCR bench, **Reliance, Indian Oil, BPCL, HPCL, HMEL, MRPL, CPCL and Nayara**, alongside **Saudi Aramco, SABIC and Shell**. At **Reliance Jamnagar**, the world's largest refining complex, TCR fielded **1,200 in-situ metallographic replicas in a single 15-day turnaround**.

POTENTIAL FAILURES WE SERVICE

Fires and process upsets in the CDU/VDU, FCCU, hydrogen-manufacturing units, REAC, reactors and their internals; storage-tank floor and shell failures. TCR investigates metallurgical degradation, creep, high-temperature hydrogen attack, polythionic and chloride stress corrosion cracking, sulphidation, naphthenic acid corrosion, reheat cracking, fastener detachments and fatigue, with in-situ replica teams reading the microstructure on site.

When a refinery reactor runs hot or a unit catches fire, the call goes to a bench that has worked the CDU, FCCU and hydroprocessing trains of nearly every Indian refiner, and read 1,200 in-situ replicas at Reliance Jamnagar in a single turnaround.

MARQUEE PROJECT

HMEL Bathinda isomerisation reactor 503-R-001 ran a **710 °C** temperature excursion. The Fitness-for-Service assessment certified it fit for service, and the unit operated to 2019 with **no shutdown**.

11a.1 Industry Context

Indian refining is spending at a scale the sector has never seen. IOCL alone runs capital expenditure of roughly Rs 30,000 to 35,000 crore a year, with brownfield expansions at Panipat, Gujarat, and Barauni estimated at about Rs 63,500 crore, and it treats whole-refinery turnaround maintenance as a formal institutional practice. Every rupee of that spend rides on pressure equipment that must be inspected during construction, watched through every run cycle, and defended at every turnaround. That is precisely the demand TCR serves: PMI and weld NDT at the project stage, turnaround inspection manpower and advanced NDT in operation, and FFS, RLA, and failure analysis when equipment ages. The ARTiS reference list alone spans eight IOCL refineries plus HPCL, BPCL, HMEL, BORL, Nayara, and CPCL.

Indian refining capacity sits at approximately 256 million metric tonnes per annum and is on a declared path to 310+ million metric tonnes per annum by 2028 to 2030. The capex pipeline in flight is large and well-anchored: the IOCL Panipat 25 MMTPA expansion, the IOCL Paradip Petrochemical Complex, the BPCL Bina expansion to 11 MMTPA plus the petrochemical complex addition, the HPCL Barmer 9 MMTPA grassroots refinery, the Numaligarh Refinery 9 MMTPA expansion, the CPCL Cauvery Basin 9 MMTPA grassroots, and a steady stream of debottlenecking and HSD-quality projects across IOCL Mathura, IOCL Koyali, MRPL, BPCL Mumbai, BPCL Kochi, and HPCL Mumbai. The Indian average refinery is roughly 30 years old; the asset-integrity bench is therefore deep and durable.

In the GCC orbit, the Saudi Aramco and SABIC ecosystem (SATORP, YASREF, Petro Rabigh, LUBEREF, MARAFIQ, SADARA, Sipchem, Advanced Petrochemical) anchors TCR Arabia's refining and petrochemicals deployment, with steady cross-package movement onto the master gas system, Jafurah, and downstream petrochemical units.

Three macro pressures shape the work: opportunity-crude processing (heavier, more sour, more contaminated feedstock margins), renewable-feedstock co-processing (waste-oil-derived and bio-feedstock streams introducing new corrosion mechanisms), and the carbon-capture and decarbonisation capex layer (CCS/CCUS at FCC and SMR units, energy-efficiency projects, hydrogen-network expansion).

Renewable-feedstock co-processing introduces free-fatty-acid corrosion on hydroprocessing trains and chloride introduction on FCC; the corrosion testing bench (Section 4.7) and the corrosion-monitoring service line carry the relevant qualification capability. Green hydrogen integration brings the API 941 HTHA discipline into expanded service (cross-vertical with Power and Fertilisers; reference Section 12 Energy Transition). Carbon capture in refining surfaces amine-system corrosion, MEA degradation, and FCC flue-gas CCS retrofit qualification. Refinery efficiency capex (energy audit, fired-heater conversion, exchanger upgrade) feeds Pillar 3 engineering consulting.

The strategic positioning sits clean: TCR's refining bench is set up for the full corrosion, integrity, and life-extension surface area as the Indian refining fleet ages, capex extends, and feedstock carbon shifts.

SECTION 11B

11a.2 Plant Sections We Inspect

Unit Cluster	Key Equipment
Crude Unit Complex (CDU/VDU)	Atmospheric column, vacuum column, crude preheat exchangers, desalter, furnace radiant and convection coils, transfer lines
Conversion Units	FCCU (riser, regenerator, main fractionator), Delayed Coker (drums, switching valves, blowdown), Visbreaker, Hydrocracker, RFCC
Hydrogen-Bearing Services	HDT, HDS, HCU (reactors, recycle gas compressor circuits, makeup hydrogen, amine treaters), MHC
Treatment	Amine recovery (regenerator, lean and rich amine exchangers), Sulphur Recovery Unit (Claus reactor, condenser train, tail gas treater), Caustic treaters, Merox

Unit Cluster	Key Equipment
Light Ends and Finishing	Catalytic Reformer (CCR or semi-regen), Isomerisation, Alkylation (HF or sulphuric), polymerisation
Storage and Movements	`API 650` atmospheric tanks (crude, intermediate, finished), `API 620` low-pressure (slop, reflux), refrigerated LPG / LNG / NH3 (where co-located)
Petrochemical Extensions	Aromatics complex, olefins cracker, polymer reactors (HDPE, LDPE, LLDPE, PP), MEG, PTA
Utilities and Support	Cooling water systems, BFW, deaerator, package boilers, flare and relief network, instrument air, hydrogen network, nitrogen, fuel gas

The static-equipment specialist framing applies: storage tanks, heat exchangers, pressure vessels, columns, reactors, transfer lines, piping. TCR does not enter rotating-equipment field service.

11a.3 Damage Mechanisms We Investigate

Anchored to API RP 571 3rd Edition (March 2020) and approximately 67 to 70 catalogued mechanisms.

Category	Mechanisms
High-temperature corrosion	Sulphidation (Couper-Gorman curves), naphthenic acid corrosion (TAN-driven), high-temperature H2/H2S corrosion (modified McConomy), HTHA per `API 941` (Nelson curves), oxidation, decarburisation, carburisation, metal dusting
Aqueous corrosion and cracking	Polythionic acid SCC (300-series stainless above ~500 °F service), chloride SCC, caustic SCC and embrittlement, amine SCC, ammonia SCC (300-series), wet H2S damage (HIC, SOHIC, SSC), sour water corrosion
Low-temperature aqueous attack	CO2 corrosion (sweet), under-deposit corrosion, microbiologically-induced corrosion
Mechanical and fatigue	Thermal fatigue (cyclic units, switching cokers, fired-heater coils), mechanical fatigue (vibrating piping, pump suction lines), creep (fired heater coils, reformer tubes, hydroprocessor reactors), reheat cracking
Thermal degradation and metallurgical	Spheroidisation, graphitisation, temper embrittlement (2.25Cr-1Mo and 3Cr-1Mo above ~371 °C), 885 °F embrittlement (12Cr ferritics), sigma phase (300-series stainless and duplex), 475 °C embrittlement
Localised attack	Pitting under deposit, crevice corrosion, dew-point corrosion, ammonium chloride salt deposition
Refractory and lining	FCC riser refractory abrasion-erosion, SRU reactor refractory degradation, anchor failure
Renewable feedstock-specific (emerging)	Free fatty acid corrosion on co-processing units, chloride introduction from waste-oil feedstock, oxygenate cracking

11a.4 Standards Coverage Matrix

Damage and FFS. API RP 571 3rd ed. (2020); API 579-1/ASME FFS-1 4th ed. (2021); BS 7910; WRC 489 (refining damage mechanisms).

Inspection codes. API 510 11th ed. (2022) pressure vessels; API 570 5th ed. (2024) piping; API 653 6th ed. (2024) tanks; API RP 572, RP 574, RP 575; API 941 HTHA; API 530 fired-heater tube design; API 936 refractory.

RBI / KBA. API 580 / API 581 4th ed. (January 2025); API RP 584 IOW 2nd ed. (December 2021); CCPS Guidelines for Mechanical Integrity Systems 1st ed.

Materials. NACE MR0103 (sulphide stress cracking in refining); NACE MR0175 / ISO 15156 (where sour service is co-located); ASME Section VIII; API 5L; ASTM A335 P5/P9/P22/P91; ASTM A234 WP91; ASTM A691 (high-pressure piping).

Welding. ASME Section IX (2023); AWS D1.1; API 1104; API 582.

NDT-specific. ASME Section V; ASTM E94, E1742, E709, E165, E1417; ISO 17636; ASTM E2884 (ECT); ASTM E2096 (RFT); ASME V Article 23 (IRIS).

11a.5 Service Applications Across the TCR Continuum

A refinery buys integrity services against three recurring pressures. In operation, the problem set is high temperature hydrogen attack in hydroprocessing reactors, sulphidation and naphthenic acid corrosion in the crude and vacuum train, polythionic acid stress corrosion cracking that forms in sensitised austenitic internals the moment a unit is opened for shutdown, creep in heater tubes, and corrosion under insulation across the tank farm and piperack. During shutdown and turnaround, the pressure is time: inspection windows are compressed, discovery work erupts mid-turnaround, scaffolding dominates cost, and qualified API 510, API 570, and API 653 inspectors are scarce exactly when every refinery in the region wants them. In procurement, the risk is material: mis-certified alloy at the pipe mill, positive material identification gaps in incoming spools, and long-lead forgings that arrive without credible test evidence. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) against exactly these pressures.

Stage One, Sourcing and Procurement. TCR runs factory audits and original equipment manufacturer qualification at pipe mills, forge shops, and valve and fitting vendors, with raw material inspection, sample picking, in-production checks, and loading supervision. Procurement samples are tested in the NABL accredited laboratory under certificate NABLT0726MH18640: mechanical testing per ASTM A370 and ASTM E8/E8M, impact per ASTM E23, sour service qualification through sulphide stress cracking per NACE

TM0177-2016 and hydrogen induced cracking per NACE TM0284, intergranular corrosion per ASTM A262, and positive material identification per API RP 578, so that hydrogen service steels and sour service materials per NACE MR0103 enter the plant with defensible evidence.

Stage Two, Construction and Commissioning. During unit construction, revamps, and capacity expansion, TCR provides baseline non-destructive testing: phased array ultrasonic testing and time of flight diffraction on thick-wall welds, radiography with robotic crawlers on piping, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX, weldability and consumable evaluation, post-weld heat treatment, and positive material identification on every alloy joint. The output is the baseline data set, thickness grids, weld maps, and material records, against which every later inspection of the unit is measured.

Stage Three, In-Service. On-stream, TCR deploys advanced non-destructive testing for high temperature hydrogen attack detection per API RP 941, hydrogen induced cracking mapping, carburisation screening, high temperature corrosion mapping on live equipment, and mid-wall fissure detection, supported by thermography of fired heaters, remote visual inspection, and robotic tools. TCR Advanced builds the risk-based inspection plan per API RP 580 and API RP 581 through the Knowledge-Based Audit method and sets integrity operating windows per API RP 584, so that inspection effort concentrates where damage-mechanism susceptibility per API RP 571 actually sits.

Stage Four, Shutdown and Turnaround. In the turnaround window, TCR delivers pipeline and weld inspection, heat exchanger tube inspection, in-situ metallographic replication on heater tubes, reactors, and hot piping by the twelve dedicated field teams, storage tank inspection per API 653 including in-service robotic crawling, coke drum and boiler condition assessment, robotic reformer tube inspection with ARTiS on hydrogen and steam methane reformer units, and turnaround inspection manpower with API 510, API 570, and API 653 qualified inspectors, sized to the shutdown and released when it closes.

Stage Five, Continuum. The forward-looking stage converts findings into operating decisions: failure analysis per API RP 585, remaining life assessment of heater tubes per API 530, fitness for service per API 579-1/ASME FFS-1 on hydroprocessing reactors, columns, and vessels, fire damage assessment per API 579-1 Part 11, integrity operating window refinement per API RP 584, engineering design and analysis, and the contract research, including renewable feed and co-processing corrosion studies, that feeds the next procurement cycle.

11a.6 Named Clients

India. Reliance Industries (Jamnagar, including the 1,200 in-situ replica engagement), Indian Oil Corporation (Panipat, Mathura, Koyali, Paradip, Barauni, Haldia), Bharat Petroleum (Bina, Mumbai, Kochi), Hindustan Petroleum (Mumbai, Visakh, Barmer), HMEL (Bathinda), MRPL, CPCL, Numaligarh Refinery, Nayara Energy.

GCC. Saudi Aramco, SABIC, SATORP, YASREF, Petro Rabigh, LUBEREF, MARAFIQ, SADARA, Sipchem, Advanced Petrochemical, KNPC (Kuwait), PDO, OQGN, QChem, QatarGas (cross-vertical with Oil and Gas).

International. Shell (multiple geographies, sour-service approved), Pemex (Mexico), PetroChina International Iraq FZE, Iraqi Ministry of Oil, Indorama (Nigeria; cross-vertical with fertilisers), Binh Son Refining (Vietnam), Casale SA (Switzerland) for licensor scope.

Equipment OEMs and Licensors. Cameron International (FAQ since 2012), NOV Inc. (March 2023), GE International, Halliburton, Schlumberger, Casale SA SX3000 (Vendor Code 1000007973, June 2025).

The India refining and petrochemical record is anchored by two marquee engagements. At HMEL's Bathinda refinery and petrochemical complex, TCR Advanced holds a three-year failure-investigation contract (Rate Contract 9830004894, valid June 2025 to June 2028) covering the full complex. At Reliance Industries, Jamnagar, the world's largest refining site, TCR led the damage assessment after the VGO-HT2 fire and fielded a 1,200-replica in-situ metallography turnaround in a fifteen-day window.

The broader India refining and petrochemical client base includes Bharat Petroleum (Kochi), Hindustan Petroleum (Mahul), Reliance Industries (Patalganga and Nagothane), and Shell India.

11a.7 Marquee Projects

Project	Service Anchor	Year
HMEL Bathinda Isomerisation Reactor 503-R-001	FFS of temperature excursion (peak 710 °C, 44 minutes above 700 °C); certified fit-for-service; monitored through 2019 with no shutdown	2012 to 2019
HMEL Bathinda VGO Unit fire response	FFS of VGO reactor under `API 579-1` Part 11	2024
HMEL Bathinda 3-year Failure Investigation Rate Contract	Rate Contract 9830004894	06 June 2025 to 06 June 2028
BPCL Bina	RBI of duplex AFC and piping in HCU	Multiple
AIO Consulting for Aramco UAE	ECA of 42-inch underground oil trunkline girth welds	2025
Saudi Aramco Jafurah Gas Compression Plants	ECA, PWIS Package-1	2024 to 2025
Reliance Industries Jamnagar	1,200 in-situ replicas in 15 days during turnaround	Multiple
Petrokemya, KSA	RLA of fire-steam-tube boiler	2023
Binh Son Refining, Vietnam	Omega Method life assessment of heater tubes	2025
Indian fertiliser-refinery corridor	1,000+ fertiliser and refinery cases all-time	Continuous

INDUSTRIES · SECTION 11B

Power Generation

SECTION 11B

11b. Power Generation

400-plus Boiler RLA studies and the **Adani Power Mundra 4,620 MW** fleet assessed under IBR at **20 days per unit**, for clients including **NTPC, Tata Power, Adani Power, JSW Energy, Torrent and Reliance Power**.

POTENTIAL FAILURES WE SERVICE

Boiler tube leaks, outlet-header and main-steam-line failures, turbine and condenser problems. TCR runs Fitness-for-Service and Remaining Life Assessment to evaluate creep, long- and short-term overheat, fireside corrosion and erosion, flow-accelerated corrosion, hydrogen damage, dissimilar-metal weld failure and thermal fatigue, with same-day creep-cavitation classification read from the field replica.

Five decades on the boiler island: 400-plus Boiler RLA studies, the Adani Mundra 4,620 MW fleet assessed at twenty days a unit, and the ASM International reference book on boiler failures written from this same bench.

MARQUEE PROJECT

Adani Power Mundra: remaining-life assessment of the **4,620 MW** boiler and piping fleet under **IBR Regulation 391A**, delivered at 20 days per unit.

11b.1 Industry Context

India's thermal fleet is being asked to run harder for longer. NTPC operates close to 80 GW with a further 32 GW under construction, and its coal stations delivered a 77.44 percent plant load factor in FY25, the highest in seven years. A fleet at that duty accumulates creep, fatigue, and tube-failure exposure faster, which is why renovation, modernisation, and life extension are board-level spend at every major generator, with NTPC's own R&M practice restoring stations such as Talcher, Unchahar, Badarpur, and Tanda. TCR sits exactly on that spend line: **1,500+ boiler tube failure investigations**, IBR-recognised remaining life assessment, in-situ metallography on live components, and oxide scale measurement that converts outage data into run-or-retire decisions.

India's installed thermal-power capacity sits at approximately 240 GW with a substantial share above 25 years of operating age. The capex pipeline carries the addition of supercritical (660 MW class, 590 °C, 281 bar) and ultra-supercritical (660 to 800 MW class, 600+ °C, 280+ bar) units; CFBC and AFBC additions for captive industrial power; HRSG additions on combined-cycle gas turbine projects; and a rolling Brownfield uplift programme on existing 250 MW and 500 MW units. TCR has worked to undertake NDT and PWHT at NTPC Talcher TTPP-III 2 x 660 MW (BHEL EPC, Power Mech Projects mechanical erection).

Two technology trends shape the integrity workload: cycling and flexible operation (the renewable-energy effect on baseload coal plant) drives low-cycle fatigue surface area, and coal-plant life-extension decisions drive RLA, KBA, and PLE workload across the Indian fleet.

The GCC orbit (Saudi Electricity Company, MARAFIQ, ACWA, NOMAC, Arabian Bemco) sits in TCR Arabia's deployment pool. Cross-border equipment OEM relationships (BHEL since 2003, GE Power, Mitsubishi, Siemens) feed source-inspection and verification testing.

Hydrogen co-firing introduces API 941 HTHA discipline expansion in boiler water-walls and superheater banks. Biomass and waste co-firing introduces fireside corrosion-mechanism shifts (chloride and alkali driven). Coal-plant life-extension decisions drive KBA and PLE workload across the Indian fleet. Battery Energy Storage System integration brings new electrochemical and fire-safety surface area at thermal-plant sites (cross-vertical with Industrial Research and Insurance). Carbon capture from power plants brings amine-system corrosion qualification into power. Solar PV integration at thermal sites brings structural-steel testing for module-mounting structures (cross-pillar with Civil).

The same-day in-situ replica interpretation service promise is the operational positioning anchor: the field team can read a creep cavitation classification on the day of replica acquisition rather than wait for laboratory turnaround, which protects the turnaround critical path.

11b.2 Plant Sections We Inspect

Cluster	Equipment
Boiler Pressure Parts (Water-Touched)	Economiser, water walls, downcomers, drum, headers (mud, water, steam)
Boiler Pressure Parts (Steam-Touched)	Superheater (primary, secondary, tertiary), reheater, attemperator, desuperheater, transfer piping
Pressure Boundary	Drums, headers, BFW lines, attemperator pipework, blowdown
Steam Turbine	HP, IP, LP rotors and diaphragms; control valves; bearings; coupling; shaft alignment
Generator	Stator, rotor (visual, NDT, demagnetisation per JPL Tamnar reference)
Condenser and Cooling	Condenser tubes, cooling-water piping, cooling-tower fill
Auxiliary	Mills, pulverisers, ID and FD fans, air pre-heaters, economiser tubes, ESPs
HRSG (CCGT)	Multi-pressure (HP/IP/LP) headers, finned-tube banks, drum, evaporator

The damage-mechanism vocabulary distinguishes water-touched and steam-touched failures, aligned to the ASM Handbook Vol. 11A chapter authored by Paresh Haribhakti and P.B. Joshi (2021).

11b.3 Damage Mechanisms We Investigate

Category	Mechanisms
Water-touched	Hydrogen damage (acid phosphate corrosion driver); acid phosphate corrosion; caustic gouging; under-deposit corrosion; pitting and oxygen pitting; corrosion fatigue; flow-accelerated corrosion (FAC)
Steam-touched	Long-term overheat creep; short-term overheat; fireside corrosion (coal-ash, oil-ash); fireside erosion; thermal fatigue; SCC; dissimilar-metal weld failure; dissimilar-metal HAZ creep
Boiler drum and headers	Ligament cracking; corrosion fatigue; thermal-shock cracking; SCC at downcomer attachment
Steam Turbine	Creep on HP / IP rotors and diaphragms; LP-blade SCC and corrosion fatigue; bearing white-metal damage
Condenser	Stress corrosion cracking on copper alloy tubes; ammonia corrosion; flow-induced erosion
Common	Boiler tube leak (BTL), metallurgical degradation, creep, erosion, pitting, general corrosion, HTHA per `API 941`, fatigue

11b.4 Standards Coverage Matrix

Damage and Failure Analysis. API RP 571; ASM Handbook Vol. 11A chapter on Failure of Boilers and Related Equipment by Haribhakti and Joshi (2021).

Indian Boiler Regulations. IBR 1950 with amendments; Form III material certification (TCR Engineering recognition since 2014); Central Boiler Board Well-Known RLA Organisation framework.

Mechanical and Material. ASTM A335 P5 / P9 / P11 / P22 / P91 (chrome-moly creep-strength-enhanced ferritic); ASTM A213 T11 / T22 / T91 (ferritic and austenitic boiler and superheater tubes); ASTM A234 WP91; ASTM A691 (high-pressure piping); ASTM A387 (chromium-molybdenum alloy steel plates); ASTM A516 (carbon steel pressure-vessel plates).

Field Inspection. API 510 / 570 / 653 (cross-pillar, where pressure-vessel and tank scope is in play); API RP 510 / 570 / 653 / RP 572 / 574 / 575; ASME PCC-2; ASME B31.1 (power piping).

ASME Boiler and Pressure Vessel Code. ASME Section I (power boilers, 2023 ed.); ASME Section II Parts A-D (materials); ASME Section IX (welding qualifications, 2023 ed.); ASME Section XI (in-service inspection of nuclear components, 2023 ed.) for nuclear scope.

11b.5 Service Applications Across the TCR Continuum

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

A power station's integrity questions are dominated by the boiler. Boiler tube leakage remains the single largest cause of forced outage in Indian thermal stations, and TCR has investigated 1,500+ boiler tube failures, the deepest such record in the country. Around the boiler sit creep in superheater and reheater headers and main steam piping in Grade 22 and Grade 91 steels, thermal fatigue driven by two-shifting and flexibilisation against renewable load, dissimilar metal weld failures, fireside corrosion and fly ash erosion, and waterside chemistry damage. During overhaul and statutory shutdown the pressure is the Indian Boiler Regulations 1950 inspection calendar and the fixed outage window; in procurement it is tube, casting, and spare quality from an increasingly stretched vendor base. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) for utility, captive, and co-generation plants.

Stage One, Sourcing and Procurement. Boiler tube, plate, casting, and forging procurement is qualified through mechanical, chemical, and metallurgical testing in the NABL accredited laboratory under certificate NABLT0726MH18640, including creep and stress rupture testing to Bharat Heavy Electricals specifications, impact and hardness per ASTM A370, and spectrometric verification of alloy grade. TCR runs vendor factory audits, sample picking, in-production checks, and loading supervision for tubes, headers, valves, and structural steel, so that a replacement pressure part enters the station with the same evidence discipline as the original build.

Stage Two, Construction and Commissioning. For new units, retrofits, and pressure part replacement, TCR provides baseline non-destructive testing on membrane walls, headers, and steam piping, phased array ultrasonic testing and time of flight diffraction on thick sections, radiography, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX and Indian Boiler Regulations, post-weld heat treatment with hardness verification, and positive material identification on alloy joints, delivering the baseline thickness and weld data set for the life of the unit.

Stage Three, In-Service. On-load, TCR deploys thermography of boiler casings, ducting, and electrical systems, oxide scale thickness measurement on superheater tubes including the Chugai Technos scale checker capability (Section 7.9), remote visual inspection, and corrosion mapping on flue gas path equipment. TCR Advanced builds risk-based inspection programmes per API RP 580 and API RP 581 for the balance of plant and sets condition-monitoring intervals so that creep-critical components in Grade 91 are tracked rather than assumed.

Stage Four, Shutdown and Turnaround. In the overhaul window, TCR delivers boiler condition assessment across the six-pillar capability stack (Section 6.4.2), tube thickness surveys, heat exchanger and condenser tube inspection, in-situ metallographic replication on headers, main steam lines, and turbine components by the twelve dedicated field teams, boiler tube sampling and residual life testing, tank and structural inspection, and turnaround inspection manpower, all sequenced to the outage plan so the inspection scope closes inside the window.

Stage Five, Continuum. Findings convert into remaining life assessment of boilers and turbines per the two-level framework in Section 6.4, accelerated creep rupture testing and the Omega method per ASTM E139 and API 579-1/ASME FFS-1 Part 10, fitness for service on drums, headers, and piping, failure analysis of tube, blade, and rotor components, flexibilisation and cycling damage studies, and plant life extension engineering, including the idle-plant restart assessments that let a mothballed unit return to the grid on evidence rather than hope.

11b.6 Named Clients

The Power vertical client roster spans central and state utilities, independent power producers, captive generation, equipment manufacturers, and GCC utilities. Utility and independent power producer clients include NTPC across multiple stations, Adani Power at Mundra, Tiroda, Kawai, Udupi, Singrauli, Raipur, Godda, and Korba, Tata Power at Trombay, Mundra, and Jojobera, Reliance Power at the Sasan ultra mega power project, Vedanta, Vidarbha Power at Butibori (2 x 300 MW remaining life assessment), Torrent Power at Ahmedabad (2 x 120 MW remaining life assessment), MAHAGENCO, Coastal Gujarat Power Limited at Mundra, JSW Energy, NLC India, and SJVN at Buxar. Captive and co-generation work runs across Tata Steel, JSW Steel, and refinery and chemical plant captive boilers, alongside sugar industry boilers. On the equipment side, TCR serves Bharat Heavy Electricals Limited, including BHEL-specification creep rupture testing, GE, Siemens, and Larsen and Toubro boiler fabrication. In the GCC, the power record includes the Ministry of Electricity and Water in Kuwait and the Saudi Electricity Company.

11b.7 Marquee Projects

Project	Service Anchor	Year
Adani Power Mundra 4,620 MW (U#5 660 MW + U#1 and U#3 330 MW)	RLA of Boiler and Piping per IBR Regulation 391A during shutdown; SO 5700366721 dated 08.03.2025. Mandatory vendor capability bundle: IBR-approved RLA authority certificate plus ACRT facility with SEM machine and minimum 2 site teams.	March 2025
Adani Power Tiroda 5 × 660 MW	RLA of Boiler and Critical Piping for Unit 1, 3 and 4 plus RLA of Turbine Generator.	June 2025 onward
Vedanta Athena 600 MW Chhattisgarh Thermal Power Plant via NTPC GE Power Services (NGSL)	Expert services visit for Boiler Inspection at Vedanta Limited CTPP, Athena Power Plant, Singhitarai Sakti, Chhattisgarh; LOI/NTPCGE/TCR/VAL/25-26/01 dated 18.04.2026.	April 2026 onward

Project	Service Anchor	Year
UltraTech Cement (Aditya Birla Group) Boiler Operation and Maintenance Training	Training session on "Best Operation and Maintenance Practices to minimise Tube Leakages in Boiler" at the Evolve by TCR Training and Development Institute Vadodara; Boiler Metallurgy, Advanced NDT for Boiler Inspection, RLA, Water chemistry, practical demonstration of tube failure analysis at the TCR laboratory.	26 to 27 May 2025
NTPC Talcher TTPP-III 2 x 660 MW	RT and NDT scope through BHEL approval refresh, via Power Mech Projects	December 2025 onward
PowerMech Projects: ARC for FI of failed boiler tubes at Vedanta Aluminium Jharsuguda 4 x 600 MW IPP	PO 6000026397, failure investigation rate contract	
PowerMech: FI of failed boiler tubes at CEPL Mutiara Thermal Tuticorin 2 x 600 MW	PO 6000029022	
PowerMech: Boroscopic inspection at PPGCL Bara U-03 660 MW	PO 6000024777	
PowerMech: In-situ metallography for LTSH and de-superheater joints at Bina Chachai Unit 2	PO 6000014939	
PowerMech: Demagnetisation of generator rotor at JPL Tamnar-Raigarh U-01 Stage-2 4 x 600 MW	PO 6000030760	
Petrokemya, KSA	RLA of fire-steam-tube boiler	2023

Indian Power (TCR Engineering plus TCR Advanced): NTPC, BHEL, Tata Power, Adani Power, Torrent Power, Reliance Power, Essar Power, CGPL Mundra, Vidarbha Power, JSW Energy, Sembcorp.

Captive and Co-Generation. Tata Steel Jamshedpur (captive 405 MW), JSW Steel (captive across multiple sites), Vedanta Aluminium Jharsuguda 4 x 600 MW IPP, JSPL Tamnar Stage-2 4 x 600 MW.

Equipment OEMs. BHEL (approved since 2003; refresh via NTPC Talcher TTPP-III December 2025), GE Power, Mitsubishi, Siemens, Doosan, Power Mech Projects (the five-PO engagement record).

The India power client base spans utility generators, boiler and balance-of-plant contractors, and equipment OEMs: NTPC, Bharat Heavy Electricals (BHEL), GE Power India, Toshiba JSW Power Systems, Power Mech Projects, Maithon Power, CG Power and Industrial Solutions, and Simhapuri Energy. The work runs to boiler and pressure-part remaining-life assessment, weld and NDT inspection, and materials testing across thermal and balance-of-plant scope.

GCC Power. Saudi Electricity Company (5002205 / 62006), MARAFIQ (3645), ACWA, NOMAC, Arabian Bemco. Petrokemya KSA (RLA of fire-steam-tube boiler 2023).

The five-decade Power vertical history runs through 400+ Boiler RLA, 1,500+ BTF investigations, and a published-author bench at ASM International (the 2018 Failure Investigation of Boiler Tubes book and the 2021 ASM Handbook Vol. 11A chapter, both reaching integrity-engineering benches in 140+ countries).

Recent boiler remaining-life assessments show the turnaround speed at scale. Adani Power Mundra, a 660 MW supercritical unit at 590 degrees Celsius and 281.3 bar, was completed in 25 days. Vidarbha Power Butibori, two 300 MW units at 552 degrees Celsius and 201.8 bar, ran 36 days. Torrent Power Ahmedabad, two 120 MW units at 540 degrees Celsius and 158 bar, ran 32 days. Tata Power Trombay, two 500 MW subcritical units at 541 degrees Celsius and 177 bar, ran 14 days. At Tata Power Jojobera, a 67.5 MW unit, a Knowledge-Based Audit supported a 12-year life extension.

INDUSTRIES · SECTION 11C

Fertilisers

SECTION 11C

11c. Fertilisers

Nearly every major Indian ammonia-urea producer, **IFFCO, RCF, NFL, GNFC, GSFC, KRIBHCO, FACT, Chambal and Paradeep Phosphates**, plus **QAFCO Qatar**, the world's largest single-site fertiliser complex, runs on TCR's integrity bench. The QAFCO relationship is now into its second decade.

POTENTIAL FAILURES WE SERVICE

Failures in the reformer section (radiant and catalyst tubes, pigtails, manifolds), ammonia converter, ISR, RGC and urea synthesis loop; ammonia storage-tank integrity. TCR investigates creep, carburisation, nitriding, metal dusting, erosion-corrosion, cavitation, intergranular corrosion and carbamate corrosion, and runs ARTiS reformer-tube inspection with built-in Fitness-for-Service.

From the primary reformer to the ammonia converter to the urea synthesis loop, TCR has held the metallurgical bench at QAFCO since 2011 and serves nearly every major Indian ammonia-urea producer.

MARQUEE PROJECT

QAFCO Qatar: a **15-year metallurgical rate contract** across multiple ammonia and urea trains, a relationship running since 2011.

11c.1 Industry Context

Urea is a policy commodity, and plant reliability is a disclosed financial variable. India produced a record 314 lakh MT of urea in FY24, six new plants added 76.2 lakh MT of capacity, and the FY26 budget carries about Rs 1.56 lakh crore of fertiliser support. Rating agencies track each producer's urea-train maintenance shutdowns plant by plant, and investor calls quantify energy-efficiency gains of even three percent, because a reformer outage moves earnings directly. Reformer tube life is therefore not a technical detail but a balance-sheet question. TCR answers it with ARTiS, the group's own reformer tube inspection system with built-in Level 3 FFS, more than 100 assignments, and a named reference list across the Indian, Gulf, African, and Southeast Asian fertiliser fleet.

The Indian fertiliser landscape carries a fleet of more than 30 large-scale ammonia-urea complexes, an aging asset base on the public-sector side (RCF, NFL, GNFC, GSFC, FACT, KRIBHCO, IFFCO), modern revival capacity through the HURL trio (Sindri, Gorakhpur, Barauni) and Talcher and Ramagundam (Gorakhpur and Barauni already in commercial operation; Talcher commissioning sequence underway), and private-sector capacity at CFCL (Chambal), DFPCL (Deepak), and Matix. Fertiliser plant downtime translates directly into national agricultural-input shortages, which keeps the integrity-engineering bench in continuous demand.

The GCC fertiliser ecosystem (QAFCO Qatar across multi-train complex; SAFCO and Maaden Phosphate KSA; OMIFCO and Salalah Methanol Oman; PIC Kuwait) is a TCR Arabia and TCR Advanced anchor pool. The North African and West African corridor (OCP Morocco, Indorama Eleme Nigeria, Notore Chemical Industries Plc Nigeria, Dangote Nigeria) is a TCR Advanced ARTiS-led footprint.

Five trends shape the workload: green-ammonia capacity coming online (electrolyser-fed ammonia synthesis loops, currently ~12 announced projects in India alone); ammonia as a marine fuel under IMO 2030+ pathways; aging Indian plant asset base driving RLA, KBA, FFS at scale; ammonia storage-tank integrity (the LBB study capability and the 10-tank track record); and catalyst improvement cycles (driving in-situ metallography and reformer-tube assessment cadence).

The fertiliser vertical fluency runs deep: trains, RGC, ISR, hairpin, pigtail, manifold, tail tube, KO drum, carbamate condenser, HP decomposer, plunger pumps, granulator, prilling tower, AdBlue, UFC-85, CAN, ANP, HDS, ZnO absorber, ammonia converter, NH3 synthesis converter, ammonia separator, ammonia accumulator, let-down drum.

Green ammonia (electrolyser-fed) brings API 941 HTHA discipline expansion into front-end synthesis sections that will run on H2 from PEM and alkaline electrolysers; the corrosion testing bench (Section 4.7) and the ARTiS reformer programme transfer cleanly. Blue ammonia (ammonia plus CCUS) introduces amine-system corrosion qualification at scale. Ammonia as marine fuel brings refrigerated-ammonia tank-integrity scope (the 18,000 MT LBB study capability) into the bunkering and marine-fuel storage segment. Ammonia for power co-firing brings combustion-side material qualification in cross-vertical work with Power. CCUS at fertiliser plants is an integrated capex offering across Pillars 1, 3, and 6.

India's National Green Hydrogen Mission target of 5 MMTPA green-H2 by 2030 implies green-ammonia capacity additions across the 12+ announced projects. The FFS, RLA, and KBA bench is positioned to take that capex into existing operating plant integrity-extension work.

TCR is the multi-disciplinary integrity partner for the multi-decade fertiliser fleet, with QAFCO 15-year rate contract evidence, ten-tank ammonia storage RBI track record, the Chambal GP-I AiOM RBI commercial reference, the published authority bench at ASM International, and the deep consultant bench.

11c.2 Plant Sections We Inspect

Cluster	Equipment

Cluster	Equipment
Ammonia Plant (Front End)	Desulphuriser (HDS, ZnO absorber); Primary Reformer (radiant tubes, cat tubes, headers, pigtails, manifolds); Secondary Reformer; Process Gas Boiler (Waste Heat Boiler / WHRB); HT Shift converter; LT Shift converter; CO2 Removal (Benfield, MDEA, aMDEA); Methanator
Ammonia Synthesis Loop	Synthesis gas compressor; ammonia converter (radial-flow basket internals); ammonia separator; ammonia accumulator; let-down drum; refrigeration system
Urea Plant	Reactor (Casale, Snamprogetti, Stamicarbon, Toyo licensor variants); Stripper; HP decomposer; LP decomposer; Carbamate condenser; HP scrubber; Ammonia preheater; Plunger pumps; Granulator; Prilling tower; UFC-85 unit
Phosphoric Acid Plant	Wet-process phosphoric acid (DH or HH process); Reactor; Filter; Evaporator (vacuum); Sulphuric acid plant supporting feedstock; SO2 / SO3 converter
NPK / DAP	Pre-neutraliser; Granulator; Dryer; Cooler; Coating drum; Bagging
Ammonia Storage	Atmospheric (refrigerated) at minus 33 °C; pressurised (semi-refrigerated); double-wall double-integrity with secondary containment
Utilities	Steam generation (waste-heat plus auxiliary boiler), cooling-water systems, instrument air, demineralised water, nitrogen, fuel gas

11c.3 Damage Mechanisms We Investigate

Equipment	Mechanisms
Primary Reformer (highest-risk)	Creep on radiant tubes (HK40, HP-Mod, HP-Nb, microalloyed; creep grades A-E per Anderson Penny method); diametric growth; carburisation; nitriding; metal dusting; cyclic thermal fatigue; pigtail and manifold creep and weld cracking; outlet header decarburisation
Secondary Reformer / WHRB	Carburisation, oxidation, creep, refractory degradation, leaking ferrules, ferritic-to-austenitic dissimilar-metal weld failure, corrosion under deposit
Ammonia Synthesis	Hydrogen attack per `API 941` (HTHA on lower-temperature converter shells); nitriding on inner basket; creep on basket internals
Urea Reactor and Stripper	Active passivation breakdown (oxygen injection control); pitting; SCC on 316L UG variants; corrosion of stainless cladding; carbamate corrosion; mechanical erosion at stripper distributor; bimetallic crack at carbon steel-stainless interface
Ammonia Storage Tanks	Stress corrosion cracking on carbon steel under wet-ammonia conditions (the LBB and FFS-driven workload); hydrogen-induced cracking; coating breakdown; settlement-induced shell distortion; refrigeration cycle thermal fatigue
Process Gas Boiler / WHRB	Creep, fireside corrosion, water-side scale buildup, tube-to-tubesheet weld cracking

Equipment	Mechanisms
CO2 Removal	Amine SCC on lean-amine piping (300-series stainless), carbon steel corrosion under amine, foaming-induced erosion
Phosphoric Acid Plant	Wet-acid corrosion (carbon steel, stainless 904L, alloy 28, alloy C-276), erosion-corrosion at agitator and pump suction
NPK / DAP	Acid-vapour corrosion on granulator scrubber, ammonia leak corrosion

11c.4 Standards Coverage Matrix

Damage and Failure Analysis. API RP 571; ASM Handbook Vol. 11A; Casale, Snamprogetti, Stamicarbon, Toyo licensor inspection guidance.

Inspection and Integrity. API 510, 570, 653; API RP 572, 574, 575; API 941 HTHA; API 530 (fired-heater tube design and inspection); API 936 (refractory); ASME PCC-2.

RBI / KBA. API 580 / 581 4th ed. (January 2025); API RP 584 IOW 2nd ed. (December 2021). EFMA (European Fertiliser Manufacturers Association) Guidance for Inspection of Atmospheric Refrigerated Ammonia Storage Tanks (the Paradeep Phosphates anchor for in-service RBI extending the 2nd internal inspection interval from 20 to 25 years).

Reformer Tube Inspection. API 530 Annex E (creep-life calculation); ASTM A608 (centrifugally cast); ASTM A351 / A608 (carburised reformer tubes); API 941; the ARTiS scan-and-FFS workflow per API 579-1 Part 10.

Material Specifications. ASTM A608 HP-Mod Nb, HK40, HK45 (centrifugally cast reformer tubes); ASTM A335 / A213 (chrome-moly piping and tubes); ASTM A516 / A537 / A537 Class 1 (refrigerated ammonia tank shells, the 18,000 MT case); IS 226 (outer shell on the 18,000 MT case).

Welding. ASME Section IX 2023; API 1104; API 582; AWS D1.1.

Renewable / Green Ammonia (Emerging). API 941 in expanded H2 service; ASTM B898 (titanium); ISO 19840 (offshore-grade coatings on green-ammonia plant equipment).

11c.5 Service Applications Across the TCR Continuum

In an ammonia-urea complex the integrity agenda concentrates on the reformer. Primary reformer tubes in HP-modified and micro-alloyed centrifugally cast grades run at the edge of their creep limit, where a 10 to 20 degree Celsius overshoot in tube metal temperature cuts life substantially; around them sit carburisation, nitriding of the ammonia converter, intergranular corrosion of austenitic internals, erosion-corrosion in the urea synthesis loop, and stress corrosion in refrigerated ammonia storage. During shutdown and turnaround, reformer tube inspection is the critical path activity, and every day of the window is priced in lost urea production. In procurement, the risk is the quality of catalyst tube castings, welded pigtails and manifolds, and high pressure exchanger components. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2), with the deepest reformer-tube practice in India.

Stage One, Sourcing and Procurement. TCR qualifies reformer tube castings, pigtail material, and high pressure equipment through chemical analysis, mechanical testing, and microstructural evaluation of procurement samples, runs factory audits and original equipment manufacturer qualification at casting foundries and fabricators, and supervises raw material inspection and loading. Weld consumables for dissimilar and high-alloy joints, including Incoloy 800H and Alloy 617 class materials, are evaluated before they reach the site.

Stage Two, Construction and Commissioning. During plant construction, revamp, and reformer re-tubing, TCR provides baseline non-destructive testing, radiography and phased array ultrasonic testing on manifold and pigtail welds, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX, post-weld heat treatment, positive material identification across the alloy population, and the baseline diameter, thickness, and attenuation data set for the new tube fleet, so that later creep-strain readings have a true zero.

Stage Three, In-Service. On-stream, TCR supports operating discipline on the reformer: pyrometry correlation and thermography for tube skin temperature and hotspot detection, pressure-differential trending as an indicator of catalyst degradation, remote visual inspection, and integrity operating windows per API RP 584 on the reformer, converter, and synthesis loop. TCR Advanced builds risk-based inspection plans per API RP 580 and API RP 581 across the complex, with damage-mechanism mapping specific to reforming, shift, and synthesis service.

Stage Four, Shutdown and Turnaround. In the turnaround, ARTiS (Section 7.1) delivers the full reformer scan, ultrasonic attenuation, diameter at 0.1 metre intervals, and bowing on every tube, supported by in-situ metallographic replication and hardness at selected elevations, manual thickness, diameter, and magnetic permeability at platform level, and inspection of pigtails, manifolds, waste heat boiler and reformed gas cooler tubes, high pressure exchangers, and refrigerated ammonia tanks. Turnaround inspection manpower is deployed to hold the critical path.

Stage Five, Continuum. The reformer data feeds a Level 3 fitness for service assessment per API 579-1/ASME FFS-1 with accumulated creep damage per tube, effective tube metal temperature, the retirement date at the 0.8 life fraction, and remaining life tube by tube, the 'when to retire tubes' answer that plans the re-tubing budget. Alongside sit failure analysis of tube, converter, and exchanger components, remaining life assessment of refrigerated ammonia storage, fire damage assessment, and contract research on green and blue ammonia materials questions that feeds the next investment cycle.

11c.6 Named Clients

India (TCR Engineering plus TCR Advanced). IFFCO (Kalol, Kandla, Paradeep, Aonla, Phulpur), KRIBHCO Hazira, GNFC Bharuch (TDI-II reformer tube RLA anchor), GSFC Vadodara, NFL (Nangal, Bathinda, Panipat, Vijaipur), RCFL Trombay (2 double-wall double-integrity ammonia tanks), DCM Shriram, HURL (Sindri, Gorakhpur, Barauni), Deepak Fertilisers and Petrochemicals Corporation (DFPCL Taloja), CFCL Chambal Fertilisers Kota (the December 2025 GP-I AiOM RBI anchor), Coromandel International, FACT, Paradeep Phosphates (3 ammonia tanks), Madras Fertilizers, SPIC, Nagarjuna Fertilizers (idle-plant restart anchor), Matix Fertilizers (idle-plant restart anchor), Heavy Water Projects.

GCC. QAFCO Qatar (15-year metallurgical rate contract, 8-year RLA partnership), SAFCO KSA (Saudi Arabian Fertilizer Company), Maaden Phosphate KSA, OMIFCO Oman (Vendor Evaluation 97/100 Grade Excellent), Salalah Methanol Oman, PIC Kuwait (NBTC RLA of 120 critical equipment in ammonia and urea plant 2024).

International. Indorama Eleme Petrochemicals Nigeria (long-term rate contract; cross-vertical with Refining), Notore Chemical Nigeria (idle-plant restart engagement), Dangote Fertilizers Nigeria (ARTiS plus tail-tube reformer life extension 2023), JIFCO Jordan (RFET and videoscopy of WHRB tubes 2025), Algerian Oman Fertilizer (consultant bench reference Ashok Kumar Srivastava).

Equipment OEMs and Process Licensors. Casale SA (Switzerland) SX3000 Vendor Code 1000007973 June 2025 (urea and melamine licensor); Snamprogetti, Stamicarbon, Toyo (urea licensor stack); Haldor Topsoe (catalyst), Johnson Matthey, Clariant (catalyst); KBR, ThyssenKrupp Industrial Solutions, MAIRE Tecnimont (ammonia licensor stack).

In fertilisers, the AiOM asset-integrity platform is referenced at Chambal Fertilisers, where the G-1 deployment covers 51 items of equipment, and the idle-plant restart practice has returned mothballed fertiliser assets to service at Matix Fertilizers and Nagarjuna Fertilizers. The broader India fertiliser client base includes Rashtriya Chemicals and Fertilizers, Hindustan Urvarak and Rasayan, KRIBHCO, and Ramagundam Fertilizers.

11c.7 Marquee Projects

Project	Service Anchor	Year
Chambal Fertilisers G-1 plant, Ammonia-I Plant Areas 02 and 05	RBI per `API 580/581` plus AiOM® software implementation for 51 equipment (pressure vessels, towers, heat exchangers, connecting piping)	December 2025
QAFCO Qatar	15-year metallurgical rate contract across multiple ammonia and urea trains; Trains 5 and 6 at 2,200 MTPD ammonia plus 3,800 MTPD urea plus 3,850 MTPD granulation each plus UFC-85 unit at 85 MTPD	2011 to date
QAFCO Qatar	8-year RLA partnership	Continuous
QAFCO Training engagement	Scorecard 92.88/100 Grade A	Multiple

Project	Service Anchor	Year
Dangote Fertilizers, Nigeria	ARTiS plus tail-tube inspection for reformer life extension	2023
Emirates Steel Industries, Abu Dhabi	ARTiS reformer tube inspection, DRP1 and DRP2 (cross-vertical with Steel)	2025
JIFCO, Jordan	RFET and videoscopy of WHRB tubes	2025
PIC, Kuwait (NBTC delivery)	RLA of 120 critical equipment in ammonia and urea plant	2024
Indorama Eleme Petrochemicals, Nigeria	Long-term rate contract for metallurgical and inspection services	Continuous
18,000 MT Refrigerated Liquid Ammonia Tank	`API 620` Appendix R, A-537 Class 1 / `IS 226`, LBB fracture mechanics study	Multiple
Ammonia Tank RBI: CFCL Kota, DFPCL Taloja, Paradeep Phosphates (3 tanks), IFFCO Kandla, IFFCO Kalol (2 tanks), RCF Trombay (2 DWDI)	RBI per `API 580/581`, FFS-supported decisions	Multiple
Paradeep Phosphates Limited (Adventz Group), 3 ammonia storage tanks 10,000 MT each	In-service RBI per EFMA / `API 580` guidelines with EFMA risk matrix; 5-year extension of 2nd internal inspection	July 2025 onward
GNFC TDI-II reformer	RLA on reformer tubes	Multiple
OMIFCO, Oman	Vendor Evaluation 97/100 Grade Excellent	Multiple
Notore Chemical, Nigeria	Idle-plant restart engagement	Multiple
Baiji Refinery, Iraq (cross-vertical with Refining)	Idle-plant restart engagement	Multiple
Godrej Industries / Matix Fertilizers / Nagarjuna Fertilizers / Heavy Water Projects	Idle-plant restart engagements	Multiple

Dangote Fertilizers in Nigeria took ARTiS reformer-tube inspection with tail-tube assessment for reformer life extension in 2023. QAFCO in Qatar runs a 15-year metallurgical rate contract across multiple ammonia and urea trains. At Chambal Fertilisers, the AiOM platform underpins risk-based inspection across 51 items of equipment, and the idle-plant restart practice has returned mothballed assets at Matix and Nagarjuna to service.

INDUSTRIES · SECTION 11D

Pipelines and City Gas Distribution

SECTION 11D

11d. Pipelines and City Gas Distribution

Most of India's cross-country pipeline EPC majors, **Larsen & Toubro, Kalpataru, Likhitha, Corrtech and Engineers India**, route weld-integrity and ECA scope through TCR: **14,000-plus girth welds radiographed across 2,600-plus km**, and a Saudi Aramco-approved Internal RT Crawler, with **$4.98 million documented cost avoidance**.

POTENTIAL FAILURES WE SERVICE

Leaks, ruptures and third-party damage on cross-country mainlines, CGD networks and station equipment. TCR investigates external and internal corrosion, microbiologically-induced corrosion, AC-interference and stray-current corrosion, high- and near-neutral-pH stress corrosion cracking, sulphide stress cracking, hydrogen-induced cracking, dent-and-gouge, girth-weld defects and pressure-cycling fatigue, and closes the loop with in-line-inspection ingestion, cathodic-protection surveys and Engineering Critical Analysis.

14,000-plus girth welds across 2,600-plus kilometres of mainline, a Saudi Aramco-approved Internal RT Crawler, and a three-tier model running from construction radiography through operator condition assessment to engineering analysis.

MARQUEE PROJECT

Saudi Aramco named TCR technology provider for the Internal RT Crawler, with **$4.98 million in documented cost avoidance** over five years (SAER-13115).

11d.1 Industry Context

India's gas grid is in a sustained build-and-operate cycle. GAIL spent Rs 10,512 crore of capex in FY25 with about a quarter of it on pipelines, has around Rs 42,200 crore planned for FY26 to FY29, moved 127 mmscmd of transmission volume, and holds roughly 47 percent of the domestic gas market. Every kilometre laid needs qualified weld inspection to build, and every kilometre operating needs integrity management under PNGRB rules to keep its licence to run. TCR's three-tier pipeline architecture is built against exactly that lifecycle: Tier 1 project NDT with owned internal RT crawlers, Tier 2 operator condition assessment, and Tier 3 engineering analysis including ECA and fitness for service.

India's cross-country oil and gas pipeline network is in active expansion under the National Gas Grid programme, with the IndianOil-anchored LPG, refined products, and crude pipelines, the GAIL gas grid (NGPL, MNJPL, Urja Ganga, KGPL), and the city gas distribution rollout under the PNGRB CGD bidding rounds. The CGD network has expanded to 305+ Geographical Areas covering 88 percent of India's population and 98 percent of its area. The ageing legacy pipelines (some now beyond 40 years of operating life) drive in-line inspection campaigns, ECA on girth welds, and life-extension engineering.

The GCC orbit covers Saudi Aramco (Master Gas System packages, Jafurah Gas Compression, multiple cross-country oil trunklines), PDO Oman, OQGN, Adani-Total Dhamra LNG, and the cross-border Nepal route (Motihari to Amlekhgunj International Pipeline). The Indian and GCC operating environment is the centre of gravity for the pipeline vertical.

Hydrogen pipelines (cross-vertical with Refining and Fertilisers) bring API 941 HTHA discipline and the ASTM F519 / API 20E hydrogen embrittlement bench into pipeline operator-side scope. CO2 transmission pipelines for CCUS (under-deposit corrosion at low temperatures, supercritical CO2 phase behaviour, dense-phase brittle fracture at low temperatures) are an emerging service surface. Re-purposed natural-gas pipelines for hydrogen transmission carry their own qualification campaign on existing material grades (the ASME PCC-2 framework on weld repair is applicable). LNG terminal and bunkering tie-in pipework brings refrigerated material qualification (cross-vertical with Marine and Offshore).

The cross-border permission framework (Nepal MAPL anchor) signals the company's capacity to take cross-border energy-pipeline integrity work into Bangladesh, Bhutan, and Sri Lanka as those corridors expand.

SECTION 11E

11d.2 Plant Sections We Inspect

Cluster	Equipment
Mainline	Cross-country trunkline (8 inch to 42+ inch, `API 5L` X42 through X70 line pipe), HDD river crossings, marine landfall, mountain crossings
Compressor and Pumping Stations	Gas compressor (recip and centrifugal), pump skids, scraper launch and receive barrels, slug catcher, surge vessel, cooler, suction and discharge piping
Metering and Pressure Reduction	Custody transfer station, pressure reduction skids, filter separator, knock-out drum
City Gas Distribution	MDPE distribution mains, service tee, PE-to-steel transition fitting, district pressure reduction stations, customer regulator and meter set
Cathodic Protection	Sacrificial anode beds, impressed-current TR units, anode beds, test posts, casing and carrier pipe, foreign-line crossings
Coating Surveys	CIPS, DCVG, Pearson, CAT, conductance
LNG Terminal and Re-gas	LNG storage tank (full-containment, double-wall double-integrity), boil-off-gas compressor, re-gas exchanger, send-out compressor, jetty piping

Cluster	Equipment
Underground Storage and Caverns	Salt cavern and depleted-reservoir gas storage tie-in pipework

11d.3 Damage Mechanisms We Investigate

Category	Mechanisms
External corrosion	Coating breakdown, soil-side general corrosion, microbiologically-induced corrosion (MIC), AC interference, stray-current corrosion, casing-and-carrier corrosion
Internal corrosion	Sweet (CO2) corrosion, sour (H2S) corrosion, top-of-line corrosion, under-deposit corrosion, MIC
Cracking	Stress corrosion cracking (high-pH and near-neutral-pH), sulphide stress cracking, hydrogen-induced cracking
Mechanical	Third-party damage (dent, gouge, dent-and-gouge), construction defect (lack of fusion, lack of penetration on girth welds), fatigue (cyclic pressure, traffic-induced)
Geohazard	Settlement, landslide, subsidence, river-crossing scour, frost heave
Operational	Slug damage, pigging-induced fatigue, hydrate-induced cooling, joule-thomson cooling at let-down

11d.4 Standards Coverage Matrix

Line Pipe and Construction. API 5L 46th Edition (line pipe); ASME B31.4 (liquid pipeline transportation); ASME B31.8 / B31.8S (gas pipeline transportation, supplement on managing system integrity); API 1104 22nd ed. (2021) Annex A (ECA on girth welds, Method 1 and Method 2 FAD); API 1102 (railroad and highway crossings); SAEP-1143 (Saudi Aramco RT engineering procedure).

Integrity Management. API 1160 (managing system integrity for hazardous liquid pipelines); ASME B31.8S (gas pipeline integrity management system); API RP 580 / 581 (where RBI is delivered as KBA on station equipment); API RP 584 IOW.

ECA / FFS. API 579-1/ASME FFS-1 4th ed. (2021); BS 7910; API 1104 Annex A; ASME Section VIII; ASTM E1820 (CTOD).

Cathodic Protection. NACE SP0169 (control of external corrosion on underground metallic piping); NACE SP0102 (in-line inspection); NACE SP0204 (SCC direct assessment); NACE SP0206 (internal corrosion direct assessment); ISO 15589 series; DNV-RP-F101 (corroded pipelines).

ECDA / ICDA / SCCDA. NACE SP0502 (ECDA); NACE SP0206 (ICDA); NACE SP0204 (SCCDA).

Materials in Sour Service. NACE MR0175 / ISO 15156; NACE TM0177 (SSC); NACE TM0284 (HIC).

ILI Methods. Magnetic Flux Leakage (the primary ingestion in AiOM-CCP); Ultrasonic Crack Detection; EMAT-ILI; Inertial Measurement Unit geometry; Caliper.

Coating. AMPP/NACE coating-inspector framework; SSPC-VIS 1; ISO 8501-1; NACE SP0188 (holiday detection); ISO 12944 (corrosion protection by coating systems).

11d.5 The Three-Tier Pipeline Service Model

The pipeline vertical is structured under the Rule 4 three-tier service architecture.

11d.5.1 Tier 1, Project NDT

Construction-stage radiography on cross-country mainline girth welds and HDD river crossings. Conventional film RT plus the Saudi Aramco-approved Internal RT Crawler family (16-52 inch, 160/200/300 kV at 5 mA, ±5 mm positioning accuracy). Computed Radiography with Carestream and 3ENDT digital plate readers. PAUT and TOFD on critical welds. Ultrasonic crack detection on heavy-wall pipe. 14,000+ pipeline girth welds radiographed across 2600+ kilometres of cross-country mainline; 9,266 weld joints digitally scanned and cloud-archived on a single project (EnProCon TJTC Kolar).

11d.5.2 Tier 2, Operator Condition Assessment

In-line inspection ingestion (MFL primary), CIPS, DCVG, Pearson, CAT, conductance, casing-and-carrier short, pipe-to-soil potential against the negative 0.85 V to negative 1.20 V band against Cu/CuSO4. Cathodic protection design and turnkey installation under the Chiral Patel CP Division (practice run out of Vadodara with a regional office in Bhubaneswar; services offered pan-India). 5-year frequency framework on coating surveys. The AiOM-CCP digital backbone consolidates ILI runs, CP records, and coating-survey output into a single integrity dashboard.

11d.5.3 Tier 3, Engineering Analysis

ECA per API 1104 Annex A on pipeline girth welds (8-step workflow: component identification, loadings, material properties, NDT inspection of coupon, destructive tests on coupon with CTOD at 12, 6, 3/9 o'clock, fracture mechanics calculations per Method 2 FAD, FEA for axial stresses on actual line layout, flaw table for acceptable size). FFS per API 579 on dents, gouges, metal-loss, and crack-like flaws. RLA for legacy pipelines. QRA workflow at design stage with fatality frequency curve and once-in-5-years through design lifespan. AiOM-CCP anonymised undersea pipeline case study (API 5L X46N, 21 km × 355 mm × 15.9 mm, ID-side CO_2/H_2S corrosion).

Flow-capacity and remaining-life assessment by C-Value (Hazen-Williams) analysis, used to quantify internal roughness and effective diameter loss on operating liquid pipelines.

11d.6 Service Applications Across the TCR Continuum

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

The three-tier pipeline service model above maps directly onto the five-stage Trusted Relationship Model (Section 3.2): Tier 1 project NDT covers Stages One and Two, Tier 2 operator condition assessment covers Stages Three and Four, and Tier 3 engineering analysis is Stage Five. A pipeline operator's problem set is external stress corrosion cracking, microbiologically influenced corrosion, and alternating current interference on the outside; carbon dioxide, hydrogen sulphide, and microbial attack on the inside; dent-and-gouge and third-party damage along the right of way; and girth weld defects inherited from construction. The construction-phase pressure is radiography productivity against lowering rates; the operating-phase pressure is proving integrity between inline inspection runs; the procurement pressure is line pipe and coating quality at the mill. Not every stage carries equal weight in this vertical, and TCR applies the model with judgment: Stages One, Two, and Five dominate cross-country projects, while Stages Three and Four dominate operating systems and city gas distribution networks.

Stage One, Sourcing and Procurement. Line pipe is qualified at the mill: mechanical and chemical testing per API Specification 5L, drop weight tear and Charpy impact testing, hydrogen induced cracking per NACE TM0284 and sulphide stress cracking per NACE TM0177-2016 for sour service lines per NACE MR0175/ISO 15156, coating system qualification, and mill audits with sample picking and loading supervision, so that the pipe that arrives at the right of way matches the pipe that was ordered.

Stage Two, Construction and Commissioning. Mainline production welding is inspected with crawler-based radiography per API 1104, the practice anchored by the Saudi Aramco approved internal radiography crawler (Section 7.2), supported by welder and procedure qualification, positive material identification, holiday detection on coating, and hydrotest witness. The construction record, weld maps, radiographs, and coating reports, becomes the baseline for the operating life of the line.

Stage Three, In-Service. In operation, the Cathodic Protection Division delivers close interval potential surveys, direct current voltage gradient coating surveys, alternating current interference studies, and turnkey cathodic protection design, installation, and remediation per NACE SP0169, alongside above-ground marker surveys and remote visual inspection of exposed crossings. Risk-based integrity planning per API RP 580 principles, delivered through AiOM-CCP (Section 6.1.4), sequences excavation and assessment across the network.

Stage Four, Shutdown and Turnaround. At dig sites and during station shutdowns, TCR provides direct examination non-destructive testing: ultrasonic thickness and corrosion mapping on exposed pipe, phased array ultrasonic testing and time of flight diffraction on suspect girth welds, dent and gouge profiling, magnetic particle and penetrant testing on fittings, and station piping, scraper trap, and valve inspection, with in-situ metallographic replication where cracking mechanisms need microstructural confirmation.

Stage Five, Continuum. Engineering analysis closes the loop: engineering critical assessment of girth welds per the eight-step workflow in Section 6.3.2, fitness for service and remaining strength assessment of corroded and dented pipe per API 579-1/ASME FFS-1 and ASME B31G, failure analysis of ruptures and leaks, cathodic protection effectiveness studies, and hydrogen and carbon dioxide service conversion assessments that feed the operator's next capital cycle.

11d.7 Named Clients

India Public Sector. IOCL (Kandla-Gorakhpur LPG Pipeline, Salaya-Mathura crude, Paradip-Haldia products), GAIL (Hazira-Vijaipur-Jagdishpur, Dahej-Vijaipur, MNJPL, KGPL, Urja Ganga), HPCL (Mumbai-Pune, Mundra-Delhi), BPCL (Bina-Kanpur, Mumbai-Manmad), ONGC (offshore export trunkline), Petronet LNG (Dahej re-gas), Indian Strategic Petroleum Reserves Limited (Mangalore, Padur, Visakhapatnam underground storage tie-ins), Mahanadi Coalfields and other coal-bed methane operators.

India Private Sector. Reliance Industries (KG-D6 onshore tie-in, Jamnagar export), Cairn Oil and Gas (Barmer crude trunkline), Adani-Total (Dhamra LNG; cross-vertical with Marine), Larsen and Toubro (EPC contractor for multiple cross-country projects), Gujarat State Petroleum Corporation, Indraprastha Gas Limited.

CGD Operators. Bhagyanagar Gas Limited (HPCL-GAIL JV, BGRL Spread-2 Maharashtra June 2021 via Tractebel ENGIE PMC; Karnataka 2022 via Tolani Projects), Green Gas Limited Lucknow GA December 2022, Torrent Gas Karaikal Puducherry June 2023, Gujarat Gas, Mahanagar Gas, Indraprastha Gas.

EPC and PMC. Engineers India Limited (12-year approval pack); Mecon; Larsen and Toubro; Kalpataru Projects International; Likhitha Infrastructure (Nepal cross-border partner); EnProCon (TJTC Kolar 9,266 weld joints); NRP Projects (Adani-Total Dhamra LNG EPCC); Wood (Adani-Total Dhamra LNG PMC); Tractebel ENGIE; Tolani Projects; Power Mech Projects.

GCC. Saudi Aramco (Master Gas System cross-package: L&T, Kalpataru Projects International, GAS Arabian Services delivery; ECA per API 1104; cross-border KSA-India workflow), PDO, OQGN, Adani-Total Dhamra LNG.

International. Nepal Oil Corporation (MAPL Phase II via Likhitha Infrastructure, the first non-GCC cross-border deployment per Ref 2080/81 dated 30 July 2023).

Representative India pipeline and city-gas-distribution clients include Corrtech International, Kalpataru Projects International, Likhitha Infrastructure, Advance Infrastructures (on JSW and ArcelorMittal Nippon Steel pipeline scope), and MAS Constructions, with field deployment across Odisha, Haryana, Rajasthan, Kerala, and Andhra Pradesh.

11d.8 Marquee Projects

Named OQ Gas Networks line-pipe qualification projects include the 42-inch Fahud-Sohar Second Loop Line and the Marsa LNG gas supply pipeline, with line pipe from Jindal Saw and Man Industries.

Project	Service Anchor	Year
Saudi Aramco Internal RT Crawler programme	SAER-13115 dated 8 September 2025; $4.98M documented cost avoidance over 5 years; demonstration 28 July 2025	2023 to 2025
IOCL Kandla-Gorakhpur LPG Pipeline	World's longest LPG pipeline, multiple spreads, Tier 1 Project NDT	Construction era

Project	Service Anchor	Year
Srikakulam-Angul Onshore Gas Pipeline 690 km	4 spreads, Tier 1 Project NDT	Construction era
EnProCon TJTC Kolar	9,266 weld joints digitally scanned and cloud-archived	Multiple
Likhitha Infrastructure for Nepal Oil Corporation, MAPL Phase II	Cross-border RT Crawler deployment, AERB and BARC permissioned, Ref 2080/81 dated 30 July 2023	2023
Adani-Total Dhamra LNG Terminal	Approved RT scope per Letter Ref 2340-RLNG-DLTPL-NRP-L-0005 dated 20 October 2021	2021 onward
Saudi Aramco Jafurah Gas Compression Plants	ECA, PWIS Package-1	2024 to 2025
Bhagyanagar Gas Limited Maharashtra and Karnataka	CGD pipeline RT under Tractebel ENGIE and Tolani Projects	2021, 2022
Jindal SAW Limited Mundra Kutch for OQ Gas Project	Line pipe sour-service material qualification for OQGN Oman: HIC per `NACE TM0284` (96 hrs, 25 ±3 °C, 92 sets of 3 specimens) plus SSCC four-point bend per `NACE TM0177` / `ASTM G39` / OQGN docs (720 hrs, 24 ±3 °C, 52 sets of 3 specimens, fixture 100 mm outer / 50 mm inner support). PO 4703000416 dated 01.07.2025.	July 2025 onward
Green Gas Limited Lucknow GA	CGD pipeline RT	December 2022
Torrent Gas Karaikal Puducherry	CGD pipeline RT	June 2023
Master Gas System (Saudi Aramco), TCR Arabia cross-package	ECA per `API 1104`, cross-border KSA-India workflow	Continuous

Project	Service Anchor	Year
AiOM-CCP undersea pipeline case study	API 5L X46N, 21 km × 355 mm × 15.9 mm, ID-side CO_2/H_2S corrosion	Anonymised

The Saudi Aramco-approved internal RT crawler, 16 to 52 inch, carries a documented cost avoidance of 4.98 million dollars over five years (Engineering Report SAER-13115). A C-Value condition study on an 8-kilometre industrial water pipeline traced a drop from 500 to 300 cubic metres per hour to a Hazen-Williams coefficient that had fallen from 130 to 75, a fouled but structurally intact line. A 48-inch API 5L X60 sweet-gas line of 42 kilometres was cleared by engineering critical analysis per API 1104 Annex A Option 2.

INDUSTRIES · SECTION 11E

Oil and Gas Upstream

SECTION 11E

11e. Oil and Gas Upstream

TCR holds **ONGC's QAD approval Serial No. 01**, the very first name on the list, held continuously since **1998**, and runs **First Article Qualification for Cameron, NOV, Halliburton, Schlumberger, Baker Hughes and Weatherford**, with active approvals at **Saudi Aramco, ADNOC and PDO**.

POTENTIAL FAILURES WE SERVICE

Leaks, blowdowns and equipment failures across wellhead hardware, tubing, risers, manifolds and offshore platforms. TCR analyses sour-service cracking (SSC, HIC, SOHIC), CO2 and H2S corrosion, sand-cut and slug erosion, riser and vibration fatigue, and weld-toe defects, plus First Article Qualification on new wellhead equipment at the manufacturing source.

Serial No. 01 on ONGC's approved-laboratory register since 1998, First Article Qualification for the world's wellhead OEMs, and the sour-service bench that qualifies tubing, risers and trees against NACE MR0175.

MARQUEE PROJECT

ONGC QAD approval Serial Number 01, in force since **1998**, the longest-tenure laboratory approval on the ONGC panel.

11e.1 Industry Context

Upstream operators carry inspection obligations at both ends of the asset life. Ageing fields and sour service drive integrity spend during operation, while decommissioning sits on the balance sheet as a formal asset retirement obligation under Ind AS and IFRS, with the worldwide oil and gas decommissioning liability independently estimated at USD 311 to 362 billion. Between those two poles sits a continuous demand for materials qualification, corrosion testing, and fitness for service judgement. TCR's sour-gas laboratory runs SSC, HIC, and SOHIC programmes to NACE and ISO 15156 against Petroleum Development Oman, Saudi Aramco, and ONGC/EIL specifications, and the group's FFS and failure analysis bench converts inspection findings into defensible run, repair, or retire decisions.

The upstream oil and gas vertical splits across three buyer pools. The Indian onshore and offshore operator pool (ONGC, Oil India, Cairn Oil and Gas, Reliance KG-D6, Vedanta) anchors the long-tenure relationships, with TCR's ONGC empanelment (QAD Sr. No. 01 since 1998) representing the single longest active vendor relationship in the company's history. The GCC and MENA upstream pool (Saudi Aramco, ADNOC, PDO, OQGN, KOC, Qatar Energy, KNPC, Iraqi Ministry of Oil, PetroChina International Iraq) carries the volume of cross-border and field-services-adjacent work via TCR Arabia and TCR Advanced. The international oilfield-services and equipment-OEM pool (Halliburton, Schlumberger, Cameron International, NOV Inc., Baker Hughes, Weatherford, GE International) sources verification testing, First Article Qualification, and audit-grade material certification.

The static-equipment specialist line is held: TCR is the laboratory and integrity bench for storage tanks, pressure vessels, separator and slug catcher, manifold piping, and wellhead-adjacent fixed equipment, not a rotating-equipment field service contractor.

The CO2 EOR (enhanced oil recovery) trend in the Indian onshore basins (Bombay High, Cambay, Krishna-Godavari, Cauvery) brings supercritical CO2 piping and reservoir-tie-in qualification work. CCUS at offshore platforms brings cross-vertical scope with Pipelines and Marine. Hydrogen blending in natural-gas trunklines brings API 941 HTHA discipline and ASTM F519 / API 20E hydrogen embrittlement bench into upstream operator-side scope. The decommissioning agenda (legacy offshore platforms, idle wells, abandoned pipelines) brings structural assessment and material recovery scope.

TCR is the laboratory and integrity bench for the sour and sweet service surface area, the wellhead-equipment First Article Qualification stream, and the Aramco-grade ECA and RT capability that the upstream vertical demands.

11e.2 Plant Sections We Inspect

Cluster	Equipment
Onshore production	Wellhead and Christmas tree (statutory inspection scope), separator (HP, MP, LP), test separator, slug catcher, manifold, gas dehydration (TEG, MEG), produced-water treatment, gas compressor station
Offshore production	Topsides separator and process train, riser and J-tube, jacket structure (cross-vertical with Marine), subsea manifold tie-in (cross-vertical with Pipelines), boat landing
Storage and Stabilisation	Crude and condensate stabilisation column, storage tanks (`API 650`, `API 620` where low-pressure), spheroids
Gas Processing	Acid-gas removal (amine, MEA, MDEA), dehydration (TEG glycol, mol-sieve), NGL extraction (turbo-expander section), LPG fractionator
Sour Service	Sour-crude and sour-gas piping, separator, slug catcher; H2S scavenger system
Pipeline Tie-In	Wellhead to manifold to gathering, pig launcher and receiver; cross-vertical with Section 11d Pipelines

Cluster	Equipment
Wellhead Equipment Verification	Cameron International, NOV Inc., Halliburton, Schlumberger, Baker Hughes equipment First Article Qualification testing

11e.3 Damage Mechanisms We Investigate

Category	Mechanisms
Sour service	Sulphide stress cracking (SSC), hydrogen-induced cracking (HIC), stepwise cracking (SWC), stress-oriented HIC (SOHIC); per `NACE MR0175` / `ISO 15156`
CO2 corrosion	Sweet (CO2) corrosion, top-of-line corrosion, mesa attack, pitting under deposit
Combined sour and sweet	CO2/H2S synergistic corrosion (the AiOM-CCP undersea pipeline case framework)
Erosion-corrosion	Sand-cut erosion at choke and elbow, slug erosion at riser bend
Mechanical and fatigue	Vibration-induced fatigue, riser fatigue, dent and gouge from third-party
Material and weld	HAZ embrittlement, weld toe cracking, lack of penetration, lack of fusion
Equipment First Article	Manufacturing defect identification at the source-inspection stage

11e.4 Standards Coverage Matrix

Sour Service. NACE MR0175 / ISO 15156 (materials for use in H2S-containing environments in oil and gas production); NACE MR0103 (for refining-adjacent service, cross-vertical); NACE TM0177-2016 Methods A through D (laboratory testing of metals for resistance to SSC and SCC in H2S environments); NACE TM0284 (HIC); NACE TM0316 (four-point bend); NACE TM0198 (slow strain rate test); EFC Publication 16 (CO2 resistance materials).

RBI / FFS / ECA. API 580 / 581 4th ed. (January 2025); API 579-1/ASME FFS-1 4th ed. (2021); BS 7910; API 1104 22nd ed. (2021) Annex A.

Inspection Codes. API 510, 570, 653; API RP 572, 574, 575; API RP 941 HTHA where hydrogen service is in scope.

Asset Integrity Management. Asset Integrity Management for Offshore and Onshore Structures, M. El-Reedy (1st ed., 2022).

Welding and Material. ASME Section IX 2023; AWS D1.1 2025; API 1104 22nd ed.; API 5L 46th ed.; ASTM A106 (carbon steel piping for high-temperature service); ASTM A335 P22, P11; ASTM A516 Grades 60, 65, 70 (carbon steel pressure-vessel plates); ASTM A537 Class 1 / 2.

Construction. ASME Section VIII Div. 1, Div. 2; ASME B31.3 (process piping); ASME B31.4 / B31.8 (pipeline transportation systems); API 650, API 620.

11e.5 Service Applications Across the TCR Continuum

STAGE 01	STAGE 02	STAGE 03	STAGE 04	STAGE 05
Sourcing and Procurement	**Construction and Commissioning**	**In-Service**	**Shutdown and Turnaround**	**Continuum**
Factory audits, OEM qualification, raw-material inspection, loading supervision.	Weld NDT, PMI, baseline thickness surveys, positive material records.	In-situ metallography, condition monitoring, RBI, on-stream inspection.	Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.	RLA, failure analysis, life extension; findings feed the next cycle.

Upstream oil and gas buys integrity against sour service. Hydrogen sulphide partial pressure governs material selection for wellheads, christmas trees, downhole tubulars, flowlines, and separators per NACE MR0175/ISO 15156, and the laboratory evidence behind that selection, sulphide stress cracking, hydrogen induced cracking, and stress-oriented hydrogen induced cracking, is where TCR runs one of the largest sour service testing capacities in India. In operation the problem set widens to carbon dioxide corrosion in flowlines, microbiologically influenced corrosion in water systems, fatigue of structural connections offshore, and erosion in sand-producing wells. Shutdown windows on production facilities are short and weather-bound; procurement risk sits in forgings, seals, and elastomers for high pressure high temperature service. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) for onshore and offshore operators and their equipment manufacturers.

Stage One, Sourcing and Procurement. Materials for sour service are qualified through sulphide stress cracking per NACE TM0177-2016 Methods A through D including four-point bend, hydrogen induced cracking per NACE TM0284, stepwise cracking and stress-oriented hydrogen induced cracking, hydrogen embrittlement testing, and NORSOK M-710 qualification of polymers, elastomers, and composites for sour exposure. Forging and valve vendor audits, sample picking, in-production checks, and loading supervision protect the supply chain for wellhead and pressure-control equipment.

Stage Two, Construction and Commissioning. For gathering stations, processing trains, and terminal construction, TCR delivers baseline non-destructive testing on piping and vessels, phased array ultrasonic testing and time of flight diffraction, radiography, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX and API 1104, post-weld heat treatment with hardness control for sour service, and positive material identification, establishing the baseline record for each facility.

Stage Three, In-Service. On producing facilities, TCR runs corrosion mapping on separators, knockout drums, and flowlines, thickness monitoring programmes, remote visual inspection of confined and buried equipment, thermography, and risk-based inspection planning per API RP 580 and API RP 581, with integrity operating windows per API RP 584 tied to produced fluid chemistry so inspection intervals track actual corrosivity rather than design assumptions.

Stage Four, Shutdown and Turnaround. In the shutdown window, TCR inspects pressure vessels internally per API 510, exchanger and cooler tube bundles, storage tanks per API 653 including in-service robotic options, flare and relief system components, and structural steel, with in-situ metallographic replication on high temperature components and magnetic particle and penetrant testing on nozzles and attachment welds, supported by turnaround inspection manpower.

Stage Five, Continuum. Findings feed fitness for service per API 579-1/ASME FFS-1 on corroded vessels and piping, engineering critical assessment of flowline and riser girth welds, failure analysis of downhole, wellhead, and surface equipment including seal and elastomer failures, remaining life assessment of ageing facilities, and the materials-selection and contract research studies that qualify equipment for the next field development.

11e.6 Named Clients

India Public Sector. Oil and Natural Gas Corporation (ONGC; QAD Sr. No. 01 since 1998), Oil India Limited, GAIL India Limited (cross-vertical with Pipelines).

India Private Sector. Reliance Industries (KG-D6), Cairn Oil and Gas (Barmer, Ravva), Vedanta Limited, Adani-Total Energies (Dhamra LNG cross-vertical), Hindustan Oil Exploration Company.

GCC Upstream. Saudi Aramco (Vendor 10040677, ANDT Contract 6601000141), ADNOC, Petroleum Development Oman (PDO; approval refresh May 2022), OQ Gas Networks (OQGN), Kuwait Oil Company (KOC), Qatar Energy, KNPC.

Iraq. PetroChina International Iraq FZE; Iraqi Ministry of Oil (approval since May 2019); Baiji Refinery (idle-plant restart cross-vertical).

International. Shell (multiple geographies, sour-service approved through Shell-approved elastomeric and corrosion testing), BP, ExxonMobil (vendor-side via OEM source inspection), TotalEnergies, Pemex (Mexico).

Equipment OEMs and Oilfield Services. Cameron International (First Article Qualification testing since 2012, ongoing), NOV Inc. (March 2023), Halliburton, Schlumberger, Baker Hughes, Weatherford, GE International (3-year contract December 2012), SABIC Global Contract 4600006798 (10 July 2012 to 9 July 2017; vendor 505239).

11e.7 Marquee Projects

Project	Service Anchor	Year
ONGC QAD Sr. No. 01 (the longest-tenure approval; original approval letter MRBC/QAD/LAB/97-98/779 dated 25 February 1998 signed by Om Veer Singh, Purchase Group, ONGC Mumbai)	Materials testing, NDT, source inspection across ONGC asset base for ferrous and non-ferrous metals, weld, glass, refractories, ceramics, and radiography	Since 1998
Jindal SAW Limited Mundra Kutch for OQ Gas / OQGN Oman line pipe	Sour-service qualification (HIC per `NACE TM0284` plus SSCC four-point bend per `NACE TM0177` / `ASTM G39` / OQGN docs); cross-vertical with Section 11d Pipelines and CGD; PO 4703000416 dated 01.07.2025	July 2025 onward

Project	Service Anchor	Year
Indorama Eleme Petrochemicals Limited, Port Harcourt, Rivers, Nigeria	Olefins furnace tubes condition assessment and NDT (in-situ metallography on SS304H with Aqua-regia etchant for 100 replicas, UCI hardness, permeability measurement, SEM analysis)	April 2025 onward
Saudi Aramco Jafurah Gas Compression Plants	ECA, PWIS Package-1	2024 to 2025
Shell sour-service material qualification	`NACE TM0177` / TM0284 / MR0175 testing campaigns	Continuous
Saudi Aramco Master Gas System (cross-package)	ECA per `API 1104`; L&T, Kalpataru Projects International, GAS Arabian Services delivery	Continuous
Cameron International	First Article Qualification testing	2012 onward
NOV Inc.	Approval and source-inspection testing	March 2023 onward
Halliburton, Schlumberger, Baker Hughes, Weatherford	Vendor source-inspection and verification testing	Continuous
GE International	3-year contract scope	December 2012 onward
SABIC	Global Contract 4600006798	2012 to 2017
Casale SA (Switzerland)	SX3000 Vendor Code 1000007973 (urea and melamine licensor; cross-vertical with Fertilisers)	June 2025 onward
Petrokemya, KSA	RLA of fire-steam-tube boiler (cross-vertical with Power)	2023
PIC Fertilizer Plant, Kuwait (NBTC delivery)	RLA of 120 critical equipment in ammonia and urea plant (cross-vertical with Fertilisers)	2024

For Petroleum Development Oman and OQ Gas Networks, TCR qualifies sour-service line pipe to PDO SP-2347 and OQGN G14-PD-PL, with hardness, HIC, and SSC acceptance read against criteria stricter than NACE. CTOD with hydrogen-sulphide pre-charging, developed for Larsen and Toubro, charges specimens for 96 hours in NACE TM0177 Solution A before loading within a 20-minute window. Storage-sphere, terminal, and transfer-line investigations cover corrosion under insulation, pitting, and stress-corrosion cracking.

INDUSTRIES · SECTION 11F

Marine and Offshore

SECTION 11F

11f. Marine and Offshore

India's defence and merchant shipyards, **Mazagon Dock, Cochin Shipyard, Garden Reach, Goa Shipyard and Hindustan Shipyard**, plus the country's largest ports, **Adani, JNPT, Mumbai, Visakhapatnam and Kandla**, draw on TCR for materials, weld qualification and structural inspection.

POTENTIAL FAILURES WE SERVICE

Failures in jacket and topside structures, risers, mooring chains, subsea pipelines, FPSO hulls and ship structures. TCR evaluates splash-zone and seawater corrosion, corrosion fatigue, pitting and crevice attack, cavitation, weld and HAZ cracking, and runs underwater robotic and ROV inspection on submerged assets.

From jacket platforms and mooring chains to FPSO hulls, ship structures and sub-water bridge piers, TCR carries the splash-zone-to-seabed integrity scope for India's offshore operators, shipyards and ports.

MARQUEE PROJECT

Mumbai Coastal Road Project: sub-water bridge-pier and abutment inspection with marine-grade coating and rebar-coupler verification.

11f.1 Industry Context

Marine and offshore assets live on survey cycles. Classification societies mandate special surveys on five-year cycles, offshore structures face underwater inspection in lieu of dry-docking, and every extension of a vessel or platform beyond design life must be argued with measured data, not opinion. As fleets and offshore infrastructure in Indian and Gulf waters age, that evidence burden grows. TCR serves it with hull and weld NDT, corrosion evaluation to marine coating standards, underwater robotic inspection through the Planys alliance, and the TCR Arabia robotic field record on submerged and difficult-access structures, backed by a laboratory that can qualify steel, welds, and coatings to DNV, API, and class requirements.

The marine and offshore vertical splits across five buyer pools. Indian offshore upstream operators (ONGC at Bombay High, Reliance at KG-D6, Cairn at Ravva and Bombay Western, Vedanta) anchor offshore platform structural integrity work. Indian shipyards (Cochin Shipyard, Mazagon Dock Shipbuilders Limited, Garden Reach Shipbuilders and Engineers, Goa Shipyard, Hindustan Shipyard) carry naval-vessel and merchant-vessel materials testing and welding qualification. Port and marine-terminal infrastructure (Mumbai Port Trust, Adani Ports, JNPT, Visakhapatnam Port, Chennai Port, Kandla, Mundra) carries jetty pile, mooring dolphin, and breakwater inspection. LNG re-gas terminals (Petronet Dahej, Adani-Total Dhamra, Hazira) bring refrigerated-material and cryogenic qualification. Maharashtra coastal infrastructure under CIDCO and the Mumbai Coastal Road Project brings sub-water bridge-pier inspection and structural testing.

The static-equipment specialist line is held: TCR is the laboratory and structural-integrity bench for jacket structures, jetty piles, mooring dolphins, refrigerated tanks, and offshore export pipework, not a rotating-equipment field service contractor.

11f.2 Plant Sections We Inspect

Cluster	Equipment
Offshore Production Topsides	Process train (cross-vertical with Oil and Gas Upstream), riser and J-tube, separator skid, gas dehydration, produced-water treatment
Offshore Jacket Structure	Jacket leg, brace, conductor guide, riser clamp, anode bracket, mudmat, pile sleeve
Subsea Pipeline	Export trunkline, inter-field flowline, manifold tie-in, riser-base tie-in, J-tube assembly
Jetty and Marine Terminal	Steel pile (tubular), concrete pile, mooring dolphin, fender system, jetty deck slab, expansion joint
Naval and Merchant Shipyard	Hull plate, structural bulkhead, deck plate, weld qualification, welder qualification, propeller shaft fastener (cross-vertical with Component and Fasteners)
Refrigerated Storage	LNG full-containment double-wall double-integrity tank (cross-vertical with Fertilisers refrigerated ammonia tanks); LPG semi-refrigerated; bunkering loading-arm tie-in
Submarine and Naval Defence	Submarine pressure hull (visual, NDT, material qualification scope where authorised)
Sub-Water Bridge	Bridge pier and abutment (cross-vertical with Civil and Infrastructure Section 8); ROV inspection across BMC March 2026 programme covering 400+ bridges

11f.3 Damage Mechanisms We Investigate

Category	Mechanisms

Category	Mechanisms
Marine corrosion	Splash-zone corrosion on jacket structures and jetty piles; submerged-zone corrosion (general, pitting, crevice); atmospheric-zone corrosion above splash; chloride-induced pitting on stainless steel; galvanic corrosion at dissimilar-metal joints
Cathodic protection	Sacrificial-anode depletion; impressed-current TR-unit failure; coating breakdown; AC interference at jetty platform
Cracking	Stress corrosion cracking on stainless steel in chloride service; sulphide stress cracking in sour offshore production; hydrogen embrittlement on high-strength bolts
Fatigue	Wave-induced fatigue on jacket bracing; vortex-induced vibration on free-spanning subsea pipeline; cyclic loading on mooring chain
Refrigerated	Brittle fracture below ductile-to-brittle transition temperature; thermal-cycling fatigue on cryogenic piping; coating breakdown under refrigeration
Composite	Delamination, fibre-matrix debonding, hydrolytic ageing on FRP/GRP pipe and tank; ageing of polymer sealing materials per NORSOK M-710
Naval-specific	Acoustic-stealth coating qualification; hull-plate weld defect; submarine pressure-hull qualification scope

11f.4 Standards Coverage Matrix

Offshore Structures. API RP 2A-WSD (planning, designing, and constructing fixed offshore platforms, 22nd ed.); ISO 19902 (offshore structures); DNV-OS-C101.

Subsea Pipelines. DNV-OS-F101 (submarine pipeline systems, 2021 ed.); API RP 1111 (design, construction, operation, and maintenance of offshore hydrocarbon pipelines); DNV-RP-F101 (corroded pipelines).

Cathodic Protection (Offshore). DNV-RP-B401 (cathodic protection of offshore structures, 2021 update); NACE SP0176 (corrosion control of submerged areas of permanently installed steel offshore structures); ISO 15589-2 (subsea CP).

LNG and Cryogenic. API 625 (tank systems for refrigerated liquefied gas storage); EN 14620 (site-built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases); ASME B31.5 (refrigeration piping); ASTM E1820 cryogenic CTOD.

Naval and Shipyard. NAVSEA / Indian Navy IS specifications; CWB Canadian welding bureau; ABS, Lloyd's Register, Bureau Veritas, DNV class-society rules; IACS Common Structural Rules.

Composite and Polymer. NORSOK M-710 Rev. 3 (qualification of non-metallic sealing, sealing-related, and load-bearing materials for sour service); ASTM D2992 (FRP/GRP pipe, hydrostatic design basis); ISO 14692 (GRP piping); BS 7159 (chemical plant in glass-reinforced plastic).

Welding. ASME Section IX 2023; AWS D1.1 (structural welding code, 2025); AWS D1.5 (bridge welding, cross-vertical with Civil); IIW guidelines.

FFS / ECA. API 579-1/ASME FFS-1 4th ed. (2021); BS 7910; API 1104 Annex A.

Materials. ASTM A572 / A588 (structural carbon steel); ASTM A36 (general-purpose carbon steel); API 5L (line pipe); ASTM A537 Class 1 / 2 (carbon steel pressure-vessel plates for moderate and lower-temperature service); ASTM A353 / A553 (9% nickel for cryogenic service).

11f.5 Service Applications Across the TCR Continuum

Marine and offshore assets live under classification society discipline: Indian Register of Shipping, DNV, American Bureau of Shipping, and Lloyd's Register rules set the survey calendar, and every intervention must produce class-acceptable evidence. The recurring problem set is hull steel wastage and ballast tank coating breakdown, weld quality in newbuilding and repair, corrosion fatigue at structural details, mooring chain and wire rope degradation, and the splash-zone corrosion that no coating fully survives. Dry-dock windows are the industry's turnaround equivalent, priced by the day; procurement risk sits in plate, section, and consumable quality at the yard. TCR Engineering and TCR Advanced service the five-stage Trusted Relationship Model (Section 3.2) for shipyards, owners, offshore operators, and the naval and defence ecosystem.

Stage One, Sourcing and Procurement. Shipbuilding plate, sections, castings, and forgings are tested to classification society requirements: tensile, impact, and bend testing, chemical analysis, and metallurgical evaluation, alongside weld consumable evaluation and coating system testing. Vendor audits, sample picking, and loading supervision cover outfitting equipment, anchors, and chain, and fastener and rigging components are qualified before installation.

Stage Two, Construction and Commissioning. At the yard, TCR provides newbuilding weld inspection: radiography, ultrasonic, magnetic particle, and penetrant testing to class rules, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX and AWS D1.1 as applicable, positive material identification on alloy systems, and the baseline thickness and weld records that follow the vessel or platform through its class life.

Stage Three, In-Service. In service, TCR supports underwater inspection in lieu of dry-docking through the Planys submersible remotely operated vehicle alliance (Section 7.6), thickness gauging campaigns, thermography of machinery and electrical systems, and corrosion monitoring of ballast and cargo spaces, with condition data structured for class survey credit.

Stage Four, Shutdown and Turnaround. In dry dock and during offshore shutdowns, TCR delivers hull thickness surveys, weld repair inspection, tank and void space examination, heat exchanger and cooler tube inspection, in-situ metallographic replication on high temperature exhaust and boiler components, and non-destructive testing of cranes, davits, and lifting appliances, sized to the docking window.

Stage Five, Continuum. Engineering closes the cycle: fatigue assessment and engineering critical assessment of structural details and girth welds, fitness for service per API 579-1/ASME FFS-1 on offshore process equipment, failure analysis of propulsion, mooring, and structural components, remaining life assessment of ageing offshore assets, and life extension studies that let a platform or vessel trade beyond its original design life on evidence.

11f.6 Named Clients

India Offshore Operators. ONGC (Bombay High, offshore export trunkline, ONGC QAD Sr. No. 01 since 1998), Oil India Limited, Reliance Industries (KG-D6 offshore tie-in), Cairn Oil and Gas (Bombay Western, Ravva offshore), Vedanta.

Indian Shipyards and Naval. Cochin Shipyard Limited, Mazagon Dock Shipbuilders Limited, Garden Reach Shipbuilders and Engineers, Goa Shipyard, Hindustan Shipyard, Indian Navy (cross-vertical with Aerospace and Defence; CQAE empanelment).

Indian Marine and Port Infrastructure. Mumbai Port Trust, Adani Ports and Special Economic Zone, JNPT, Visakhapatnam Port Authority, Chennai Port, Kandla Port, Mundra Port; Mumbai Coastal Road Project; CIDCO eMTL Maharashtra empanelment.

LNG and Cryogenic. Petronet LNG (Dahej re-gas), Adani-Total Dhamra LNG (cross-vertical with Pipelines), Hazira LNG, Indian Strategic Petroleum Reserves Limited (Mangalore, Padur, Visakhapatnam underground storage cross-vertical).

International. Saudi Aramco (Master Gas System cross-package), ADNOC offshore, PDO offshore, KOC offshore, Petrokemya KSA (cross-vertical with Power and Refining).

Class Societies (vendor-side relationships). American Bureau of Shipping (ABS), Lloyd's Register, DNV, Bureau Veritas (peer benchmark, also a client framework via vendor empanelment).

Equipment OEMs and Subsea. Cameron International (subsea wellhead equipment, FAQ since 2012), NOV Inc., Schlumberger Subsea, TechnipFMC, Saipem.

11f.7 Marquee Projects

Project	Service Anchor	Year
Mumbai Coastal Road Project	Civil testing, sub-water bridge-pier and abutment inspection, marine-grade coating, rebar coupler (cross-vertical with Civil)	Continuous
BMC March 2026 robotic underwater bridge programme	400+ bridges, AI-assisted underwater inspection (cross-vertical with Civil and Robotics)	March 2026 onward
ONGC offshore export trunkline	Long-tenure NDT, source inspection, structural integrity (since 1998)	Continuous

Non-metallic sealing and sealing-related components for subsea service are qualified to NORSOK M-710, with rapid gas decompression and ageing resistance assessed for offshore duty. High-tensile strand for marine and coastal prestressed structures is tested per IS 14268 and ASTM A416, including stress-corrosion and 2 million-cycle fatigue. Submersible ROV inspection with SONAR silt assessment and an ultrasonic gimbal covers sub-water structures and basins.

INDUSTRIES · SECTION 11G

Steel and Metals

SECTION 11G

11g. Steel and Metals

Every integrated Indian steel major certifies incoming and finished product on TCR's classical wet-chemistry bench, while ARTiS inspects sponge-iron reformer tubes from Bhilai to Abu Dhabi.

MARQUEE PROJECT

Emirates Steel Abu Dhabi: **ARTiS reformer-tube inspection** across the DRP1 and DRP2 direct-reduction plants.

11g.1 Industry Context

In steel, maintenance events are earnings events. Tata Steel's relining of the G blast furnace at Jamshedpur pulled India crude steel output down about three percent quarter on quarter in Q4 FY25, and its Netherlands Blast Furnace 6 reline drove the region to an EBITDA loss on higher maintenance, spares, and capex, within a group capex of Rs 15,671 crore in FY25. Campaign-life decisions of that scale rest on condition data: refractory state, shell integrity, and the metallurgical health of hot equipment. TCR supplies that data through in-situ metallography on live plant, failure analysis of rolls, bearings, and furnace components, refractory and materials testing, and RLA of reheating furnaces and process equipment across the integrated and secondary steel sector.

The Indian steel sector is on a stated path from approximately 145 MTPA installed crude-steel capacity (FY24) to 300 MTPA by 2030 to 2035 under the National Steel Policy. The brownfield and greenfield capex pipeline runs across Tata Steel (Kalinganagar Phase II, Meramandali), JSW Steel (Vijayanagar Phase II, Dolvi expansion), SAIL (Bhilai, Bokaro, Rourkela, Durgapur, IISCO Burnpur modernisation), ArcelorMittal Nippon Steel India (Hazira expansion to 15 MTPA), and the Vedanta ESL Bokaro programme.

Three integrity-load drivers shape the workload: aging blast-furnace and coke-oven asset bases (some now beyond 30 years operating life); the Direct Reduction Plant (DRP) sponge-iron route which uses reformer-tube inspection methodology (ARTiS cross-vertical with Fertilisers); and the captive-power and waste-heat boiler footprint at integrated steel plants which uses the boiler RLA practice (cross-vertical with Power).

The sector also brings a large and recurring classical wet-chemistry buyer pool: every integrated producer runs a chemical certification programme on incoming raw materials (iron ore, coke, limestone, dolomite, alloying additions) and outgoing finished product (HR coil, CR coil, plate, structural sections, special bar, wire rod). TCR's wet-chemistry capacity is a structural fit.

Green-steel pathways (hydrogen-based DRP, cross-vertical with Fertilisers and the API 941 HTHA scope) bring API 941 discipline into shaft-furnace and reformer-tube qualification. Carbon capture on integrated steel BOF flue gas brings amine-system corrosion qualification (cross-vertical with Refining and Fertilisers). Electric-arc-furnace (scrap-route) capacity expansion brings refractory-and-shell qualification scope. Captive-renewable integration (solar PV at integrated plant sites) brings structural-steel testing for module-mounting structures (cross-vertical with Civil). Hydrogen blending in coke-oven gas brings cross-pillar qualification for HTHA-prone equipment.

The Tata Steel and JSW Steel hydrogen-DRP demonstration projects, the SAIL Bhilai modernisation programme, and the ArcelorMittal Nippon Steel India Hazira expansion to 15 MTPA all point to a multi-decade integrity-and-life-extension workload on the existing fleet alongside green-steel capex.

11g.2 Plant Sections We Inspect

Cluster	Equipment
Coke Oven Battery	Oven wall (silica refractory), regenerator, coke-side door, push-side door, ascension pipe, gas main, by-product plant (ammonia, tar, naphthalene, BTX)
Sinter Plant	Sinter strand, mixing drum, ignition furnace, cooler, dust-collection system
Blast Furnace	Hearth, bosh, stack, throat, hot-blast stove, bustle pipe, tuyere, copper plate, downcomer, gas-cleaning plant
Basic Oxygen Furnace	Vessel shell, refractory, lance, hood, off-gas duct, fume extraction
Continuous Casting	Mould, secondary cooling, segments, drive rollers, withdrawal-and-straightening unit, oscillator
Direct Reduction Plant (DRP)	Reformer (cross-vertical with Fertilisers), sponge-iron shaft furnace, briquetting machine, gas reforming, top-gas scrubber
Hot Rolling and Cold Rolling	Reheating furnace, walking-beam reheating furnace, descaling, roughing mill, finishing mill, runout table, coiler, pickling line, cold mill, annealing line
Captive Power Plant	Boiler (cross-vertical with Power), turbine, condenser, ESP, coal-handling plant
Storage and Handling	Crude-steel ladle, tundish, refractory bricks, copper conductor (electric arc furnace adjacent)

119.3 Damage Mechanisms We Investigate

Equipment	Mechanisms
Coke oven	Refractory wear and spalling, oven-wall slump, ascension pipe corrosion, gas main fouling, by-product plant amine corrosion
Blast furnace	Hearth wear (the critical operating constraint), copper plate cracking, stove refractory degradation, downcomer cracking, gas-cleaning plant corrosion
BOF	Refractory wear, vessel-shell external corrosion, hood and off-gas duct erosion-corrosion
Continuous caster	Mould-copper-plate wear, segment bearing failure, oscillator drive-bearing fatigue, descaling-spray nozzle erosion
DRP reformer	Creep on radiant tubes (HK40, HP-Mod, HP-Nb), carburisation, nitriding, metal dusting, pigtail and manifold creep
Reheating furnace	Refractory degradation, skid-rail heat loss, recuperator fouling, scale formation on charge
Hot rolling	Roll bearing fatigue, mill-stand chock failure, roll-cooling spray erosion
Captive boiler	Boiler tube failure HTHA per `API 941`; creep

119.4 Standards Coverage Matrix

Steel Materials. ASTM A36 / A572 / A588 (structural); ASTM A516 / A537 (pressure-vessel plate); ASTM A335 / A213 (chrome-moly piping and tubes for captive power; cross-vertical); ASTM A572 (high-strength low-alloy structural); IS 2062 (structural steel for general construction); IS 1786 (high-strength deformed steel bars and wires for concrete reinforcement; cross-vertical with Civil and Pillar 1 BIS-accredited rebar capability); IS 1239 (steel tubes for structural and water purposes); IS 1875 (forging-grade carbon and alloy steel).

Refractory. ASTM C155 (insulating firebrick); ASTM C24 (refractory pyrometric cone equivalent); IS 8 (firebrick); IS 1528 (basic refractories).

Welding. ASME Section IX 2023; AWS D1.1 2025 (structural welding code, steel); AWS D1.5 (bridge welding); IS 7318 (welder qualification to Indian standards); EN ISO 9606 series.

FFS / RBI / RLA. API 579-1/ASME FFS-1 4th ed. (2021); BS 7910; API 580 / 581 4th ed. (January 2025).

Inspection Codes. API 510, 570, 653 (where pressure-vessel and tank scope is in play, cross-vertical with Refining and Power).

Composition. ASTM E1086, E415, E1019, E1479, E350-E353 series; IS 228 series; EN 10204 Type 2.2, 3.1, 3.2; SAE/ASTM Unified Numbering System (UNS) per the Casti Metals Red Book and Metals Black Book references; SAE ferrous and non-ferrous specifications.

11g.5 Service Applications Across the TCR Continuum

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

A steel plant is simultaneously a producer and a heavy consumer of integrity services. On the production side, the plant certifies its own product, and TCR's role is independent verification: mechanical, chemical, and metallurgical testing of primary steels to ASTM, EN, JIS, and IS specifications. On the asset side, the plant carries some of the harshest equipment duty in industry: blast furnace shells and stoves, basic oxygen furnace and electric arc furnace hoods, ladles and tundish structures, caster segments, reheating furnace tubes in creep service, rolling mill rolls and gearboxes, and direct reduced iron reformers running the same creep and carburisation mechanisms as fertiliser reformers. Shutdown windows are set by campaign life and relines; procurement risk sits in rolls, refractories, castings, and spares. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) for integrated, secondary, and direct reduction producers.

Stage One, Sourcing and Procurement. TCR qualifies rolls, castings, forgings, refractory anchor systems, and structural steel through mechanical, chemical, and metallurgical testing, runs vendor factory audits and original equipment manufacturer qualification for mill equipment, and verifies incoming ferroalloys, scrap-mix inputs, and consumables through the chemical analysis laboratory, with sample picking and loading supervision on high-value procurement.

Stage Two, Construction and Commissioning. During expansion projects, mill revamps, and furnace rebuilds, TCR provides baseline non-destructive testing on structural steel and pressure systems, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX and AWS D1.1, radiography and ultrasonic testing of critical welds, post-weld heat treatment, and positive material identification, so the rebuilt asset starts its campaign with a documented baseline.

Stage Three, In-Service. In operation, TCR deploys thermography of furnace shells, ladles, and torpedo cars for refractory hotspot detection, thickness monitoring of gas cleaning plant and ducting, remote visual inspection of stacks and confined spaces, and oxide scale and corrosion mapping on boiler and power block equipment in captive plants, with risk-based inspection planning per API RP 580 principles adapted to metallurgical plant equipment.

Stage Four, Shutdown and Turnaround. During relines, capital shutdowns, and mill stops, TCR inspects blast furnace shell welds, hood and lance systems, crane girders and structural members, reheating furnace tubes with in-situ metallographic replication, direct reduced iron reformer tubes with ARTiS (as deployed at Emirates Steel Industries on DRP1 and DRP2), and captive power boiler pressure parts, supported by turnaround inspection manpower.

Stage Five, Continuum. The engineering stage delivers failure analysis of rolls, gears, shafts, and furnace components, remaining life assessment of reheating furnaces, reformers, and captive boilers, fitness for service per API 579-1/ASME FFS-1 on pressure systems, structural stability assessment of ageing mill buildings and crane structures, and contract research including hydrogen-based direct reduced iron materials questions that carry the plant into low-carbon steelmaking.

11g.6 Named Clients

India Integrated Steel Producers. Tata Steel (Jamshedpur, Kalinganagar, Meramandali, Tata Steel Long Products), JSW Steel (Vijayanagar, Dolvi, Salem, Salav), Steel Authority of India (Bhilai, Bokaro, Rourkela, Durgapur, IISCO Burnpur), Rashtriya Ispat Nigam Limited (Visakhapatnam Steel Plant), Jindal Steel and Power (Raigarh, Angul), ArcelorMittal Nippon Steel India (Hazira), Vedanta ESL (Bokaro), Jindal Saw (Hisar, Mundra), Welspun (Anjar), MAN Industries.

India Specialty Steel. Mukund Limited, Sunflag Iron and Steel, Mahindra Sanyo Special Steel, Jayaswal Neco, Usha Martin (wire rod and special bar).

Captive Power within Steel (cross-vertical with Power). Tata Steel captive 405 MW (Jamshedpur), JSW Steel captive across multiple sites, SAIL captive across all integrated plants, Vedanta Aluminium Jharsuguda 4 x 600 MW IPP.

International. Emirates Steel Industries Abu Dhabi (DRP1 and DRP2 ARTiS, 2025), HADEED KSA, ALBA Bahrain, POSCO India.

EPC and Equipment OEMs. Larsen and Toubro, Tata Projects (the JSOL Coke Oven Battery 5 and 6 PWHT engagement; JSOL Blast Furnace 2 PWHT), Power Mech Projects (cross-vertical with Power), Danieli, SMS Group, Primetals Technologies.

On the steel and forging side, representative India clients include Bharat Forge, ArcelorMittal Nippon Steel India, Maharashtra Seamless, Investment and Precision Castings, Gala Precision Engineering, Dextra India, and Azad Engineering, with work across mechanical testing, metallography, chemical analysis, and failure analysis.

11g.7 Marquee Projects

Project	Service Anchor	Year
Emirates Steel Industries, Abu Dhabi	ARTiS reformer tube inspection, DRP1 and DRP2 (cross-vertical with Fertilisers)	2025
Tata Projects JSOL Coke Oven Battery 5 and 6	PWHT engagement	2023 to 2025
Jindal Saw, MAN Industries, Welspun	Source inspection and material certification on line-pipe production	Continuous
Statue of Unity, Larsen and Toubro	Mechanical, chemical, metallurgical, NDT through construction	Construction era
Aditya Birla Hindalco Dahej	Crane FEA stress analysis (December 2024); cross-vertical with non-ferrous metallurgical	December 2024

ARTiS inspects sponge-iron and direct-reduction reformer tubes from Bhilai to Abu Dhabi, and Welspun Maxsteel at Alibaug is among the in-situ metallography clients.

INDUSTRIES · SECTION 11H

Aerospace

SECTION 11H

11h. Aerospace

The **rocket-motor casing hardware for Chandrayaan-3**, India's moon landing, cleared TCR's bench with **no non-conformity observed**. TCR serves **ISRO, DRDO, NPCIL, HAL, MIDHANI and Bharat Forge**, and holds NADCAP AC7101 Materials Testing accreditation.

POTENTIAL FAILURES WE SERVICE

Cracking, fastener failures and process escapes in 7xxx and 2xxx aluminium, titanium and nickel-base flight hardware, forgings and rocket-motor casings. TCR investigates stress corrosion cracking, hydrogen embrittlement, low- and high-cycle fatigue, fracture-toughness shortfalls, inclusion and grain-size non-conformities, and verifies heat-treatment on NADCAP-route samples.

The rocket-motor casing hardware for Chandrayaan-3 cleared this bench with no non-conformity, and the bench holds NADCAP AC7101 Materials Testing accreditation, awarded 2026.

MARQUEE PROJECT

Rocket-motor casing hardware tested for the **Chandrayaan-3 moon mission** through Larsen and Toubro Defence for VSSC-ISRO, with no non-conformity observed.

11h.1 Industry Context

Indian aerospace has moved from promise to order book. HAL closed FY26 with orders of about Rs 2.54 lakh crore against annual revenue near Rs 33,000 crore, repair and overhaul alone contributed over Rs 20,000 crore of that revenue, and the FY26 defence budget of Rs 6.81 lakh crore earmarked more than Rs 1.1 lakh crore for domestic procurement. Every airframe, engine, and overhaul cycle in that pipeline pulls a supply chain behind it, and every supplier in that chain must prove material conformance through accredited testing. TCR serves the ecosystem with NABL ISO/IEC 17025 accredited mechanical, chemical, metallurgical, and fatigue testing, aerospace SCC programmes, and NADCAP AC7101 materials testing accreditation within the group through TCR Advanced Engineering.

The Indian aerospace and defence vertical sits at a structural inflection point. The Vande Bharat Mission for indigenisation of defence equipment, the Atmanirbhar Bharat framework on defence-vendor sourcing, the Indian Space Research Organisation's mature programme cadence (Chandrayaan-3 moon-mission success, Aditya-L1 solar mission, Gaganyaan crewed-flight programme, the LVM3 launch vehicle and the Reusable Launch Vehicle development), the Defence Acquisition Procedure 2020 with its emphasis on Indian-IDDM (Indigenously Designed, Developed and Manufactured) categorisation, and the export-oriented thrust under the Strategic Partnership model collectively expand the aerospace verification-testing surface area.

TCR's ISRO relationship runs back to Project ASLV, the Augmented Satellite Launch Vehicle programme, where the bench carried materials testing and earned ISRO's written appreciation. Set beside the Chandrayaan-3 rocket-motor casing work, the two engagements place TCR on both India's early launch-vehicle development and its lunar-mission hardware.

The buyer pool spans defence public-sector undertakings (HAL, BEL, BEML, BDL, MIDHANI, Bharat Forge), the Defence Research and Development Organisation (DRDO) and its laboratories (DMRL, DMSRDE, R&DE, NMRL the long-term contract), ISRO and its centres (VSSC, LPSC, SHAR, SAC), the Atomic Energy framework (NPCIL, BARC), private aerospace component manufacturers (Bharat Forge Aerospace, Tata Advanced Systems, Mahindra Aerostructures, Dynamatic Technologies), and the captive aerospace manufacturing programmes at HAL Bangalore, Nashik, and Koraput.

Hydrogen-fuelled aviation (cross-vertical with Refining and Fertilisers; expanded API 941 HTHA discipline and ASTM F519 / F1624 / API 20E hydrogen embrittlement bench) brings new material qualification scope. Sustainable Aviation Fuel (SAF) production at Indian refineries brings cross-vertical capex (Refining vertical, refinery efficiency block). Electric Vertical Take-Off and Landing (eVTOL) and the urban-air-mobility frame bring battery-cell mica thermal-insulation testing (cross-vertical with Automotive). Lightweight composite-aerostructure adoption brings ASTM D3039, D6641, D3479, D3518 testing scope. Rocket reusability programmes (ISRO Reusable Launch Vehicle, the LVM3 evolution) bring fatigue, CTOD, and re-qualification scope on heritage hardware.

11h.2 Plant Sections We Inspect

Cluster	Equipment / Material
Aerospace structural alloys	7xxx series aluminium (7050, 7075, 7150, 7475 wrought and forged); 2xxx series aluminium (2024, 2090, 2099, 2219); titanium alloys (Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo, Ti-15-3, Ti-10-2-3); nickel-base superalloys (Inconel 718, 625, Waspaloy, Rene 95); maraging steel; PH stainless (15-5 PH, 17-4 PH, A286); high-strength low-alloy steel (300M, 4340, 4330V)
Aerospace fasteners	NAS series, MS series, AN series; titanium fasteners; high-strength bolts under MIL-DTL-spec
Defence component	Forged shafts, gears, transmission housings, armour-grade rolled homogeneous armour (RHA) plate, naval-grade HSLA
Rocket motor and launch	Solid-rocket-motor casing hardware (the Chandrayaan-3 anchor), nozzle, igniter, propellant-grain interface, payload fairing structure
Satellite	Aluminium honeycomb panel, CFRP composite, optical-bench substrate (Invar 36)
Aero engine	Turbine disc, turbine blade, combustor liner, bearing component (cross-vertical with the Pillar 1 fatigue and fracture-toughness bench)
Naval	Submarine pressure-hull plate (HY-80, HY-100), surface-vessel hull plate (E36, EH36), naval-grade fastener

Cluster	Equipment / Material
Aircraft component	Landing-gear forging, wing-spar forging, fuselage frame
Heat-treatment verification	Hardness, microstructure, grain size, case depth, retained austenite, mechanical properties on samples submitted by NADCAP-accredited heat treaters

11h.3 Damage Mechanisms We Investigate

Category	Mechanisms
Aerospace SCC	Stress corrosion cracking on 7xxx and 2xxx aluminium per `ASTM G47` (alternate immersion) and `ASTM G44` (cyclic immersion); chloride-induced SCC on stainless
Hydrogen embrittlement	Internal hydrogen embrittlement on plated and coated fasteners (`ASTM F519`, `ASTM F1624` incremental step-load, `API 20E)`; environmental hydrogen embrittlement
Fatigue	Low-cycle fatigue per `ASTM E606`; high-cycle fatigue per `ASTM E466`; fatigue crack growth rate per `ASTM E647`; turbine-disc burst margin
Fracture toughness	K1c per `ASTM E399`; J1c per `ASTM E1820`; CTOD per `BS 7448`
Creep and thermal	Creep on turbine-disc and combustor liner alloys; thermal-mechanical fatigue
Microstructural	Inclusion rating per `ASTM E45`, grain size per `ASTM E112`, retained austenite per `ASTM E975`, decarburisation depth per `ASTM E1077`
Corrosion	Pitting (`ASTM G48)`, intergranular (`ASTM A262` for stainless), galvanic (`ASTM G71)`, salt-spray (`ASTM B117)`, exfoliation per `ASTM G34` (aluminium)
Heat-treatment verification	Hardness traverse, case-depth profiling per SAE J423, retained austenite, microstructure characterisation per AMS 2750, AMS-H-6875

11h.4 Standards Coverage Matrix

NADCAP / Aerospace Materials. SAE Aerospace Material Specifications (AMS) series; SAE AMS 2750 Pyrometry (heat-treatment process specification); SAE AMS-H-6875 (heat treatment of steel raw material); SAE J423 (case-depth methods); MIL-DTL-spec series (US military fastener and material specifications); ASTM E18, E10, E92, E384 (hardness); ASTM E112 (grain size); ASTM E407 (etching); ASTM E45 (inclusion rating); ASTM E1077 (decarburisation depth).

Aerospace SCC. ASTM G47 (alternate immersion stress corrosion cracking); ASTM G44 (alternate immersion procedure); ASTM G34 (exfoliation corrosion of 7xxx and 2xxx aluminium).

Hydrogen Embrittlement. ASTM F519 (mechanical hydrogen embrittlement, plated and coated fasteners); ASTM F1624 (incremental step-load); API 20E (alloy and carbon steel bolting for use in the petroleum and natural gas industries; also applicable to defence-vendor frameworks).

Aerospace Prime Specifications. Boeing BAC, Airbus AIPS, Pratt & Whitney PWA, GE EM&S, Rolls-Royce RPS (where relevant under heat-treatment verification scope).

Fatigue and Fracture. ASTM E466, E606, E647, E399, E1820, E1290, E561; BS 7448; ISO 12108; API 5L3.

Composite. ASTM D3039 (tensile properties of composite materials); ASTM D6641 (compressive properties of composites); ASTM D3479 (tension-tension fatigue of composites); ASTM D3518 (in-plane shear of composites).

Defence-Specific. Indian defence specifications (JSS, Naval, Air Force material specifications); CEMILAC framework (Centre for Military Airworthiness and Certification); CQAE empanelment for defence-vendor evaluation.

11h.5 Service Applications Across the TCR Continuum

Aerospace does not run shutdowns; it runs qualification gates. The five-stage Continuum therefore adapts to the component lifecycle: material qualification, process verification, production surveillance, maintenance-repair-overhaul inspection, and failure analysis with life assessment. The recurring problems are raw material pedigree in a supply chain where a mis-certified bar can ground a programme, heat treatment verification for aerospace heat treaters, hydrogen embrittlement and stress corrosion cracking of high-strength fasteners and landing gear steels, and fatigue as the governing failure mode of nearly everything that flies. TCR Advanced Engineering holds NADCAP AC7101 Materials Testing accreditation, and TCR Engineering's own NADCAP AC7101 accreditation was awarded in 2026; together the group serves the aerospace, space, and defence ecosystem across this adapted lifecycle.

Stage One, Material Qualification (Sourcing and Procurement). Raw material entering aerospace production is verified against AMS, ASTM, and programme specifications: tensile testing per ASTM E8/E8M including elevated temperature per ASTM E21, hardness, chemical analysis by optical emission spectrometry and X-ray fluorescence, microstructure and grain size per ASTM E112, inclusion rating per ASTM E45, and fastener testing, with vendor audits and sample picking on bar, plate, forging, and casting supply.

Stage Two, Process Verification (Construction Equivalent). Manufacturing processes are qualified rather than constructed: heat treatment verification testing for aerospace heat treaters, the core of the NADCAP AC7101 verification scope, weld and braze procedure qualification, case depth and decarburisation measurement, residual stress determination by X-ray diffraction, and coating and plating evaluation including hydrogen embrittlement relief verification.

Stage Three, Production Surveillance (In-Service Equivalent). Through the production run, TCR provides batch and lot conformance testing, periodic requalification of processes, stress corrosion cracking testing of aerospace alloys (Section 4.7.7), and third-party witness of acceptance testing, giving primes and their suppliers an independent laboratory signature on continuing conformance.

Stage Four, Maintenance, Repair, and Overhaul (Shutdown Equivalent). For operators and maintenance-repair-overhaul shops, TCR supports component inspection during overhaul: non-destructive testing by penetrant, magnetic particle, ultrasonic, and radiographic methods, metallurgical evaluation of service-exposed parts, and hardness and conductivity verification after repair heat treatment.

Stage Five, Failure Analysis and Life Assessment (Continuum). When a component fails or a life extension is contemplated, TCR delivers failure analysis with scanning electron microscopy fractography, fatigue and fracture toughness testing per ASTM E466, ASTM E606, ASTM E399, and ASTM E1820 including sub-zero temperature programmes for defence and naval aviation work, and the materials research that supports indigenisation of aerospace components under Indian defence procurement preference.

11h.6 Named Clients

ISRO and Space. ISRO (Indian Space Research Organisation) headline appreciation for Project ASLV; VSSC (Vikram Sarabhai Space Centre) for the Chandrayaan-3 rocket motor casing hardware engagement (delivered through the Larsen and Toubro Defence IC); LPSC (Liquid Propulsion Systems Centre); SHAR (Satish Dhawan Space Centre); SAC (Space Applications Centre).

DRDO and Atomic Energy. Defence Research and Development Organisation (DRDO) across multiple laboratories; DMRL (Defence Metallurgical Research Laboratory); DMSRDE; R&DE; NMRL (Naval Materials Research Laboratory; long-term contract); NPCIL (Nuclear Power Corporation of India Limited) for elevated-temperature tensile and pressure-boundary qualification; BARC (Bhabha Atomic Research Centre); Heavy Water Projects.

Defence Public-Sector Undertakings. HAL (Hindustan Aeronautics Limited; Bangalore, Nashik, Koraput, Lucknow); BEL (Bharat Electronics Limited); BEML; BDL (Bharat Dynamics Limited); MIDHANI (Mishra Dhatu Nigam Limited); Bharat Forge (defence forging division); Tata Advanced Systems Limited; Mahindra Aerostructures; Dynamatic Technologies; Walchandnagar Industries.

Defence-Adjacent EPC and OEM. Larsen and Toubro Defence IC (the VSSC-ISRO Chandrayaan-3 anchor); Tata Advanced Systems Limited; Reliance Aerostructure; Naval shipyards (Mazagon Dock, Garden Reach, Goa Shipyard, Cochin Shipyard, Hindustan Shipyard; cross-vertical with Marine and Offshore).

Private Aerospace Suppliers. SQuAD Forging (the aerospace SCC ASTM G47/G44 anchor); Bharat Forge Aerospace; Anand Group; Sansera Engineering; Arjas Steel.

Empanelment. CQAE (Centre for Quality Assurance for Electronics; defence vendor framework); CEMILAC framework reach where applicable.

The aerospace and defence base centres on precision-component and forging suppliers to the space and defence programmes: MTAR Technologies, the Vikram Sarabhai Space Centre, Sri Venkateswara Aerospace, Gemsons Precision Engineering, Shalco Industries, Bhukhanvala Industries, SE Forge, Walchandnagar Industries, and Bharat Aerospace Metals. The work runs to mechanical and metallurgical testing, fracture and fatigue testing, and qualification of flight- and mission-critical materials, and is the home of the NADCAP AC7101 Materials Testing programme.

11h.7 Marquee Projects

Project	Service Anchor	Year
Larsen and Toubro Defence IC for VSSC-ISRO	Rocket Motor Casing Hardware testing for the Chandrayaan-3 moon mission	2023
ISRO Project ASLV	Materials testing appreciation	Multiple
DRDO/NMRL	Long-term contract for naval materials testing	Continuous
NPCIL	Elevated-temperature tensile (300/500/800 °C protocol; cert dated 6 December 2013, returned in service 2025-26)	2013 to 2026
SQuAD Forging	Aerospace SCC `ASTM G47/G44` on 7xxx and 2xxx aluminium	2025 to 2026
HAL Bangalore, Nashik, Koraput, Lucknow	Materials testing, NDT, source inspection	Continuous
MIDHANI Hyderabad	Special-alloy materials testing and certification	Continuous
Bharat Forge (defence and aerospace forging)	Forging-grade material testing, hardness verification, microstructural evaluation	Continuous
Tata Advanced Systems Limited	Aerospace component materials testing	Continuous

INDUSTRIES · SECTION 11I

Railways

SECTION 11I

11i. Railways

India's first bullet train, the **Mumbai-Ahmedabad High Speed Rail**, and nearly every metro system in the country, **Mumbai, Delhi, Bangalore, Chennai, Hyderabad and Pune**, run their materials and NDT scope through TCR, alongside the **Dedicated Freight Corridor** and the **Haramain High Speed Rail** in Saudi Arabia.

POTENTIAL FAILURES WE SERVICE · FOR REVIEW

Rail and weld failures, wheel and axle fatigue, viaduct and bearing deterioration. TCR investigates rolling-contact fatigue, head checking and squats, flash-butt and thermite weld defects, high-tensile-strand stress corrosion cracking, prestress loss, and bridge-bearing and expansion-joint wear across track, rolling stock and structures.

India's first bullet train and nearly every metro system in the country run their materials and NDT scope through TCR, from HT strand and rebar couplers to flash-butt welds and viaduct bearings.

MARQUEE PROJECT

Mumbai-Ahmedabad High Speed Rail, **India's first bullet train**: HT strand, coupler, concrete, and soil testing to NHSRCL specification across Packages C1 to C3.

11i.1 Industry Context

Indian Railways is running the largest safety-led capital programme in its history. The FY26 outlay stands at Rs 2,52,200 crore, with safety-related expenditure budgeted at Rs 1,16,514 crore covering track renewals, bridges, road over bridges, level crossings, and the Kavach train protection rollout. Safety spend of that order is, at its core, materials assurance spend: every rail weld, casting, coupler, and bridge member has to be proven against RDSO and IS requirements before it carries traffic. TCR has served that proof chain for decades, running rail-weld fatigue programmes to RDSO IRS:T-19 out to five million cycles, testing couplers and components to IS 16172, and inspecting railway bridges and structures in the field.

The Indian railway sector is in the deepest capex cycle in its history.

The Mumbai-Ahmedabad High Speed Rail (MAHSR), India's first bullet-train corridor, is in active execution under the National High Speed Rail Corporation Limited (NHSRCL) with three civil EPC packages (C1, C2, C3) running in parallel through MEIL-HCC, Afcons, and Larsen and Toubro joint ventures.

The Vande Bharat semi-high-speed rolling-stock programme has expanded to multiple corridors; the dedicated freight corridor (Eastern DFC and Western DFC) is in operating phase; metro-rail capex is active across approximately 30 Indian cities; and conventional Indian Railways modernisation (track renewal, electrification, station redevelopment).

The GCC orbit covers the Haramain High Speed Rail (Mecca-Medina, KSA; cross-vertical with TCR Arabia delivery), the Riyadh Metro, the Dubai Metro, and the Doha Metro programmes.

Railway electrification and the shift to 25 kV AC traction across the Indian network reduces diesel emissions but increases AC interference scope on adjacent cathodic protection systems on parallel pipelines (cross-vertical with Pipelines and CGD). Hydrogen-fuelled rail (the Indian Railways hydrogen-train demonstrator) brings cross-vertical hydrogen embrittlement and storage scope. Battery-traction multiple units (where deployed on un-electrified branch lines) bring battery-cell qualification scope (cross-vertical with Automotive). The HSR-driven concrete-and-rebar capex pulls civil-testing volume into the multi-decade fleet.

TCR is the materials-testing and NDT bench for the HSR programme (the MAHSR three-package civil EPC engagement), the metro-rail rollout (Mumbai, Delhi, Bangalore, Chennai, Hyderabad, Pune), and the conventional Indian Railways modernisation calendar.

11i.2 Plant Sections We Inspect

Cluster	Equipment / Material
Track	Rail (UIC 60, Indian Railways IRS T-12), sleeper (PSC concrete), fastener system (Pandrol, fast-clip), ballast, sub-grade
HSR-Specific	Slab track (slab-on-mat or slab-on-asphalt), high-speed turnout, expansion joint, flash-butt welded long rail, thermite welded joint
Bridges and Viaducts	Box girder (segmental concrete), composite girder (steel-concrete), cable-stayed and arch structures, bearings (POT-PTFE, elastomeric, spherical), expansion joint
HT Strand and Tendons	High-tensile strand (`IS 14268`, `ASTM A416`) for prestressed concrete sleepers and viaduct girders
Tunnel	NATM and TBM tunnel lining, segmental lining, waterproofing membrane, drainage system
Station and Depot	Reinforced-concrete shells, steel canopy, depot maintenance pit, gantry rail
Rolling Stock	Wheel forging, axle forging, bogie frame, suspension component, brake rigging, traction motor mount, body shell

11i.3 Damage Mechanisms We Investigate

Category	Mechanisms
Rail	Rolling contact fatigue, shelling, head checking, squat, internal flaw (transverse and longitudinal), wear
Wheel and axle	Surface fatigue, thermal cracking from braking, shelling, tread wear, axle bending fatigue

Category	Mechanisms
Bridge / viaduct	Reinforcement corrosion (cross-vertical with Civil Section 8), HT strand stress corrosion cracking, bearing wear, expansion joint deterioration, prestressed concrete creep and shrinkage
Welded joint	Flash-butt weld fusion defect, thermite weld porosity, HAZ embrittlement
Track foundation	Sub-grade settlement, ballast contamination, drainage failure
Slab track	Slab cracking, mat fatigue, asphalt rutting under cyclic load
Rolling-stock fastener	Hydrogen embrittlement, fatigue

11i.4 Standards Coverage Matrix

HSR-Specific. Japanese Shinkansen specifications (cross-referenced under MAHSR via the JICA-funded scope); UIC 60 (international rail profile); EN 13674 (European rail-steel grades); IS 11682 (Indian Railways rail steel grades); EN 14587 (flash-butt welding of rails); IS 5950 (thermite welding of rails).

HT Strand and Tendons. IS 14268 (uncoated stress-relieved low-relaxation seven-ply strand for prestressed concrete); ASTM A416 (steel strand, uncoated seven-wire for prestressed concrete); EN 10138 (prestressing steels); IS 2090 (high-tensile steel bars used in prestressed concrete).

TMT Rebar and Couplers (cross-vertical). IS 1786 (TMT rebar); IS 16172 (rebar couplers; the BIS-accredited first-in-India anchor); ACI 318; ASTM A615.

Concrete (cross-vertical with Civil). IS 456 (plain and reinforced concrete code of practice); IS 1343 (prestressed concrete code of practice); IS 516 (Part 5/Sec 1) (UPV) and IS 516 (Part 5/Sec 4) (rebound hammer); ASTM C39, C496, C617.

Bridge. IRC SP 35, IRC SP 18, IRC SP 40 (bridge inspection and rehabilitation); BS 5400; AASHTO LRFD Bridge Design Specifications.

Welding. ASME Section IX 2023; AWS D1.1 2025; AWS D1.5 (bridge welding code); IS 7318 (welder qualification).

Indian Railways and IRSE. Indian Railway Standard (IRS) specifications; Research Designs and Standards Organisation (RDSO) specifications; Institution of Railway Signal and Telecommunication Engineers (IRSE) framework; Commissioner of Railway Safety (CRS) inspection regime.

Tunnel. IS 4880 (criteria for design of tunnels conveying water); EN 1990 (Eurocode basis of structural design); FHWA Tunnel Design Guidelines.

11i.5 Service Applications Across the TCR Continuum

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

Indian railways, metro systems, and the high-speed rail programme buy integrity across two distinct asset families: rolling assets (rail, wheelsets, axles, couplers, coach and wagon components) and fixed infrastructure (bridges, viaducts, station structures, overhead equipment masts). The recurring problems are rolling contact fatigue and weld failure in rail, fatigue of bogie components, corrosion of ageing riveted and welded bridges, and the sheer scale of the bridge inspection backlog, which is why TCR's 500+ bridge record matters to zonal railways and metro operators alike. The maintenance block is the railway's turnaround: possession windows are short, night-bound, and unforgiving. Procurement risk concentrates in rail steel, fastening systems, couplers, and structural steel quality. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) across both asset families.

Stage One, Sourcing and Procurement. Rail steel is qualified through fatigue crack growth rate testing per EN 13674 and ISO 12108, the programme TCR has run for Jindal Steel and Power rail supply, alongside tensile, hardness, and impact testing, chemical analysis, and microstructural evaluation. Reinforcement couplers and mechanical splices for viaduct construction are tested per IS 16172 and ISO 15630 under the BIS-accredited coupler programme, and fastening systems, elastomeric pads, and structural steel are verified against Indian Railway Standard and RDSO specifications, with vendor audits and sample picking.

Stage Two, Construction and Commissioning. On new corridors, metro viaducts, and station structures, TCR provides construction-stage quality assurance: welding procedure and welder qualification including thermit and flash-butt rail weld evaluation, radiography and ultrasonic testing of structural welds, concrete testing per IS 516, non-destructive concrete evaluation by ultrasonic pulse velocity per IS 516 (Part 5/Sec 1) and rebound hammer per IS 516 (Part 5/Sec 4), theodolite-based plumbness surveys on piers, and baseline records for every structure.

Stage Three, In-Service. In service, TCR delivers bridge inspection programmes drawing on the Federal Highway Administration Bridge Inspector's Reference Manual methodology and Indian Railways bridge codes, corrosion assessment of steel girders and overhead equipment masts, ground penetrating radar and subsurface mapping around foundations, and thermography of traction and electrical systems, structured so zonal railways and metro operators can prioritise the backlog by condition rather than age alone.

Stage Four, Maintenance Blocks (Shutdown and Turnaround). Inside possession windows and workshop periodical overhauls, TCR provides non-destructive testing of axles, wheelsets, and coupler components by ultrasonic, magnetic particle, and penetrant methods, weld inspection on repaired girders, load testing support for strengthened spans, and component testing for workshops, sequenced to block timings so traffic resumes on schedule.

Stage Five, Continuum. Findings feed failure analysis of rails, axles, springs, and bridge components, fatigue life assessment of rolling stock and structural details, residual life certification of ageing bridges, structural stability assessment of station buildings and workshops, and engineering design review for strengthening and rehabilitation schemes, closing the loop back into the next procurement specification.

11i.6 Named Clients

India High Speed Rail. National High Speed Rail Corporation Limited (NHSRCL); MAHSR civil EPC: MEIL-HCC (Package C1), Afcons (Package C2), Larsen and Toubro (Package C3); NHSRCL VMAC Meeting No. 13 dated October 23 2023 sets the materials and NDT scope.

India Metro Rail. Mumbai Metro Rail Corporation (MMRCL), Delhi Metro Rail Corporation (DMRC), Bangalore Metro Rail Corporation Limited (BMRCL), Chennai Metro Rail Limited, Kolkata Metro, Hyderabad Metro, Pune Metro, Nagpur Metro, Lucknow Metro, Jaipur Metro, Kochi Metro, Ahmedabad Metro, Surat Metro.

Indian Railways and DFCC. Indian Railways (Centre for Railway Information Systems CRIS, Research Designs and Standards Organisation RDSO, Northern, Western, Central, Southern, Eastern, South Central Railway zones); Dedicated Freight Corridor Corporation of India Limited (DFCCIL).

India Mass Transit and Light Rail. RITES (PSU consultancy and PMC); Mumbai Metropolitan Region Development Authority (MMRDA); CIDCO (Maharashtra empanelment for materials testing); Mumbai Coastal Road Project (cross-vertical reference).

India EPC and Component Manufacturers. Larsen and Toubro Construction; Afcons Infrastructure; HCC; MEIL; Tata Projects; Hindustan Construction Company; Patel Engineering; SAIL Bhilai (rail steel); Tata Steel and JSW Steel (structural sections; cross-vertical with Steel); Jindal Saw and MAN Industries (cross-vertical with Pipelines for HT strand-grade wire rod).

International HSR. Haramain HSR (Mecca-Medina, KSA; TCR Arabia delivered ultrasonic testing and NDT services).

11i.7 Marquee Projects

Project	Service Anchor	Year
Mumbai-Ahmedabad High Speed Rail (NHSRCL Packages C1, C2, C3)	Civil testing under MEIL-HCC, Afcons, Larsen and Toubro; HT strand; rebar coupler; concrete; soil; HSR-spec materials per NHSRCL VMAC Meeting No. 13	October 2023 onward
Haramain High Speed Rail, KSA	TCR Arabia delivered ultrasonic testing and NDT services	Construction era
Mumbai Metro Rail (MMRCL)	Materials testing, NDT, structural-steel verification	Continuous
Mumbai Coastal Road Project (cross-vertical reference)	Civil testing, sub-water bridge-pier inspection	Continuous
500+ Bridges Maharashtra PWD	Robotic NDT, structural audit	Continuous

On the Mumbai-Ahmedabad High Speed Rail corridor, TCR is engaged across all three civil packages (MEIL-HCC, Afcons, and Larsen and Toubro) under NHSRCL VMAC No. 13 dated 23 October 2023, covering concrete, reinforcement, structural steel, and track materials. Rail-weld qualification runs to RDSO IRS:T-29 and IRS:T-19, with flash-butt and aluminothermic welds taken to 5 million cycles. High-tensile strand for high-speed-rail viaducts and prestressed bridge decks is qualified for tensile, stress-relaxation, and 2 million-cycle fatigue per IS 14268, ASTM A416, and ISO 15630-3.

INDUSTRIES · SECTION 11J

Infrastructure

SECTION 11J

11j. Infrastructure

500-plus bridges assessed for Maharashtra PWD and a **400-plus-bridge robotic underwater inspection programme** for BMC, plus the **Statue of Unity**, the world's tallest statue, tested through construction with L&T.

POTENTIAL FAILURES WE SERVICE

Bridge, flyover and highway-structure distress, foundation settlement, and corrosion in ageing reinforced concrete. TCR investigates carbonation- and chloride-induced reinforcement corrosion, prestress-tendon stress corrosion cracking and grout voids, fatigue at steel connections, bearing and expansion-joint failure, and delivers robotic and underwater bridge inspection with structural audit.

500-plus bridges assessed for Maharashtra PWD, a 400-plus-bridge robotic underwater inspection programme for BMC, and the Statue of Unity tested through construction; this is the bench India's infrastructure ages into.

MARQUEE PROJECT

500-plus bridges assessed for Maharashtra PWD through robotic NDT, structural audit, and rehabilitation engineering.

11j.1 Industry Context

Infrastructure spending has reached a scale where asset condition is an investment-grade question. NHAI recorded its highest-ever capital expenditure of about Rs 2.5 lakh crore in FY25 and monetised Rs 28,724 crore of built assets through InvIT and toll-transfer structures in the same year. Monetisation changes the inspection equation: institutional investors buying twenty-year concessions demand independent, documented evidence of structural condition, not the builder's assurance. TCR provides that evidence layer, with **more than 500 bridges** inspected including underwater robotic scope, statutory structural audits, GPR and UPV subsurface mapping, pavement evaluation, and NABL-accredited materials testing that stands behind every number reported.

The Indian infrastructure capex programme runs to approximately INR 1.7 trillion across FY24-30 under the National Infrastructure Pipeline framework.

The Ministry of Road Transport and Highways carries the National Highways Authority of India (NHAI) capex (~12,000 km of national-highway construction per year at peak), the Bharatmala Pariyojana programme, and a steady backlog of bridge and ROB/RUB construction. The state highways and rural roads programme (Pradhan Mantri Gram Sadak Yojana) continues.

Urban infrastructure (metro rail covered under Section 11i; municipal roads, water supply, sewerage, street lighting; structural audit under Section 353B of the Mumbai Municipal Corporation Act 1888) carries the city-government buyer pool.

The flagship monumental construction programme (Statue of Unity, Statue of Oneness) brings capex-grade materials and NDT testing scope.

Solar-PV mounting structures on highway-corridor land brings structural-steel testing for module-mounting structures (cross-vertical with Civil and Steel). Electric-vehicle charging-station infrastructure on national highways brings small-cell foundation engineering and electrical-asset structural verification (cross-vertical with Automotive). The Indian Government's hydrogen-fuel-station rollout for hydrogen-fuelled trucking on the highway corridor brings cross-vertical hydrogen-storage and pressure-vessel scope (cross-vertical with Pipelines and Refining). The shift from diesel-traction railway crossings to electrified crossings reduces ROB / RUB structural-load profiles. The growing climate-resilience capex (flood-resistant bridge design, scour-mitigation engineering) brings sub-water bridge-pier inspection volume.

The strategic positioning carries: TCR is the materials-testing, NDT, and structural-audit bench for the Indian infrastructure capex pipeline, with the 500+ bridge book of work as the proof point and the BMC March 2026 robotic underwater 400+ programme as the next-generation anchor.

11j.2 Plant Sections We Inspect

Cluster	Equipment / Material
National Highway and Expressway	Pavement (flexible bituminous, rigid concrete), embankment, sub-grade, cross-drainage works
State and District Road	Pavement, ROB / RUB, culvert, side drain
Bridges and Viaducts	Box girder (segmental and cast-in-place), composite girder, cable-stayed and arch, prestressed concrete sleepers and girders, bearings, expansion joints, deck slabs
Sub-water bridge	Bridge pier (concrete and steel tubular), abutment, intake structure, jetty pile (cross-vertical with Marine Section 11f and the BMC robotic underwater 400+ programme)
Tunnel	NATM and TBM, segmental lining, waterproofing membrane, drainage system
Monumental Construction	Reinforced-concrete shell, steel cladding, structural-steel core, foundation engineering
Structural Audit	Buildings older than 30 years (Section 353B, Mumbai Municipal Corporation Act 1888), heritage structures, industrial sheds, gantry rails, plant buildings (cross-vertical with Civil Section 8)
Drainage and Civic Infrastructure	Manhole and gully top per `BS EN 124-5` up to 900 mm; sewer; storm-water drain
Urban Civic Asset	Reinforced-concrete water tank, elevated service reservoir (ESR), ground service reservoir (GSR), pumping-station shell

Cluster	Equipment / Material
Stadium and Public Building	Reinforced-concrete shell, steel canopy, foundation, post-tensioned slabs

11j.3 Damage Mechanisms We Investigate

Category	Mechanisms
Pavement	Rutting, cracking, raveling, pothole, shoving, longitudinal cracking, transverse cracking, alligator cracking
Bridge concrete	Reinforcement corrosion (carbonation-driven, chloride-driven), prestress loss, alkali-silica reaction (ASR), delayed ettringite formation (DEF), creep and shrinkage, freeze-thaw
Bridge steel	HAZ embrittlement, weld toe cracking, fatigue at riveted connections, corrosion under coating, thermal-cycling fatigue at expansion joints
Bearing	Wear, corrosion, frozen bearing, neoprene ageing, PTFE wear
Building structural audit	Reinforcement corrosion, concrete spalling, plaster delamination, settlement-induced cracking, slab punching shear, beam-column joint deterioration
Sub-water bridge	Splash-zone corrosion, submerged-zone corrosion, scour-induced settlement
Drainage	Manhole and gully top fatigue, sewer line corrosion, sub-grade settlement at trench reinstatement

11j.4 Standards Coverage Matrix

Bridge. IRC SP 35 (inspection and maintenance of bridges); IRC SP 18 (inventory and condition survey); IRC SP 40 (rehabilitation of bridges); IRC 6 (loads and load combinations on bridges); IRC 22 (composite construction); IRC 78 (foundations and substructures); BS 5400; AASHTO LRFD Bridge Design Specifications; Load Testing of Bridges, Eva Lantsoght (2019); FHWA Bridge Inspector's Reference Manual (2022).

Pavement and Road. IRC 37 (flexible pavement design); IRC 58 (rigid pavement design); IS 73 (paving bitumen); IS 1203 (penetration), IS 1206 (viscosity); IRC SP 53 (modified bitumen); MoRTH Specifications for Road and Bridge Works.

Concrete (cross-vertical). IS 456; IS 1343 (prestressed); IS 516 (Part 5/Sec 1) (UPV); IS 516 (Part 5/Sec 4) (rebound hammer); ASTM C39, C496, C617, C876 (half-cell potential), C1383 (impulse-echo); ACI 318, ACI 224 (cracking).

Reinforcement and HT Strand. IS 1786; IS 14268; ASTM A615, A416; ACI 318.

Structural Steel. IS 800 (general construction in steel); IS 1893 (criteria for earthquake-resistant design); AISC 360; AWS D1.1 (structural welding); AWS D1.5 (bridge welding).

Tunnel. IS 4880 (criteria for design of tunnels conveying water); EN 1990 (Eurocode); FHWA Tunnel Design Guidelines.

Drainage. BS EN 124-5 (manhole and gully top fatigue); IS 3597 (manhole covers).

Structural Audit (cross-vertical with Civil Section 8.5). Section 353B of the Mumbai Municipal Corporation Act 1888; Section 265A of the Maharashtra Municipal Corporations Act 1949; BIS guidance.

Grout Fatigue. CEB-FIP Model Code 1990 / 2010 (the first-in-India lab capability anchor).

11j.5 Service Applications Across the TCR Continuum

For infrastructure, the Continuum adapts from the process-plant frame to the built-asset lifecycle: materials qualification, construction quality assurance, in-service condition assessment, repair and rehabilitation, and residual life engineering. The recurring problems are chloride-induced reinforcement corrosion in coastal structures, alkali-aggregate and sulphate attack, carbonation of ageing concrete, foundation settlement, and the structural distress that accumulates silently until a structural audit under Section 353B of the Mumbai Municipal Corporation Act 1888 forces the question. The rehabilitation window is this vertical's turnaround: traffic diversions and occupancy constraints price every day. Procurement risk sits in cement, aggregate, reinforcement, coupler, and bitumen quality across a fragmented supply base. TCR Engineering services all five adapted stages, anchored by one of the largest NABL-accredited civil testing operations in Western India.

Stage One, Materials Qualification (Sourcing and Procurement). Construction materials are qualified at intake: cement per IS 4031, aggregates per IS 2386, concrete mix design support, TMT reinforcement per IS 1786, reinforcement couplers per IS 16172 under the BIS-accredited programme, structural steel, bitumen and road materials, soil and geotechnical investigation, and water quality for construction, with sampling by the TCR-branded free pickup van across the Mumbai Metropolitan Region.

Stage Two, Construction Quality Assurance (Construction and Commissioning). During construction, TCR provides cube and core testing per IS 516, non-destructive concrete evaluation by ultrasonic pulse velocity per IS 516 (Part 5/Sec 1) and rebound hammer per IS 516 (Part 5/Sec 4), welding inspection of structural steel per IS 800 and AWS D1.1, theodolite-based plumbness and straightness surveys on towers and piers, anchor and fastener pull-out testing, and pavement evaluation on road projects, building the baseline record for the asset.

Stage Three, In-Service Condition Assessment. On operating assets, TCR delivers structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888, bridge inspection per Indian Roads Congress codes and the Federal Highway Administration Bridge Inspector's Reference Manual methodology, half-cell potential and carbonation surveys for reinforcement corrosion, ground penetrating radar and subsurface mapping, and thermography of building services, converting visual distress into measured condition.

Stage Four, Repair and Rehabilitation (Shutdown and Turnaround Equivalent). In the rehabilitation window, TCR supports distress mapping and repair specification, cathodic protection of reinforced concrete (Section 8.10), load testing of strengthened members, quality assurance on repair materials including micro-concrete and grouts, and post-repair verification by the same non-destructive methods that found the distress, so the intervention is proven, not assumed.

Stage Five, Residual Life Engineering (Continuum). The engineering stage delivers residual life assessment of structures, structural stability certification, failure and collapse investigation, engineering design review of strengthening schemes, and the durability studies, chloride profiles, mix optimisation, and coating evaluation, that feed the specification for the next asset.

11j.6 Named Clients

India Government and PSU. National Highways Authority of India (NHAI); Ministry of Road Transport and Highways (MoRTH); Public Works Department (Maharashtra PWD anchor; the 500+ bridge programme); Brihanmumbai Municipal Corporation (BMC; Roads Department registration March 2026 onward, plus the AI-assisted underwater 400+ bridge programme); Mumbai Metropolitan Region Development Authority (MMRDA); CIDCO; Pune Municipal Corporation; Greater Mumbai Civic body framework; State PWDs (Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Madhya Pradesh, Rajasthan, West Bengal, Odisha); Indian Roads Congress (IRC) standards interface; RITES (PSU consultancy).

India EPC. Larsen and Toubro Construction; Afcons Infrastructure; HCC; Patel Engineering; J. Kumar Infraprojects; Tata Projects; IL&FS Engineering; Reliance Infrastructure; Dilip Buildcon; PNC Infratech; KNR Constructions.

India Real Estate (cross-vertical with Construction). Godrej Properties (3-year LRC, all Mumbai Zone, April 2026 onward), Kalpataru, Shapoorji Pallonji, Rustomjee, Lodha, Oberoi, K. Raheja, DLF, Prestige, Brigade.

India Monumental Construction Anchors. Larsen and Toubro for Statue of Unity (Sardar Vallabhbhai Patel); Adi Shankaracharya Statue of Oneness (Madhya Pradesh); Antilia (Mumbai); Wankhede Stadium redevelopment.

International (cross-vertical reference). Haramain HSR (Mecca-Medina; Section 11i); Master Gas System bridges and crossings (Section 11d).

Civil and infrastructure clients span construction majors, bridge and metro builders, and the railways: Afcons Infrastructure, Hindustan Construction Company, J. Kumar Infraprojects, Kalpataru, Shapoorji Pallonji, Patel Engineering, the U.P. State Bridge Corporation, and Bridge and Roof; on the cement and concrete side JSW Cement, UltraTech, and Heidelberg Cement; and on the railway side RITES, Mumbai Metro One, and the Municipal Corporation of Greater Mumbai. The scope covers structural audit, concrete and building-material testing, high-tensile strand and rebar-coupler qualification, and bridge NDT.

11j.7 Marquee Projects

Project	Service Anchor	Year
500+ Bridges Maharashtra PWD	Robotic NDT, structural audit, rehabilitation recommendation	Continuous
BMC March 2026 robotic underwater bridge programme	400+ bridges, AI-assisted underwater inspection	March 2026 onward
Statue of Unity, Larsen and Toubro	Mechanical, chemical, metallurgical, NDT through construction	Construction era
Statue of Oneness, Adi Shankaracharya	Conventional NDT for structural fabrication	Multiple
Mumbai Coastal Road Project	Civil testing, sub-water bridge-pier and abutment inspection (cross-vertical with Marine and Civil)	Continuous
Godrej Properties 3-year LRC, all Mumbai Zone	Long-Term Rate Contract for materials testing across Godrej properties	April 2026 onward
Kalpataru, Shapoorji Pallonji, Rustomjee	Long-Term Rate Contracts for property-development testing	Continuous

At the Statue of Unity, TCR carried the mechanical, chemical, metallurgical, and non-destructive verification through construction. High-tensile strand for prestressed bridge decks, Mumbai and Pune flyovers, and high-speed-rail viaducts is qualified for tensile, stress-relaxation, and 2 million-cycle fatigue per IS 14268, ASTM A416, and ISO 15630-3. The bridge record runs to more than 500 structures inspected across India.

INDUSTRIES · SECTION 11K

Chemical and Specialty Chemicals

SECTION 11K

11k. Chemical and Specialty Chemicals

The single largest Fitness-for-Service bench in the group, **20 verified API 579-1 engagements** across speciality, agrochemical, fluorochemical and bulk-chemical plants, serving **Aarti Industries, SRF, Atul, UPL, Tata Chemicals and GACL**, with international scope at **BASF, Huntsman and Casale**.

POTENTIAL FAILURES WE SERVICE

Leaks, runaway reactions and corrosion failures in glass-lined and alloy reactors, distillation columns, acid plants and chlor-alkali cells. TCR investigates chloride, caustic, amine and polythionic stress corrosion cracking, HF and acid-dew-point corrosion, glass-lining cracking, intergranular attack and weld decay, corrosion under insulation and fatigue, and runs Fitness-for-Service on degraded pressure boundaries.

Twenty verified API 579-1 Fitness-for-Service engagements, the single largest such bench in the group, across speciality, agrochemical, fluorochemical and bulk-chemical plants.

MARQUEE PROJECT

Twenty Fitness-for-Service engagements per API 579-1 across speciality, agrochemical, fluorochemical, and bulk-chemical plants.

11k.1 Industry Context

Chemical plants concentrate risk: aggressive chemistries, high temperatures, and pressure equipment in continuous service, frequently inside dense industrial corridors such as Dahej, Ankleshwar, and the Bharuch belt where TCR maintains a dedicated division. A single integrity failure in this sector is rarely a maintenance line item; it is a production loss, an insurance claim, and a regulatory event at once. The inspection answer has to combine chemistry with metallurgy, which is TCR's home ground: corrosion and sour-service testing to NACE and ASTM programmes, HIC and SCC qualification of construction materials, in-situ metallography on reactors and piping, fitness for service assessment, and root cause failure analysis when a chemistry-metallurgy interaction does find a weak point.

The Indian chemical-processing sector is the third-largest globally and is growing through the Production Linked Incentive (PLI) scheme on bulk chemicals and the China Plus One supply-chain reorganisation.

The capex pipeline runs across speciality chemicals (Aarti Industries, SRF, Atul, UPL, Tagros, Anupam Rasayan, Vinati Organics), agrochemicals (UPL, Coromandel International, PI Industries, Bayer CropScience, Sumitomo Chemical India), pharmaceuticals API and intermediates, dyes and pigments, fluorochemicals, and the integrated petrochemical-to-chemical complexes (Reliance Jamnagar, IOCL Paradip, BPCL Bina, GAIL Pata, ONGC Mangalore, NRL Numaligarh).

The integrated petrochemicals expansion (Reliance, IOCL, BPCL, ONGC, GAIL, HMEL) carries cross-vertical scope with Refining (the BPCL Bina HCU duplex AFC RBI, the HMEL Bathinda Isomerisation Reactor 503-R-001 FFS, the HMEL Bathinda VGO Unit fire response).

The chemical-vertical FFS bench at TCR Advanced carries 20 verified engagements in chemicals (the single largest segment of the 48-job FFS ledger), positioning the vertical as a deep operating-side capability.

Bio-based chemicals and bio-refining (lactic acid, succinic acid, bio-ethylene, furfural; cross-vertical with Refining) bring new corrosion mechanism scope on bio-feedstock streams. Green hydrogen produced from chlor-alkali by-product brings cross-vertical hydrogen storage and pressure-vessel scope (cross-vertical with Pipelines, Fertilisers, and Refining). Carbon capture at chemical plants brings amine-system corrosion qualification (cross-vertical with Refining). The Production Linked Incentive (PLI) scheme on bulk chemicals and the China Plus One reshoring effect drive new-plant capex with full integrity-engineering scope from front-end design through commissioning.

TCR is the multi-disciplinary integrity partner for the Indian chemical-plant fleet, the largest single-vertical FFS bench (20 verified engagements), the classical wet-chemistry bench for compositional certification, and the cross-vertical static-equipment specialist for chemical-plant pressure boundaries.

11k.2 Plant Sections We Inspect

Cluster	Equipment
Chlor-alkali	Membrane-cell electrolyser, brine purification, chlorine compressor, hydrogen storage, hypochlorite production, caustic concentrator, salt cake / glauber salt purification
Speciality and Agrochemicals	Glass-lined reactor, hastelloy reactor, jacketed crystalliser, distillation column (vacuum and atmospheric), thin-film evaporator, scrapped-surface evaporator, centrifugal filter, dryer (spray, fluid-bed)
Polymers and Resins	Tubular and autoclave reactor (polyethylene), loop reactor (polypropylene), MEG (mono-ethylene glycol) reactor, PTA reactor, polyester polymerisation reactor
Aromatics	Reformer column complex (cross-vertical with Refining), aromatics extraction, paraxylene crystalliser, benzene-toluene-xylene splitter
Methanol and Melamine	Methanol synthesis reactor, melamine reactor (Casale licensor), CO2 compression train
Fluorochemicals	HF reactor (highly corrosive service), refrigerant production train, fluoropolymer reactor
Acids	Sulphuric acid plant (cross-vertical with Phosphoric Acid in Fertilisers); nitric acid plant; phosphoric acid plant; HCl recovery; HNO3 concentrator
Pharmaceuticals API	Glass-lined reactor, jacketed reactor, crystalliser, dryer, sterile vessel; CIP / SIP system
Dyes and Pigments	Sulphonation reactor, diazotisation vessel, coupling reactor; effluent treatment

Cluster	Equipment
Utilities	Steam generation (cross-vertical with Power), demineralised water, cooling water, instrument air, nitrogen, fuel gas

11k.3 Damage Mechanisms We Investigate

Equipment	Mechanisms
Chlor-alkali	Hypochlorite-induced corrosion on titanium and 316L; chloride SCC on stainless steels; H2 embrittlement; mercury-cell decommissioning hazards
Glass-lined reactor	Glass-lining cracking and spalling; substrate corrosion under failed lining; thermal-cycling fatigue
Hastelloy / nickel alloy reactor	Pitting and crevice corrosion; intergranular corrosion; weld decay (sensitisation in 300-series); high-temperature embrittlement
Distillation column	Tray and packing corrosion; condenser corrosion; reboiler tube corrosion; vacuum-system air ingress corrosion
Polymer reactor	Coke deposition; hot-spot corrosion; agitator-shaft fatigue; thermal-shock cracking on jackets
Aromatics	High-temperature corrosion (cross-vertical with Refining); naphthenic acid where co-located
Methanol / Melamine	High-temperature creep on methanol synthesis reactor; carbamate corrosion (cross-vertical with Urea / Fertilisers); HF corrosion (where adjacent)
Fluorochemicals	HF-induced corrosion on Inconel and Monel; thermal-stress cracking
Acid plants	Acid-dew-point corrosion in sulphuric acid plants; nitric-acid corrosion at concentrator; HCl corrosion on graphite and tantalum equipment
Cross-cutting	Stress corrosion cracking (chloride, caustic, ammonia, amine, polythionic acid); HIC and SOHIC in sour-service co-located piping; corrosion under insulation (CUI); microbiologically-induced corrosion (MIC); fatigue at vibrating piping

11k.4 Standards Coverage Matrix

Damage and Failure Analysis. API RP 571; ASM Handbook Vol. 11A.

Inspection. API 510, 570, 653; API RP 572, 574, 575; ASME PCC-2.

RBI / KBA. API 580 / 581 4th ed. (January 2025); API RP 584 IOW 2nd ed. (December 2021).

FFS. API 579-1/ASME FFS-1 4th ed. (2021); BS 7910.

Material Specifications. ASTM A516 / A537 (carbon steel pressure-vessel plates); ASTM A240 (chromium and chromium-nickel stainless steel plates); ASTM B575 (Hastelloy C-22, C-276); ASTM B127 (Monel); ASTM B626 (Inconel); ASTM B265 (titanium); ASTM B564 (nickel-alloy forgings); ASTM A312 (welded and seamless austenitic stainless-steel pipes); IS 6911 (Indian stainless-steel plate spec).

Welding. ASME Section IX 2023; AWS D1.1 2025; AWS D1.6 (stainless-steel structural welding); API 582; ISO 15614 series.

Corrosion Testing. NACE TM0177-2016 Methods A through D (SSC); NACE TM0284 (HIC); NACE MR0103 (refining); NACE MR0175 / ISO 15156; ASTM A262 Practices A through F (intergranular for stainless); ASTM G28 (intergranular); ASTM G48 (pitting); ASTM G36 (chloride SCC); ASTM G44 (alternate immersion); ASTM B117 (salt spray).

Coating. ASTM D3359, D4541, D7091, B117; ISO 2808, 4624, 12944.

11k.5 Service Applications Across the TCR Continuum

Chemical and speciality chemical plants run the widest materials palette in industry: glass-lined steel, high-alloy austenitics and duplex grades, nickel alloys, titanium, graphite, and fibre-reinforced plastic, often within a single unit. The problem set follows: chloride stress corrosion cracking of stainless steels, dew-point acid corrosion in flue and vent systems, microbiologically influenced corrosion in cooling water circuits, selective leaching, erosion-corrosion in slurry service, and the degradation of non-metallic linings and FRP scrubbers that no thickness gauge sees. Shutdowns are frequent but short, batch campaigns tolerate little slippage, and procurement risk concentrates in exotic alloy verification and gasket, lining, and polymer quality. TCR Engineering and TCR Advanced service all five stages of the five-stage Trusted Relationship Model (Section 3.2) across organic, inorganic, agrochemical, and speciality operations.

Stage One, Sourcing and Procurement. Alloy verification by positive material identification and optical emission spectrometry protects the exotic-material supply chain, supported by intergranular corrosion testing per ASTM A262 and ASTM G28, pitting and crevice testing per ASTM G48, chloride stress corrosion cracking per ASTM G36, polymer, rubber, and FRP/GRP testing, gasket and lining material evaluation, and vendor audits with sample picking on reactors, columns, and exchangers.

Stage Two, Construction and Commissioning. During plant construction and unit addition, TCR provides baseline non-destructive testing, welder certification and procedure qualification per ASME Boiler and Pressure Vessel Code Section IX including high-alloy and dissimilar joints, radiography and phased array ultrasonic testing, post-weld heat treatment, positive material identification across the alloy population, and holiday testing of linings, delivering the baseline record for the unit.

Stage Three, In-Service. In operation, TCR runs corrosion mapping and thickness monitoring on columns, reactors, and piping, thermography of reactors and electrical systems, remote visual inspection of confined equipment, and risk-based inspection planning per API RP 580 and API RP 581 through the Knowledge-Based Audit method, with integrity operating windows per API RP 584 tuned to process chemistry excursions rather than calendar intervals.

Stage Four, Shutdown and Turnaround. In the shutdown, TCR inspects reactors, glass-lined equipment, columns, and exchanger bundles, runs in-situ metallographic replication on high temperature components, tank inspection per API 653, boiler condition assessment on captive utilities, and magnetic particle and penetrant testing on nozzles and agitator components, with turnaround inspection manpower matched to short, dense windows.

Stage Five, Continuum. The engineering stage delivers failure analysis across metallic and non-metallic components, including microbiologically influenced corrosion, selective leaching, and stress corrosion cracking investigations, fitness for service per API 579-1/ASME FFS-1, remaining life assessment of captive boilers and ageing units, fire damage assessment, and the contract research and custom test rigs, autoclaves and simulated-environment apparatus, that answer the process questions standard methods cannot.

11k.6 Named Clients

India Speciality Chemicals. Aarti Industries (Mumbai, Vapi, Jhagadia), SRF (Bhiwadi, Dahej, Bharuch), Atul (Atul, Ankleshwar), UPL (Ankleshwar, Halol), Tagros Chemicals, Anupam Rasayan, Vinati Organics, Galaxy Surfactants, Hindustan Petroleum (cross-vertical with Refining).

India Bulk Chemicals. Tata Chemicals, Gujarat Alkalies and Chemicals Limited (GACL; Vadodara, Dahej), Aditya Birla Chemicals, DCM Shriram (cross-vertical with Fertilisers), Grasim Industries, Reliance Industries (Jamnagar petrochemicals; cross-vertical with Refining), Indian Oil Corporation (Paradip Petrochemical Complex), GAIL Pata, ONGC Mangalore Petrochemicals.

India Agrochemicals. UPL, Coromandel International (cross-vertical with Fertilisers), PI Industries, Bayer CropScience, Sumitomo Chemical India, Heranba Industries, Sharda Cropchem.

India Pharmaceuticals (API and intermediates). Aurobindo Pharma, Dr. Reddy's Laboratories, Lupin, Cipla, Sun Pharmaceutical, Cadila, Torrent Pharma, Glenmark.

India Polymers and Petrochemicals (cross-vertical with Refining). Reliance Industries, IOCL Paradip, GAIL Pata, ONGC Mangalore, HMEL Bathinda, BPCL Bina, IFFCO (urea-melamine; cross-vertical with Fertilisers).

International. BASF (Mannheim, Ludwigshafen, India operations), Huntsman, Casale SA Switzerland (urea and melamine licensor; cross-vertical with Fertilisers), Bayer (Germany operations).

EPC and Process Licensors. Larsen and Toubro Heavy Engineering; Tata Projects; Toyo Engineering India; Technip Energies; ThyssenKrupp Industrial Solutions; Casale SA SX3000 Vendor Code 1000007973; Haldor Topsoe.

Representative India chemical-processing clients include Sulzer Pumps India, Elliott Ebara Turbomachinery, and Godrej and Boyce, with work across corrosion testing, metallography, and failure analysis.

11k.7 Marquee Projects

Project	Service Anchor	Year
The 20 verified chemical-vertical FFS engagements (per the 48-job FFS ledger)	FFS per `API 579` across speciality, agrochemical, fluorochemical, and bulk chemical plants	Continuous
BPCL Bina (cross-vertical with Refining)	RBI of duplex AFC and piping in HCU	Multiple
HMEL Bathinda Isomerisation Reactor 503-R-001 (cross-vertical with Refining)	FFS of temperature excursion (peak 710 °C); certified fit-for-service; monitored through 2019 with no shutdown	2012 to 2019
HMEL Bathinda VGO Unit fire response (cross-vertical with Refining)	FFS of VGO reactor under `API 579-1` Part 11	2024
GACL Vadodara, Dahej	Chemical-plant materials testing, NDT, FFS	Continuous
Tata Chemicals	Materials testing across soda-ash, salt, and bromine plants	Continuous
Aarti Industries, SRF, Atul, UPL, Tagros	Speciality and agrochemical plant integrity	Continuous
BASF, Huntsman	International chemical-OEM source inspection and verification testing	Continuous
Gujarat Fluorochemicals Limited (GFL) Ranjitnagar plant	Theoretical Life Assessment of 124 equipment based on study of GA drawings and process parameters; team of metallurgical, corrosion, and design experts; coverage shell, dished-ends, nozzles. PO 1251101026 dated 04.06.2025	June 2025
Sulzer Chemtech Middle East W.L.L Bahrain	Finite Element Analysis (FEA) simulation study of bulged area of reactor 59-V-104 and 59-V-105 (Qty 02). PO 4500.14.3609 dated 04 January 2026. Sulzer Chemtech is a Swiss process-equipment licensor specialising in mass-transfer and separation columns.	January 2026
Indorama Eleme Petrochemicals Limited, Port Harcourt, Rivers, Nigeria	Olefins furnace tubes condition assessment and NDT scope: in-situ metallography on SS304H with Aqua-regia etchant for 100 replicas UCI hardness measurement	April 2025

For Sulzer Chemtech Middle East in Bahrain, TCR ran a finite-element simulation of bulged reactors in January 2026. Microbiologically influenced corrosion studies, refractory testing, and failure analysis on FRP and GRP tanks carrying aggressive chemicals round out the specialty-chemical record, supported by the classical wet-chemistry bench described in Section 4.4.

INDUSTRIES · SECTION 11L

Automotive

SECTION 11L

11l. Automotive

Nearly every Indian vehicle maker, **Tata Motors, Mahindra, Maruti Suzuki, Hyundai, Royal Enfield, Bajaj, TVS and Ashok Leyland**, plus EV entrants **Ola and Ather**, has used TCR at some point to qualify their materials and components.

POTENTIAL FAILURES WE SERVICE

Field and durability failures in crankshafts, connecting rods, gears, springs, chassis, fasteners and EV battery hardware. TCR investigates high- and low-cycle fatigue, gear pitting and spalling, hydrogen embrittlement of fasteners, stress corrosion cracking of advanced high-strength steel, coating delamination, and battery thermal-runaway and mica-barrier performance.

From crankshaft fatigue to EV battery thermal-runaway barriers, nearly every Indian vehicle maker and Tier-1 supplier qualifies materials and components on TCR's bench, backed by the classical wet-chemistry bench described in Section 4.4.

MARQUEE PROJECT

Royal Enfield qualified its motorcycle frames on TCR's low-cycle fatigue bench per `ASTM E606`.

11l.1 Industry Context

Automotive competes on reliability economics. Platform localisation, warranty exposure, and the electric-vehicle transition have each raised the cost of a material or component failure, and IATF-driven quality systems push that assurance burden down the supply chain to every forging, casting, fastener, and spring supplier. The testing behind that assurance is exactly TCR's catalogue: tensile, impact, and hardness qualification, component and fastener testing, fatigue programmes on springs and safety-critical parts, chemical analysis and PMI for alloy conformance, RoHS compliance testing, and failure analysis when a field return needs a defensible metallurgical answer. Lightweighting and EV structures add composite, battery-enclosure, and dissimilar-joint questions that the laboratory already handles for aerospace and rail clients.

The Indian automotive sector is the third-largest globally by passenger-vehicle production and a top-five producer in commercial vehicles, two-wheelers, and three-wheelers. The sector is in transition across three vectors: electric-vehicle adoption (the PM E-DRIVE scheme (launched October 2024, successor to FAME-II, which closed on 31 March 2024), the PLI scheme on advanced chemistry cell manufacturing, the ARAI homologation framework, and the rapid two-wheeler EV ramp-up); BS-VI emission compliance and the next-cycle stricter framework; and the global supplier relationship under the Make-in-India and PLI auto-component schemes.

The buyer pool spans original equipment manufacturers (Tata Motors, Mahindra and Mahindra, Maruti Suzuki, Hyundai Motor India, Hero MotoCorp, Bajaj Auto, Royal Enfield, TVS Motor, Ashok Leyland, Volvo Eicher, Force Motors, Mahindra Trucks and Buses, Daimler India, JBM Auto).

Tier 1 component manufacturers (Bharat Forge, Anand Group, Sansera Engineering, Bosch India, Continental India, Schaeffler India, Mother Sumi, JBM Auto, Endurance Technologies).

Tier 2 component fabricators, EV-specific entrants (Ola Electric, Ather Energy, TVS Motor (iQube), Bajaj Auto (Chetak), Tata Motors (Nexon EV), Mahindra and Mahindra (XUV400 EV)), and the parallel programmes at HAL Bangalore for automotive-adjacent component manufacturing.

The EV transition brings new buyer engagement: battery-cell housing qualification, mica thermal-insulation barrier qualification (introduced in 2026), motor-stator and rotor magnetic-material qualification, battery-pack structural-mounting fatigue testing, and BMS housing qualification. The hydrogen-fuel-cell vehicle programme (Tata Motors, Toyota, Hyundai pilot programmes; cross-vertical with Pipelines and Refining for hydrogen fuelling stations) brings hydrogen embrittlement and pressure-vessel scope. The PLI advanced chemistry cell scheme drives gigafactory-grade quality assurance scope. Lightweight-aluminium and AHSS body adoption brings new corrosion-mechanism and fatigue testing scope. Recyclability and end-of-life-vehicle compliance brings RoHS-adjacent material-content verification scope.

TCR is the materials-testing, NDT, and component-qualification bench for the Indian automotive OEM and Tier 1 base, with the classical wet-chemistry bench for compositional certification, and the EV-specific battery-cell mica thermal-insulation test capability.

11l.2 Plant Sections We Inspect

Cluster	Equipment / Material
Fastener	Engine bolt, suspension fastener, body bolt, wheel stud

11l.3 Damage Mechanisms We Investigate

Equipment	Mechanisms
Engine and powertrain	High-cycle fatigue (HCF) on crankshafts and connecting rods per `ASTM E466`; thermal fatigue on cylinder heads; piston-ring scuffing; valve-spring fatigue; turbocharger blade creep
Transmission	Gear-tooth pitting and spalling; shaft fatigue per `ASTM E466`; shaft-end key-slot crack; bearing fatigue
Fastener	Hydrogen embrittlement per `ASTM F519`, F1624, `API 20E`, fastener fatigue; thread stripping
Body and chassis	Stress corrosion cracking on AHSS; weld toe cracking; coating delamination (cross-vertical with Pillar 1 Section 4.8); galvanic corrosion at dissimilar-metal joints

Equipment	Mechanisms
EV battery	Thermal-runaway propagation (mica thermal-insulation barrier qualification); battery-cell can corrosion; module-mounting fatigue; busbar joint resistance creep

111.4 Standards Coverage Matrix

Mechanical and Material. ASTM E8/E8M-22; ASTM E466 (HCF); ASTM E606 (LCF, the Royal Enfield motorcycle anchor); ASTM E647 (FCGR); ASTM E399 (K1c); ASTM E1820 (J1c); IS 1786 (TMT rebar adjacent); IS 1367 (fasteners); IS 3757 (HSFG); SAE J series (automotive specifications); JIS automotive specifications; ISO automotive specifications.

Component Testing and Fasteners. ASTM F606 (proof load testing of fasteners); IS 1367; ISO 898; ASTM F1624 (incremental step-load); ASTM F519 (mechanical hydrogen embrittlement); API 20E (alloy and carbon steel bolting).

Corrosion. ASTM B117 (salt spray); ASTM G85 (modified salt-spray); ASTM B368 (CASS); ASTM G47 / G44 (aerospace SCC; cross-vertical with Aerospace via SQuAD Forging); ASTM F2129 (electrochemical corrosion of medical-device implant materials; cross-vertical reference).

Coating. ASTM D3359 (cross-cut adhesion); ASTM D4541 (pull-off adhesion); ASTM D7091 (coating thickness); ISO 2808; ISO 12944.

Polymer and Composite. ASTM D638 (tensile of plastics); ASTM D790 (flexural); ASTM D695 (compression); ASTM D256 (Izod impact); ASTM D2240 (Shore hardness); ISO 527, 178, 179, 180.

RoHS. IEC 62321 series; EU Directive 2011/65/EU.

EV-Specific. IEC 60079 (electrical apparatus for explosive gas atmospheres; ATEX/PESO cross-reference); IEC 62133 (secondary cells and batteries containing alkaline or other non-acid electrolytes; safety requirements); UN 38.3 (transport of lithium batteries); IS 16893 (sealed nickel-cadmium); IS 16270 (Li-ion); ASTM C177 (thermal conductivity guarded hot plate; mica thermal-insulation testing for EV battery).

Welding. ASME Section IX 2023; AWS D1.1 2025 (structural); AWS D1.3 (sheet steel); IS 4353 (welding sub-arc); IS 7318 (welder qualification).

111.5 Service Applications Across the TCR Continuum

Automotive is a component-lifecycle vertical, so the Continuum adapts to the way vehicle programmes actually buy testing: supplier and material qualification, process validation, production surveillance, field-return investigation, and failure analysis with durability engineering. The recurring problems are raw material and heat treatment consistency across a deep supplier pyramid, fastener and spring quality, weld integrity in chassis and body structures, and the fatigue duty that governs suspension, transmission, and steering components. The launch gate is this vertical's turnaround: a production part approval process deadline moves for no laboratory. TCR Engineering services all five adapted stages for original equipment manufacturers and their tier suppliers.

Stage One, Supplier and Material Qualification (Sourcing and Procurement). Incoming steel, aluminium, castings, and forgings are verified through mechanical testing per ASTM and IS methods, chemical analysis by optical emission spectrometry, microstructure, grain size, and inclusion rating, hardenability testing, and fastener testing per ISO 898, with supplier audits and sample picking that give the vehicle programme confidence in its material pedigree.

Stage Two, Process Validation (Construction Equivalent). Manufacturing processes are validated before launch: heat treatment verification including case depth and decarburisation measurement, weld macro and micro examination on body and chassis joints, coating and plating evaluation including salt spray per ASTM B117, and component testing of springs, seat belts, and safety-critical items against programme specifications.

Stage Three, Production Surveillance (In-Service Equivalent). Through series production, TCR provides batch conformance testing, periodic requalification, production part approval process support testing, and RoHS compliance testing (Section 4.6) for export programmes, giving purchasing and quality functions an independent laboratory signature on continuing conformance across the supplier base.

Stage Four, Field-Return Investigation (Shutdown Equivalent). When warranty and field returns arrive, TCR runs structured teardown and examination: fractography, metallurgical evaluation, hardness and case depth verification, and comparison against the qualified baseline, separating material, process, and application causes quickly enough to protect a running production line.

Stage Five, Failure Analysis and Durability Engineering (Continuum). The engineering stage delivers root cause failure analysis of engine, transmission, suspension, and steering components, fatigue testing per ASTM E466 and ASTM E606 and fracture toughness programmes for lightweight and high-strength materials, and the materials development support, including electric vehicle battery enclosure and lightweight-structure questions, that feeds the next platform.

11.6 Named Clients

India OEM. Tata Motors (Pune, Sanand, Pantnagar, Lucknow, Jamshedpur), Mahindra and Mahindra (Chakan, Nashik, Igatpuri, Haridwar), Maruti Suzuki (Gurgaon, Manesar, Gujarat), Hyundai Motor India (Sriperumbudur), Royal Enfield (Oragadam, Vallam Vadagal), Hero MotoCorp, Bajaj Auto (Chakan, Akurdi, Aurangabad, Pantnagar), TVS Motor (Hosur, Mysuru, Nalagarh), Ashok Leyland (Ennore, Hosur, Pantnagar, Bhandara), Volvo Eicher (Pithampur), Force Motors, Daimler India Commercial Vehicles, JBM Auto.

India Tier 1 and Tier 2. Bharat Forge (Pune; cross-vertical with Aerospace), Anand Group (Mando, Gabriel, Henkel-Anand), Sansera Engineering, Bosch India, Continental India, Schaeffler India, Endurance Technologies, Mother Sumi, JBM Auto, Subros, Sundram Fasteners, Lumax, Spark Minda.

India EV. Ola Electric (Krishnagiri Gigafactory), Ather Energy, TVS Motor (iQube), Bajaj Auto (Chetak), Hero MotoCorp (Vida), Tata Motors (Nexon EV), Mahindra and Mahindra (XUV400 EV), MG Motor India (Astor EV), Hyundai (Kona EV).

Component-Fabrication and Forging. SQuAD Forging (the aerospace SCC ASTM G47/G44 anchor; cross-vertical with Aerospace); Bharat Forge defence forging division.

International (Source Inspection and Verification). International OEM source-inspection scope where India suppliers are involved.

Representative India automotive clients include Schaeffler India, Endurance Technologies, and Sundram Fasteners, with work across mechanical testing, metallography, and failure analysis.

11l.7 Marquee Projects

Project	Service Anchor	Year
Royal Enfield motorcycle low-cycle fatigue per `ASTM E606`	Frame and structural fatigue qualification	2025 to 2026
SQuAD Forging	Aerospace SCC `ASTM G47/G44` on 7xxx and 2xxx aluminium (cross-vertical with Aerospace)	2025 to 2026
Tata Motors, Mahindra and Mahindra, Maruti Suzuki, Hyundai Motor India	OEM materials testing, NDT, source inspection	Continuous
Bharat Forge	Forging-grade material testing, hardness verification, microstructural evaluation	Continuous
Bosch India, Continental India, Schaeffler India	Tier 1 component qualification	Continuous
Ola Electric, Ather Energy, TVS iQube	EV battery thermal-insulation mica testing; component qualification	Continuous

INDUSTRIES · SECTION 11M

Construction and Built Environment

SECTION 11M

11m. Construction and Built Environment

India's leading developers build on TCR-tested materials: **Godrej Properties** (a three-year, all-Mumbai-zone rate contract), plus **Lodha, Shapoorji Pallonji, Kalpataru, Oberoi, K. Raheja, DLF, Prestige and Brigade**, backed by **1,200-plus statutory structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888.**

POTENTIAL FAILURES WE SERVICE

Cracking, deflection and water-ingress distress in reinforced and prestressed structures, façades and waterproofing; structural-audit findings on ageing buildings. TCR investigates carbonation and chloride corrosion of reinforcement, alkali-silica reaction, sulphate attack, prestress-tendon corrosion, façade-panel and sealant failure and tile-bond loss, and verifies repair and rehabilitation under Section 353B of the Mumbai Municipal Corporation Act 1888.

India's leading developers build on TCR-tested materials, anchored by Godrej's three-year Mumbai-zone rate contract and 1,200-plus statutory structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888.

MARQUEE PROJECT

Godrej Properties: a three-year materials-testing rate contract spanning the entire Mumbai zone.

11m.1 Industry Context

The built environment has a statutory inspection clock. Maharashtra's structural audit regime alone requires buildings between 15 and 30 years of age to be audited every five years and buildings older than 30 years every three years, and the redevelopment wave across Mumbai and Thane keeps thousands of structures moving through that cycle each year. Municipal corporations will only accept audits from registered, competent agencies. TCR is a registered structural auditor with BMC and CIDCO among others, and pairs the statutory audit with the full evidence chain: visual inspection, non-destructive evaluation, materials testing in a NABL-accredited laboratory, and repair and rehabilitation consultancy through to structural stability certification.

The Indian real-estate and construction sector is the second-largest employer after agriculture and contributes approximately 7 percent of GDP. The capex pipeline runs across residential (the Pradhan Mantri Awas Yojana, the Mumbai Metropolitan Region high-rise stock, the Pune-Bangalore-Hyderabad gated community wave, the Delhi-NCR National Capital Region housing programme), commercial (Grade A office towers in Mumbai BKC, Pune Hinjewadi, Bangalore Whitefield-ORR, Hyderabad HITEC City, Gurugram, Noida), retail (mall expansion in Tier 2 and Tier 3 cities), industrial (warehousing under the National Logistics Policy, cold storage, data centres at Chennai, Mumbai, Hyderabad, Bangalore), and the monumental construction programme (cross-vertical with Infrastructure Section 11j).

The Section 353B of the Mumbai Municipal Corporation Act 1888 structural-audit mandate on Greater Mumbai's ageing building stock is the highest-volume civic-mandate scope. The buyer pool is the property developer, the building society, the housing federation, and the local self-government (Brihanmumbai Municipal Corporation BMC). The Long-Term Rate Contracts (LRCs) with Godrej Properties (3-year, all Mumbai Zone, April 2026 onward), Kalpataru, Shapoorji Pallonji, Rustomjee, plus second-tier developers, anchor the recurring revenue stream.

Net-zero building design brings new structural-load demands (lighter mass, alternative materials), recycled-aggregate concrete qualification, geopolymer cement qualification, and embodied-carbon-driven material substitution scope (steel-to-engineered-timber, conventional concrete to low-clinker mixes). Building-integrated photovoltaics (BIPV) bring structural-steel testing for panel-mounting structures (cross-vertical with Civil and Steel). The shift to electric building services (EV charging, all-electric kitchen, heat-pump-based HVAC) brings load-density-driven structural-audit recalibration. Climate-resilience capex (flood-resistant building design, scour-mitigation engineering, cyclone-resistant façade and cladding) brings new testing scope. The Section 353B structural-audit mandate continues at scale as the Mumbai building stock ages.

TCR is the materials-testing, NDT, and structural-audit bench for the Indian real-estate and construction industry, with named LRCs at Godrej, Kalpataru, Shapoorji Pallonji, and Rustomjee, the BIS-accredited rebar coupler capability is the structural moat.

11m.2 Plant Sections We Inspect

Cluster	Equipment / Material
Concrete	Cast-in-place reinforced concrete (RCC) shell, post-tensioned slab, prestressed concrete beam, AAC block masonry, ready-mix concrete (RMC) plant production
Steel Structural	Hot-rolled structural sections (`IS 2062`), built-up girders, hollow structural sections (HSS), pre-engineered building (PEB) framing
Reinforcement	TMT rebar (`IS 1786`), reinforcement coupler (`IS 16172`, the BIS-accredited first-in-India anchor), HT strand for prestressed concrete (`IS 14268`), pull-out test per `IS 2770`
Cement and Aggregate	OPC and PPC cement, fly ash, GGBFS, river sand, manufactured sand (M-sand), coarse aggregate, fine aggregate

Cluster	Equipment / Material
Building Material	AAC blocks (`IS 2185` Part 3 plus thermal conductivity per `ASTM C177` / `ISO 8302; introduced in 2026), tile` adhesive (`IS 15477` comprehensive), tile, glass and glazing (`IS 2553`, `IS 16231`), aluminium formwork
Coating and Membrane	Waterproofing membrane (PVC, TPO, EPDM, bitumen-based), exterior paint, anti-carbonation coating, waterproof admixture per `IS 2645`
Façade and Cladding	Aluminium composite panel (ACP), glass curtain wall, terracotta cladding, stone cladding
Plumbing and Drainage	Manhole and gully top (`BS EN 124-5` fatigue), CPVC and PPR piping, cast-iron sewer line
Heritage and Restoration	Stone pieces, lime mortar, traditional roofing, structural-stability assessment of heritage buildings
Civic Infrastructure	Street furniture, park infrastructure, pedestrian overpass, public-toilet structural verification

11m.3 Damage Mechanisms We Investigate

Equipment	Mechanisms
Reinforced concrete	Carbonation-induced corrosion of reinforcement, chloride-induced corrosion (coastal exposure), alkali-silica reaction (ASR), sulphate attack, freeze-thaw, plastic and drying shrinkage, creep, delayed ettringite formation (DEF), settlement-induced cracking
Prestressed concrete	Stress corrosion cracking on HT strand under tendon ducts; prestress loss; grout voids in tendon ducts; corrosion at tendon anchorage
Structural steel	Coating breakdown, atmospheric corrosion, weld toe cracking, fatigue at riveted and bolted connections, fire-damage residual capacity
Façade and cladding	Sealant failure, ACP delamination, panel pull-out, glass spontaneous fracture (NiS inclusion), curtain-wall thermal-cycling fatigue
Tile and adhesive	Bond failure (low pull-off strength), sub-floor crack propagation, efflorescence under tile, tile fracture under traffic load
AAC block	Compressive-strength loss under wet condition, thermal-conductivity drift under humidity, dimensional instability
Waterproofing	Membrane puncture, seam failure, UV-induced ageing, root penetration, root-thermal-cycling failure
Plumbing and drainage	Manhole and gully top fatigue per `BS EN 124-5`; sewer line corrosion; trench reinstatement settlement
Heritage	Lime-mortar weathering, masonry-joint erosion, stone weathering, settlement-induced cracking, salt efflorescence

11m.4 Standards Coverage Matrix

Concrete and Cement. IS 456 (plain and reinforced concrete); IS 1343 (prestressed concrete); IS 4031 (cement physical tests); IS 8112 (43-grade OPC); IS 12269 (53-grade OPC); IS 1489 (Portland Pozzolana Cement); IS 516 (compressive strength); IS 1199 (sampling); IS 2386 (aggregate methods); IS 383 (aggregate specification); ASTM C39, C496, C617; EN 12390 series.

Reinforcement and Couplers. IS 1786 (TMT rebar); IS 16172 (rebar couplers, the BIS-accredited first-in-India anchor); IS 2770 (pull-out test); IS 14268 (HT strand for prestressed concrete); IS 2090 (high-tensile bars); IS 1367 (fasteners); ACI 318; ASTM A615, A416, A1064; EN 10138.

Structural Steel. IS 800 (general construction in steel, code of practice); IS 1893 (criteria for earthquake-resistant design of structures); IS 875 Parts 1 to 5 (loads); AISC 360; AWS D1.1; IS 1239 (steel tubes); IS 2062 (structural-grade steel).

Building Material. IS 2185 Part 3 (AAC blocks); ASTM C177 / ISO 8302 (thermal conductivity Guarded Hot Plate; introduced in 2026); IS 15477 (tile adhesive); IS 2553 (safety glass); IS 16231 (glass cladding); IS 9498 (linear thermal expansion); IS 2645 (waterproofing admixtures); IS 14209 (fly-ash bricks).

NDT for Concrete. IS 516 (Part 5/Sec 1) (UPV); IS 516 (Part 5/Sec 4) (rebound hammer); ASTM C876 (half-cell potential); ASTM C1383 (impulse-echo); BS 1881 series (testing concrete).

Drainage and Civic. BS EN 124-5 (manhole and gully top fatigue up to 900 mm); IS 3597 (manhole covers).

Structural Audit. Section 353B of the Mumbai Municipal Corporation Act 1888; Section 265A of the Maharashtra Municipal Corporations Act 1949; BIS guidance.

Coating (cross-vertical). ASTM D3359, D4541, D7091; ISO 12944.

11m.5 Service Applications Across the TCR Continuum

STAGE 01
Sourcing and Procurement
Factory audits, OEM qualification, raw-material inspection, loading supervision.

STAGE 02
Construction and Commissioning
Weld NDT, PMI, baseline thickness surveys, positive material records.

STAGE 03
In-Service
In-situ metallography, condition monitoring, RBI, on-stream inspection.

STAGE 04
Shutdown and Turnaround
Turnaround crews, advanced NDT campaigns, fitness-for-service decisions.

STAGE 05
Continuum
RLA, failure analysis, life extension; findings feed the next cycle.

For construction and the built environment the Continuum adapts to the building lifecycle: materials qualification, construction and finishing quality assurance, occupancy-stage condition assessment, redevelopment and repair, and residual life certification. The recurring problems for developers and societies are material quality across a fragmented vendor base, finishing works defects that surface after handover, reinforcement corrosion and structural distress in the ageing Mumbai building stock, and the statutory trigger of the Section 353B structural audit under the Mumbai Municipal Corporation Act 1888. The redevelopment decision is this vertical's turnaround: repair or rebuild, and the evidence has to survive scrutiny by societies, developers, and municipal authorities alike. TCR Engineering services all five adapted stages, with the real-estate developer interface led through the business development bench.

Stage One, Materials Qualification (Sourcing and Procurement). Building materials are qualified at intake: cement, aggregates, and concrete constituents, TMT reinforcement per IS 1786 and couplers per IS 16172, autoclaved aerated concrete blocks, tiles, aluminium formwork systems, waterproofing and finishing materials, and structural steel, with the free TCR-branded sample pickup van serving developer sites across the Mumbai Metropolitan Region.

Stage Two, Construction and Finishing Quality Assurance (Construction and Commissioning). Through the build, TCR provides cube and core testing per IS 516, non-destructive concrete evaluation per IS 516 (Part 5/Sec 1) and IS 516 (Part 5/Sec 4), anchor and fastener pull-out testing, plumbness surveys on towers, welding inspection on structural and facade steel, and building finishing works testing, tiles, blocks, and fit-out materials, so handover happens against measured quality rather than visual acceptance.

Stage Three, Occupancy-Stage Condition Assessment (In-Service). On occupied buildings, TCR delivers structural audits under Section 353B of the Mumbai Municipal Corporation Act 1888, half-cell potential and carbonation surveys, facade and waterproofing condition assessment, ground penetrating radar for embedded services and voids, and thermography for moisture ingress and electrical hotspots, producing the condition evidence societies and municipal authorities require.

Stage Four, Redevelopment and Repair (Shutdown and Turnaround Equivalent). At the repair-or-redevelop decision, TCR provides distress mapping, repair specification support, cathodic protection of reinforced concrete, load testing of strengthened members, and post-repair verification, and for redevelopment, the dilapidation surveys and material recovery assessments that de-risk the transition.

Stage Five, Residual Life Certification (Continuum). The engineering stage delivers residual life assessment and structural stability certification, collapse and distress investigation, engineering design review of retrofit schemes, and durability engineering for the next generation of the asset, closing the lifecycle for developer, society, and authority together.

11m.6 Named Clients

India Real Estate Developers (LRC anchors). Godrej Properties (3-year LRC, all Mumbai Zone, April 2026 onward), Kalpataru, Shapoorji Pallonji, Rustomjee, Lodha (Macrotech Developers), Oberoi, K. Raheja, DLF, Prestige Group, Brigade Group, Sobha, Embassy, Phoenix Mills, Hiranandani, Wadhwa Group, Piramal Realty, Tata Realty, Mahindra Lifespaces, Adani Realty, Sunteck Realty, Ajmera, Runwal.

India EPC and Construction. Larsen and Toubro Construction, Tata Projects, Hindustan Construction Company (HCC), Afcons Infrastructure, J. Kumar Infraprojects, Patel Engineering, Reliance Infrastructure, Dilip Buildcon, PNC Infratech, KNR Constructions, IRB Infrastructure.

India Government and Civic. Brihanmumbai Municipal Corporation (BMC; the March 2026 Roads Department registration; Section 353B structural-audit empanelment); Mumbai Metropolitan Region Development Authority (MMRDA); CIDCO (Maharashtra empanelment for materials testing); Maharashtra Public Works Department (cross-vertical reference).

Cement and RMC. UltraTech Cement, ACC, Ambuja Cements, Lafarge-Holcim, Birla Corp, Shree Cement, Dalmia Cement, Heidelberg Cement, JSW Cement.

Anchor Monumental Construction (cross-vertical reference). Larsen and Toubro for Statue of Unity; Adi Shankaracharya Statue of Oneness; Antilia (Mumbai); Wankhede Stadium.

11m.7 Marquee Projects

Project	Service Anchor	Year
Godrej Properties (3-year LRC, all Mumbai Zone)	Long-Term Rate Contract for materials testing across Godrej Mumbai-Zone properties	April 2026 onward
Kalpataru, Shapoorji Pallonji, Rustomjee	Long-Term Rate Contracts	Continuous
1,200+ structural audits (Section 353B, Mumbai Municipal Corporation Act 1888)	Visual condition survey, GPR, UPV, rebound hammer, half-cell potential, cover meter, drone capture, core extraction	Continuous
BMC March 2026 Roads Department registration	Mumbai municipal roads programme	March 2026 onward
Mumbai Coastal Road Project	Civil testing, sub-water bridge-pier inspection	Continuous
Larsen and Toubro Statue of Unity year-long onsite engagement	Continuous on-site materials and NDT	Construction era

Godrej Properties signed a long-term rate contract for civil testing across its Mumbai zone in April 2026. Reinforcement-coupler qualification runs to the full IS 16172:2023 scope, where TCR is the first and only BIS-accredited commercial laboratory in India, and structural-audit work proceeds under Section 353B of the Mumbai Municipal Corporation Act 1888. The Mumbai-Ahmedabad High Speed Rail civil packages draw on the same concrete, reinforcement, and structural-steel testing.

INDUSTRIES · SECTION 11N

Metal Trading and Recycling

SECTION 11N

11n. Metal Trading and Recycling

TCR is the **preferred laboratory partner to Bharat Metal Exchange member traders** and an **ICCL/BSE-approved assayer** (since 2018), the neutral referee for a **2,500-plus-trader** bullion and non-ferrous market, with the classical wet-chemistry bench and ILAC-recognised reports.

POTENTIAL FAILURES WE SERVICE

Disputed assays, off-specification consignments and contamination in bullion, non-ferrous and ferro-alloy trade. TCR resolves purity and composition disputes by fire assay, optical-emission and ICP spectrometry, atomic absorption and classical wet chemistry, acting as the neutral arbitration assayer for exchange-settled and physical-market consignments.

The preferred laboratory partner to Bharat Metal Exchange member traders and an ICCL/BSE-approved assayer, TCR is the neutral arbitration bench for a market of 2,500-plus bullion and non-ferrous traders.

MARQUEE PROJECT

TCR is the **preferred laboratory partner to Bharat Metal Exchange member traders** and an **ICCL/BSE-approved assayer since 2018**, the neutral arbitration bench for the bullion and non-ferrous market.

11n.1 Industry Context

Metal trading runs on assay trust. Every consignment of ferro-alloys, scrap, ingots, or finished product changes hands against a composition certificate, and a disputed assay moves real money between buyer and seller with no room for argument by opinion. The referee in that dispute must be independent, accredited, and fast. TCR has played that role for decades from its BME House metal market office in Mumbai's Gulalwadi trading district, backed by NABL-accredited spectrometry, classical wet chemistry, and LECO analysis, **more than 700 PMI projects**, and sampling protocols that stand up in commercial arbitration. For traders, the TCR certificate is not a formality; it is the instrument that settles the trade.

The Indian bullion and precious-metals trading market routes through three buyer pools. The commodity-exchange empanelled assayer pool serves the Bombay Stock Exchange (BSE) and National Stock Exchange (NSE) bullion contracts, the Indian Clearing Corporation Limited (ICCL) settlement workflow, and the Bharat Metal Exchange Association (BMEA) BME House physical assay operation. The jewellery and refining pool serves bullion refiners, jewellery houses, hallmarking centres, and gold and silver bar manufacturers. The non-precious metal trading pool serves traders in copper, aluminium, lead, zinc, nickel, tin, brass, bronze, and ferro-alloys (FeV, FeMo, FeNi, FeSi, FeCr) operating off the LME-Comex price discovery and the local Bharat Metal Exchange physical settlement market.

The vertical is positioned operationally rather than on a damage-mechanism basis. The differentiators are statutory empanelment (BSE/NSE/ICCL/BMEA), classical wet chemistry capacity at scale (Section 4.4), and the NABL certificate NABLT0726MH18640 ISO/IEC 17025:2017 accreditation that gives every assay report international ILAC MRA reciprocity.

11n.2 Plant Sections We Inspect (Material Vocabulary)

Material Class	Examples
Industrial non-ferrous	Copper (electrolytic, fire-refined), aluminium (alloy and wrought), lead, zinc, nickel, tin
Brass and bronze	C260, C272, C360, gunmetal, naval brass, manganese bronze
Ferro-alloys	FeV, FeMo, FeNi, FeNiMo, FeSi, FeCr, FeMn, FeTi, FeNb
Iron ore and concentrates	Hematite, magnetite, fines, sinter feed, pellet feed
Specialty alloys	Inconel scrap, monel scrap, hastelloy scrap; refractory-metal scrap (Ti, Mo, W, Ta, Nb)
Galvanised coatings	Radiator fins, sheet G.I., wire G.I.
Fasteners (commodity grade)	Screws and spring washers per `IS 1573`

11n.3 Test Methods We Apply (Assay Vocabulary)

Fire assay. Cupellation method for gold and silver bullion; weighing on micro-balance to ±0.0001 g resolution. ASTM E1335 (gold) and ASTM E1338 (silver) reference frameworks.

Optical Emission Spectrometry (OES). Bulk compositional analysis on metals and alloys to ASTM E1086, E415, E1019, E1479, E350-E353 series.

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Trace element scanning, multi-element capability.

Atomic Absorption Spectrometry (AAS). Trace and minor element quantification.

Combustion Analysis (LECO). Carbon and sulphur in metals; IGA for nitrogen and oxygen.

Classical wet chemistry. Volumetric, gravimetric, and titrimetric methods for verification, arbitration, and reference-standard calibration. Retained at full bench scale for arbitration and referee analysis.

X-Ray Fluorescence (XRF). Hand-held and bench-top units for rapid bulk identification at field-level (cross-pillar with PMI under Section 5.1).

Density and specific gravity. Archimedes method for bullion verification.

Hallmarking-grade testing. BIS-aligned hallmarking workflow for jewellery centres.

11n.4 Standards Coverage Matrix

Non-Ferrous and Specialty. ASTM E478 (copper); ASTM E54 (aluminium); ASTM E607 (lead and tin); ASTM E663 (zinc); ASTM E76 (nickel and nickel alloys); IS 191, IS 21, IS 1944, IS 8492, IS 1366 (Indian non-ferrous specs); SAE/ASTM Unified Numbering System (UNS) per Casti Metals Red Book and Metals Black Book references.

Ferro-alloys. IS 1170, IS 1559, IS 4226, IS 4225 series; FeV, FeMo, FeNi compositional standards.

Coating and Plating. IS 1573 (galvanised coating on screws and spring washers); IS 4759 (galvanising); ASTM A123, ASTM A153 (galvanising).

Reference Materials. ARMI / MBH (USA / UK) Certified Reference Material panel (cross-listed under Industrial Research vertical); ISO 17034.

11n.5 Named Clients

Statutory. Bombay Stock Exchange (BSE), National Stock Exchange (NSE), Indian Clearing Corporation Limited (ICCL; ICCL/BSE Approved Assayer since November 2018), Bharat Metal Exchange Association (BMEA), Chamber of Commerce.

Industrial non-ferrous traders. BME House catchment of approximately 2,500+ traders; ferro-alloy traders supplying steel and foundry buyers; copper and aluminium traders supplying construction, automotive, and electrical buyers.

SECTION 110

11n.6 Service Applications Across the Assay and Trade Cycle

STAGE 01	STAGE 02	STAGE 03	STAGE 04
Pre-Shipment Sampling	Assay	Umpire Analysis	Settlement Support

Metal trading and recycling is not a plant vertical, so the Continuum adapts to the trade cycle: pre-shipment sampling, assay, umpire analysis, and settlement support. TCR's role is the neutral laboratory signature that both sides of a trade can accept. The recurring problems are sampling integrity on heterogeneous scrap and ferroalloy lots, assay disputes between buyer and seller certificates, and the settlement risk that follows, which is why the BSE and NSE empanelment and the bullion fire-assay operation anchor this vertical.

Pre-Shipment Sampling. Representative sampling of scrap, ferroalloy, ingot, and concentrate lots at yards, ports, and warehouses, with sample splitting and chain-of-custody discipline, supported by the TCR-BME Metal Market office serving the Mumbai ferroalloy catchment.

Assay and Analysis. Chemical analysis by classical wet chemistry, optical emission spectrometry, and X-ray fluorescence across ferrous, non-ferrous, and precious metals, including bullion fire assay, run on the classical wet-chemistry bench under NABL certificate NABLT0726MH18640.

Umpire and Dispute Analysis. Where buyer and seller certificates diverge, TCR acts as the umpire laboratory, retesting retained splits under agreed protocols and issuing the neutral certificate that settles the trade.

Settlement and Exchange Support. Assay certification supporting exchange-linked settlement, including the BSE and NSE empanelment scope, and periodic verification programmes for recurring trade counterparties.

INDUSTRIES · SECTION 110

Insurance Referee Surveying

110. Insurance Referee Surveying

When a boiler ruptures or a plant catches fire, India's insurers and the global reinsurers, **New India Assurance, ICICI Lombard, Bajaj Allianz, Tata AIG, GIC Re, Munich Re and Swiss Re**, send the claim to TCR as independent technical referee.

POTENTIAL FAILURES WE SERVICE

Boiler explosions, pressure-vessel ruptures, pipeline and tank fires, equipment-breakdown and process-safety incidents. TCR establishes the technical cause through root-cause failure analysis, Fitness-for-Service and pressure-equipment incident investigation per `API 585`, standing as the independent referee between insurer and policyholder.

When a boiler ruptures or a plant burns, insurers and reinsurers from New India Assurance to Munich Re and Swiss Re send the claim to TCR, the neutral referee with the largest failure-investigation archive in India.

MARQUEE PROJECT

9,000+ failure investigations, the largest independent evidence base in India, anchor TCR's standing as the neutral referee between insurer and policyholder.

110.1 Industry Context

Industrial insurance losses in India have reached a severity where forensic quality decides outcomes. A single 2025 plant fire at Nashik was reported by the insurance market at over Rs 2,000 crore across six insurers, with about 80 percent of the loss ceded to reinsurers including GIC Re, and the post-detariffication market is repricing industrial risk on evidence rather than habit. In claims of that size, the difference between an opinion and a laboratory-proven root cause is measured in crores. TCR serves insurers, reinsurers, surveyors, and counsel as an independent referee: fire damage assessment, metallurgical failure analysis with SEM fractography, and NABL-accredited test evidence, extended into Southeast Asia through the Approved Group International alliance.

The insurance referee market routes through three buyer pools.

The general insurer pool covers the public-sector quartet (New India Assurance, United India Insurance, National Insurance, Oriental Insurance) and the private market (HDFC ERGO, ICICI Lombard, Bajaj Allianz, Tata AIG, IFFCO Tokio, Reliance General, SBI General, Future Generali, Cholamandalam MS, Royal Sundaram, Liberty General, Kotak Mahindra General, Universal Sompo, Magma HDI).

The reinsurer and broker pool covers GIC Re, foreign reinsurers operating in India (Munich Re, Swiss Re, SCOR, Lloyd's syndicates), and broker firms (Marsh, Aon, Willis Towers Watson, JLT, Howden) routing claim-investigation work to the independent third-party referee. The policyholder pool covers the operating-side buyer engaging TCR ahead of an insurance claim to establish the technical narrative (root-cause failure analysis, fitness-for-service, plant-life-extension review).

The vertical sits cleanly under TCR Advanced.

The positioning is neutral third-party referee: TCR has no equity in the insured asset, no contractual relationship with the manufacturer or EPC, and no operational interest in the outcome.

The 9,000+ failure investigation archive is the foundational evidence base. The two ASM International publications (which sit on integrity-engineering benches in 140+ countries) and the in-house Scanning Electron Microscope fleet (three SEMs at TCR Advanced Vadodara) provide the courtroom-and-arbitration credibility.

110.2 Failure Types We Investigate

Claim Category	Examples
Boiler and pressure-equipment failure	Boiler tube leak, header crack, pressure-vessel rupture, heat-exchanger tube failure, ammonia tank leak, cryogenic tank brittle fracture
Fire damage	Refinery and petrochemical fire, fertiliser-plant fire, captive-power-plant fire, transformer fire, warehouse fire, residential and commercial property fire
Pipeline failure	Cross-country pipeline rupture, CGD distribution-network failure, offshore export-trunkline failure, third-party damage, geohazard failure, corrosion-induced leak
Structural collapse	Chimney and stack failure
Marine and offshore	Vessel grounding, jacket-structure damage, mooring failure, jetty-pile failure
Process incident	Reactor temperature excursion (the HMEL 503-R-001 case framework), urea-reactor passivation breakdown, ammonia synthesis-loop failure
Equipment OEM warranty	First Article Qualification dispute, manufacturing-defect verification, vendor-source-inspection dispute

110.3 Damage Mechanism Coverage

Aligned to API RP 571 (refining), the ASM Handbook Volume 11A chapter on boilers, the WRC 489 / 488 / 490 series. The full damage-mechanism taxonomy spans approximately 70 mechanisms (the AiOM platform damage-mechanism library reach).

The investigative workflow: visual, NDT, replication per ASTM E1351, hardness, mechanical and chemical, fractography (SEM and EDS), microstructural analysis, FEA where loading is in question, damage-mechanism attribution, and a written report fit for litigation, insurance, or operator action. The 5-role TCRADV/TM-66 team architecture (metallurgical engineer, mechanical and design engineer, ASNT Level III inspection engineer, site in-charge, certified NDT technicians) extends to the referee engagement.

110.4 Standards Coverage Matrix

Failure Analysis. ASM Handbook Vol. 11A (2021, the Haribhakti and Joshi co-authored chapter on boilers); API RP 571 3rd ed. (2020); WRC 489, WRC 488, WRC 490; ASTM E1351 (in-situ replication).

Fitness for Service. API 579-1/ASME FFS-1 4th ed. (2021); BS 7910.

Fire Damage. API 579-1 Part 11; BS 8408 (fire-damaged concrete assessment).

Insurance and Loss Adjustment. IRDAI guidelines for surveyors and loss assessors (India); Lloyd's of London Underwriting Code; Munich Re, Swiss Re, SCOR loss-adjustment frameworks where the reinsurer is the buyer.

Forensic. Locard's Exchange Principle (the foundational forensic framework); SWGMAT (Scientific Working Group on Materials Analysis); IAI (International Association for Identification) framework where applicable.

110.5 The Buyer Pool (Indian General Insurers and Reinsurers)

Public-sector general insurers. New India Assurance, United India Insurance, National Insurance, Oriental Insurance. Reinsurer. GIC Re. Private general insurers. HDFC ERGO, ICICI Lombard, Bajaj Allianz, Tata AIG, IFFCO Tokio, Reliance General, SBI General, Future Generali, Cholamandalam MS, Royal Sundaram, Liberty General, Kotak Mahindra General, Universal Sompo, Magma HDI. Foreign reinsurers (operating in India). Munich Re, Swiss Re, SCOR, Lloyd's syndicates. Brokers. Marsh, Aon, Willis Towers Watson, JLT, Howden. Surveyor firms. IRDAI-licensed loss-adjusters and surveyors routing referee work for technical adjudication.

110.6 Marquee Engagements

Engagement Class	Reference
The HMEL Bathinda Isomerisation Reactor 503-R-001 FFS file	The 2012 temperature-excursion event later monitored through 2019 with no shutdown, no replacement

As an independent referee, TCR investigates catastrophic explosions, fires, and equipment failures for general insurers and reinsurers, with cause-and-origin findings that hold up in litigation. The evidentiary base is the 9,000-plus failure investigations in the technical database. Fire-damage assessment of refinery and storage assets, including the HMEL Bathinda VGO reactor following a 2024 fire, anchors the post-loss engineering work.

110.7 Service Applications Across the Claim Lifecycle

STAGE 01	STAGE 02	STAGE 03	STAGE 04	STAGE 05
Incident Response	Damage Assessment	Root Cause Determination	Reinstatement Verification	Subrogation Support

Insurance referee work follows the claim, not the plant, so the Continuum adapts to the claim lifecycle: incident response, damage assessment, root cause determination, reinstatement verification, and subrogation support. The recurring pressures are speed, an insurer needs a defensible technical position before positions harden, neutrality between insured, insurer, and reinsurer, and evidence quality that survives legal scrutiny.

Incident Response. Rapid site attendance after fire, explosion, machinery breakdown, or structural failure, with evidence preservation, photographic and dimensional records, and sampling protocols that keep every later finding admissible.

Damage Assessment. Quantification of damage extent: fire damage assessment per API 579-1/ASME FFS-1 Part 11 methodology on process equipment, hardness and in-situ metallographic surveys to map heat-affected zones, structural condition assessment, and the repair-versus-replace boundary drawn on measurement.

Root Cause Determination. Root cause failure analysis in the NABL-accredited laboratory, fractography, metallurgical evaluation, chemical analysis, and mechanical verification, distinguishing design, material, operation, and maintenance causes, the distinction on which liability and subrogation turn.

Reinstatement Verification. Independent verification that repairs and replacements meet specification: material certification review, weld inspection, post-repair non-destructive testing, and fitness for service confirmation before the asset returns to duty.

Subrogation and Litigation Support. Expert technical reports structured for loss adjusters, insurers, reinsurers, and counsel, with the laboratory evidence chain, standard citations, and the neutral third-party position that makes the TCR signature usable in recovery proceedings.

110.8 Why Insurers Choose TCR

1. Neutral third-party referee position. TCR has no equity in the insured asset, no contract with the manufacturer or EPC, and no operational interest in the outcome.
2. 9,000+ failure investigation archive. The single largest evidence base in India to compare a disputed event against historical patterns.

3. Published authority on the highest-stakes integrity classes. The two ASM International titles distributed in 140+ countries make the Haribhakti and Joshi names defensible in courtroom and arbitration testimony.
4. In-house SEM and EDS at scale. Three Scanning Electron Microscopes at TCR Advanced Vadodara: Pemtron SS100, Jeol JCM 6000+, and Phenom XL G2 at 60,000x magnification with CeB6 source. The fractography record sits at the appellate evidentiary threshold.
5. NABL ISO/IEC 17025:2017 accreditation with ILAC MRA reciprocity. Reports are accepted across 90+ economies without re-testing, which removes a procedural objection in cross-border claims.
6. The integrated FFS-and-RCFA workflow. TCR can issue a single end-to-end report covering damage mechanism attribution, FFS calculation against the relevant code, and remediation recommendation; the insurer does not have to coordinate multiple specialists.
7. The TCRADV/TM-66 5-role team architecture for FFS engagements applies on referee work as well, which keeps the technical-adequacy threshold aligned with the API 579 / BS 7910 framework.
8. The IBR Well-Known RLA Organisation status under Indian Boiler Regulations for boiler-related insurance referee work.

INDUSTRIES · SECTION 11P

Industrial Research

SECTION 11P

11p. Industrial Research

TCR builds the corrosion-autoclave methodology cross-checked against **ITER**, the world's largest fusion-energy project at Cadarache, France, TCR Advanced has been a recognised **PhD research institute since 2012**, and has held the **NPCIL elevated-temperature tensile** programme since 2013.

POTENTIAL FAILURES WE SERVICE

Unproven materials, novel damage mechanisms and one-off engineering questions that standard testing cannot answer. TCR Advanced builds custom autoclaves and test rigs, develops publication-grade methodologies, and runs long-duration creep, electrochemical and fractographic studies for atomic-energy, space and industrial R&D buyers.

When standard testing cannot answer the question, TCR Advanced builds the autoclave, develops the method and runs the study, with a corrosion-rig methodology cross-checked against ITER and a recognised PhD research institute since 2012.

MARQUEE PROJECT

The corrosion-autoclave methodology built for the **Institute of Plasma Research** is cross-checked against **ITER**, the international fusion reactor at Cadarache, France.

11p.1 Industry Context

Industrial research buys capability, not capacity. When a laboratory partner is asked to run a custom creep frame, a non-standard corrosion cell, or a fatigue programme outside any published method, the question is whether the partner can design the apparatus, defend the uncertainty budget, and publish-grade the data. TCR has answered that question for research institutions and corporate R&D centres for five decades, with custom test rigs, contract research and development under Section 6.20, three scanning electron microscopes, and a 9,000-plus failure investigation archive that turns individual experiments into pattern-level insight. For research buyers, the draw is a partner fluent in both the standard and the exception.

The Industrial Research vertical is the contract-research-and-custom-apparatus scope under TCR Advanced. The buyer pool routes through three classes. The government and atomic-energy pool covers DRDO and its laboratories, NPCIL, BARC, the Heavy Water Projects, ISRO and its centres (cross-vertical with Aerospace and Defence Section 11h), and the Institute of Plasma Research (the ITER-India anchor).

The academia and PhD research pool runs through the MS University of Baroda PhD Research Institute relationship (TCR Advanced has been recognised as a PhD research institute since 2012). The industrial R&D pool covers contract corrosion-coupon supply, reverse engineering, foundry-setup consultancy, custom test-rig design, and proprietary IP-development engagements where the client buys exclusive use of the TCR Advanced bench and equipment over a multi-year window.

The differentiator framing is operational and methodology-led rather than damage-mechanism-led. The vertical positions TCR Advanced as the place industrial buyers go when they need a custom test, a custom apparatus, a publication-grade methodology development, or a long-term proprietary research relationship that the testing-only competitors cannot deliver.

11p.2 Research Capabilities and Custom Apparatus

Capability	Detail
Custom corrosion coupons	Supplied since 2012; geometries, materials of construction, and exposure protocols designed to client specification; cross-listed with Steel and Metal Trading
Microstructure Image Characterizer (MiC)	Proprietary image-analysis software developed since 2008; quantitative grain-size, inclusion-rating, and phase-distribution analysis at automation grade; deployed across the metallurgical bench and as a commercial software product
Custom test-rig and autoclave fabrication	The ITER France autoclave deliverable is the marquee international cross-check anchor for the rig-fabrication capability
Reverse engineering	Documented service since October 2008; component characterisation against design intent for indigenous-replacement and aftermarket-supply scope
Foundry-setup consultancy	Materials selection, melt-shop design review, sand-casting and investment-casting workflow audit, gating-and-risering review
Three Scanning Electron Microscopes	Pemtron SS100, Jeol JCM 6000+, Phenom XL G2 (CeB6 source, 60,000x magnification); the fractography and high-resolution imaging bench
Long-duration creep	Six creep frames at 50 kN to 1,100 °C, duration to 100,000 hours (the largest in India per Section 4.13)
NPCIL elevated-temperature tensile	Three-temperature 300/500/800 °C protocol qualified since 6 December 2013; returned in service 2025-26 via Avinash Tambewagh as Technical Head
Tribology and ferrography research	Lube-oil and wear-particle research bench (cross-pillar with Section 4.5 Oil Analysis Ferrography)

11p.3 Research Methodologies

The MS University of Baroda PhD Research Institute relationship. TCR Advanced has been recognised as a PhD research institute since 2012. The relationship enables doctoral research on metallurgy, corrosion, and asset integrity from the TCR Advanced Vadodara bench, with Dr. P.B. Joshi (ex-Head, Department of Metallurgical Engineering, MS University Vadodara, 50+ research publications, ASM book co-author) as the senior academic anchor.

The ITER-France autoclave cross-check. The Institute of Plasma Research engagement (Indian contribution to the international thermonuclear experimental reactor at Cadarache, France) carries crevice-corrosion and electrochemical-study scope, with cross-checking of the autoclave-deliverable methodology against the international fusion-research consortium's quality framework.

The ARMI / MBH (USA-UK) CRM panel access. Certified Reference Material access through the Analytical Reference Materials International / MBH Analytical UK panel underpins the calibration and verification methodology.

11p.4 Standards Coverage Matrix

Contract R&D Methodology. ISO/IEC 17025:2017 (NABL certificate NABLT0726MH18640 base accreditation extended to research scope); ISO 17034 (reference material producer competence); ASTM E177 (precision and bias in test methods); ASTM E691 (inter-laboratory study to determine precision); ISO 5725 series (precision and trueness of measurement methods).

Aerospace Materials Testing (NADCAP AC7101 accredited). SAE AMS 2750 Pyrometry; SAE AMS-H-6875; SAE J423; ASTM E18, E10, E92, E384, E112, E407, E45.

Atomic-Energy and Nuclear-Adjacent. AERB Safety Manuals; ASME Section III (nuclear components, where in scope); ASME Section XI (in-service inspection of nuclear components); IAEA Safety Standards Series.

Custom Apparatus. ASTM E1820 (CTOD); ASTM E139 / E292 (creep); ASTM E466 / E606 (fatigue); NACE TM0177 / TM0284 (corrosion); ITER quality-assurance framework where in scope.

11p.5 Named Clients and Partners

Government and Atomic-Energy. ITER-India for the Institute of Plasma Research; NPCIL; BARC; DRDO laboratories (DMRL, DMSRDE, R&DE, NMRL long-term contract); Heavy Water Projects; ISRO and centres (VSSC, LPSC, SHAR, SAC; cross-vertical with Aerospace).

Academia. MS University of Baroda (PhD research institute relationship since 2012)

International Reference Material Panel. ARMI / MBH USA-UK CRM panel.

Industrial R&D Buyers. Multi-year proprietary research engagements with refining, petrochemical, fertiliser, power, and steel buyers where the TCR Advanced bench is contracted on an exclusive-use basis.

Foundry-Setup Consultancy Buyers. Greenfield and brownfield foundry capex programmes routed through TCR Advanced for materials and methodology audit.

11p.6 Why Research Clients Choose TCR (Differentiators)

1. The proprietary IP base. Custom corrosion coupons since 2012; MiC software since 2008; the autoclave-deliverable methodology cross-checked at ITER France.
2. The PhD-grade research bench. The MS University of Baroda relationship since 2012; senior consultants with 50+ research publications and ASM authorship.
3. The three-SEM fractography stack at TCR Advanced Vadodara. Pemtron SS100, Jeol JCM 6000+, Phenom XL G2 (60,000x with CeB6 source).
4. The NPCIL elevated-temperature tensile continuity since 2013. Twelve years and counting of methodology continuity on a single high-stakes contract-R&D programme.
5. The NADCAP AC7101 Materials Testing accreditation, awarded 2026. The aerospace-grade methodology threshold.
6. The NABL ISO/IEC 17025:2017 plus ILAC MRA reciprocity. Cross-border research collaborations accept the test reports without re-testing.
7. The integrated long-duration-creep capacity. Six frames at 50 kN to 1,100 °C, 100,000-hour duration; the international peer set typically runs two or three frames at most.
8. The end-to-end contract-R&D lifecycle. From custom apparatus design through methodology development through NABL-validated execution through publication-grade reporting; the testing-only competitors cannot match the lifecycle.

11p.7 Service Applications Across the Research Lifecycle

STAGE 01
Problem Definition

STAGE 02
Apparatus Development

STAGE 03
Testing Campaign

STAGE 04
Interpretation

STAGE 05
Publication and IP Support

Industrial research engagements follow the research lifecycle rather than the plant lifecycle: problem definition, apparatus development, testing campaign, interpretation, and publication or intellectual property support. TCR's differentiator here is operational: the willingness to build the rig the question needs, custom autoclaves, simulated-environment cells, and instrumented fixtures, rather than bending the question to standard apparatus.

Problem Definition. Joint scoping with the client's research or reliability team: the materials question, the service environment to be simulated, the acceptance criteria, and the standard framework, ASTM, NACE, ISO, or a bespoke protocol, the campaign will run under.

Apparatus Development. Design and fabrication of custom test apparatus: autoclaves for high pressure high temperature exposure, sour-service cells, electrochemical rigs, and instrumented mechanical fixtures, commissioned and calibrated with full metrological traceability under the ISO/IEC 17025:2017 management system.

Testing Campaign. Execution of the exposure and testing matrix with the uncertainty budgets, replicate discipline, and interlaboratory comparison behaviour of an NABL accredited laboratory under certificate NABLT0726MH18640, so that research data carries the same defensibility as certification data.

Interpretation. Metallurgical and analytical interpretation by the senior bench, microstructural characterisation, fractography, electrochemical analysis, and correlation against the 50-year institutional database of failure investigations and corrosion behaviour.

Publication and Intellectual Property Support. Reporting structured for peer review, patent filing, or regulatory submission, with co-authorship where appropriate, in the tradition of the group's ASM International publications and conference record (Section 15).

12. Energy Transition

Energy transition is not a vertical for TCR. It is a cross-cut that runs through every existing vertical. Industrial decarbonisation, electrification of mobility, hydrogen-based chemistry and steelmaking, ammonia bunkering for marine fuel, captive renewable integration at thermal plants and the carbon-capture-and-storage capex layer are all programmes that touch the same buyers TCR already serves.

The static-equipment specialist line continues to apply: the equipment that holds hydrogen, ammonia, supercritical CO2, refrigerated cryogens, and the chemistry of bio-feedstock streams is the surface area where TCR's testing, NDT, FFS, RLA, KBA, and ECA practices remain the work.

Six cross-cutting capability themes anchor the section.

12.1 Hydrogen Service Across the Catalogue

Hydrogen has been an integrity-engineering priority since the early refining vertical work. The decarbonisation expansion (green-hydrogen production at electrolyser plants; hydrogen blending in natural-gas trunklines; hydrogen-fuelled aviation, automotive, and rolling stock; hydrogen-DRP green steel; hydrogen co-firing in thermal power) extends the existing capability surface. The base capability is mature and the buyer pool is now scaling.

Capability	Standard	Cross-Reference
Hydrogen embrittlement screening on plated and coated fasteners	`ASTM F519`, `ASTM F1624` incremental step-load	Section 4.2, 4.7.5; Section 11h Aerospace; Section 11l Automotive; Section 11d Pipelines
Hydrogen embrittlement on alloy and carbon-steel bolting in petroleum and natural gas	`API 20E`	Section 4.2, 4.7.5; Section 11e Oil and Gas Upstream
Hydrogen Induced Cracking on sour-service line pipe	`NACE TM0284` (Solution A and Solution B)	Section 4.7.2; Section 11d Pipelines; Section 11e Oil and Gas
Stepwise cracking and Stress-Oriented HIC	`NACE TM0284` plus `NACE TM0177` Method A combined	Section 4.7.3; Section 11d, 11e
Hydrogen Induced Disbonding (HID, the April 2026 test facility)	`ASTM G146`	Section 4.7.4; clad pressure vessels and overlays in refining and petrochemical sour service; Section 11a, 11k

Capability	Standard	Cross-Reference
High-Temperature Hydrogen Attack detection in operating equipment	API 941 (Nelson curves)	Section 5.2.4; Section 6 (FFS); Section 11a Refining; Section 11b Power; Section 11c Fertilisers; Section 11g Steel
CTOD with H2S hydrogen pre-charging on sour-service material	ISO 15653, ISO 12135, BS 8571, NACE TM0177, NACE MR0175 / ISO 15156, NACE TM0284; the L&T-developed 96-hour H2S charge plus 20-minute load window	Section 3.8; Section 11e Oil and Gas; Section 11f Marine

The capability set crosses cleanly into the green-hydrogen orbit (PEM and alkaline electrolyser equipment qualification; hydrogen storage and transmission pipework; hydrogen-fuel-station compressor and dispenser equipment; ammonia synthesis loops fed by green hydrogen; aerospace hydrogen-fuel pressure vessels).

12.2 The Ammonia Value Chain

Ammonia is the single largest near-term play in the energy-transition space. The Indian National Green Hydrogen Mission target of 5 million metric tonnes per annum of green hydrogen by 2030 implies green-ammonia capacity additions across the 12+ announced Indian projects.

The IMO 2030+ marine-fuel decarbonisation pathway is bringing ammonia bunkering capability into the GCC, Singapore, and Indian port ecosystems. Ammonia co-firing for thermal power decarbonisation is the third leg.

TCR's ammonia-value-chain capability is anchored in the Fertilisers vertical (Section 11c) and extends across:

- Green ammonia (electrolyser-fed): API 941 HTHA discipline expansion in front-end synthesis; corrosion testing bench for high-purity hydrogen feed handling.
- Blue ammonia (ammonia plus CCUS): amine-system corrosion qualification (cross-vertical with Refining).
- Ammonia as marine fuel: refrigerated-ammonia tank-integrity scope (the 18,000 MT API 620 Appendix R LBB study capability) into bunkering vessels and port-side storage; cross-vertical with Marine and Offshore Section 11f.
- Ammonia for power co-firing: combustion-side material qualification cross-vertical with Power Section 11b.
- 6 ammonia-tank RBI sites and 10 tanks track record (CFCL Kota, DFPCL Taloja, Paradeep Phosphates 3 tanks at 10,000 MT each per the EFMA / API 580 framework, IFFCO Kandla, IFFCO Kalol 2 tanks, RCF Trombay 2 double-wall double-integrity).

12.3 Carbon Capture, Utilisation, and Storage (CCUS)

CCUS surfaces across three integrity-engineering scopes.

Scope	Surface
Amine-system corrosion qualification	MEA degradation, regenerator and rich-amine exchanger corrosion, foaming-induced erosion; cross-vertical with Refining (FCC retrofit, SMR) and Fertilisers (blue ammonia)
Supercritical CO2 transmission piping	Dense-phase brittle-fracture qualification at low temperatures; under-deposit corrosion at low temperatures; `ASME B31.4` / B31.8 cross-pillar adaptation; cross-vertical with Pipelines Section 11d
FCC flue-gas CCS retrofit qualification	High-temperature material qualification at the post-combustion capture interface; cross-vertical with Refining Section 11a and Power Section 11b

The CO2 EOR (enhanced oil recovery) trend in the Indian onshore basins (Bombay High, Cambay, Krishna-Godavari, Cauvery) brings supercritical CO2 piping and reservoir-tie-in qualification work; cross-vertical with Oil and Gas Upstream Section 11e.

12.4 Renewable Feedstocks and Sustainable Aviation Fuel (SAF)

Renewable-feedstock co-processing on existing refining hydroprocessing trains brings new corrosion-mechanism scope: free fatty acid corrosion on co-processing units; chloride introduction from waste-oil feedstock; oxygenate cracking. The corrosion-testing bench (Section 4.7) and the corrosion-monitoring service line carry the relevant qualification capability.

Sustainable Aviation Fuel production at Indian refineries (BPCL Bina, IOCL Paradip Petrochemical Complex, HPCL Mumbai, Reliance Jamnagar) brings cross-vertical capex (Refining vertical, refinery efficiency block).

Bio-based chemicals and bio-refining (lactic acid, succinic acid, bio-ethylene, furfural; cross-vertical with Refining and Chemical Processing Section 11k) bring new corrosion mechanism scope on bio-feedstock streams.

12.5 Electric Vehicles, Battery Energy Storage, and the Lightweight-Structure Layer

The EV transition runs through Automotive Section 11l. Three new test surfaces have been opened up.

Mica testing for EV battery thermal insulation. Per ASTM C177 / ISO 8302 (Guarded Hot Plate) for thermal conductivity. The barrier-material qualification protects against thermal-runaway propagation. Introduced in 2026; client base spans Ola Electric, Ather Energy, TVS Motor (iQube), Bajaj Auto (Chetak), Tata Motors (Nexon EV), Mahindra and Mahindra (XUV400 EV).

Battery-pack structural-mounting fatigue. Cyclic-load qualification per ASTM E466 / E606 for module-mounting structures.

Battery cell housing and BMS housing. Compositional and mechanical qualification of cell-can materials and BMS chassis.

The Battery Energy Storage System integration at thermal-plant sites (cross-vertical with Power Section 11b) brings new electrochemical and fire-safety surface area; cross-pillar with Section 11o Insurance Referee where BESS fire-event referee work emerges.

The hydrogen-fuel-cell vehicle programme (Tata Motors, Toyota, Hyundai pilot programmes; cross-vertical with Pipelines and Refining for hydrogen fuelling stations) brings hydrogen embrittlement and pressure-vessel scope.

12.6 Captive Renewable Integration at Thermal and Industrial Sites

Solar-PV integration at thermal-plant sites brings structural-steel testing for module-mounting structures. Wind-turbine foundation pile, transition-piece, and monopile-to-tower flange testing brings cross-vertical scope from Steel and Marine. Floating offshore wind brings dynamic-fatigue and cathodic-protection scope.

The cycling-and-flexible-operation effect of renewables on baseload coal plant drives low-cycle fatigue surface area on existing thermal fleet.

The growing Indian Government hydrogen-fuel-station rollout for hydrogen-fuelled trucking on the highway corridor brings cross-vertical hydrogen-storage and pressure-vessel scope.

12.7 Climate-Resilience Capex

Flood-resistant bridge design, scour-mitigation engineering, sub-water bridge-pier inspection, cyclone-resistant façade and cladding, hurricane-resilient structural-steel framing, and fire-resilient industrial structures all add new testing scope as the climate-impact-and-adaptation capex layer scales.

12.8 The Strategic Position

TCR is built for the energy-transition cross-cut. The static-equipment specialist line, the 9,000+ failure-investigation archive, the 100,000+ replicated microstructure database, the published-author bench at ASM International, the in-house long-duration creep, fatigue and CTOD, sour-service corrosion, and HID test infrastructure, the AiOM digital backbone with AiOM-CCP for cross-country pipelines, the NABL ISO/IEC 17025:2017 accreditation with ILAC MRA reciprocity, and the cathodic-protection turnkey under the CP Division all transfer cleanly into the new buyer pools.

The strategic frame holds: the energy transition is a continuation of the integrity-engineering work TCR has done since 1973, applied to new equipment, new materials, and new operating envelopes, rather than a separate practice that requires new capability builds.

13. Global Capability, India-Based Delivery

90+	140+	100,000 h	2,600+ km
ILAC MRA SIGNATORY ECONOMIES	COUNTRIES REACHED, ASM PUBLICATIONS	CREEP DURATION CAPABILITY	CROSS-COUNTRY PIPELINE RADIOGRAPHY

Seven capability wedges anchor the group's international offering.

Seven capability wedges anchor the international section. The seven wedges run across reciprocity, scale, robotics, equipment, capability, talent, and footprint.

13.1 Wedge 1, One Report, Global Validity, No Re-Testing (ILAC MRA)

NABL is a signatory to the International Laboratory Accreditation Cooperation Mutual Recognition Arrangement. The ILAC MRA gives TCR test reports acceptance across 90+ signatory economies without re-testing. The reciprocity covers A2LA (United States), UKAS (United Kingdom), DAkkS (Germany), Cofrac (France), JAB (Japan), KOLAS (Korea), CNAS (China), Standards Australia, ENAC (Spain), Accredia (Italy), and the broader ILAC framework. For an Indian buyer sourcing material destined for a Saudi Aramco hookup, a UK-North-Sea offshore platform, a Japanese petrochemical complex, or a German auto OEM, the test report is accepted at face value. The reciprocity extends across the group. TCR Arabia in Dammam holds ISO/IEC 17025:2017 accreditation from the International Accreditation Service, testing laboratory TL-783, and IAS is itself an ILAC MRA signatory, so a mechanical or metallurgical report issued in Saudi Arabia carries the same cross-border acceptance as one issued from Navi Mumbai.

The wedge in one sentence. One report. Global validity. No re-testing.

13.2 Wedge 2, Specialised Methods at Scale

Three specialism clusters separate TCR from the average lab.

Sour-service corrosion testing. NACE TM0177 Methods A through D; NACE TM0284; NACE MR0175 / ISO 15156; NACE MR0103. Numerous Shell projects executed. PDO and OQGN approved. NACE Excellent Laboratory in the Private Sector award. CTOD with H2S hydrogen pre-charging per ISO 15653, ISO 12135, BS 8571 (96-hour H2S charge plus 20-minute load window) developed for Larsen and Toubro; few labs in the world execute the protocol.

Long-duration creep at scale. Six constant-load creep frames at 50 kN, operating up to 1,100 degrees Celsius, with duration capability up to 100,000 hours. The international peer set typically runs two or three frames at most with a 700 degree Celsius ceiling.

Cryogenic CTOD to negative 70 degrees Celsius for Arctic, cryogenic, LNG bunkering, and floating offshore-wind material qualification.

13.3 Wedge 3, Reformer Tube Robotics with Integrated FFS (ARTiS)

ARTiS is TCR-owned. The system carries reformer tube inspection through helical scan with embedded FFS reporting per API 579-1/ASME FFS-1 Part 10 and API 530. **50,000+ reformer tubes** scanned cumulatively. Named international engagements include Dangote Fertilizers Nigeria (2023), Emirates Steel Industries DRP1 and DRP2 Abu Dhabi (2025), JIFCO Jordan (2025), and continuous Indian fertiliser engagements at CFCL, IFFCO, RCF, and GNFC.

The ARTiS paper by Upadhyaya, Haribhakti, Patel, and Bafna (TCR Advanced, 2013-2014) is the published authority anchor.

13.4 Wedge 4, Saudi Aramco-Approved Internal RT Crawler with Documented Cost Avoidance

The Saudi Aramco-approved Internal RT Crawler is the marquee robotic-inspection IP in the catalogue.

Element	Detail
Engineering Report	SAER-13115 dated 8 September 2025 names TCR as technology provider
Documented cost avoidance	$4,980,000 over 5 years (approximately 80 percent reduction)
Demonstration	CAT Fabrication Shop, Dammam, 28 July 2025
Approved Radiographic Standard Procedure	TCR.QCP.REV-02 (2023), conformant with SAEP-1143 (6 September 2020)
Diameter range	16 inch to 52 inch
X-ray heads	160, 200, 300 kV at 5 mA
Positioning accuracy	±5 mm
Operating temperature	minus 10 to plus 70 °C
Cross-border deployment	Nepal Oil Corporation MAPL Phase II via Likhitha Infrastructure (Ref 2080/81 dated 30 July 2023; first non-GCC cross-border deployment)

13.5 Wedge 5, Three Scanning Electron Microscopes plus the In-Situ Metallography Bench

Three SEMs sit at TCR Advanced Vadodara: Pemtron SS100, Jeol JCM 6000+, Phenom XL G2 with 60,000x magnification using a CeB6 source. The in-situ metallography programme is anchored by 12 dedicated field teams across the group and a 100,000+ replicated microstructure database that supports same-day replica interpretation at the field site. The Reliance Industries Jamnagar engagement (1,200 in-situ replicas in 15 days) is the operational benchmark.

13.6 Wedge 6, Talent Depth, Not Cost Arbitrage

The India advantage is framed as talent and expertise depth, never cost arbitrage. The senior bench is named, credentialled, and accessible.

The published-author bench at ASM International (Haribhakti, Joshi, Kumar 2018; Haribhakti and Joshi 2021) reaches the integrity-engineering bench in 140+ countries through the two ASM publications.

The peer-style technical papers (NACE Paper No. 09012; the ARTiS paper; the high-temperature RLA paper) and the four foundational TCR white papers (2004 to 2010) extend the publication footprint.

The expert consultant bench at TCR Advanced adds named subject-matter authorities with 30 to 47 years of operating experience (Prof. Awadhesh Kumar Singh, Ashok Kumar Srivastava, Dr. M.M. Pandya, M.N. Patel, Dr. P.B. Joshi, Subrahmanya Bhat, Narendra Kumar Roy, Dinesh Butala, J.N. Agarwal). No competitor lab carries this depth of named expertise on call.

13.7 Wedge 7, The Operating Footprint

Element	Detail
Operating countries	7 (India, KSA, Oman, Kuwait, Qatar, Japan, Nigeria)
Past projects	Iraq, Vietnam, Mexico, Nepal, Jordan
Sample-origin countries	15+ (lab logistics footprint, separate from operating presence)
TCR Engineering	India operations (Mumbai-Mahape and Bhubaneswar TC-15993 plus Bangalore and UP)
TCR Arabia	KSA operations since 2007 (18 years); HQ at King Abdulaziz Seaport Facility Dammam; offices in Dammam, Jubail, Yanbu; 100+ NDT professionals; registered with 40+ major KSA companies; SAGIA approved; ASNT Corporate Partner; PP SIMTECH UK alliance for RBI and FFS; Saudi Aramco ANDT Contract 6601000141; IAS ISO/IEC 17025:2017 accredited testing laboratory TL-783
TCR Advanced	Vadodara HQ; the high-margin engineering consulting and contract R&D arm; AiOM platform development; ARTiS programme home

Element	Detail
Evolve by TCR	Vadodara training academy; ASNT, PCN, API, AMPP/NACE programmes; QAFCO Training scorecard 92.88/100 Grade A

The footprint is operationally consolidated. The TCR Engineering Mahape lab is the centre of gravity for high-volume sample work (3,000+ samples per month). TCR Advanced Vadodara is the consulting and R&D centre. TCR Arabia Dammam is the GCC delivery channel. The cross-border project bench in Nigeria, Iraq, Vietnam, Mexico, Nepal, and Jordan is delivered through fly-in fly-out crews from these centres.

13.8 The International Buyer Pool

The buyers reached through these wedges include Saudi Aramco, ADNOC, PDO, OQGN, KOC, Qatar Energy, KNPC, Iraqi Ministry of Oil, Indorama Eleme Nigeria, Notore Chemical Industries Plc Nigeria, Dangote Fertilizers Nigeria, Binh Son Refining Vietnam, Pemex Mexico, Emirates Steel Industries, JIFCO Jordan, QAFCO Qatar, OMIFCO Oman, PIC Kuwait, Petrokemya KSA, SABIC, MAADEN, TASNEE, SATORP, SADARA, YASREF, Petro Rabigh, Advanced Petrochemical, LUBEREF, MARAFIQ, plus the international OEM stack (Cameron International, NOV Inc., Halliburton, Schlumberger, Baker Hughes, Weatherford, GE International, Sulzer Chemtech Middle East, Casale SA Switzerland), plus ITER France for the Institute of Plasma Research, plus the broader cross-border project bench. The ASM publication reach in 140+ countries underwrites the credibility for any new buyer who has not yet engaged TCR directly.

13.9 The Chugai Technos Alliance (Japan)

On 29 April 2026 TCR signed a memorandum of understanding with Chugai Technos Corporation (Hiroshima, founded 1953) and Chugai Technos India Pvt. Ltd. (Bengaluru). TCR testing and integrity work reaching Japanese asset owners, and Chugai drone inspection, Scale Checker, and environmental testing reaching Indian and Middle East owners.

Both firms are founder-rooted, technically led inspection houses that have stayed independent across three generations in an industry dominated by global conglomerates. The shared view is simple: inspection is not a commodity but a trust contract between asset owner, inspector, and regulator, built over years rather than quarters. That alignment opened the conversation. The legal frame only gave it shape.

Into Japan, TCR offers rail and weld butt-joint fatigue (IS 16172, ISO 15630, EN 10138, ASTM A1034), coupler and TMT rebar fatigue, creep and stress rupture (ASTM E139) with accelerated creep rupture for boiler tube remaining-life work, boiler tube failure investigation and remaining life assessment through TCR Advanced, sour-service corrosion testing (HIC per NACE TM0284, SSCC per NACE TM0177 Methods A to D), fracture toughness (CTOD per BS 8571 and ISO 15653, K1c per ASTM E399, J-integral per ASTM E1820, fatigue crack growth per ASTM E647), ARTiS reformer tube inspection for HK and HP modified alloy tubes, root cause analysis from a base of 9,000+ group investigations, high-temperature inspection to 350 degrees C, helium leak testing, and radiographic film digitisation, where TCR has converted 250,000+ films for clients including IOCL and GAIL.

Into India and the Middle East, Chugai brings three blocks that complement rather than overlap the TCR catalogue: drone structural inspection of bridges, tanks, flare stacks, and heritage structures with crack detection to 0.2 mm, alongside TCR's 500+ bridge robotic and AI audit record in Maharashtra; the Scale Checker, a radioisotope system that measures scale, sludge, and shellfish fouling inside live pipelines without removing insulation or stopping flow, directly relevant to Indian refineries and to Saudi refining and desalination intakes; and Japanese-grade environmental and emissions testing (stack and ambient monitoring, AIG, SCR, APH, ESP and FGD performance testing, PFAS analysis, and greenhouse-gas inventory work) as Indian CPCB norms and Saudi NCEC standards tighten.

The Saudi leg runs through TCR Arabia, the joint venture with Gas Arabian Services (Tadawul: 4146) operating from Dammam under Country Manager (KSA) Syed Ameen Hassan, where Aramco and SABIC approvals are already in place. A more unusual element sits below the test methods: under the MOU, TCR shares its agent-based AI workflow layer and LIMS methodology with Chugai. Most cross-border inspection alliances exchange test methods. This one also exchanges an operating system. The first public commitment is a joint stand at a major Japanese industrial inspection exhibition in September 2026, covering reformer tube inspection, drone inspection, materials testing, the Scale Checker, and environmental testing.

13.10 International Project Record

The international project record is organised by region.

Saudi Arabia (Aramco and SABIC ecosystem). TCR Arabia has delivered across the Saudi industrial base since 2007, approved by Saudi Aramco and SABIC and accepted by Fluor Daniel, Technip, Tecnicas Reunidas, and Foster Wheeler.

Advanced NDT and time-of-flight diffraction for SINOPEC and TEKFEN at Petro Rabigh, TEKFEN at Khurais, ENCOCORP at Jeddah Airport, SABIC Al Bayroni and SABIC United, Advanced Petrochemical Company at Jubail, McDermott at Khursaniyah, SABIC JUPC, and Zamil Heavy Industries.

Heat treatment for Saudi Aramco at the Hawiyah, Shedgum, Haradh, and Karan gas plants, MARAFIQ Jubail, SABIC Ibn Zahr, and on the Jizan SWCC project.

Boiler remaining-life assessment at SWCC Jubail (Boiler 6). Metallurgical failure investigation for Advanced Petrochemical Company, SABIC KEMYA, Luberef, SIPCHEM, Saudi Railway, NOMAC, and Saudi Aramco at Qurayyah.

Welder qualification for Saudi Kayan, Tamimi, Petrojet, BEMCO, Zamil Steel, SABIC Ar-Razi, and ISCOSA.

Plus the decade-long robotic remote-visual and submersible inspection record for SABIC affiliates, MARAFIQ, SWCC, the Royal Commission, SAMREF, and Saudi Aramco.

GCC. Kuwait: Kuwait Oil Company, time-of-flight diffraction and tank inspection. Bahrain: GPIC, failure investigations on boiler furnace tubes, waste-heat-boiler ferrules, and economiser tubes, and Olayan Kimberly-Clark. Qatar: Q-Chem, failure investigation on furnace convection-section preheater tubes and high-sulphur piping welds, delivered through the TCR Qatar and BIEWU presence in Doha. Oman: Petroleum Development Oman and OQ Gas Networks approved, listed on the PDO AVME MCI-121 register, holding the JSRS three-year certificate with In-Country Value registration, with line-pipe qualification for Galfar Engineering and Contracting and Tsingshan Steel Pipe.

Africa, Asia, and the Americas. Iraq: Baiji Refinery, damage assessment of hydrocracker reactors. Vietnam: Binh Son Refining, accelerated creep-rupture testing and Omega-method remaining-life assessment of heater tubes (2025). Nigeria: Notore Chemical, idle-plant restart and integrity assessment.

Project record in numbers. More than 9,000 documented failure investigations, more than 750 remaining-life assessments (including more than 400 boiler RLA), more than 1,500 boiler-tube-failure investigations, **more than 700 PMI projects**, and more than 500 bridges, with an India client master of over 10,000 records across the sixteen verticals.

14. Training

Training is a revenue-generating vertical, not a corporate-social-responsibility initiative.

Training is a revenue-generating vertical, not a corporate-social-responsibility initiative. The buyer is the L&D head, the plant manager, the HR director, or the operating-side reliability lead, and the sales motion is catalogue-led rather than RFQ-led. The revenue model is course fees and in-plant programme fees rather than project fees.

Three delivery channels run under the umbrella. Evolve by TCR is the Vadodara-based training academy established 2017. TCR Arabia Training Centre is the Dammam-based parallel programme. In-plant training runs at the buyer's facility (the UltraTech Cement engagement at Vadodara, the QAFCO engagement at Mesaieed, the Larsen and Toubro engagements at Mumbai and Vadodara, etc.) on bespoke syllabus and schedule.

14.1 Evolve by TCR (Vadodara)

Parameter	Detail
Established	2017
Legal entity	Subsidiary of TCR Advanced Engineering Pvt. Ltd.
Location	215, Pancham Icon, Vasna Road, Vadodara, Gujarat 390007
Vice President	Deepak Chandarana
Web	www.evolvetcr.com
Position	Revenue-generating training vertical with industry-relevant technical education programmes; not a CSR initiative

14.1.1 Programme Catalogue

Non-Destructive Testing. ASNT NDT Level I, II, III. PCN. All five conventional methods (RT, UT, MT, PT, VT) plus advanced (PAUT, TOFD, ECT). BARC Level-1 radiography support. AERB radiation safety officer (RSO) training.

API Inspector Programmes. API 510 (Pressure Vessel Inspector). API 570 (Piping Inspector). API 653 (Above-Ground Storage Tank Inspector). API 580 (Risk-Based Inspection). API 936 (Refractory).

Coating Inspection. AMPP/NACE Coating Inspector Programme (CIP) Level 1, 2, 3. SSPC framework. FROSIO (where in scope).

Welding Inspection. CSWIP 3.1 / 3.2 / 3.4. AWS Certified Welding Inspector (CWI). IS 7318 framework.

Metallurgy. Five-level programme covering structure-property relationships, phase diagrams, heat treatment, failure analysis, and case studies from the 9,000+ TCR archive.

Corrosion. Three-level programme covering electrochemistry, sour-service corrosion (NACE TM0177, TM0284, MR0175 / ISO 15156, MR0103), high-temperature corrosion (HTHA per API 941, sulphidation, naphthenic acid), and corrosion control (cathodic protection, coatings, materials selection).

Engineering Consulting. FFS per API 579-1/ASME FFS-1. Damage mechanisms per API RP 571. RBI per API 580/581 (delivered as the KBA practice). Root Cause Analysis methodology. The integrated FFS and RBI programme is delivered alongside the AiOM software training.

Plant Operational, Inspection, and Reliability. IBR boiler-plant operational training (cross-vertical with Power Section 11b). Reformer-tube inspection workflow (the ARTiS practice). Cross-country pipeline integrity workflow. Asset Integrity Management programme alignment.

Safety Training. AERB radiation safety. ATEX/PESO. ISO 45001 occupational health and safety. Confined-space entry. Working at heights.

14.1.2 Anchor Clients

Tata Power. Gujarat Alkalies and Chemicals Ltd. (GACL). Reliance Industries. UltraTech Cement (Aditya Birla Group; the May 2025 boiler-training engagement). Larsen and Toubro. QAFCO Qatar (cross-channel with TCR Arabia delivery). Multiple refining, fertiliser, power, and steel clients across India and the GCC.

14.2 TCR Arabia Training Centre (Dammam)

Parameter	Detail
Location	Dammam (within the TCR Arabia operating campus)
Position	The KSA-side training delivery channel for the GCC client base; SAGIA-approved entity
Standing	ASNT Corporate Partner
Strategic alliance	PP SIMTECH (United Kingdom) for RBI and FFS implementation training (BP, Dow, GPIC, ADNOC-Fertil, BASF, INEOS track record)
Buyer pool	Saudi Aramco, SABIC, MAADEN, TASNEE, SATORP, SADARA, Sipchem, Advanced Petrochemical, LUBEREF, MARAFIQ, Saudi Electricity Company, plus the broader Aramco vendor universe

14.2.1 Programme Catalogue (KSA-Specific)

Programme	Coverage
Metallurgy (5 levels)	Structure-property, heat treatment, failure analysis, refining and petrochemical material classes
Corrosion studies (3 levels)	Sour-service per NACE / `ISO 15156`, refining per `NACE MR0103`, high-temperature, electrochemistry, CP framework
Engineering consulting	FFS per `API 579`, `API 571` damage mechanisms, RBI per `API 580/581`, RCA methodology

Programme	Coverage
NDT (all methods, Level I-III)	RT, UT, MT, PT, VT, ET; advanced PAUT, TOFD, EMAT
Welding (GTAW, SMAW)	Welder qualification per ASME Section IX, AWS D1.1, API 1104
Plant operational / inspection / reliability	API 510 / 570 / 653, AIM framework
Safety training	AERB-equivalent KSA framework, confined space, working at heights, fire safety

14.2.2 QAFCO Anchor Engagement

QAFCO Qatar returned a Training scorecard of 92.88 out of 100, Grade A on the multi-year training engagement. The engagement covers metallurgy, corrosion, NDT, FFS, and plant reliability programmes across the QAFCO operating bench, integrated with the TCR-QAFCO 15-year metallurgical rate contract and 8-year RLA partnership.

14.3 In-Plant Training Engagements

The in-plant model brings the TCR senior bench, equipment, and case-study library to the buyer's facility on a bespoke syllabus and schedule. Recent named engagements include:

Client	Programme	Date / Period	Reference
UltraTech Cement Ltd (Aditya Birla Group)	Best Operation and Maintenance Practices to Minimise Tube Leakages in Boiler (Boiler Metallurgy, Advanced NDT Techniques for Boiler Inspection, RLA, Water chemistry; practical demonstration of tube failure analysis at the TCR laboratory)	26 to 27 May 2025 at Vadodara	Appreciation letter dated 5 June 2025 from Kashyap Thorve, Sr. Vice President BCOE L&D
QAFCO Qatar	Multi-year metallurgy, corrosion, NDT, FFS, plant reliability	Continuous	92.88/100 Grade A scorecard
Larsen and Toubro Defence IC for VSSC-ISRO	Aerospace materials testing methodology training adjacent to the Chandrayaan-3 engagement	2023	Cross-vertical

Client	Programme	Date / Period	Reference
Tata Power, GACL, Reliance, IFFCO	In-plant integrity and reliability training	Continuous	EvolvebyTCR client roster

14.4 Why Buyers Choose Evolve by TCR Over Generic Training Providers

Three structural advantages.

Practical demonstration access to the live TCR laboratory. Trainees walk to the bench and watch a CTOD test, an ARTiS reformer-tube scan, an in-situ replica acquisition, an SEM fractograph, and a creep specimen rupture. The reference is direct and the methodology continuity is preserved.

The case-study library from **9,000+ failure investigations**. Programmes on tube failure analysis, FFS, RLA, RBI, and root-cause analysis run on real cases from the TCR archive (anonymised where required) rather than textbook examples.

The senior-bench faculty. ASM book co-authors, API 580 RBI Cert. holders, ASNT Level III credential holders across four methods, and the consultant bench with 30 to 47 years of operating experience deliver the programmes themselves rather than handing the programme to junior trainers.

The UltraTech Cement appreciation captures the proposition explicitly: "Your insights into Boiler Metallurgy, Advanced NDT Techniques for Boiler Inspection, RLA and Water chemistry to sustain and increase life of boiler assets, and practical demonstration of tube failure analysis at your laboratory have greatly enriched the participants' understanding and skillset." That sentence is the strategic positioning of the entire training section in one quote.

15. Published Authority and Conference Presence

The capability is backed by published authority.

Published authority sits behind the rest of the catalogue. When a buyer in Houston, London, Singapore, or Dubai opens this profile and reaches the Asset Integrity pillar, the question they ask is not "Can TCR test a sample?" The question they ask is "Will the report stand up under peer review, in arbitration, or in front of a regulator?" The published authority section answers that question with a defined inventory of two ASM International publications, three peer-style technical papers, one institutional product white paper, and four foundational TCR white papers spanning 2004 to 2021.

The defensible publication footprint is 10 formal publications plus an active senior-bench blog corpus. The two ASM International titles are the public anchor. The peer-style papers establish authorship priority on specialised methodology. The white papers establish the institutional voice on practice areas. The blog corpus extends reach but does NOT count toward the formal Published Authority claim.

15.1 The ASM International Anchor

15.1.1 Failure Investigation of Boiler Tubes (2018)

Haribhakti, P., Joshi, P.B., Kumar, R. (2018), Failure Investigation of Boiler Tubes: A Comprehensive Approach, ASM International, ISBN 978-1-62708-156-6, ~500 pages.

The book is the public-facing anchor for the Boiler RLA and KBA practice. Authored by Paresh U. Haribhakti (Managing Director, TCR Advanced) with Dr. P.B. Joshi (ex-Head, Department of Metallurgical Engineering, MS University Vadodara) and Mr. R. Kumar. The book reaches the integrity-engineering bench in 140+ countries through ASM International's distribution channel and is cited extensively in the boiler-vertical literature on tube-failure mechanisms, root-cause analysis methodology, and life-extension strategies.

15.1.2 ASM Handbook Volume 11A, Chapter on "Failure of Boilers and Related Equipment" (2021)

The chapter is the highest-credibility public reference on TCR Advanced's boiler-failure-analysis bench. Co-authored by Paresh U. Haribhakti and Dr. P.B. Joshi, the chapter sits in the ASM Handbook framework that integrity-engineering practitioners across the world treat as the authoritative reference. The 840-page Vol. 11A volume reaches the same 140+ countries distribution.

15.2 Peer-Style Technical Papers

15.2.1 NACE Paper No. 09012 (2009 to 2010)

Haribhakti, P.U. (2009-2010), NACE Paper No. 09012, NACE International Annual Conference and Exposition. Authored by Paresh U. Haribhakti at TCR Arabia. Establishes the in-situ metallography authorship priority and frames the TCR Arabia entry into the Aramco vendor universe.

15.2.2 ARTiS Reformer Tubes Paper (2013 to 2014)

Upadhyaya, K., Haribhakti, P., Patel, G., Bafna, V.K. (2013-2014), ARTiS Reformer Tubes Paper. Co-authored by Ketankumar Upadhyaya, Paresh Haribhakti, Gopul Patel, and V.K. Bafna at TCR Advanced. Establishes the published authority anchor for the ARTiS practice (**50,000+ reformer tubes** scanned cumulatively as of May 2026).

15.2.3 High-Temperature Remaining Life Assessment Paper (2014)

Haribhakti, P., Upadhyaya, K., Patel, G., Baad, S., Bafna, V.K. (2014), High-Temperature RLA Paper. Co-authored by Paresh Haribhakti, Ketankumar Upadhyaya, Gopul Patel, S. Baad, and V.K. Bafna at TCR Advanced. Establishes the published authority anchor for the elevated-temperature RLA practice (the 750+ all-asset-class RLA work; the 400+ Boiler RLA programme).

15.3 The 2026 AiOM White Paper

TCR Advanced, 2026, AiOM White Paper. The public-facing complement to the three internal AiOM source decks. Frames the six-pillar architecture (Asset Master, Asset Strategy, Asset Maintenance, Asset Integrity and Reliability, Asset Optimisation, Asset Analytics) and the AiOM-CCP cross-country-pipelines application against the API 580/581/584/579-1 standards stack.

15.4 Foundational TCR White Papers

15.4.1 Need for Failure Analysis in India and the Middle East (2004 to 2005)

The 2004-2005 institutional white paper that frames the failure-analysis practice for the Indian and Middle East buyer pool.

15.4.2 Failure and Root Cause Analysis: Investigating Material and Component Failure (July 2004)

The methodology white paper that codifies the TCR root-cause-analysis workflow (visual, NDT, replication per ASTM E1351, hardness, mechanical and chemical, fractography via SEM and EDS, microstructural analysis, FEA where loading is in question, damage-mechanism attribution, written report fit for litigation, insurance, or operator action).

15.4.3 Outsourcing Laboratory Practices (V.K. Bafna, June 2006)

Bafna, V.K. (2006), Outsourcing Laboratory Practices. Authored by V.K. Bafna (Co-founder, TCR Engineering, 1940 to 2013). Frames the ILAC MRA reciprocity and the outsourced-testing model for international buyers.

15.4.4 An Introduction to Ferrography (Paresh Haribhakti, March 2010)

Haribhakti, P. (2010), An Introduction to Ferrography. Authored by Paresh Haribhakti at TCR Advanced. Frames the lube-oil-condition-monitoring practice for predictive maintenance of rotating equipment.

Beyond the technical corpus, TCR published a 50th-anniversary volume, TCR Engineering: A 50-Year Journey in Material Testing Excellence, marking the 1973 to 2024 span and available on Amazon (ISBN 979-8347661930). It records the founding by Neelam Bafna and the late metallurgist V.K. Bafna and the build-out across mechanical testing, advanced NDT, civil testing, asset integrity, boiler audit, and failure analysis.

15.5 Conference and Industry Forum Presence

Beyond the ten formal publications, the TCR senior bench maintains an active conference-and-forum presence across 17 years of technical presentations. Forums include:

- ASNT (American Society for Nondestructive Testing) annual conferences and the ASNT Corporate Partner network (TCR Arabia is an ASNT Corporate Partner).
- NACE / AMPP (Association for Materials Protection and Performance) annual conferences and chapter events; the NACE Excellent Laboratory in the Private Sector award.
- Saudi Aramco ITEME (International Technical Exchange Meeting and Exhibition) and the broader Aramco vendor-and-licensor forum stack.
- World NDT Conference (WCNDT).
- SABIC STC (Scientific and Technical Conference).
- Fertilizer Show USA (2026).
- AIChE Ammonia Plant Safety Committee (Ahmed Esmael Rahimi of QAFCO sits on the committee; the committee is the international reference frame for ammonia-plant integrity).
- NDE conferences in India (NDE 2025 Mumbai launched the Chugai Technos Scale Checker product).
- Boiler India (Avinash Tambewagh delivered the Boiler India 2022 keynote).

15.6 Authored Blog Articles by Senior Bench

Across tcreng.com (320 unique posts) and tcradvanced.com (96 unique posts), named TCR senior personnel author approximately 400+ blog posts. The blog corpus extends technical reach and search-visibility surface but does not count toward the formal Published Authority claim. Blog articles do not extend the 140+ countries distribution claim.

16. Organisation and People

The organisation runs three operating entities (TCR Engineering, TCR Arabia, TCR Advanced), one training subsidiary (Evolve by TCR), one strategic equity investment (into partner companies). The senior bench is named, credentialled, and accessible. The expert consultant network at TCR Advanced is a structural differentiator; competing labs do not field this depth of named subject-matter authorities on call.

16.1 Co-founder and Leadership Transition

V.K. Bafna (1940 to 2013), Co-founder and Chairman Emeritus.

Late Shri Virendra K. Bafna was far more than just a co-founder of TCR Engineering Services; he was a true pioneer, a visionary, and the foundational guiding force in the fields of materials science, asset integrity, and non-destructive testing. In 1973, he established TCR Engineering Services and led the organisation with an unwavering commitment to excellence for four decades, transforming it into the ultimate reference point for independent materials testing in India. Driven by an indomitable entrepreneurial spirit and a profound passion for innovation, he successfully built a globally recognised institution whose signature clients could trust without qualification. He was, and remains, the true heart and soul of the company.

His remarkable journey began with a brilliant academic foundation in India, where he graduated as a gold medalist from the University of Indore. Eager to expand his horizons and deepen his technical acumen, his thirst for knowledge took him across the globe to pursue advanced international training. He earned two distinguished postgraduate degrees: a Master's degree in Engineering from the prestigious University of Toronto in Canada, and a Master's degree in Industrial Management from the Clarkson College of Technology in New York. Armed with this world-class education, he chose to return home to India, bringing back sophisticated training and global perspectives to revolutionise the domestic materials testing landscape.

With over 35 years of hands-on technical and managerial experience, Mr. Bafna fundamentally redefined industry standards through significant advancements in materials characterisation. He performed pioneering work in X-ray fluorescence (XRF)-based Positive Material Identification (PMI), effectively setting the definitive Indian benchmark for precision and reliability in the method. Furthermore, his seminal contributions to corrosion studies, advanced chemical analysis, mechanical testing, and failure investigations built the unshakeable institutional foundation on which the entire TCR group stands today.

Under his strategic stewardship, TCR Engineering drastically expanded its geographic and industrial footprint. He successfully guided the company's growth across India and orchestrated its strategic expansion into the Middle East through the creation of TCR Arabia. Today, TCR Arabia stands as a premier centre of excellence in the region, serving major global industries and carrying forward his blueprint for cross-border technical dominance. His foresight ensured that the company evolved in tandem with global industrial demands, bridging the gap between sophisticated laboratory science and heavy industrial application.

Beyond his executive and technical responsibilities, Mr. Bafna was a deeply respected thought leader and an active member of elite global scientific organisations. He contributed his vast expertise to the progress of institutions such as ASTM International, ASM International, NACE (now AMPP), the Indian Institute of Metals, and the Non-Destructive Testing Society of India. His invaluable contributions to national progress were recognised at the highest echelons of science, highlighted by a prestigious appreciation award from the Indian Space Research Organisation (ISRO) for TCR's pivotal role in Project ASLV (Augmented Satellite Launch Vehicle), a major milestone that cemented his impact on India's aerospace and defence advancements.

Though Mr. Bafna passed away in 2013, his extraordinary legacy continues to inspire generations of engineers, scientists, and industry professionals. The core principles he established—absolute independence, uncompromising technical rigour, and an ironclad refusal to ever dilute the signature on a report—remain the active, daily operating values embedded in the DNA of the company. Every milestone and achievement realised by TCR Engineering today stands as a direct tribute to his pioneering spirit, ensuring that while his earthly journey has ended, his vision remains permanently etched into the very fabric of the global industry he helped build.

Neelam Bafna, Chairperson and Managing Director (since 2013). Co-founder of TCR Engineering in 1973 alongside V.K. Bafna, and the person who has led the company since 2013. She steered the leadership transition with no private-equity recapitalisation, no break-up of the operating entities, and no sale of the institutional failure database, keeping the firm independent and family-held. She oversees operations, finance, and administration across the group. TCR has been woman-led under her since 2013, which still places it in a small minority of independent testing and inspection companies anywhere.

She is also a Director of TCR Advanced. Her approach to leadership rests on long-term relationships with clients, partners, and staff, and on keeping the institutional knowledge of the firm intact across generations. Beyond TCR she has founded ventures in Indian handicrafts, luxury textiles, and medical products, and supports several charitable causes privately.

It's rare to find a company in India so firmly led by a woman of Mrs. Bafna's vision and tenacity. Under her guidance, TCR has not only thrived in India but expanded internationally, with trusted partnerships and joint ventures around the globe. Mrs. Neelam Bafna is more than a leader; she is the heart of TCR Engineering Services, embodying a legacy of quality, respect, and enduring impact.

Mrs. Neelam Bafna, the powerhouse behind TCR Engineering Services, has been steering the company forward since she co-founded it in 1973 alongside her late husband, Mr. V.K. Bafna. Together, they built TCR from a visionary idea into a global leader in material testing, one renowned for its integrity, precision, and consistent excellence. Mrs. Bafna has not only kept this legacy alive but propelled it to new heights, meticulously overseeing daily operations, finance, and administration with an unyielding dedication that has kept TCR firmly anchored and always reaching.

Her leadership style is as authentic as it is inspiring. Mrs. Bafna leads by example, believing deeply that a company's true strength lies in its people. Her energy and commitment are infectious, fostering an environment where every team member is encouraged to excel. She has an innate gift for building relationships, seamlessly blending intuition with a genuine warmth that transforms colleagues, clients, and partners alike into an extended family. By welcoming diverse perspectives and focusing on collaborative solutions, she has become the glue that binds the TCR family together, setting a standard for leadership that is as empathetic as it is effective.

Her passion for entrepreneurship doesn't stop at TCR. A natural innovator, Mrs. Bafna has founded ventures that champion India's rich handicrafts, luxury textiles, and even innovative medical products. She is always buzzing with new ideas, exploring synergies, and thinking up solutions to enhance both business and social impact. Although her contributions to various charitable causes are quiet and private, her community commitment speaks volumes. Beyond the office, she's known for her love of yoga, her passion for travel, and her culinary skills, which are as vibrant as her personality.

Paresh Haribhakti, Managing Director, TCR Advanced; Chief Metallurgist and Global Technical Consultant to the TCR Group.

Mr. Paresh Haribhakti is MD of TCR Advanced Engineering Services in Baroda, India (a TCR Engineering Services partner company) and the Global Technical Consultant to TCR group of companies. With over two decades of experience in the field of metallography and microstructure examination Mr Haribhakti has solved more than 5000 industrial problems. He is pioneer in promoting in situ-metallography as an acceptable and reliable technique for process plant monitoring and components in the industries.

He has experience of failure investigation, remaining life assessment and FFS 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.

Having expertise in corrosion Mr Haribhakti was a principal team member in conducting the study on high temperature electrochemistry study to select the boroted stainless steel for thermo nuclear reactors, a project led by France along with 8 countries consortium. He has solved many critical corrosion problems pertaining to chemical and petrochemical industries. The expertise lies in identifying the root cause including MIC, selective leaching, SSCC, hydrogen embrittlement, PASCC.

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 down hole 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 colour metallography to increase the capabilities of interpretation of microstructure. He has also developed custom electrolytic polishing for carbon and alloy steel material.

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

Mr. Haribhakti is the co-author of the book titled “Failure Investigation Of Boiler Tubes: A Comprehensive Approach” which has been published by American Society of Metals (ASM)

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.

PUBLICATION'S

- Book on “Failure Investigation of Boiler Tube - A comprehensive approach” 2019 | American Society of Metals
- Article on “Optimising Tube Life” 2019 | World Fertilizer Magazine
- Published article on “Knowledge Based Life Management of Boilers” 2018 | SteamTech-2018
- Paper given on “Preventive Approach for Failure Free Boilers” 2016 | SteamTech-2016
- Presentation and Paper on “An Integrated Approach for RLA of Reformer Tubes by NDT (ARTis)” 2014 | APCNDT 2013 Session: NDT for Life Assessment
- Paper on “Boiler Tube Failure, Root Cause Investigation & Mitigation: Case Studies” 2014 | SteamTech-2014
- Paper on “Corrosion Failures in Water-Wall Tubes” 2014 | Corcon-2014
- Paper on “Material Testing and Characterisation” 2014 | American Society of Metals
- Paper on “Fitness For Service: Using NDT & Inspection” 2013 | 14th Asia Pacific Conference on NDT
- Paper on “In-situ Metallography for the Plant Health Assessment study and Failure Investigation” 2008 | MENDT-2007
- Technical Paper titled “Fitness for Service: Using NDT and Inspection” by Paresh Haribhakti, Katan Upadhyaya, Jaidev Patel & V.K. Bafna presented at the 14th Asia Pacific conference on NDT (2013)

APPRECIATION & AWARDS

- Indian Institute of Metals (Baroda Chapter) confers the IIM-KK Award in recognition of outstanding, selfless & meritorious contribution towards Professional field in particular and Metallurgical society in general, in the state of Gujarat. (2016)
- Recognition of Active Participation as an invited speaker at 4th Middle East Conference by Saudi Arabian Section of ASNT (2007)

- Recognition of Active Participation at Inspection Technical Exchange Meeting & Exhibition by Saudi Aramco, Inspection Department (2008)
- Appreciation from 5th Middle East NDT Conference by Saudi Arabian Section of ASNT for Active Participation as an invited speaker (2009)
- Recognition of Participation as an invited speaker at 6th International Conference by MICMEP (2009)
- Appreciation from 'NACE West Africa (Africa Region), Dhahran (Saudi Arabia section) & Bahrain society for engineers' for presenting a technical paper at the 13th Middle East Corrosion Conference & Exhibition (February 14th – 17th 2010)
- Recognition of Active Participation as an invited speaker at International conference & exhibition by American Society of Metals (Heat treat show in 2010)
- Appreciation from 13th Middle East Corrosion Conference by NACE, Middle East Section for Active Participation as an invited speaker (2010)
- Appreciation from Saudi Aramco GO Inspection & Corrosion Forum, Shedgum Gas Plant for Active Participation as an invited speaker (2010)
- Recognition of Active Participation as an invited speaker at 1st NACE – Jubail Industrial Forum organised by NACE – Jubail KSA Section (2011)
- Recognition of Joint partnership with Indian Institute of Metals (IIM) for delivering an advance workshop on Remaining Life Assessment of Power & Progress Boilers (December 13th – 14th 2013) Awarded for valuable participation at Saudi Aramco: Corrosion Awareness Day (June 5th 2014) Appreciation from American Society of Metals as author during International Conference on Material Testing and Characterisation (December 4th - 6th 2014)
- Appreciation from Jeddah Refinery for a valuable presentation on "Fitness For Service" (2015)
- Recognition of Active Participation as an invited speaker at SABIC STM 12 organised by SABIC (2016) Appreciation from HADEED, SABIC, KSA for active participation in Reliability Campaign (2016)
- Recognition of Active Participation as an invited speaker at M.S. University (Baroda) for Meta-Fiesta organised by Society of Metallurgical Engineering (SME) (March 30th 2017)
- Recognition of Active Participation as an invited speaker at Indian Society for Non-Destructive Testing (September 1st 2018)
- Recognition of Active Participation as an invited speaker at "Two Day symposium on Corrosion & Its Control, SCES 2018" organised by Society of Metallurgical Engineering at M.S. University Baroda (October 3rd & 4th 2018)
- Recognition of Active Participation as an invited speaker at 12th National Conference on Boiler & Steam Systems (SteamTech 2019)

A B.E. (Metallurgy) and M.E. (Materials Technology) from M.S. University, Vadodara, and a founder member of the Metallography Society of India. He has been at the helm of TCR Advanced since its inception, leading a bench of over 200 engineers and consultants, and is the pioneer who established in-situ metallography as a reliable technique for process-plant health monitoring in India. Over thirty years he has solved over 9,000 industrial problems and is an acclaimed boiler-tube-failure investigation expert. He is the author of "Failure Investigation of Boiler Tubes: A Comprehensive Approach", published by ASM International, USA, and a senior signatory on the group's fitness-for-service, remaining-life, knowledge-base, and ARTiS reports. His marquee failure-investigation work includes damage assessment for the VGO-HT2 fire at Reliance Jamnagar, hydrocracker reactor assessment at Baiji refinery in Iraq, and a high-temperature electrochemistry study to select borated stainless steel for a France-led eight-country thermonuclear reactor consortium. He developed the Microstructure Characterizer (MiC) image-analysis software, now used by research laboratories worldwide including National Oilwell Varco in the United States, along with a chemical-composition mapping method for weld-dilution identification and custom colour-metallography and electrolytic-polishing techniques.

His innovation record carries patents. He developed and patented the robotic crawler behind ARTiS, the reformer-tube ultrasonic inspection system, and the IOT-enabled in-situ metallographic replica system marketed as INSIPOL-2000. He led the team that built the Asset Integrity Optimisation and Management (AiOM) cloud platform on API RP 580 and API RP 581 risk-based-inspection principles, and is currently extending the Microstructure Characterizer work into artificial-intelligence-driven microstructure interpretation.

As lead consultant he has signed the group's highest-stakes integrity work. The fitness-for-service of a hydrogen isomerisation reactor for an oil-and-gas major, run to API 579-1/ASME FFS-1, returned a direct cost saving of more than 15 million US dollars. He has directed remaining-life and fitness-for-service work on high-pressure high-temperature components at QAFCO in Qatar, the Omega-method furnace-tube remaining-life study for Saudi Aramco, failure-investigation and RLA programmes for SABIC in the Kingdom, reformer-tube and gasket failure investigation at OMIFCO in Oman, and reformer-tube life assessment with ARTiS at Pemex in Mexico and at Notore Chemical Industries Plc in Nigeria. The full health assessment of a hydrogen plant relocated from England to Valia in Gujarat for Godrej Industries, and the Incoloy 800H ammonia-header repair-weld solution at Gujarat State Fertilizers and Chemicals, sit in the same record.

The Indian Institute of Metals, Baroda Chapter, conferred the IIM-KK Award on him in 2016 for outstanding and meritorious contribution to the metallurgical profession in Gujarat. He is an invited speaker across the Saudi Aramco inspection and corrosion forums, the NACE and AMPP Middle East corrosion conferences, the ASNT Middle East NDT conferences, the SABIC technical meetings, and ASM International events, and he is the principal expert at Evolve by TCR. He sits on the board of TCR Arabia. Before building the TCR Advanced practice he spent nine years as a troubleshooting metallurgist on failure investigation and remaining-life assessment at Gujarat State Fertilizers and Chemicals.

Rohit Bafna, President.

With an innate drive to propel companies to their full potential, Rohit has dedicated his career to identifying opportunities that align with his values of integrity, precision, and growth. His investment philosophy is rooted in a deep respect for the legacy of TCR, yet his focus is distinctly modern, channeling his expertise into ventures that create tangible, impactful change. Rohit Bafna doesn’t just lead with purpose—he redefines what leadership means, carrying TCR’s legacy forward with boundless vision and heart.

Rohit Bafna embodies the vision, energy, and bold foresight that drives TCR Engineering to new heights. Fuelled by a relentless passion for building and transforming businesses, Rohit has been instrumental in propelling TCR’s global presence with a unique mix of strategic insight and hands-on leadership.

Passionate about every facet of business, Rohit is known for his strategic acumen and keen eye for value creation, whether he’s analysing emerging markets or expanding TCR’s influence across borders. He stands on the shoulders of his family’s pioneering spirit, carrying forward his father’s legacy while introducing fresh perspectives to stay ahead of industry advancements. Rohit has also cultivated relationships with partners worldwide, seamlessly expanding TCR's footprint and enabling innovative solutions that resonate globally.

Leads strategy, operations, digital transformation, business development, and compliance across the group. He drives the AI and digital agenda, the AiOM asset-integrity platform, the brand and website, HR policy, and group investment. He carries the firm's international footprint across India, the GCC, and Southeast Asia, and has built the partner relationships that extend TCR's reach into new markets and service lines.

Rohit's leadership is driven by his innate ability to see the big picture and his unmatched knack for rallying high-performance teams. Under his guidance, TCR transformed the landscape of material testing, forging ahead with digital solutions and building a robust online community. His career has been defined by a hands-on approach that's strategic, visionary, and laser-focused on the customer. With previous leadership roles in international business development at Mphasis and Verizon, Rohit earned a reputation for deeply understanding customer pain points and crafting powerful, tech-forward solutions for clients like Chase, ABN AMRO, and Singapore Airlines.

Rohit is a true people-first leader whose joi de vivre and dedication to empowering others have a lasting impact on everyone he meets. His commitment goes beyond business: he's a dedicated board member of "Each One, Teach One," a philanthropic organisation dedicated to educating and uplifting underprivileged children in India.

In the Bafna tradition, Rohit sees investment as more than just financial growth—it's about nurturing companies to embody excellence, ethics, and endurance. His commitment to these ideals drives him to uphold the family's core values, making each venture a testament to TCR's legacy of trust and quality. Through his unique blend of passion and expertise, Rohit Bafna ensures that TCR's story continues, reaching new heights with every investment and every partnership.

Viren Khandwala, Director.

Mr. Khandwala 's deep expertise and broad experience make him a valuable asset to TCR's Board of Directors, adding both strategic depth and financial rigour. His contributions continue to be instrumental in TCR's ongoing success and its reputation as a leader in the materials testing and engineering industry.

Viren Chandrasen Khandwala is a seasoned Chartered Accountant with over 25 years of extensive experience in accountancy and taxation. Graduating with a Bachelor of Commerce from Bombay University in 1988, he pursued his Chartered Accountancy qualification, which he completed in 1995 through the prestigious Institute of Chartered Accountants of India. His early career included a rigorous three-year articleship with Lovelock & Lewes Chartered Accountants in Bombay, then affiliated with Coopers & Lybrand Deloitte (now a key part of Price Waterhouse Coopers). Following his article ship, he continued with the firm as a Junior Assistant for two years, gaining a solid foundation in accounts, audits, and income tax.

Since joining TCR Engineering as a Consultant in 1999, Mr. Khandwala has played an integral role in shaping the company's financial strategies. In 2014, he was appointed to the Board of Directors, where he brings his expertise in accountancy, audit, and taxation to the forefront of TCR's leadership. His comprehensive understanding of financial systems and regulatory compliance enhances TCR's commitment to sound governance, supporting the company's growth in a complex and competitive landscape.

Beyond his technical skills, Mr. Khandwala is a trusted advisor, offering insights that benefit not only TCR but also the broader business community. He has been invited to deliver lectures on topics such as wills, investment opportunities for senior citizens, and budget proposals at esteemed platforms like SGBMM and the Rotary Club. His dedication to sharing his knowledge reflects his commitment to enhancing financial literacy and supporting community empowerment.

16.2 TCR Engineering Senior Bench

Avinash Tambewagh, Technical Head.
Mr. Avinash is a highly accomplished metallurgical expert with over 34 years of robust, hands-on experience spanning advanced material testing, corrosion engineering, root cause failure analysis, and foundry operations. Over his distinguished career, he has specialised in technical support, laboratory administration, and consultancy, helping both national and international companies establish state-of-the-art corrosion testing laboratories for sour service applications. Well-versed in a massive array of national and international codes—including ASTM, BS, EN, BIS, IS, ISO, and NACE—he seamlessly bridges the gap between complex metallurgical science and rigorous industrial quality assurance.

Currently managing an entire advanced testing department, Mr. Avinash commands deep expertise in High-Cycle Fatigue (HCF), Low-Cycle Fatigue (LCF), and Fatigue Crack Growth Rate (FCGR) evaluations. He is exceptionally well-versed in fracture mechanics, regularly executing critical testing programmes for plane-strain fracture toughness (KIC), elastic-plastic fracture toughness (JIC), and Crack Tip Opening Displacement (CTOD) at both ambient and sub-zero temperatures. His operations strictly comply with standards such as ASTM E466, E606, E399, E1820, E647, BS 7448, ISO 12135, and ISO 15653. Because of this specialised capability, he has been entrusted with successfully executing high-stakes, tailor-made testing programmes in fracture appearance, fatigue, and fracture toughness for strategic Navy and Defence projects.

In the domain of corrosion and chemical testing, Mr. Avinash possesses thorough, authoritative knowledge of international specifications governing material integrity in harsh environments. His expertise encompasses NACE MR0175/ISO 15156, NACE MR0103/ISO 17945, NACE TM0177, NACE TM0284, NACE TM0103 and NACE TM0316, alongside the extensive ASTM G-series (including B117, G28, G31, G36, G39, G47, G48, G66, G67, G78), ISO 3651-2, and GOST-6032. A major highlight of his corrosion portfolio includes handling the complex Four-Point Bend Sulphide Stress Cracking (SSC) Testing by the strain gauge method for Thai-Nippon Steel during their Myanmar Oil & Gas Project.

Beyond standard mechanics, Mr. Avinash applies advanced testing methodologies to address specialised engineering challenges across the infrastructure, rail, and energy sectors. He successfully managed the Accelerated Creep Rupture Testing (ACRT) per ASTM E139 and API standards for Saudi Aramco's Yanbu Refinery, utilising the Larson-Miller parameter and the Omega Method for a critical Remaining Life Assessment (RLA) study. Additionally, he has handled FCGR Testing per EN 13674 and ISO 12108 for Jindal Steel & Power Limited (JSPL) for railway track-rail applications, and routinely oversees slip testing for reinforcement bar couplers and mechanical splices under ASTM A1034, IS 16172, and ISO 15630.

Mr. Avinash's foundational expertise extends directly to the foundry floor, where he holds in-depth knowledge of melting, moulding, methoding, and gating systems for specialised corrosion and heat-resistant alloy steel castings. Notably, he was recognised and rewarded at M/s. Kirloskar Brothers Limited (KBL) for his valuable contributions to reducing casting rejection rates for chemical-handling centrifugal pump impellers. This deep understanding of manufacturing defects fuels his work in Failure Analysis and Root Cause Analysis (RCA), where he diagnoses component failures for products sourced from aggressive environments like chemical plants, petroleum refineries, and active oil wells.

A certified ISO Internal Auditor holding ASNT Level II certifications in Ultrasonic Testing (UT) and Penetrant Testing (PT), Mr. Avinash has an unparalleled record in organising, handling, and clearing strict Second and Third-Party Inspections (TPI). He has successfully steered plant integrity audits on behalf of MECON and routinely coordinates with the world's premier regulatory and inspection bodies, including: LRIS, BVIS, IRS, NTPC, TOYO, ONGC, BHEL-CQS, TPL, QUEST, IL, ABS, Multitex, GESCO, DNV, TUV, NPCIL, BARC, EIL, UDHE, FEDO, IBR, L&T, IQC, and HPCL.

Dr. Ajay Essampally, Sr. Metallurgist and Head of Quality Assurance; NADCAP AC7101 Materials Testing Lead.

Ajay Essampally is a metallurgical engineer with deep expertise in corrosion engineering, failure analysis, welding, and advanced material characterisation. He holds a Ph.D. from the Indian Institute of Technology Bombay, specialising in the corrosion and stress corrosion cracking behaviour of super duplex stainless steel welds. His career spans extensive hands-on R&D work involving mechanical testing, microstructural analysis (SEM, EBSD, XRD), electrochemical testing, and customised test rig fabrication for aggressive environments.

Ajay has played a lead role in consultancy projects for major clients such as SHELL and ELEMENT, where he designed and executed high-temperature deaerated corrosion testing systems. His work reflects strong cross-functional abilities in project execution, test protocol development, research mentoring, and technical documentation. At IIT Bombay, he served as a Teaching Assistant in the Department of Metallurgical Engineering and Materials Science and mentored several M.Tech and undergraduate students.

He is well-versed in welding technologies like Gas Tungsten Arc Welding (GTAW) and Friction Stir Welding (FSW), with a deep understanding of their metallurgical and electrochemical performance in critical service environments such as marine and desalination. Ajay’s technical software expertise includes SolidWorks, AutoCAD, EChemAnalyst, and Origin.

Ajay has presented his work at numerous national and international conferences and has been the recipient of several Best Paper awards. His contributions to the field are further reflected in his peer-reviewed publications. At TCR, Ajay leads the accreditation and audit function. He handles the NABL ISO/IEC 17025:2017 assessments, the NADCAP AC7101 Materials Testing accreditation, and the BIS, IBR, PDIL, and RITES audits, and he leads the preparation, the assessment response, and the corrective-action closure for each of them.

Selected Publications:

1. *Role of microstructure on the varying corrosion behaviour across the UNS S32750 super duplex stainless-steel friction stir weld - Journal of Materials Science, 2025, 60, 1628–1646*

2. *Effect of wide range of heat treatments on the corrosion resistance of additively manufactured 316L stainless steel (316L SS) via PBF-LB/M (powder bed fusion of metals using a laser beam) - Progress in Additive Manufacturing, 2025*
3. *Stress corrosion cracking behaviour of welded UNS S32750 in aggressive chloride environments*

Parul Hariya, Head of Civil and Building Materials Testing.

With over 15 years of expertise in the field of building material testing, Parul Hariya is a seasoned professional known for her technical precision, leadership, and commitment to quality assurance. As the Head of Civil Testing, she plays a pivotal role in ensuring the highest standards of material integrity, reliability, and compliance in the construction industry.

Armed with a Master of Science in Physics, Parul combines her strong academic foundation with deep hands-on experience in mechanical and physical material testing. Her expertise spans material durability assessment, structural performance evaluation, and adherence to National and International testing standards. She has been instrumental in developing and validating mechanical building material test reports, ensuring data-driven insights that empower engineers, architects, and construction firms to build with confidence.

Parul's leadership in civil testing has led to the optimisation of testing protocols, enhancing efficiency and accuracy across laboratory operations. Her ability to bridge the gap between theoretical material science and real-world application has made her an invaluable asset to industry stakeholders looking for cutting-edge solutions in material evaluation.

A results-driven professional, Parul is dedicated to continuous improvement, innovation, and industry best practices. Her expertise helps clients mitigate risks, enhance structural safety, and ensure compliance with regulatory requirements. She is passionate about pushing the boundaries of material science to support sustainable and high-performance construction practices.

Shaila Kadam, Head of Chemical Analysis Testing.

With over 25 years of experience in chemical testing and quality assurance, Ms. Shaila Kadam brings extensive expertise in analytical procedures, laboratory supervision, and regulatory compliance. Her deep understanding of chemical testing methodologies, combined with her meticulous attention to detail, ensures the highest standards of accuracy and reliability in laboratory operations.

Shaila specialises in operating chemical test equipment, conducting precise chemical analyses, and supervising testing procedures to maintain consistency and adherence to industry standards. Her role involves overseeing laboratory teams, reviewing and authorising test data, and ensuring compliance with national and international regulatory guidelines.

With a strong background in preparing and validating chemical test reports, Shaila plays a critical role in maintaining the integrity of analytical results. She is also instrumental in developing and implementing work instructions for chemical testing, optimising processes to enhance efficiency and quality.

As a senior professional in chemical testing and quality control, Shaila Kadam is committed to upholding the highest levels of accuracy and reliability, contributing to a culture of excellence in laboratory operations.

Manoj Prabhakar Singh, Department Head, Conventional and Corrosion Testing.

Mr. Manoj Prabhakar Singh serves as the Department Head of Conventional and Corrosion Testing, bringing a wealth of multi-disciplinary expertise that spans foundry operations, fabrication, and advanced material testing laboratories. A science graduate from Venkateshwara Open University, Itanagar, Mr. Singh has built an extensive career grounded in both national and international testing specifications. He seamlessly pairs his profound knowledge of material behaviour with practical industrial design experience, allowing him to approach metallurgical challenges with a holistic, highly analytical perspective.

One of Mr. Singh's standout professional characteristics is his exceptional ability to analyse complex technical documents, interpret intricate general arrangement drawings, and synthesise this information to reach definitive, valid engineering conclusions. This diagnostic capability is backed by a deep understanding of the heat treatment of industrial ferrous materials, alongside practical experience in design for steel and alloy development. His material expertise is remarkably broad, encompassing cast iron, general engineering steels, stainless steels, aluminium, copper alloys, nickel-base alloys, and titanium.

Throughout his career, Mr. Singh has mastered the mechanical investigation of critical components across the offshore, marine, refinery, and automotive sectors. His diagnostic portfolio includes evaluating high-stress assets such as turbine blades, compressors, gearboxes, motors, pumps, rotors, shafts, valves, and pipe work. He is equally adept at analysing smaller, high-precision components like fasteners, boilers, pressure vessels, plain and rolling bearings, gears, pistons, spark plugs, crankshafts, camshafts, and engine valves. This vast component knowledge ensures that testing is always conducted with a clear understanding of the asset's real-world operational environment.

In the lab, Mr. Singh maintains hands-on practice in conventional mechanical testing for specialised components, including industrial springs, automotive seat belts, reinforcement couplers, and aluminium profiles. Complementing his mechanical background is an authoritative command over specialised corrosion testing methodologies. He routinely oversees critical evaluations including inter-granular corrosion testing per ASTM A262, pitting and crevice corrosion testing, Hydrogen-Induced Cracking (HIC), Sulphide Stress Corrosion Cracking (SSCC), and Chloride Stress Corrosion Cracking (CSCC) under strict NACE TM0177, TM0284, MR0175, and MR0103 standards, as well as salt spray testing per ASTM B117.

As a departmental leader, Mr. Singh balances rigorous technical supervision with an approachable, highly collaborative management style. He is widely recognised for his articulate diplomacy and strong interpersonal skills, which allow him to effectively motivate subordinates and optimise workflow efficiency. Beyond managing internal lab operations and supervising the machining department to ensure strict compliance with standard preparation codes, he acts as the primary technical interface for all Third-Party Inspections (TPI). He efficiently resolves complex technical queries from international auditors, interprets advanced testing results, and provides vital strategic support to senior leadership.

Shemi Bhaskaran, ASNT NDT Level III (RT, MT, PT); RSO (BARC Level II).

Mr. Shemi Bhaskaran is a distinguished quality assurance and control (QA/QC) authority with over 25 years of extensive expertise pioneering high-standard inspection protocols across the oil and gas, petrochemical, and refinery sectors. As a seasoned specialist in Non-Destructive Testing (NDT), he has built an impeccable reputation for ensuring asset integrity and regulatory compliance in some of the energy industry's most demanding and hazardous environments. His profound technical knowledge, combined with decades of field leadership, positions him as a premier expert in managing complex industrial quality management frameworks.

At the pinnacle of his technical qualifications, Mr. Bhaskaran holds prestigious ASNT Level III certifications in Radiographic Testing (RT), Magnetic Particle Testing (MT), and Penetrant Testing (PT). This elite credentialing underscores his comprehensive mastery of both surface and volumetric inspection methodologies. His deep-rooted expertise allows him to not only execute complex field testing but also to design rigorous inspection procedures, interpret stringent international codes, and provide authoritative technical oversight that guarantees the highest levels of structural safety.

Throughout his career, Mr. Bhaskaran has accumulated deep, hands-on experience in the structural evaluation of critical static equipment and the execution of rigorous third-party inspections (TPI). He is highly adept at operating directly at vendor manufacturing sites, conducting meticulous quality audits and structural assessments of heavy industrial components, including plates, pipes, forgings, and castings. His acute eye for metallurgical and manufacturing anomalies ensures that all raw materials and fabricated components strictly align with the rigid operational tolerances required by global energy firms.

A definitive core strength of Mr. Bhaskaran’s professional portfolio lies in his mastery of advanced radiographic testing, with a particular specialisation in mega-scale, cross-country pipeline networks. He possesses specialised expertise in the deployment and operation of sophisticated crawler-based radiographic systems and modern computerised radiography technologies. Widely respected as a master of radiographic film interpretation and field-level NDT techniques, his exceptional technical depth and sharp problem-solving acumen enable him to decisively diagnose flaws and mitigate risks in high-stakes, fast-paced inspection environments.

Lalit Surve, General Manager, Operations and Finance.

Mr. Lalit Surve is a dynamic, results-driven General Manager with a distinguished 25-year career specialising in laboratory operations, strategic management, and commercial growth. A graduate holding a Bachelor of Commerce (B.Com) from Mumbai University, Mr. Surve uniquely bridges the gap between technical operations and fiscal precision. As a visionary leader, he ensures the seamless, day-to-day functioning of complex laboratory environments while relentlessly maintaining the highest standards of operational efficiency, regulatory compliance, and analytical accuracy. His dedication to fostering safety, driving innovation, and expanding institutional capabilities makes him an invaluable asset to senior leadership and the organisation at large.

Drawing heavily upon his strong commercial background, Mr. Surve is a strategic thinker possessing a deep, intuitive understanding of financial analysis, budgeting, and corporate resource allocation. His extensive domain experience enables him to execute precise budget management, ensuring that laboratory resources are optimally deployed to maximise productivity without compromising on quality. This financial acumen extends directly into his oversight of procurement transactions, where he critically reviews and manages supply chains to secure cost-effectiveness and eliminate waste, thereby directly bolstering the organisation's bottom line.

In the arena of business development, Mr. Surve excels at building and maintaining robust, high-value client relationships that stand the test of time. He actively champions a customer-centric philosophy among the sales division, implementing tailored account strategies that empower teams to consistently achieve aggressive sales targets. By personally managing key corporate accounts, he identifies new market opportunities and fosters strategic partnerships that fuel sustainable, long-term business expansion.

Under Mr. Surve’s stewardship, laboratory workflows are continuously optimised to enhance overall team performance and accelerate service delivery. He is deeply well-versed in the intricate web of modern industry regulations, ensuring the entire laboratory strictly adheres to changing compliance mandates. Furthermore, his exceptional proficiency in data synthesis allows him to prepare and scrutinise comprehensive operational reports—including monthly sales performance metrics, intricate annual forecasts, and detailed account status evaluations. He routinely translates these dense data points into clear, actionable presentations for senior management, providing the critical intelligence required for high-level strategic decision-making.

At the heart of Mr. Surve's success is his exceptional leadership capability and innate motivational skills. He does not merely supervise staff; he actively cultivates a collaborative, high-performance workplace culture that inspires cross-functional teams to meet and exceed organisational targets efficiently. By aligning individual talents with the overarching corporate vision, he guides the laboratory through continuous evolutionary cycles, ensuring the facility remains at the cutting edge of industrial service innovation.

Samir Choudhury, General Manager, TCR Eastern.

Mr. Samir Choudhury is a seasoned professional in the oil and gas industry with over two decades of diverse experience in managing cross-country pipeline projects and a wide range of specialised NDT (Non-Destructive Testing) assignments both in India and abroad. A Science graduate from Utkal University and a Diploma holder in Mechanical Engineering, he also holds prestigious certifications including CSWIP 3.1 Welding Inspector and ASNT Level II in RT, UT, MPI, and PT.

Currently serving as the General Manager of TCR Eastern, Mr. Choudhury leads a multidisciplinary field services team, providing strategic direction and technical leadership. His expertise spans advanced NDT technologies and project execution methodologies, making him instrumental in ensuring high-quality deliverables and client satisfaction across all engagements.

Throughout his career, Mr. Choudhury has consistently demonstrated a strong entrepreneurial mindset. He actively fosters business growth, identifies new opportunities, and builds lasting relationships with key clients in the oil and gas sector. His hands-on approach and commitment to excellence have helped TCR Eastern maintain its competitive edge in the industry.

He is also deeply invested in cultivating collaborative work environments by promoting team building and cross-functional participation. His responsibilities extend across technical performance, proposal coordination, budgeting, scheduling, and overall project management, making him a critical driver of operational success at TCR.

Atul Yadav, HR Manager.

Mr. Atul Yadav is a highly accomplished and forward-thinking human resources executive with over 15 years of comprehensive experience spearheading strategic HR initiatives, public relations, and corporate governance across diverse and fast-paced industries. Serving as HR Manager with the PR and Government Liaison brief, he occupies a critical intersection within organisational leadership, aligning human capital strategies directly with high-level macroeconomic business objectives. Driven by a resolute people-first philosophy, Mr. Yadav is widely recognised for his ability to transform workforce dynamics, nurture top-tier talent, and shape a resilient, future-ready corporate ecosystem.

At the core of Mr. Yadav’s professional expertise is a sophisticated approach to organisational design and full-lifecycle talent management. He plays a pivotal role in engineering comprehensive workforce planning strategies that balance immediate operational efficiency with long-term institutional scalability. By designing and executing advanced recruitment, performance management, and employee retention frameworks, he ensures that the organisation continuously attracts and maintains a competitive advantage in the market. His methodology fosters a pervasive corporate culture of high performance and continuous professional growth, transforming the HR department into a true engine of business acceleration.

Renowned for his dynamic leadership style and emotional intelligence, Mr. Yadav possesses a proven track record of guiding large, cross-functional teams through complex organisational transitions and change management initiatives. He stands as a passionate champion for the cultivation of inclusive, psychologically safe, and high-performing workplaces. By emphasising transparent employee relations and proactive conflict resolution, he seamlessly bridges the gap between frontline employees and executive leadership. His strategic interventions ensure that during periods of corporate evolution, workforce morale remains exceptionally high, and internal friction is mitigated.

In an era of rapid digital transformation, Mr. Yadav excels at integrating modern HR technology platforms to streamline administrative workflows and enhance employee engagement metrics. He heavily leverages data-driven insights and people analytics to provide executive board members with actionable intelligence regarding workforce productivity, turnover risks, and resource utilisation. This analytical depth extends directly into his management of complex compensation and benefits planning, where he designs balanced remuneration structures that are both financially sustainable for the enterprise and deeply competitive within the global talent marketplace.

Complementing his formidable internal HR capabilities, Mr. Yadav manages the organisation's external corporate reputation through his dual mandate in Public Relations and Government Liaison. He serves as a vital strategic bridge between the enterprise and external stakeholders, navigating the intricate nuances of regulatory compliance, local labour laws, and industrial best practices. His sophisticated understanding of governmental frameworks allows him to successfully manage statutory interfaces, mitigate legal risks, and ensure that all corporate policies strictly adhere to changing regulatory mandates. Through this multifaceted leadership, he secures the organisation's standing as a highly compliant corporate citizen and an employer of choice.

Ashwant Singh, Assistant General Manager, Project Management.

Mr. Ashwant Singh is a high-performing and strategically minded corporate leader currently serving as the Assistant General Manager of Project Management at TCR Group. Working in close alignment with the President of TCR Group and the executive leadership team, Mr. Singh plays a vital role in driving the organisation’s financial planning, cross-border operational management, and high-value international client engagements. He acts as a central catalyst for the group's development, providing essential analytical and managerial support for wide-ranging strategic, operational, and digital transformation initiatives designed to future-proof the global enterprise.

With a strong fiscal acumen, Mr. Singh commands full accountability over complex financial operations across multiple corporate divisions. Alongside the President, he anchors the company's annual financial reviews and assumes strict responsibility for tracking revenue targets, performing detailed variance analyses, and mitigating financial risks. His day-to-day financial portfolio encompasses comprehensive Profit and Loss (P&L) management, intricate budgeting, rolling forecasting, receivables optimisation, and rigorous Management Information Systems (MIS) reporting. Through the production of sophisticated management reports, he delivers deep analytical clarity into high-level financial KPIs—including revenue projections, Return on Capital Employed (ROCE), and intensive working capital analysis—empowering executive leadership with data-driven insights for long-term planning.

On the international stage, Mr. Singh is a seasoned coordinator of multi-jurisdictional operations, successfully leading high-stakes client engagements across India, Saudi Arabia, Oman, and China. He masterfully harmonises operational workflows and resources across various corporate entities, including TCR Engineering, TCR Arabia, and TCR Advanced. Navigating diverse international regulatory, legal, and compliance frameworks, he ensures that complex, cross-border projects are executed seamlessly, on schedule, and in strict alignment with global industrial standards, thereby strengthening TCR's international footprint and brand equity.

Demonstrating strong capabilities in complex operational logistics and human capital management, Mr. Singh directly oversees major international service agreements, most notably a substantial manpower outsourcing contract with Gas Arabian Services in Saudi Arabia. In this capacity, he manages a vast network of deployed technical professionals, ensuring optimal resource allocation and operational continuity for the client. His oversight extends to the meticulous administration of complex, cross-border monthly payroll architectures and contractual adherence, showcasing his ability to manage both the macroeconomic and microeconomic facets of heavy industrial project management.

Mr. Singh's robust practical achievements are deeply rooted in a stellar academic background tailored for corporate leadership. He holds a Bachelor of Commerce (B.Com) from the University of Mumbai and is further elevating his strategic capabilities by pursuing a Master of Business Administration (MBA) in Finance. This ongoing advanced academic training perfectly complements his four years of direct, hands-on operational and financial accountability at TCR Group. His unique blend of rigorous financial theory, cross-border project management experience, and a results-oriented mindset marks him as an invaluable leader shaping the operational excellence of the organisation.

Hemant Sakpal, Business Development Manager. Leads business development into the real-estate and infrastructure developer base, with the LRC interface to Godrej, Kalpataru, Shapoorji Pallonji, and Rustomjee, and is a deployment lead for turnaround inspection manpower.

Chiral Patel, Cathodic Protection Division Lead. Over 20 years in cathodic protection and pipeline integrity. He runs the turnkey CP practice and the pipeline-integrity business development, with the practice run out of Vadodara with a regional office in Bhubaneswar, and CP services offered pan-India to match the geography of cross-country pipeline and city gas operators. He is cross-listed as a business-development lead for refinery, petrochemical, and pipeline work at TCR Advanced.

Anil K. Lund, Digitalisation Expert; Bangalore Operations Team Partner.
Leads the conversion of plant blueprints and drawings into AI-ready data and the digitalisation of radiographic film archives, runs the Bangalore operations team, and leads the AI initiatives.

Mukesh Kumar, Senior Metallurgist, Metallography and Corrosion.

Mukesh brings over 17 years of specialised experience in metallurgical and mechanical testing, having been an integral part of TCR Engineering Services since 2008. His technical expertise spans metallography, microstructure analysis, grain size determination, inclusion rating, decarburisation, case depth measurement, and hardenability testing all conducted as per ASTM, IS, ISO, and DIN standards.

He is proficient in corrosion testing including Intergranular Corrosion (IGC) as per ASTM A262, pitting and crevice corrosion per ASTM G48, hydrogen induced cracking (HIC), and corrosion testing per G28. His mechanical testing expertise covers tensile, hardness (HRC, HV, BHN), micro hardness, impact (Izod & Charpy), flattening, flaring, shear load, and proof load testing. He is also familiar with SEM and EDS analysis and handles in-situ metallography. His experience extends to testing ferrous and non-ferrous materials including copper, nickel alloys, and Inconel.

Mukesh actively participates in NABL audits as an auditee and is experienced in customer handling, failure analysis, corrective and preventive action management, and non-conformance resolution.

He holds a B.Tech in Metallurgical Engineering from BIT Sindri, Dhanbad (Jharkhand), providing a strong academic foundation that underpins his extensive practical expertise at TCR.

Manoj Bhandari, Senior Engineer, Mechanical Testing.

Manoj brings over 15 years of hands-on experience in mechanical testing, with deep expertise in tensile, hardness, impact, and metallographic (micro) testing as per ASTM and ISO standards. He plays a central role in TCR Engineering's mechanical testing operations, overseeing lab management, ensuring test procedures are followed accurately, and maintaining the quality and integrity of results.

He actively coordinates with customers, serving as a dependable point of contact throughout the testing process. His responsibilities include report finalisation, ensuring that deliverables meet both technical requirements and client expectations. His broad experience across mechanical and metallurgical testing makes him a key contributor to TCR's testing and inspection capabilities.

He holds a B.Sc. in Physics, Mathematics, and Chemistry (PMC) which forms the scientific foundation for his extensive practical expertise in materials testing.

Mohd. Rehan Baig, Assistant Technical Head, Advanced Testing.

Mr. Mohd. Rehan Baig brings over six years of hands-on experience in Advanced Testing, specialising in various national and international specifications such as NACE MR0175/ISO15156, ASTM B117, G28, G31, G36, G47, and G48. His expertise extends to conducting advanced Fatigue Tests (ASTM E466, ASTM E606) and Fracture Mechanics analysis, including KIC, JIC, and CTOD testing at both room temperature and sub-zero temperatures.

Rehan is skilled in Failure Analysis and Root Cause Analysis, especially for products from industries such as chemical plants, petroleum refineries, and oil fields. He is proficient in assessing material performance under extreme conditions and providing technical support to resolve complex engineering challenges.

His in-depth knowledge of national and international codes and standards—including ASTM, BS, EN, ISO, and NACE—combined with his hands-on experience in corrosion testing, makes him an invaluable asset to the team. Rehan also contributes to Third-Party Inspections, handling audits and ensuring compliance with industry standards, and has successfully organised numerous audits for prominent organisations such as ONGC, BHEL, and NPCIL.

As the Assistant Technical Head (Advanced Testing), Rehan is instrumental in managing fatigue and fracture toughness testing, and is constantly exploring innovative solutions for specialised testing requirements, particularly in the Defence and Navy projects. His ability to apply advanced testing techniques to solve real-world problems sets him apart as a leader in the field.

Through his work, Rehan continues to push the boundaries of what's possible in advanced testing and failure analysis, ensuring the highest level of technical excellence in every project he manages.

Aarti Bhawari, Senior Chemist, Chemical Analysis.

Aarti brings over nine years in chemical analysis and NABL-accredited laboratory operations, with the building-material chemistry, water, and R&D product-testing bench as her core. Her construction-materials work spans six years across cement, fly ash, GGBFS, aggregates, admixtures, soil, and water, and she carries three and a half years of elemental analysis on metal samples by ICP-OES and Atomic Absorption Spectrophotometry. She is a proficient hand on ICP-OES, AAS, UV-Visible Spectrophotometer, and Flame Photometer.

Her remit runs the quality spine of the laboratory: NABL documentation, PT and ILC coordination, measurement-uncertainty estimation, certified-reference-material management, method development, and scope expansion under ISO/IEC 17025. She has contributed to successful NABL assessments and to bringing new analytical capabilities on stream, holding to technical competence and traceable results as the standard.

Abhay Dhuri, NDT Operations Manager; RSO (BARC Level II), ISNT Level II (UT, MT, PT).

Mr. Abhay Dhuri is an accomplished NDT professional with over 20 years of experience in the Oil & Gas industry, specialising in Non-Destructive Testing across both onshore and offshore projects, including significant contributions to Cross Country Pipeline and Station Piping projects.

As the NDT Operations Manager, Mr. Dhuri brings a wealth of technical expertise and project leadership to his role. He has served as an NDT Coordinator on various high-profile projects, demonstrating a deep understanding of American and British Standard Codes and Specifications. His strong command over Radiographic Film Interpretation and Digitalisation reflects his commitment to maintaining high inspection standards and leveraging evolving technologies.

Abhay is known for his leadership qualities and his ability to train and mentor NDT personnel, fostering a work environment that is both results-driven and collaborative. His approachable demeanor, combined with his enthusiasm for continuous learning, makes him a valuable asset not only as a manager but also as a motivator and team builder.

One of Mr. Dhuri's core strengths lies in successfully managing and coordinating NDT and Cross-Country Pipeline audits, including those related to BARC and NABL certifications. His extensive qualification portfolio includes: BARC RT Level I, ASNT Level II in RT, UT, PT, and MT, and ISNT Level II in PT and MT

His comprehensive field knowledge and hands-on approach make him a respected leader in the industry and a key contributor to operational excellence.

Sagar Salvi, Head of Accounts and Purchase.

With over 15 years of extensive experience in Accounts and Procurement, Mr. Sagar Salvi is a seasoned professional who brings strategic insight and operational excellence to the organisation. His vast experience spans across managing financial operations, procurement processes, and ensuring seamless integration between accounting and purchasing functions.

Sagar is highly proficient in financial management, including budgeting, financial reporting, and ensuring that all financial activities align with the company's goals and industry standards. He also oversees the purchasing department, managing supplier relationships, contract negotiations, and procurement strategies to ensure cost-effective sourcing of materials and services.

He has a deep understanding of financial compliance, internal controls, and audit procedures, ensuring the company maintains financial integrity and meets regulatory requirements. Sagar's ability to streamline processes and create synergies between accounts and purchasing enables the organisation to function efficiently and effectively.

As the Head of Accounts and Purchase, Sagar Salvi plays a key role in driving both financial stability and operational excellence, supporting the organisation's growth, and enhancing its procurement capabilities to achieve long-term success.

16.2.1 TCR Engineering Operational and Support Team

Rafi Ahmad Baig, Senior Engineer, Mechanical and Fatigue Workshop.

Rafi brings hands-on technical expertise in mechanical and materials testing, with practical experience in fatigue, tensile, impact, hardness, and micro testing. At TCR Engineering, he oversees workshop operations, ensuring that testing activities are carried out efficiently and in accordance with established standards.

His academic background is strongly rooted in engineering he holds an M.Tech in Production and Industrial Engineering from Integral University, Lucknow, and a B.Tech in Mechanical Engineering from Dr. A.P.J. Abdul Kalam Technical University, Lucknow. This dual specialisation in mechanical and production engineering provides him with a solid foundation for managing workshop processes and technical operations.

He is proficient in AutoCAD-2D, MS Excel, and MS Word, supporting both technical documentation and workshop planning. His project experience includes analysis of TIG welding defects in mild steel, reflecting his understanding of fabrication processes and quality assessment.

Nishat Baig, Laboratory Coordinator and Witness-Test Scheduling.

Nishat plays a vital role in the smooth functioning of TCR's laboratory operations, serving as the primary bridge between clients and the internal lab team. He is responsible for client coordination, ensuring that customers are kept informed at every stage of the testing process and that their requirements are clearly communicated to the relevant teams. His ability to manage multiple client interactions simultaneously ensures that service standards are consistently upheld.

A key part of his role involves witness arrangement coordinating and scheduling witness inspections on behalf of clients, ensuring that the right personnel, documentation, and lab resources are in place at the right time. His organised approach and proactive communication style help TCR deliver a seamless experience for clients requiring third-party or customer-witnessed testing.

He holds an MBA in Finance & HR from Integral University, Lucknow, and a B.Sc. in Science an academic foundation that equips him with both the analytical and interpersonal skills needed to manage client relationships and coordinate complex lab schedules effectively.

Harshal Tambe, Administration and Accounts Executive (NDT).

At TCR Harshal supports day-to-day operations and plays a key administrative role. He manages accounts and documentation for TCR Engineering's operations as well as the NDT Department, ensuring smooth coordination between administrative and financial workflows. His work spans record-keeping, accounts management, and operational support contributing to the efficient functioning of TCR Engineering as a whole.

Beyond internal operations, Harshal actively coordinates with customers, ensuring timely delivery of reports and maintaining service standards. He serves as a reliable point of contact for clients, bridging communication between the operations team and customers to ensure commitments are met and service quality is upheld.

He holds a B.Com from the University of Mumbai, and his academic background in commerce complements his hands-on role in accounts, customer coordination, and operational administration at TCR.

Umar Ahmad Baig, AI Transformation Architect.

Umar supports TCR Engineering's technology and digital initiatives, contributing to the organisation's growing focus on IT infrastructure and AI-driven solutions. As part of TCR's IT & AI function, he plays a role in supporting internal systems, digital workflows, and technology adoption across the organisation.

He has a degree in Computer Science and Engineering, building his technical foundation in software development and systems. His skills include Python, HTML, and CSS, reflecting a hands-on approach to software and web technologies. He is also proficient in MS Office tools, complementing his technical capabilities with practical workplace productivity skills.

Young and eager to grow, Umar brings a learning-oriented mindset to TCR's evolving digital environment contributing to the team's efforts in leveraging technology for operational efficiency and innovation.

16.3 TCR Advanced Senior Bench

TCR Advanced is the group’s asset-integrity and reliability arm, based at Vadodara, carrying the failure-investigation, fitness-for-service, remaining-life, and knowledge-base practice and the AiOM platform.

Ketankumar Upadhyaya, Senior General Manager, Reliability Engineering. Over 35 years in reliability engineering, corrosion, inspection, testing, and metallurgical analysis, specialising in Engineering Critical Assessment, fitness-for-service (API 579-1 / ASME FFS-1), remaining-life assessment, failure analysis, and NDT. He is the FFS technical lead and the reformer-tube ARTiS programme lead, and combines deep technical depth with proven leadership on large-scale projects and client advisory.

Gopul Patel, General Manager; AiOM Software Development. An API 580 certified Risk-Based Inspection practitioner who has led the development of the AiOM asset-optimisation platform from inception, including the material library, engineering tools, FFS calculations, semi-quantitative risk analysis to API 581, spare refurbishment, Integrity Operating Window, and the intelligent-plant interface. He brings deep understanding of plant operations and of identifying and categorising risk.

Sohel Vaidya, Deputy General Manager, Business Development and Projects. Over 15 years at TCR, with a Master's in Applied Physics and in Sales and Marketing. He leads the business-development and projects division, designing customised proposals and converting them into long-term engagements, and is known for client retention across industry sectors.

Deepak Chandarana, Vice President, Evolve by TCR. Heads Evolve, the training and knowledge-sharing vertical, delivering industry-relevant technical training aligned to applicable standards and regulatory frameworks across India's industrial sectors.

Pooja Mehta, Senior Manager, Failure Investigation. Over 15 years in failure investigation, leading the metallurgical testing and root-cause analysis team.

Nikhil Sabhaya, Technical Manager, NDT and RLA. An M.Tech in Metallurgy holding ASNT Level III in ET, UT, PT, and MT, API 510, and CSWIP 3.1. He leads boiler remaining-life assessment and the ARTiS reformer-tube workflow.

Kamlesh Rana, Technical Manager, Testing. Over 35 years in the fabrication and forging industries with deep quality-assurance and process-control expertise. A qualified ISO 9001 internal auditor with hands-on API audit experience, he has led QA departments across multiple forge shops.

Ankoor Haribhakti, Senior Manager, Laboratory. Ensures testing activities meet technical requirements and deliver accurate, reliable results, balancing operational efficiency with client satisfaction and laboratory excellence.

Henil Shah, Quality Manager. An M.Sc. in Applied Physics with over six years in materials testing, specialising in OES, XRF, and wet chemical analysis and in corrosion methods including IGC, electrochemical, salt spray, and immersion testing. A certified ISO/IEC 17025:2017 internal auditor, he leads QMS and process audits.

M.Y. Joshi, Reliability Advisor. Over 38 years, formerly at GNFC, serving as a cross-vertical reliability advisor with particular depth in fertilisers and chemical processing.

16.4 TCR Arabia Senior Bench

TCR Arabia Company Limited, founded 2007, is a Saudi-Indian joint venture headquartered at the King Abdulaziz Seaport Facility, Dammam. TCR Engineering Services holds 60 percent as technical and operational lead and brand custodian, with GAS Arabian Services (Tadawul: 4146.SR) holding 40 percent.

Khalid A. Al-Dabal, Chairman. Chairman of TCR Arabia, representing GAS Arabian Services.

Khalid J. Al-Dabal, Managing Director. Managing Director of TCR Arabia, leading Kingdom operations on behalf of GAS Arabian Services.

Syed Ameen Hassan, Country Manager (KSA). A B.Com with an MBA in Marketing and Finance from Chifley University, Australia, and over 17 years in the Saudi and Middle East market. He has led TCR Arabia from its incubation stage to a profitable operation, securing long-term contracts with Saudi Aramco, SABIC, TASNEE, MAADEN, and Petro Rabigh. He built out new service areas including the microbiology laboratory, the welder-qualification department, and the mechanical testing laboratory, and formed delivery alliances with PP Simtech of the UK for RBI studies, CANAP Engineering of India for stress analysis, CIA of Canada for coker-drum inspection, and Cronholm of Sweden for advanced inspection.

Abdul Waheed, NDT Manager (ASNT Level III). Holds ASNT NDT Level III and PCN Level 2 international certification, with eight years of advanced NDT in refineries, petrochemical and power plants, in-service pipelines, FPSOs, and offshore projects worldwide. His expertise covers tube inspection, PAUT, LRUT, SRUT, high-temperature corrosion inspection, CUI and CUS, leak testing, and MFL, and the development of scan plans, technique sheets, and procedures, with data interpretation on heat exchangers, vessels, reactors, and gas coolers.

Syed Ahsan Ali, Senior Metallurgist. A B.E. in Materials Engineering holding API 510, 653, 571, and 580, with metallurgical failure-investigation experience on power-utility boilers and pressure vessels, corrosion failures, and welding defects, including studies for SABIC affiliates, MAADEN Phosphate, and Saudi Railway. He has mastered in-situ metallographic replication for the condition assessment and microstructural remnant-life evaluation of high-temperature components such as boilers, main steam lines, and pressure vessels.

Mohamed Mubeen, ASNT Level III and Radiation Safety Officer. A B.Tech Mechanical Engineer holding an NRRC-approved RSO licence and API and ASNT Level III RT certification, responsible for radiation risk assessment, radiation-protection compliance, and the qualification of NDT Level II technicians.

16.5 Expert Consultant Network (TCR Advanced)

The named subject-matter consultant bench is a structural differentiator. Competing labs do not field this depth of named expertise on call.

Prof. Awadhesh Kumar Singh, Power Plant and Turbine. Over 40 years in thermal power and turbo-machinery; formerly with BHEL, ABB, and ERDA.

Ashok Kumar Srivastava, Fertiliser Asset Integrity. Over 47 years in NDT and QA/QC; formerly with Dangote, Indorama Eleme, and Algeria Oman Fertilizer.

Dr. M.M. Pandya, Corrosion. Over 30 years and 200-plus industrial cases in online corrosion monitoring and urea, ammonia, and caprolactam material selection; associated with Avesta, Krupp VDM, and Cormon.

M.N. Patel, SEM and EDS. 33 years teaching metallurgy, with 16 published papers in microscopy and characterisation.

Dr. P.B. Joshi, Metallurgical Engineering. Former Head of Metallurgical Engineering at M.S. University, Vadodara, co-author of the ASM boiler-failure book, with over 50 publications.

Subrahmanya Bhat, Corrosion. 32 years at ONGC, 24 papers, and a patent for a non-carcinogenic inhibitor, with PETROFED and NACE awards.

Narendra Kumar Roy, FEA and FFS. A mechanical engineer who has delivered FEA and fitness-for-service training across more than ten countries.

Dinesh Butala, Process Safety. A chemical engineer with over 47 years, former Executive Director of GSFC, and a process-safety consultant with over 50 papers.

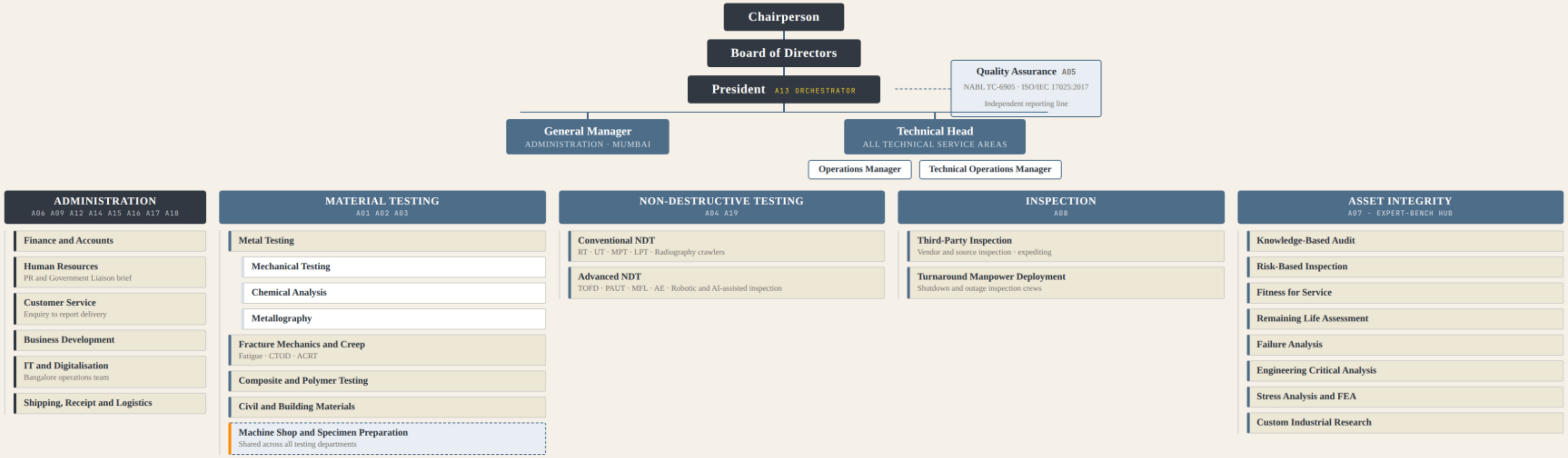
Jaiprakash N. Agarwal, Cathodic Protection and Pipeline Integrity. 33 years, 28 of them at GAIL; ICorr Level 4 (UK) and Fellow, author of three CP books, CP4-certified, and a 2023 AMPP Corrosion Awareness Award winner.

16.6 Group Headcount and Distribution

The group bench at a glance:

Metric	Value
Group employees (consolidated)	750+
Engineering staff (within the 750+)	400+
TCR Advanced employees (including consultants)	200+
TCR Arabia NDT professionals	100+
Field crews, in-situ metallographic replica	12 dedicated teams
ASNT NDT Level III credentials in-house	4 (Shemi Bhaskaran for RT/LPT/MPI; Vishal Gherwada for UT; Nagesh Shinde at TCR Arabia for RT/UT/LPT/MPI; Nikhil Sabhaya at TCR Advanced for ET/UT/PT/MT)
ASNT NDT Level II field crew	Multiple
BARC Level-1 radiography certifications	11+

16.7 Organisation Charts



CODIFIED AI AGENT NETWORK
tcr-brand skill v7.9.1

19 core operating agents (A01 to A19)
Mirror the functional structure above: every service area and administration function carries a codified agent with its reference library and applicable-standards block. Orchestrated by the President agent (A13); quality authority A05, safety veto A16.

16 industry expert agents
Mirror the vertical practices below, one per vertical, each carrying the nine-part damage-mechanism and standards depth of the 2026 Company Profile, Section 11.

3 named-asset experts
Boiler integrity (Power), reformer integrity (Fertilisers and Petrochemical), storage tank integrity (cross-vertical), feeding the Asset Integrity expert-bench hub (A07).

Sixteen Industry Vertical Practices

GROUP EXPERTISE BENCH · TCR ENGINEERING · TCR ADVANCED · TCR ARABIA

Refining and Petrochemicals	Power Generation	Fertilisers	Pipelines and City Gas Distribution	Oil and Gas Upstream	Marine and Offshore	Steel and Metals	Aerospace
Railways	Infrastructure	Chemical and Specialty Chemicals	Automotive	Construction and Built Environment	Metal Trading and Recycling	Insurance Referee Surveying	Industrial Research

Every industry vertical carries a named practice lead and a codified expert agent; each vertical runs the nine-part practice template of the 2026 Company Profile, Section 11. Human bench and agent bench are one system: tacit knowledge codified, reviewed, and signed.

Transparency. Competence. Reliability.

17. Careers and Culture

A company that signs reports for a living lives or dies on the culture that produces those reports. The way TCR hires, develops, and treats its people is not separate from the quality of the work. It is the source of it. This is how the firm runs.

17.1 The TCR Way

TCR is a laboratory that does technical work, and that one fact shapes everything. A laboratory cannot run a culture where the most senior voice is automatically the right voice, because the technical truth has its own voice and every employee, whatever their grade, is expected to speak it without fear. Across 53 years and five turns of the Indian engineering-services landscape, what has kept the firm standing is not a clever business model but a coherent set of values held by everyone on the team.

Precision over speed. Our clients have urgent deadlines and we will move heaven and earth to meet them, but we will not cut a step in a test method to do it. The test takes the time the test takes. We have lost work occasionally because we refused to compress an audit cycle, and we will keep refusing, because compressing it would mean signing a report we cannot defend.

Technical truth above all. When the data says the weld failed, the report says the weld failed. We do not soften the language because the client is unhappy, and we do not retest in the hope of a different number. A client who wants a result they did not get is welcome to take their sample elsewhere. They are not welcome to pressure ours.

Safety, every shift, every person. Materials testing involves moving machinery, hazardous chemicals, ionising radiation, and high temperatures. Every employee, including the President, wears the required PPE in PPE zones, follows lockout-tagout, observes radiation exclusion zones, and reports near-misses honestly. Safety is not a poster on the wall. It is what we do without thinking, every day.

A flat structure. The hierarchy is deliberately flat. The President sits in the same canteen as the laboratory helper, and decisions move quickly because they do not climb six rungs of approval. In a flat structure you are expected to think for yourself, raise concerns directly, and own outcomes. We do not micro-manage, because we trust you. The trust is the deal.

17.2 No Sir, No Madam, and the Open Door

At TCR nobody is addressed as Sir or Madam. We use first names, in every direction, from the President to the newest lab helper. The reason is technical, not ideological: in a NABL ISO/IEC 17025 accredited laboratory, the most junior technician has to be able to look at the most senior engineer and say, the calibration drifted. In a Sir-and-Madam culture that sentence does not get said, and that is how reports go wrong. Alongside it runs an open door. Every member of management, up to the President, is reachable without appointment or protocol for the day-to-day, the technical disagreement, the suggestion, or the wellbeing concern, with the formal grievance channels reserved for matters that need a formal record.

17.3 Town Halls and Transparency

A company-wide town hall runs every month, alternating between location-level in person and video across all sites. A senior leader presents the financial position, technical wins, audit and accreditation outcomes, and client wins and losses, and the floor is then open for questions on any topic, with no filtering and no questions submitted in advance. Town halls are mandatory and treated as work, because a leadership team that hides from its own employees is hiding from itself.

17.4 How We Hire

We hire for two things, technical competence and character, and one without the other is not enough. A skilled engineer who will sign a wrong report under pressure is no use to us, and a person of impeccable character who cannot read a UTM trace is no use either. Roles are posted internally before they go out, because we grow TCR talent into the next role wherever we can. We interview honestly, telling candidates what the role actually involves including the hard parts, and we expect the same honesty back. Every interview involves at least two TCR people, never one, and the outcome is documented with reasons.

17.5 How We Grow People

A laboratory depends on the depth of its people, the senior radiographer, the metallurgist with twelve years of failure-investigation behind them, the chemist who has run the spectrometer for fifteen years. Every employee from probation onwards holds an Individual Development Plan, agreed with their manager and refreshed each year, that sets out where they are, where they want to go, what they need to learn, and what support TCR will provide. Defined career ladders run for each principal track: NDT from trainee through ASNT or ISNT Level I, II, and III across the methods; the laboratory track from helper through chemist or metallurgist to specialist and lead investigator in failure investigation, fitness-for-service, and RLA; field engineering and asset integrity; and the QMS, audit, and compliance track from coordinator to Head of Quality. Movement up is earned on competence, contribution, and certification, not tenure. TCR sponsors role-relevant external certifications in line with each plan, and cross-trains and moves people between domains as they grow.

17.6 The TCR Family

Once a year the offices open to the families of employees for the Diwali Open House, so that spouses, partners, children, and parents can see where their family member spends their days and meet the colleagues they hear about, with a child-friendly tour, a cultural programme, and activities for visiting children. Through the year, an inter-departmental cricket tournament with deliberately mixed teams, informal walking groups run by department heads, and an annual outdoor team-building day keep a multi-location community connected, fit, and engaged. Participation is voluntary and there is no penalty for sitting out.

17.7 Community and the Profession

TCR has grown alongside the engineering, refining, manufacturing, and infrastructure communities of India, and contributing professional skill and time back to that community is treated as a natural extension of the work. Employees volunteer on their own time in causes they choose, from teaching at engineering colleges and mentoring at women's career programmes to blood-donation drives and beach cleanups, and many serve on the professional bodies that set the standards the firm works to, ASNT and ISNT, NABL assessor panels, BIS standards committees, and AERB technical advisory work. Significant contribution is recognised in the annual awards.

18. Health, Safety, Environment

The HSE block sits at the centre of the operating-side workflow. The radiography practice runs under AERB licence; the field-deployed robotic crawler runs under ATEX/PESO certification; the laboratory runs under ISO 45001 occupational health and safety; environmental management runs against the State Pollution Control Board consents at each operating site.

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18.1 Management Systems

TCR runs an integrated health, safety, and environment management system aligned with ISO 45001 for occupational health and safety, with environmental management run against the State Pollution Control Board consents at each operating site, built on the statutory base of the Occupational Safety, Health and Working Conditions Code 2020, the Atomic Energy (Radiation Protection) Rules 2004, and the AERB licensing regime. The work carries real hazards, ionising radiation, hazardous chemicals, high-pressure systems, moving machinery, hot surfaces, and field environments that run from refineries to bridges to underground tanks, so the system is written to control them rather than to paper over them. The policy framework sits in the company manual; the detailed operational protocols, PPE matrices, and method-level controls are maintained in a controlled TCR Safety Manual owned by the HSE function.

System	Standard	Scope
Environmental Management	`State Pollution Control Board consents (MPCB, GPCB, OSPCB); statutory hazardous-waste framework`	Group
Occupational Health and Safety	`ISO 45001:2018`	Group
Laboratory Quality	ISO/IEC 17025:2017 (NABL certificate NABLT0726MH18640, in lieu of TC-6905, with 1,483 scope items; TC-15993 with 409 scope items for TCR Eastern)	Laboratory operations
Auditing Framework	`ISO 19011:2018`	Internal audit and second-party-audit response

18.2 Radiation Safety Regime

The radiography practice is governed by the Atomic Energy Regulatory Board (AERB) framework. Two AERB-approved Source Storage Facilities, two named Radiation Safety Officers, an AERB Operation Licence in the name of the Chairperson and Managing Director, and the BARC Level-1 field certifications anchor the regime.

Element	Reference
AERB Operation Licence	23-IRLOP-893925 (licensed to Mrs. Neelam Bafna), valid and current
AERB Source Storage Facility, Mumbai	22-ASSF-793303, valid 28 June 2027
AERB Source Storage Facility, Bhubaneswar	23-ASSF-927086, at Plot 125/2094 Vishnu Vihar, valid 30 August 2027
AERB Radiation Safety	Shemi K B (21-RSO-681725), Ananta Kishore Parida (22-RSO-734005, Bhubaneswar SSF) and others
Field crew certifications	11+ BARC Level-1 radiography certifications
BARC leak certificates	Multiple, 2024
Cross-border permission	Nepal Oil Corporation Ref 2080/81 dated 30 July 2023 (MAPL Phase II via Likhitha Infrastructure; the first non-GCC cross-border deployment)
Standards	AERB Safety Manual AERB/RF-IR/SM-1 Rev. 2; SMPV(U) Rules 2016; Gas Cylinder Rules 2016 (PESO)
Personnel monitoring	TLD badges issued and tracked through AERB-approved monitoring service

18.3 Site Safety Programme

Field and laboratory work runs to a single safety programme, applied the same way on a client site as in the home laboratory.

18.3.1 PPE and safe work

PPE is mandatory in PPE zones without exception, against a role-and-zone matrix posted at each zone entrance.

18.3.2 Permit to work

Energy isolation, hot work, and confined-space entry run under formal permit-to-work systems, with documented isolation, gas testing, attendant cover, and emergency response. Bypassing an interlock, working without a permit, or skipping gas testing is treated as a major breach. Hazardous chemicals are stored, handled, and disposed of to their safety data sheets and the statutory hazardous-waste framework under the State Pollution Control Board consents, with spills reported and cleaned up under procedure.

18.3.3 Fitness for duty, drugs, and alcohol

TCR holds a zero-tolerance line on alcohol and drug impairment at work, with the highest scrutiny on safety-critical roles, drivers, radiography technicians, and chemists handling hazardous material. Fitness for duty is checked at the start of each shift, breath analysers are held at every location, and safety-critical roles are subject to random monthly checks. An Employee Assistance Programme provides confidential counselling and de-addiction support, and an employee who comes forward for help before any incident is treated as seeking help, not as a misconduct case.

18.3.4 Accident and near-miss reporting

In line with Sections 10 to 12 of the OSH&WC Code, the prescribed authorities are notified of any accident causing death or serious injury, any dangerous occurrence, and any notifiable occupational disease. Every employee is required to report accidents, near-misses, and unsafe conditions promptly, and concealing an accident or near-miss is itself treated as misconduct, because it endangers the next person and corrupts the safety record.

18.3.5 Safety committee and occupational health

A Safety Committee with both employer and worker representation sits at each location, meets monthly, and reviews accident and near-miss reports, PPE compliance, and the TLD radiation record. Every employee takes a pre-employment medical appropriate to the role, vision and colour vision for inspection work, audiometry for high-noise areas, lung function for dust exposure, and a free annual health check is provided to all employees aged 40 and above and to everyone engaged in hazardous processes regardless of age.

18.3.6 Mental health and wellbeing

Mental health is treated as health. The same Employee Assistance Programme provides confidential counselling for stress, anxiety, and personal difficulty, managers are trained to recognise distress and direct people to support, and a mental-health concern is handled with the same straightforwardness as a physical injury.

Element	Detail
Permit-to-Work cycle	Hot-work permits, height-work permits, confined-space-entry permits, and isolation-and-lockout permits issued before any field activity
Personal Protective Equipment	Helmets, safety boots, ear and eye protection, harnesses for working at height, full-body coveralls; specialised PPE for radiography, confined-space, and ATEX-certified zones
Behavioural safety	Pre-task safety briefings, stop-work authority for any worker, near-miss reporting culture
Workmen's Compensation insurance	Maintained for every field-deployed worker; submitted to client gate-pass authority before site entry
Medical fitness	Annual medical examination required for every field worker; specialised pre-deployment fitness for height work, confined-space entry, and overseas deployment

Element	Detail
Training cadence	Annual refresher safety training; site-specific induction for every new client engagement; AERB radiation safety refresher every two years
Toolbox talks	Daily site briefings before shift commencement; logged and reviewed
Incident discipline	Lost Time Incident reporting; root-cause analysis; corrective and preventive action loop; client notification within agreed timeline

18.4 Equipment Certification and Calibration

The 300+ instruments across the group are maintained on a calibration calendar managed through the QMS (Section 10.3). The radiography sources are leak-certified through BARC. The storage tank robotic crawler fleet operating in classified zones (refinery and petrochemical sites with ATEX zoning) carries ATEX / PESO certification for the robotic tank inspection rover.

18.5 Environmental Management

Hazardous-waste handling for laboratory chemical disposal (etchants, polishing media, corrosion-test solutions, oil samples, paint and coating samples) follows the Maharashtra Pollution Control Board (MPCB), Gujarat Pollution Control Board (GPCB), and Odisha Pollution Control Board (OSPCB) frameworks for the respective sites. Effluent and emission monitoring runs against the State Pollution Control Board consents at each operating site.

18.6 HSE Performance Discipline

The discipline runs at three levels.

Compliance level. Every regulatory licence (AERB, BIS, IBR, MoEF&CC, State Pollution Control Boards, BMC, CIDCO, NABL, NABCB) is current and the renewal calendar is managed centrally. The audit cadence (Section 10.7) catches expiry windows three months ahead of lapse.

Operational level. Every site engagement carries a documented HSE plan, a permit-to-work cycle, a workman-compensation insurance pack, and a daily toolbox talk. Field-crew supervisors carry stop-work authority.

Cultural level. The senior bench is named, accessible, and reachable for HSE escalation. The Quality Assurance Head (Dr. Ajay Essampally) and the AERB Radiation Safety Officers (Shemi K B, Ananta Kishore Parida) are the formal escalation points. The HR Manager (Atul Yadav) handles the regulatory-authority interface under his PR and Government Liaison brief.

19. Statutory and Regulatory Approvals

The statutory and client-approvals universe is the procurement gate. Every formal credential here represents a vendor-evaluation cycle that the buyer no longer has to repeat. The four-tier framework keeps the surface area readable: Statutory authorities; Owners; Engineering Procurement Construction

ACCREDITATIONS

NABL ISO/IEC 17025:2017 under certificate NABLT0726MH18640 (in lieu of TC-6905), 1,483 scope items. NADCAP AC7101 Materials Testing accredited 2026. BIS, IBR, and AERB recognised.

19.1 Tier 1, Statutory and Regulatory Registrations

The statutory tier covers laboratory accreditations, radiation-safety licences, sector-specific recognitions, and government empanelments.

Authority	Reference	Scope	Validity
NABL (ISO/IEC 17025:2017)	Certificate NABLT0726MH18640 (in lieu of TC-6905)	1,483 scope items at TCR Engineering Mahape: mechanical, civil, NDT, PMI, RoHS, chemical analysis	03 March 2026 to 02 March 2030
NABL (ISO/IEC 17025:2017)	Certificate TC-15993	409 scope items at TCR Eastern Bhubaneswar: chemical analysis, mechanical properties, and metallography of metals and alloys	30 April 2025 to 29 April 2029
Bureau of Indian Standards	Reference LRMD/LRS/OSL-7103506	Materials testing for ISI mark; first BIS-accredited commercial lab in India for IS 16172 rebar coupler testing across all diameters (8 mm to 40 mm); covers IS 15103:2002 and IS 17875:2022 (added August 2024)	Active
Indian Boiler Regulations (Central Boiler Board)	Well-Known Material Testing Laboratory recognition; Form XVI-H certificate 38 (Serial MTL/15/019)	IBR Form III material certification	Since 2014; current certificate valid to 02 April 2029

Authority	Reference	Scope	Validity
Central Boiler Board	Well-Known RLA Organisation under Indian Boiler Regulations	RLA on boiler pressure parts	Active
AERB	Operation Licence 23-IRLOP-893925	X-ray and gamma-ray radiography across India	Active
AERB	Source Storage Facility, Mumbai, 22-ASSF-793303	Mumbai source storage	Valid 28 June 2027
AERB	Source Storage Facility, Bhubaneswar, 23-ASSF-927086	Bhubaneswar source storage	Valid 30 August 2027
ISO management systems	`ISO 45001:2018 (QRO certificate 3050260220154HS, valid to 19 February 2029)`	Group-wide	Active
ILAC MRA (via NABL)	Mutual Recognition Arrangement; NABL 133 Combined ILAC MRA Mark permission NABL/ILAC/11591 (CAB ID T-0294)	Reports accepted across 90+ signatories including A2LA (US), UKAS (UK), DAkkS (Germany), Cofrac (France), JAB (Japan), KOLAS (Korea), CNAS (China), Standards Australia, ENAC, Accredia	Coterminous with the NABL certificate, to 02 March 2030
`NADCAP AC7101` (Materials Testing)	Performance Review Institute, certificate 29415245997	Aerospace verification testing	Accredited 2026, valid to 31 May 2027
BSE / NSE empanelled assayer	Precious metals and bullion	Bullion and precious-metals trading	Active
ICCL / BSE Approved Assayer	Precious metals and bullion	Active since November 2018	
Bharat Metal Exchange Association	Approved laboratory	BME House Mumbai	Active

Authority	Reference	Scope	Validity
CIDCO eMTL	Empanelled Material Testing Laboratory, Maharashtra	Active	
JSRS Certification (Oman)	KSA-adjacent reciprocity	Sultanate of Oman operations	August 2025 onward
MSME Registration	Udyam	Small Enterprise category	Active
BMC Roads Department	Registration ChE/Rds/8292/NF dated 25 March 2026	Mumbai municipal roads programme	Valid until 02 June 2026, extendable to 24 March 2028
Government of Maharashtra (Director DSB)	Statutory IBR-laboratory recognition	Active	

19.2 Tier 2, Owner Approvals

The longest-tenure approvals are the structural moat. Five to seven years is the minimum new-vendor onboarding window for these owners. TCR has held them for one to three decades.

Owner	Reference / Origin	Tenure
ONGC (Oil and Natural Gas Corporation)	QAD Sr. No. 01 since 1998. Original approval letter MRBC/QAD/LAB/97-98/779 dated 25 February 1998	Since 1998 (28+ years)
BHEL Bhopal	Approved test house	Since 2003

Owner	Reference / Origin	Tenure
PDIL (Projects and Development India Limited)	Empanelment. Certificate of Approval 4004008183/PBIS/24-25/5000077313 dated 28 June 2024, issued after assessment of the laboratory on 14 June 2024. Ten approved test categories: universal-testing-machine physical tests (tensile, elevated-temperature tensile, flattening, bending, flaring, flanging, surface roughness); impact and drop weight; metallurgical (macro, micro, IGC); chemical analysis (wet, spectroscopy, PMI, LECO, electrolytic); hardness, micro hardness, and hardenability; corrosion (HIC, SSC, SCC, NACE); welding; stress rupture; fatigue and CTOD; and non-destructive testing (MPI, LPT, UT, RT).	Approved since 2021
Saudi Aramco	Vendor 10040677; ANDT Contract 6601000141. Approved Radiographic Standard Procedure TCR.QCP.REV-02 (2023) conformant with SAEP-1143	Held under contract
SABIC	Vendor 505239; SABIC Global Contract 4900001302 (and historical Global Contract 4600006798 valid 10 July 2012 to 9 July 2017)	Continuous
Saudi Electricity Company	Vendor 5002205 / 62006	Continuous
MAADEN	Vendor 10118	Continuous
TASNEE	Vendor 101972	Continuous
SIPCHEM	Vendor 102111	Continuous
SATORP	Vendor 10175	Continuous
SWCC	Vendor 2522	Continuous
SADARA	Vendor 1000001784	Continuous
YASREF	Vendor 100657	Continuous
Petro Rabigh	Vendor 100764	Continuous
Advanced Petrochemical	Vendor 100561	Continuous
LUBEREF	Vendor 0000062147	Continuous
MARAFIQ	Vendor 3645	Continuous
Cristal Global	Vendor 39735	Continuous
PDO (Petroleum Development Oman)	Approval refresh	May 2022 onward
OQGN (OQ Gas Networks)	Approval	Active

Owner	Reference / Origin	Tenure
KNPC (Kuwait National Petroleum Company)	Approval	Continuous
MEW Kuwait (Ministry of Electricity and Water)	Approval	Continuous
Iraqi Ministry of Oil	Approval	Since May 2019
Indian Oil Corporation Ltd. (IOCL)	Approved test house	Multi-decade
Reliance Industries	Approved	Multi-decade
Bharat Petroleum (BPCL)	Approved	Multi-decade
Hindustan Petroleum (HPCL)	Approved	Multi-decade
GAIL India Limited	Approved	Multi-decade
NTPC	Approved	Multi-decade
NPCIL	Approved	Multi-decade
DRDO / NMRL	Long-term contract	Continuous
CQAE	Defence vendor framework	Active
ISRO	Project ASLV appreciation; VSSC engagement (Chandrayaan-3 via Larsen and Toubro Defence IC)	Continuous
BMC, CIDCO, MMRDA, NHSRCL	Approved for civil and infrastructure	Continuous
QAFCO Qatar	15-year metallurgical contract; 8-year RLA partnership	2012 to date
Indorama Eleme Petrochemicals Nigeria	Long-term rate contract	Continuous
Cameron International	First Article Qualification testing (FAQ)	Since 2012

19.3 Tier 3, EPC Approvals

EPC	Reference	Tenure
Engineers India Limited (EIL)	12-year approval pack covering BPCL Kochi NHDS/SRR Health Check IREP (2012), OPaL Petrochemical Complex Dahej (2013), PNCPL/NRL Bhubaneswar (2023), multiple EIL-approved Procedure Qualification Records spanning 16-24 inch diameter on GAIL MNJPL, NRL Brahmaputra River Crossing, ADPL HDD Odisha Rivers, KGPL, plus EIL Approval renewals 2024-2025	2012 onward
Mecon	Approved	Continuous

EPC	Reference	Tenure
RITES	Approved (PSU consultancy and PMC)	Continuous
Larsen and Toubro	Approved across Defence IC, Construction, Hydrocarbon, Power, Infrastructure	Multi-decade
Tata Projects	Approved (JSOL Coke Oven Battery 5 and 6 PWHT; JSOL Blast Furnace 2 PWHT)	Continuous
Hindustan Construction Company (HCC), Afcons, J. Kumar Infraprojects, Patel Engineering, IRB, Dilip Buildcon, PNC Infratech, KNR Constructions, Reliance Infrastructure	Approved across infrastructure	Continuous
MEIL-HCC, Afcons, Larsen and Toubro joint ventures	Mumbai-Ahmedabad HSR Packages C1, C2, C3 under NHSRCL VMAC Meeting No. 13 (October 2023)	October 2023 onward
Toyo Engineering and Technip dual approval	Mumbai and Bhubaneswar for IOCL Paradip PTA	Continuous
NRP Projects	EPCC for Adani-Total Dhamra LNG (Letter Ref 2340-RLNG-DLTPL-NRP-L-0005 dated 20 October 2021)	2021 onward
Wood	PMC for Adani-Total Dhamra LNG	2021 onward
Tractebel ENGIE	PMC for Bhagyanagar Gas Limited Maharashtra (June 2021)	Continuous
Tolani Projects	Bhagyanagar Gas Karnataka (2022)	Continuous
Power Mech Projects	Approved for boiler erection and BHEL NTPC Talcher TTPP-III (December 2025)	December 2025 onward
Likhitha Infrastructure	Cross-border MAPL Phase II for Nepal Oil Corporation (Ref 2080/81 dated 30 July 2023)	2023 onward
EnProCon	TJTC Kolar 9,266 weld joints digitally scanned and cloud-archived	Multiple

19.4 Tier 4, OEM and Licensor Approvals

OEM / Licensor	Reference	Tenure
BHEL	Approved since 2003; refresh via NTPC Talcher TTPP-III December 2025	2003 onward
GE International	3-year contract	December 2012 onward

OEM / Licensor	Reference	Tenure
NOV Inc.	Approval	March 2023 onward
Cameron International	First Article Qualification testing	2012 onward
Halliburton, Schlumberger, Baker Hughes, Weatherford	Vendor source-inspection	Continuous
Casale SA (Switzerland)	SX3000 Vendor Code 1000007973 (urea and melamine licensor)	June 2025 onward
Shell	Multiple geographies, sour-service approved	Continuous
Bureau Veritas, Lloyd's Register, American Bureau of Shipping, DNV	Class-society reciprocity (cross-vertical with Marine)	Continuous
Adani-Total Dhamra LNG Pvt Ltd	Letter Ref 2340-RLNG-DLTPL-NRP-L-0005 dated 20 October 2021	2021 onward
CGD operators	Bhagyanagar Gas Limited, Green Gas Limited, Torrent Gas	2021 onward
NHSRCL	VMAC Meeting No. 13 (October 23 2023; full HSR Packages C1/C2/C3)	October 2023 onward
NTPC GE Power Services Private Limited (NGSL)	LOI/NTPCGE/TCR/VAL/25-26/01 dated 18 April 2026 (Vedanta Athena 600 MW CTPP Boiler Inspection)	April 2026 onward
Adani Power Ltd / Adani Infrastructure Management Services Ltd	Multiple SOs (5703024310 Tiroda; 5700366721 Mundra IBR 391A)	March 2025 onward

20. Offices and Contact

TCR ENGINEERING

HEADQUARTERS
Mahape Laboratory and Research Centre, Navi Mumbai, Maharashtra
Registered Office: 35 Pragati Industrial Estate, N.M. Joshi Marg, Lower Parel, Mumbai 400011

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Established 1973 · NABL (TC-6905) ISO/IEC 17025:2017 · NADCAP AC7101 · BIS, IBR, BMC, CIDCO Approved

Group Footprint

The group footprint at a glance, entity by entity, with the detailed address and contact record in the subsections that follow:

Entity / Facility	Location	Role
TCR Engineering, Mahape Laboratory and Research Centre	Navi Mumbai, Maharashtra	Group headquarters laboratory, NABL certificate NABLT0726MH18640
TCR Engineering, Registered Office	Lower Parel, Mumbai	Corporate and registered office
TCR-BME Metal Market Office	Gulalwadi, Mumbai	Metal-market sampling and trader interface
TCR Engineering (North)	Gorakhpur, Uttar Pradesh	Northern facility and cathodic protection regional base
TCR Engineering (Assam)	Guwahati, Assam	Northeast India project and sampling base
TCR Eastern	Bhubaneswar, Odisha	Eastern laboratory, NABL TC-15993
TCR Eastern-2	Paradip, Odisha	Refinery, port, and fertiliser cluster support
Bangalore Operations Team	Bengaluru, Karnataka	Digitalisation and southern operations
Cathodic Protection Division	Vadodara (base) with a regional office in Bhubaneswar	Turnkey cathodic protection network; services offered pan-India
TCR Arabia Company Limited	Dammam, Jubail, Yanbu, Saudi Arabia	KSA joint venture and primary GCC laboratory
TCR Qatar (BIEWU International Trading W.L.L.)	Doha, Qatar	Qatar market representation

Entity / Facility	Location	Role
TCR Advanced Engineering	Vadodara and Bharuch, Gujarat	Asset integrity and consulting arm, NABL TC-6739, 431 scope items, valid 14 October 2025 to 13 October 2029
Evolve by TCR	Vadodara, Gujarat	Training academy
Chugai Technos Corporation	Hiroshima, Japan	Japan alliance
Approved Group International	Selangor, Malaysia	Malaysia alliance, forensic engineering and restoration

20.1 TCR Engineering Services Pvt. Ltd. (Parent)

Registered Office	35 Pragati Industrial Estate, N.M. Joshi Marg, Lower Parel, Mumbai 400 011, Maharashtra, India
Operating Laboratory (Mahape)	Plot EL-182, MIDC-TTC Industrial Area, Electronic Zone, Behind NELCO, Mahape, Navi Mumbai 400 710, Maharashtra, India
GST	27AAACT1966D1ZG
Web	www.tcreng.com
Telephone (Mumbai Corporate Office)	+91-22-23097921, +91-22-67492324
Telephone (Mahape Laboratory and Research Centre)	+91-9833530200, +91-22-67380900
Email	sales@tcreng.com
TCR Engineering India Network (Additional Sites)	
TCR-BME Metal Market (Mumbai)	BME House, 88/90 Kika Street, 2nd Floor, Room 18, Gulalwadi, Mumbai 400 004, Maharashtra. Telephone: +91-9699210864, +91-9920011298, +91-9820008656, +91-8779216510. Metal-market sampling and trader-interface office serving the BME House ferro-alloy catchment.
TCR Engineering (North), Gorakhpur	Gangotri Niwas, Ward 51, Parshuram Nagar, Shivpur, New Colony, Gorakhpur 273 016, Uttar Pradesh. Telephone: +91-9967267412. Email: up@tcreng.com. Northern facility and CP regional base for the Indo-Nepal cross-border corridor.
TCR Engineering (Assam), Guwahati	8th Floor, Block B, Room No. F8, GSK Purnima Residency, Garal Dharapur, Guwahati 781 017, Assam. Telephone: +91-9932034791. Northeast India project and sampling base.

20.2 TCR Eastern (Bhubaneswar)

Operating Laboratory	Plot 125/2094, Vishnu Vihar, Bhubaneswar 752 101, Odisha
NABL	TC-15993, 409 scope items (valid 30 April 2025 to 29 April 2029)
AERB	Approved Source Storage Facility 23-ASSF-927086 (valid 30 August 2027)
Telephone	+91-6744602472, +91-9776704680
Email	odisha@tcreng.com
TCR Engineering (Eastern-2), Paradip	Plot 831/29, Ground Floor, Sriram Nagar, Paradeepgarh, Udaya Bhatta, Cuttack-Paradip Road, Jagatsinghapur 754 141, Odisha. Telephone: +91-9348280626, +91-6744602472. Email: odisha2@tcreng.com. The Paradip-corridor facility supporting the refinery, port, and fertiliser cluster.

20.3 Bangalore Operations Team

Bangalore office under Anil K. Lund, AI and Digitalisation Head and Bangalore Operations Team Head.

20.4 CP Division Bases (Cathodic Protection Turnkey)

The CP Division under Chiral Patel as CP Division Lead (20+ years cathodic protection) runs its practice out of Vadodara with a regional office in Bhubaneswar, and offers CP services pan-India. Its engineers also work out of the group offices below, which puts a mobilisation base within reach of the geography of cross-country pipeline and city gas distribution operators:

Group Office (CP Mobilisation Base)	
Mumbai (Maharashtra)	Covering the Konkan coast and the offshore oil-and-gas tie-in scope
Navi Mumbai (Maharashtra)	Group headquarters base at Mahape covering Western India
Bhubaneswar (Odisha)	Covering Eastern India and the Northeast
Gorakhpur (Uttar Pradesh)	Covering Northern India and the Indo-Nepal cross-border corridor
Bangalore (Karnataka)	Covering Southern India, alongside the Bangalore Operations Team (Section 20.3)

20.5 TCR Arabia Company Limited (Joint Venture)

Headquarters	P.O. Box 32211, King Abdulaziz Seaport Facility, Dammam, Kingdom of Saudi Arabia

Branches	Dammam (headquarters and primary laboratory); Jubail (industrial city support); Yanbu (Red Sea petrochemical corridor)
Telephone	+966-13-8475784 / 85
Email	sales@tcr-arabia.com
Strategic Affiliations	SAGIA-approved entity; ASNT Corporate Partner; PP SIMTECH (United Kingdom) alliance for RBI and FFS implementation training

20.6 TCR Qatar (BIEWU International Trading W.L.L. Alliance)

BIEWU International Trading W.L.L. is TCR's agent in Qatar, representing TCR Qatar in-market. Founded in 2007 and headquartered at Al Khalidiya Street, Najma, Doha, BIEWU is a multidisciplinary engineering solutions provider specialising in asset integrity, corrosion protection, and industrial safety, with electrical and instrumentation solutions and HSE consulting alongside. The company fields over 100 engineering and sales professionals and serves oil and gas, power, infrastructure, and environmental engineering clients across Qatar and the UAE.

Through the alliance, Qatari clients procure TCR's materials testing, non-destructive testing, inspection, and asset integrity services under local representation, with BIEWU handling in-country commercial and logistics interface and the TCR laboratories and field teams delivering the technical scope.

Alliance	Market alliance for Qatar through BIEWU International Trading W.L.L.
Contact	Firas El Nakuzi, General Manager
Address	P.O. Box 24534, Doha, Qatar
Telephone	+974 55508704
Email	firas@biewuinternational.com

20.7 TCR Advanced Engineering Pvt. Ltd. (Joint Venture)

Headquarters	250-252/9, Naren Hardware Lane, GIDC Estate, Makarpura, Vadodara 390 010, Gujarat, India
GST	24AABCT3473E1ZL
Bharuch Division	Survey No. 01, Ground Floor, Signature House, Mira Park Society, Bharuch 392 001, Gujarat. Telephone: +91-9898084235. Serving the Dahej and Ankleshwar chemical and petrochemical belt.

20.8 Evolve by TCR (Training Academy)

Location	215, Pancham Icon, Vasna Road, Vadodara 390 007, Gujarat, India
Vice President	Deepak Chandarana

Web	www.evolvetcr.com

20.9 Chugai Technos Corporation (Japan Alliance)

Chugai Technos Corporation is TCR's Japan alliance partner, headquartered in Hiroshima and founded in 1953. On 29 April 2026 TCR signed a memorandum of understanding with Chugai Technos Corporation and Chugai Technos India Pvt. Ltd. (Bengaluru), pairing two founder-led technical services firms of similar vintage and temperament. The alliance carries TCR's testing and asset integrity work to Japanese asset owners, and brings Chugai's drone inspection, Scale Checker, and environmental testing capabilities to Indian and Middle East owners.

The first operational fruit of the alliance is the Chugai Technos Scale Checker for internal oxide scale measurement on boiler tubes, now part of TCR's power-sector inspection stack (Section 7.9). The wider alliance context, including the joint go-to-market logic, is covered in Section 13.9.

Address	9-12 Yokogawashinmachi, Nishi-ku, Hiroshima City, Hiroshima 733-0013, Japan
Telephone	+81-82-295-2222

20.10 Approved Group International (Malaysia Alliance)

Approved Group International (AGI) is TCR's Malaysia alliance partner. Founded in 2001, AGI brings together forensic scientists and engineers and experienced restoration specialists under one roof, with in-house teams covering forensic engineering, fire and explosion forensics, vehicle accident investigation, digital forensics, damage assessment (including plant and machinery, lift, escalator, and lightning damage), disaster restoration, and business continuity management including plant residual life analysis. AGI operates in more than 22 countries and works for the loss adjuster, insurer, reinsurer, broker, and legal community, with work product built to pass legal scrutiny.

For TCR, the alliance extends the group's failure investigation and insurance referee practice into Southeast Asia and gives AGI access to NABL-accredited laboratory evidence, in-situ metallography, and fitness for service engineering behind its forensic conclusions. The two firms present a combined incident-to-laboratory response on major industrial losses in the region.

Address	6, Jalan Dbp 3, Dolomite Business Park, 68100 Batu Caves, Selangor, Malaysia
Office Number	+603 618 86311
Contact	Kirit Kumar, Managing Director (+6012 2992 172)

TCR ENGINEERING

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