

Materials Technology Division - Overview and Way Forward

Materials Technology Division came into existence during the year 1985–1986 and is significantly contributing to R&D, Testing and Evaluation, Consultancy Services and IPR. The division is equipped with advanced and sophisticated materials evaluation facilities aimed at providing technical services in the areas of materials for the power sector.

Considering the significance of the growth of scientific and technological advancements in the power sector for generation, transmission and distribution including renewable in the country, the division has focused its efforts in pursuance of the mission of the organization and the engineering services provided in the area of condition monitoring, renovation, modernization and life extension of power plant and equipment through diagnostic and life extension studies for achieving economy and reliability in the power sector.

The text of the paper describes the overall growth of the division as well as its contributions to other divisions / units and the Way Forward.

1.0 REMINISCENCE

The Materials Technology Division known as MTD was established during 1985-86 encompassed the already functioning Liquid Dielectrics Lab. which was generally known as the Chemistry Laboratory. Since inspection, MTD was nurtured to grow into a full-fledged R&D and testing division also with a strong inclination to undertake technically significant field and industrial consultancy programmes benefitting the utilities and industries serving the power sector. The Laboratories were set up in the following areas of work - (1) Materials Science and Engineering; (2) Liquid Dielectrics; (3) Power Station Technology (Condition Monitoring, Tribology and Environmental); (4) Coal Analysis and Testing; (5) Energy and Combustion; and (6) Fly Ash Utilization.

During the first decade of operation, Fly Ash Utilization and Development Centre (FAUDC) was successfully established at Raichur Thermal Power Station, KPCL. In the quest of expansion on Thermal Research, a full fledged “Thermal Research Center” was established at

Nagpur in 1992–1993. Further, to effectively handle R&D and Demonstration activities on renewable energy as well as energy conservation programmes, “Energy Research Center” was established at Thiruvananthapuram in 1994–1995. Subsequently, owing to the massive progress in the activities of Materials and Energy Research in the country and also considering the demand for R&D, testing and consultancy activities, the facilities have been expanded. The erstwhile Materials Technology Division has now been transformed into three divisions and three units viz., Materials Technology Division, Dielectric Materials Division and Energy Efficiency and Renewal Energy Division in Bangalore and Thermal Research Center at Nagpur, Regional Testing Laboratory at Kolkata and Regional Testing Laboratory at Guwahati. The overall performance of the group, viewed comprehensively, has been extremely vibrant and progressive. The group has established capital facilities to the tune of 8% of the overall CPRI and the total annual revenue has grown above 8%. The progress in the consultancy programmes is quite significant and matches more than 40% of the overall consultancy revenue of the Institute.

In respect of R&D efforts, significant contributions have been made in terms of reviewed Journal publications to the tune of 65% of the total and the patentable innovations in terms of patents obtained and those under process amounts to more than 60% of the Institute.

1.1 Major Activities of the Materials Technology Division

MTD has evolved from being a generic laboratory to a large division and has focused its activities in respect of the following:

- Establishing comprehensive laboratories to cater to the applied research and consultancy activities in the area of materials engineering, energy and environment.
- R&D projects in areas of National importance under different schemes such as projects in research contingency funds, RSOP and NPP programmes. The efforts have led to several patents, hundreds of technical papers in peer reviewed journals and presentations (National and International forums).
- Testing and Certification as per National and International standards such as IS, ASTM, IEC, DIN, ANSI, etc..
- Special consultancy programmes support the utilities, Government agencies and the engineering industries, promoting Industry and Academia collaborations, undertake import substitution programmes, product development and problem solving.

Since mid-eighties, MTD has been built from the rudimentary level to a highly sophisticated and goal oriented division. The onset of rapidly changing technologies and advent of new materials, higher environmental restrictions and regulations, newer products and components, emergence of nano-science and technology make the characterization of materials highly scientific and challenging. In this aspect, MTD has progressed and pursuing domain expertise in the following broad areas.

- (i) Fuel analysis and testing involving advanced consultancy services including

coal combustion, blending and performance audit for TPS including CFD modeling, environmental audit and distributed power generation programmes.

- (ii) Materials Characterization and Engineering including Analytical Facilities (SEM, XRD, XRF, Microscopy, Spectroscopy, etc)
- (iii) Condition Assessment and RLA of power plant components (thermal and hydro through Advanced Nondestructive Evaluation (NDE) and Engineering modeling.
- (iv) Mechanical and Wear Testing Laboratory (strength, hardness, fatigue and wear and residual stress facilities), Structural Integrity and Failure Analysis Studies.
- (v) Fly Ash Utilization - value added products from fly ash and cenospheres.

Some of the major achievements are highlighted below

- Revenue earning capability owing to research programmes, consultancy and testing activities have improved considerably since 1998 and shown 10 fold improvement in seven years and 25 fold in twelve years.
- The Officers of the Division have received various prestigious National awards viz., CBIP – Jawaharlal Nehru Birth Centenary Research Award, CBIP Jawaharlal Nehru Award for Young Women Scientists, NRDC Award for Innovative products and CBIP award for the best research station and Center of Excellence in CPRI for eight consecutive years from 1999–2000. The division has bagged best paper awards such as CBI and P (1991), ASM International award (2002), ICBM8 (2010). The Officers of the Division have delivered invited memorial lectures in several conventions.
- The Division has been awarded seven patents and eleven patents are in process. Presently, the division has scaled a higher level of application R&D enabling formulation of 3 to 4 patentable innovations, annually.

- The reviewed Journal publications have increased considerably and presently the growing expertise has reflected in the competence to publish more than 10 reviewed Journal publications every year. Since 1985, the division has published 90 reviewed Journal publications. The conference presentations have increased up to 25 per year in leading National and International Conventions.
- Fifteen officers from the division have gone through higher education (Masters and Doctoral Programmes). This channel and the facilities as well as the expertise in the division has also contributed to improve the qualifications of ten faculty members from reputed universities to obtain doctoral degree and guidance has also been imparted to 45 M.Tech students. Further, the officers of the division have been entrusted to review the technical papers received from peer reviewed Journals as well as dissertation and doctoral thesis. The division is taking up keen interest in promoting the sponsored research and network research programmes through closer interactions with BARC, BHEL, IGCAR, RDSO, DST (TDB), DSIR, CSIR and ongoing schemes in RSOP and NPP programmes of CPRI.
- The division has organized so far 36 National and International symposiums and also played a leading role in conducting events for USAID, NTPC, IEEE and National sponsoring agencies. The first seminar organized was in 1986 on the “Thermal Power Station Problems” and in 2012, an internationally acclaimed IEEE International conference on ICPADM 2012 is being coordinated by this division with the support of the dielectrics group in CPRI. The division is gearing up to organize annually two International Conventions of class and virtue on par with the major International technical events conducted across the world.

The various activities that have taken place over the last three decades are covered briefly in the following sections.



NATIONAL SEMINAR ON “THERMAL POWER STATION PROBLEMS” HELD IN 1986.



NATIONAL WORKSHOP ON “REMAINING LIFE ASSESSMENT OF POWER PLANT COMPONENTS” HELD IN 2004.

2.0 LABORATORY ACTIVITIES

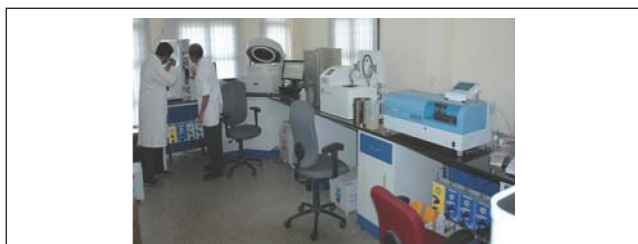
2.1 Fuel Analysis, Environment and Distributed Generation

Coal laboratory in MTD has been accredited by NABL for various tests on coal samples. The laboratory has sophisticated facilities for characterizing coal samples. Numerous research projects were carried out by the laboratory in respect of design and development of Drop Tube Furnace, combustion of coal, blended coal firing, oxy-coal combustion and computational fluid dynamics modeling. The capabilities of the laboratory and some of the notable consultancy projects carried out are given below:

- *Arbitration work and analysis of referee coal samples:* An arbitration work was carried out for ECL and BSEB under the supervision of CEA.
- *Design and Development of Drop Tube Furnace (DTF):* One pilot scale instrumented DTF was designed and developed for CFRI, Dhanbad as a sponsored project and one bench scale DTF was designed and developed for CPRI for studying coal combustion behavior.
- *Abrasion Index evaluation:* The Abrasion Index machines were specially designed and developed for BHEL and Ahmedabad Electric Company.
- *Statistical analysis:* Comprehensive index survey of TPS was carried out for CPCB.
- *Clinker formation in power plants:* Consultancy was carried out for MSEB
- *Coal combustion studies:* Evaluation of long flame characteristics of coal samples was carried out for MSEB and MPEB.
- *Techno-economic feasibility study of blended coal firing:* A consultancy work was carried out at 210MW units for RTPS, KPCL, Raichur.
- *Assessment of the methodology of sampling and analysis of coal at power plants –* Consultancy works were carried out for Bellary and Raichur TPS, Karnataka.

2.2 Environmental Audit

- Environmental audit studies in 5 TPS (MOEF, KPCL and TNEB).
- Pollution monitoring (MSEB, MPEB, APSEB and ISRO). Description of

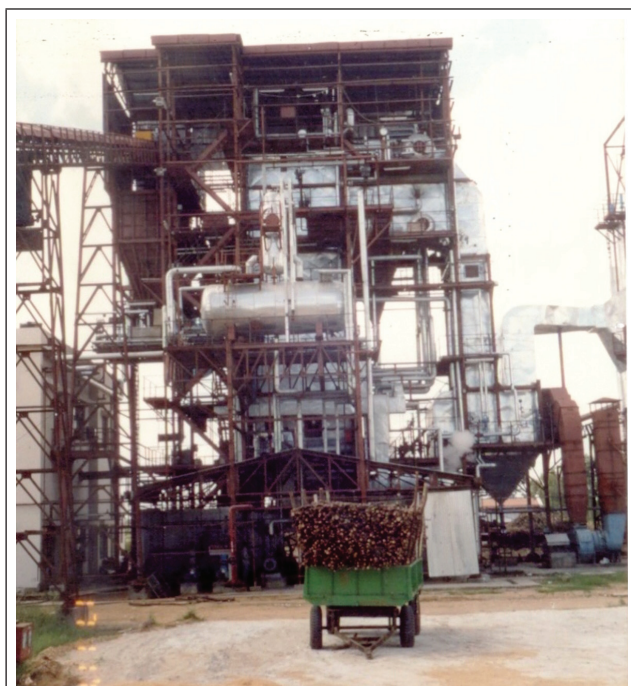


COAL ANALYSIS AND TESTING EQUIPMENTS

technologies for removal of SO₂ from flue gases (CPCB).

2.3 Distributed Power Generation

- Analysis and evaluation of biomass fuels for different utilities.
- Evaluation of 4.5 MW biomass power plant at Malavalli, Karnataka for M/s. IGEEP, New Delhi.
- Technical feasibility on 4.5 MW biomass based power project (M/s. Manjunatha Bioenergies Pvt., Ltd., Karatagi, Karnataka).
- Amorphous Phase contents in ash collected during rice husk combustion in FBC facilities for BHEL, Tiruchirapalli.



BIO-MASS PLANT



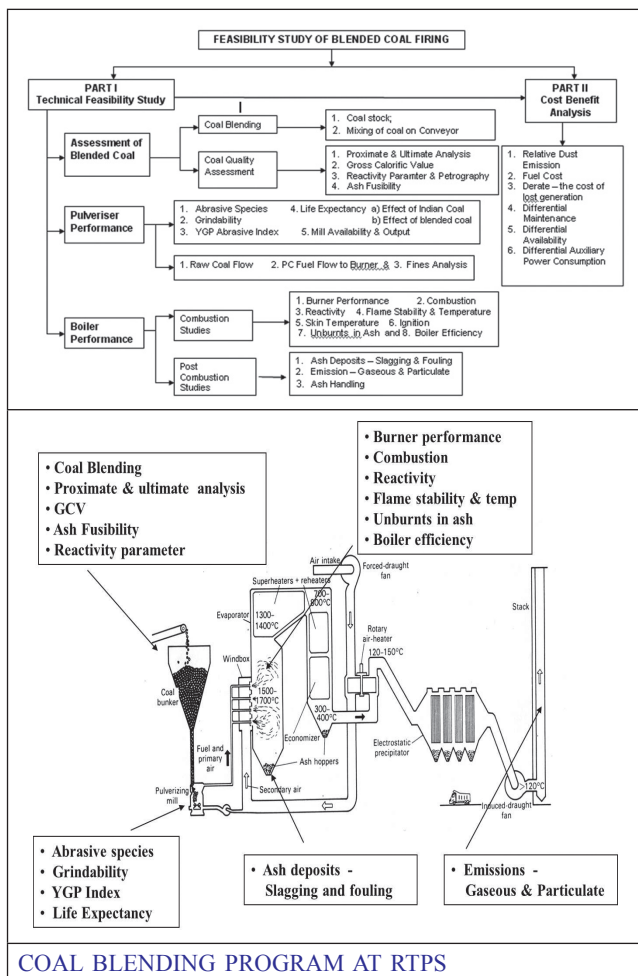
ABRASION (YGP) INDEX FACILITY

The coal laboratory carries out the training program for the power plant chemists and engineers on the coal quality analysis and impact on power plant performance.

3.0 ANALYTICAL FACILITIES

The Analytical Facilities Laboratory was established during 1987–1988 with a view to carryout in-depth material characterization like microstructural and phase studies, composition, physical parameters like particle size, surface area etc. Further, these facilities are used as a part of failure analysis and product development investigations as well as life assessment study of plant components. In addition to the above, they are extensively utilized for testing of various engineering materials including metals, ceramics, composites, thin films and coatings etc. The efforts resulted in analytical inputs for R&D and substantial testing revenue earned. Some of the notable achievements of the laboratory are given below.

- Development of High and Low Voltage Ceramic capacitor Di electric materials for Bharath Electronics Limited, Bangalore.
- Development of Thermal Shock Resistant Ceramics for Ceramic industries and foundries. Successful trial runs were carried out as MHD (Magneto Hydro Dynamics) channel insulator and electrodes at BHEL Trichy.
- Developed thermal barrier coatings for diesel engine applications using CPRI developed plasma sprayable powders. An increase in the fuel efficiency of 8% with low particulate and CO emissions when compared to non coated engine components observed. Totally three patents have been filed in this project. A novel and cheaper method for large scale preparation of plasma sprayable powders was established for space applications in the form of coatings at LPSC, ISRO, Mahendragiri.
- Performance assurance studies were conducted from the point of structural integrity assessment of Alumina based porcelain insulators used in traction lines for Railways resulting in substantial revenue for the division.
- Various kinds of failure analysis and product development studies were undertaken in the





SCANNING ELECTRON MICROSCOPE SETUP

field of electrical, automotive and process industries which resulted in revenue for the division.

- Subsequent to the latest development in the world on super conducting power devices, the group is working in the research project on HTS fault current limiters.
- A comprehensive test facility for CRGO electrical steels is being set up at MTD to cater to the needs of Transformer manufacturers in the country. CPRI will act as third party Government inspection body for testing and certifying electrical steels used in transformers and motors.



CRGO ELECTRICAL STEEL TEST FACILITY

4.0 CONDITION ASSESSMENT AND RLA OF POWER PLANT COMPONENTS

The condition assessment of power plant components has been initiated during 1996 upon registration as a consultant for Power Finance Corporation and obtained certification from the Central boiler Board as an accredited agency for

carrying out Remaining Life Assessment (RLA) programmes in Indian Thermal Power Stations. The activities have been expanded over the years and establishment of “Thermal Research Center” at Nagpur has been completed to cater to the need of thermal power stations.

Establishment of advanced Non-Destructive Test (NDT) facilities has been taken up to increase the productivity and reliability of inspection methodologies. The established RLA facilities include:

1) Conventional Non-Destructive Techniques:

- Visual Inspection
- Dye Penant
- Magnetic Particle Inspection
- Eddy Current,
- Ultrasonic Testing.

2) Advanced Non-Destructive Techniques:

- Fibroscopic Inspection
- Ultrasonic based High frequency flaw detectors
- UT based Thickness of coating
- Ultrasonic B-scan system
- Acoustic Emission Testing system
- Magnetic Barkhusen Noise
- Thermography
- Low frequency Electromagnetic technique (LFET)
- Multi View IRSI system.
- In-situ metallography kit

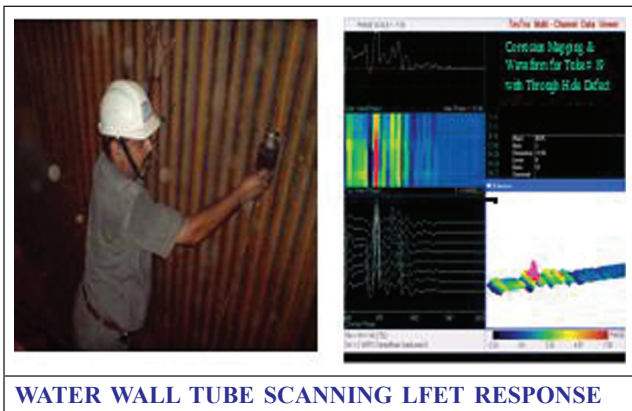
3) Standard and Calibration blocks:

- Different calibration blocks for convention NDT including different weld inspection, Boiler tubes with artificial defects

4) RLA Software:

- In-situ oxide scale based remaining life estimation of boiler tubes

- CAPIPE for Stress analysis for High Energy Piping components



WATER WALL TUBE SCANNING LFET RESPONSE



FIBROSCOPIC INSPECTION OF LTRH TUBES

5) Inspection Capabilities:

- Thickness survey of Boiler tubes using ultrasonic method
- In-situ oxide scale measurement by High frequency UT probe
- Metallurgical degradation through in-situ replication and hardness
- High energy Pipeline Hangers support inspection
- High energy pipeline stress analysis using CAPIPE software
- Surface damage assessment through Fibroscopy
- Corrosion mapping of water wall boiler tube by LFET method
- B-scan for weld inspection
- Ultrasonic based Phased array system
- Internal Rotatory inspection system (IRIS) for Boiler banking tube
- Condenser and Heat exchangers inspection by Multi scan and Mutli view
- Penstock inspection for Hydro Electrical Plant (HEP)
- Crank shaft Inspection for Diesel Power Plant



ULTRASONIC TEST ON THE PENSTOCK PIPES

Consultancy services offered

- National Thermal Power corporation (NTPC)
- Domaodar Valley Corporation (DVC)
- State Electric Boards, privates power sectors
- Hydro power generation boards
- petrochemical and other processing industries
- Automotive Industries

Research Contributions

- Establishment of methodology of In-situ oxide scale thickness measurement in boiler tubes and development of life estimation software to estimate the remaining creep life.
- Corrosion mapping of water wall boiler tubes.
- Inspection of Economizer tubes.

- Inspection of High energy pipeline hangers support system and stress analysis.
- UT based Phased array Inspection for Turbine shaft Ultrasonic based B-scan method for Boiler tube DMW inspection.
- Design and Development of Robotics system for water wall boiler tube inspection.
- Condition Assessment of plant components (in-situ oxide scale thickness survey, corrosion mapping, pipes and hanger inspection, fibroscopic inspection) etc. in more than 125 TPS have been covered in respect of RLA work.
- Weld restoration of LP turbine at OEM.
- Lead agency in the National Perspective Plan involving CSIR/IIT and other R&D labs on RLA.

CFD modeling studies - Cooling water sump modeling studies were carried out for cooling water sump design for M/s. Bhushan energy, New Delhi.

5.0 MECHANICAL AND WEAR TESTING

The laboratory for mechanical and tribological properties characterization (friction-wear-lubrication) was setup to cater to the needs of power plant material's comparative fatigue and wear performance evaluation. Comprehensive indigenously developed test facilities for wear



JET EROSION TEST SETUP

and erosion resistance of power plant materials has been established during 1987. The study was initially centred around National programs, boiler tube failure analysis, understanding water chemistry in boilers, erosion of coal conduits and performance evaluation of Electro-static Precipitators.

The present national programs mainly focuses on mitigation of silt erosion problems in hydro plants, development of specialty test rigs for assessment of coal abrasivity and assessment of high temperature creep properties.



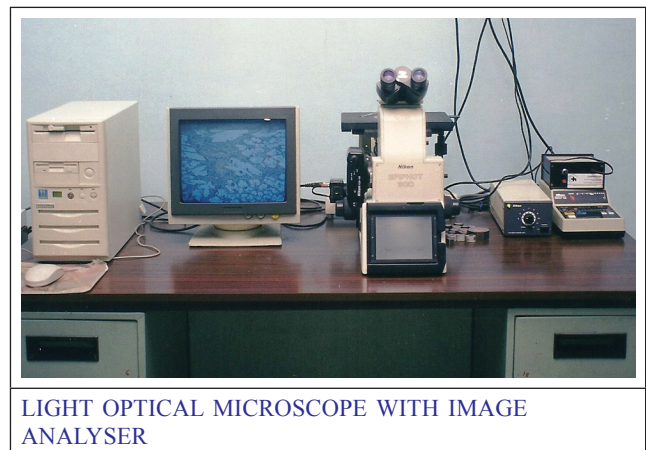
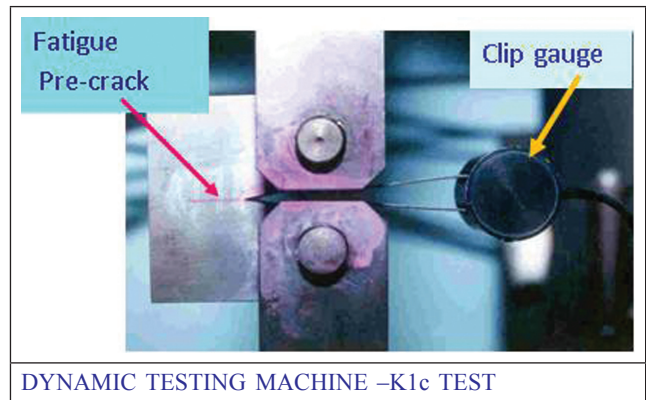
RUBBER WHEEL ABRASION SETUP



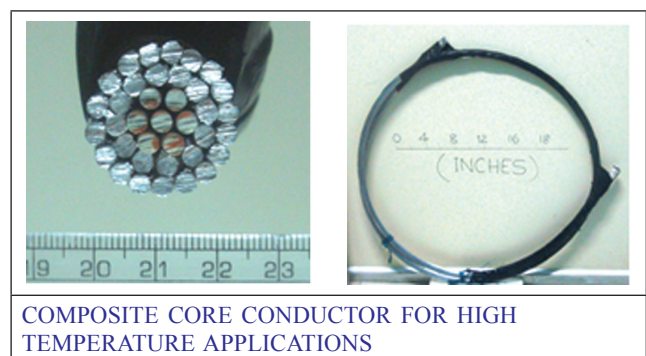
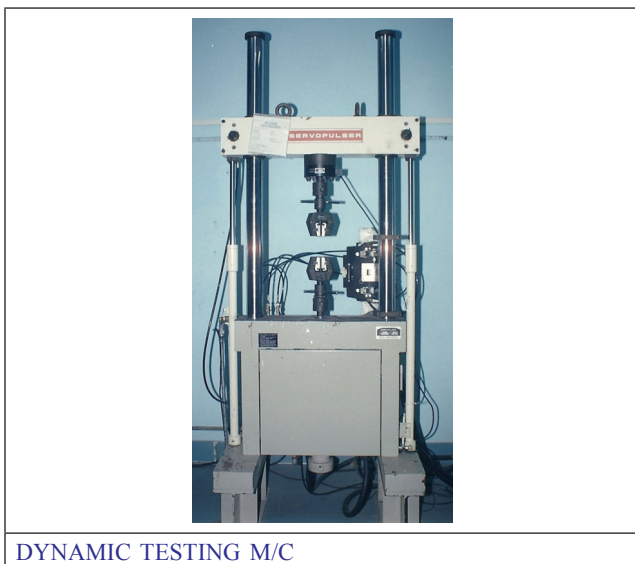
PIN-ON-DISC SETUP

Different R&D programs on materials study keeping in view the improvement of service life of components have been completed. Typical studies include.

- Design and Development of high velocity silt erosion test rig for assessment of relative silt erosion resistance of hydro turbine steels and coatings.
- Establishment of wear index of carbon steels, nodular irons, chromium irons, Nihard, Sintered alumina and cast ceramics, HDPE and Teflon polymers, ceramic and metal coatings used in pulverizers, coal chutes and bunkers, fuel pipes, bends and elbows orifice and burner nozzles, pressure parts, slurry media including wear estimation modelling studies.
- Development and comprehensive wear and erosion characterization of high chromium alloyed irons, transition metal hard carbide deposits, duplex steels and austempered ductile irons.
- Evaluation of fracture toughness and fatigue crack propagation studies on structural steels.
- Consultancy program on “Fatigue and Fracture surface examination of pipe and elbows” (BARC, Mumbai)
- Assessment of boiler steels and coatings for fluidized combustor applications.

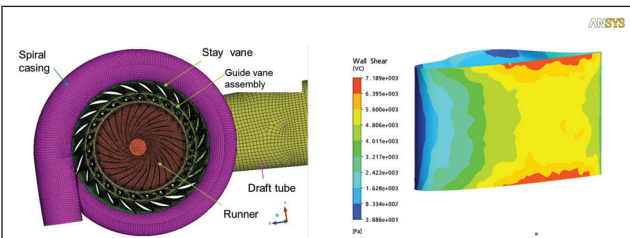


- The group is also catering to the materials engineering aspects in Generation as well as transmission. Failure analysis of ACSR conductors, porcelain insulators, evaluation of energy meter components are some of the areas presently being addressed. The constructive efforts on the development of high temperature aluminium conductors with composite core are also in progress.
- Modelling of fluid flow process and identification of critical erosion prone regions of hydro turbine is extensively studied.





IN-HOUSE DEVELOPED JET TYPE SILT EROSION TEST RIG



HYDRO TURBINE EROSION MODELLING

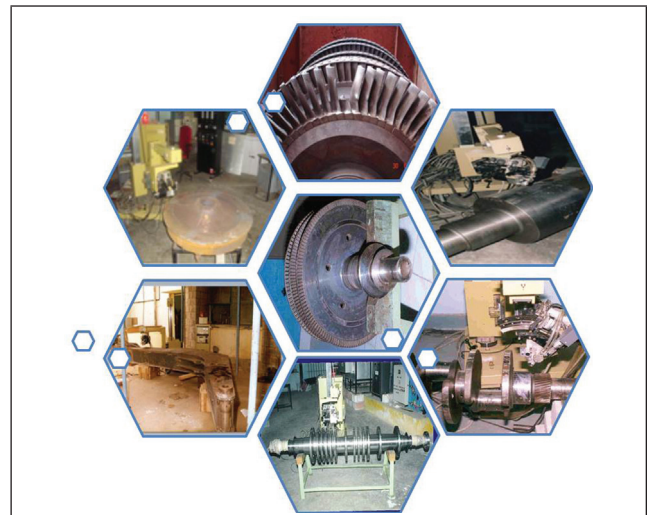
5.1 Structural Integrity and Failure Analysis

Assessment of structural integrity of critical power plant and industrial components through establishment of quality assurance and control of process parameters has been considered important from the view point of improving the service life and performance of the component. Assessment of surface residual stresses and their distribution through non-invasive techniques based on X-ray diffraction (XRD) and magnetic (MBN) techniques of the materials have been established and a number of components has been evaluated for their integrity.

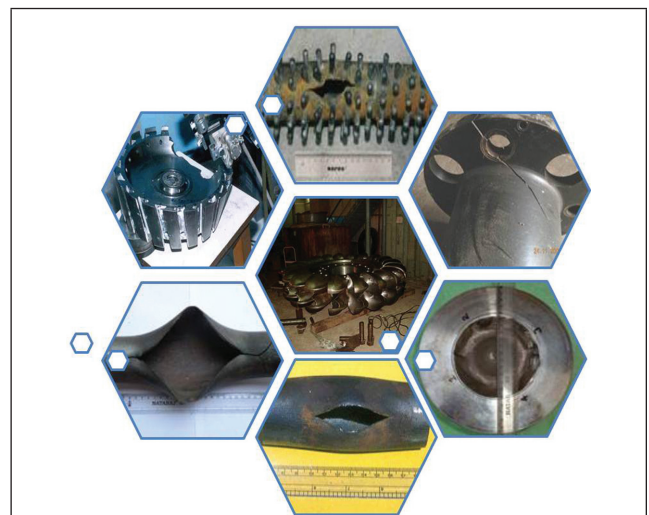
Root cause analysis of critical power plants and industrial components Typical components covered are:

- Automotive steering arm, leaf spring SS hook components.
- 66 MW pelton runner of M/s Tillary Hydro power station.

- Captive Steam Turbine blade failure of fertilizer plant.
- Flexible Couplings, Diesel engine crank shaft, Cylinder liners, valve stem.
- SH/RH/Water wall tubes of thermal plants
- Babbitt material forged and heat treated drawing die, shot peened gears and roller bush.
- Aerospace components - Compressor disk, Collector gear, metal gaskets, helicopter gear casings, blade and rib components, propeller tank, etc..
- Assessment of failure of diesel engine crankshaft, hydrogen embrittlement of water wall tubes, corrosion of heat exchanger tubes.



ASSESSMENT OF POWER PLANT COMPONENTS



TYPICAL FAILURE ANALYSIS CASE STUDIES

The CPRI's expertise in this unique area is extensively utilized by various utilities and industries serving the power sector, heat treatment industries, and other institutions.

6.0 FLY ASH UTILIZATION

The Centre for Industrial Solid Waste Utilization (CISWU) in the Materials Technology Division is actively involved in the development of process / product technologies for fly ash, its derivatives and other industrial solid waste utilization. Consultancy projects with power plants and industries are being undertaken. Production of certain value added construction products from fly ash have been successfully demonstrated on a commercial scale. Showcased novel construction practices with fly ash materials, viz., autoclaved aerated concrete (AAC) panels for wall and roof in a composite structure, mosaic tiles for flooring, interlocking pavers and kerbstones for road and ground granulated blast furnace slag (GGBS) based designer tiles for pathways. The concept and design of the centre has taken into account natural lighting, ventilation, and energy conservation aspects.



VISIT OF HONORABLE MINISTER OF STATE FOR POWER

The group is also looking after the environmental audits, pollution monitoring and technical feasibility studies of distributed power generation (Bio-mass and municipal solid waste).

The flyash research centre is well equipped with sophisticated infrastructure facilities for fly ash characterization.



CISWU LABORATORY



INAUGURATION OF CISWU LABORATORY

Product Development and Evaluation Centre (PDEC) - consists of equipment for materials processing, product development and evaluation.

- Comprehensive Characterization of Fly Ash and Cenospheres.
- Development of value added products from fly ash.



FLY ASH CONCRETE



POLYMER COMPOSITE PRODUCTS

- Establishment of Centre for Ash Utilization Technologies and Environment Conservation (CASHUTEC) at Raichur Thermal Power Station.
- Characterization and Beneficiation of fly ash cenospheres generated at NTPC, Ramagundam and Simhadri.
- Establishment of Centre for Industrial Solid Waste Utilization (CISWU) for development of value added products from industrial solid wastes.
- Gainful Utilization of Marble Slurry Waste.
- Study to Assess Pozzolanic Property of Ground Fly Ash (Characterization of Ground Fly Ash).
- Techno-Environment Feasibility Report on the Integrated Waste to Energy.



CASHUTEC

7.0 THE WAY FORWARD

7.1 Projects

- HTS power devices (FCL and cables) and HTS Energy storage devices (Fly wheel battery and SMES)
- Advanced Technology enabled material schemes for increased wear, corrosion and heat resistance for UMPP and Hydro plants.
- Robotized vehicle incorporating inspection tools with advanced sensors and transducers for conditioning monitoring and service degradation assessment of power plants and devices aimed at improved productivity.
- Materials engineering aspects involved in solar thermal projects.
- Development of Aluminium and polymer composites for high temperature conductors and transmission towers.
- Technology Demonstration Centres for value added products from fly ash and fly ash cenospheres.

7.2 HRD and Networking

Networking with leading Industries, R&D Institutions and Universities in the country for creating a R&D platform for the power sector to enable introduction of state of art technologies. Improvements in qualifications (M.Tech and Ph.D) in focused thrust areas pertaining to generation, transmission, distribution including renewable will create experienced manpower to alleviate core competence in the power sector. This will also further encourage collaborative sponsored programmes for the power sector engineers. Provisions as available in RSOP and NPP programmes will be attempted to enhance the R&D output in key areas of Materials Science, Energy and Environmental Engineering in the power sector.