Best R&D Laboratory in Industry, NACE International (2004)

In Pursuit of Intellectual Property

Globalisation has brought severe competition and placed a high value on technology ownership. Realising this, Tata Steel embarked in 2001 on an aggressive programme for intellectual property protection.

The world has seen a phenomenal rise in the value of intellectual assets such as patents and other intangible assets. For example, since 1975 the value of these intangible assets in the S&P500 stock index has risen from 20% to 80% of its total value. This has spurred attention to the protection of intellectual property. Worldwide patent applications have doubled in the last decade and currently stand around 2 million each year.

National patenting activity is often seen as a yardstick for innovation in a country. In the wake of growing economic activity and reforms of patent laws, India too is witnessing rapid changes in its patenting landscape. Foreign entities presently account for approximately 80% of patent filings. These span across all major industries and include many international corporate giants. This dominance of foreign filings may be seen as a threat to the Indian private industry. Realising this, Tata Steel embarked on an aggressive programme to protect its Intellectual Property (IP).

Today, Tata Steel (India) has nearly 190 granted patents and another 400 patents are in the application stage. The takeover of Corus in 2007 has brought a portfolio of another 930 patents, so that today Tata Steel's global portfolio now contains 1500 patents. These cover inventions ranging from raw materials processing, steel production processes, steel products and steel applications in a wide range of uses.

In 1938, Tata Steel filed its first patent. It was granted in 1939 and was the first patent of the Indian steel industry. However, by the end of the millennium, the total number of granted patents was only 8, with another 16 in application stage. At the same time, the first signs of consolidation in the international steel industry were emerging. It was foreseen that, once global technology leaders emerge, they will harden their positions on the exclusive ownership of technology. Therefore, Tata Steel also needed to improve the protection of its own intellectual property.


INTELLECTUAL PROPERTY INDIA

Annual Intellectual Property Awards

2011

This certificate is awarded to

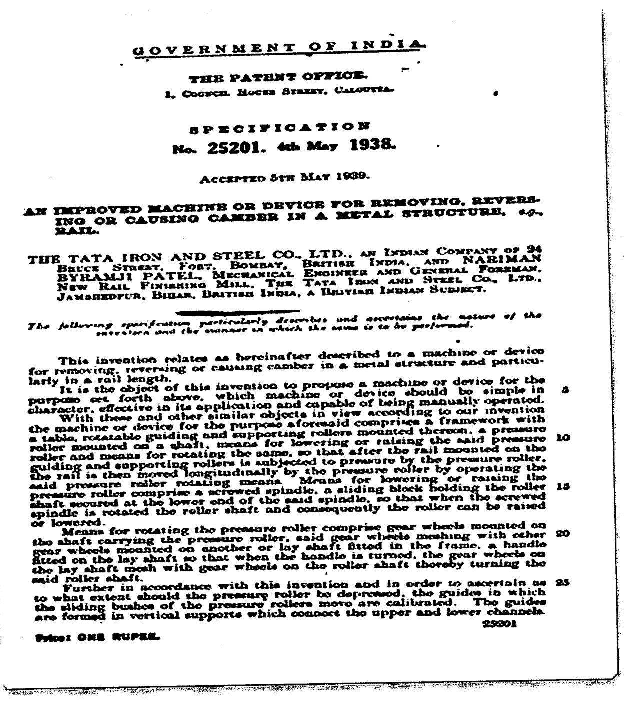
TATA STEEL LIMITED

In appreciation of securing highest number of Patents in the category of INDIAN OWNED PRIVATE COMPANY for the last five years (2006-07 to 2010-11)

26th Day of April 2011
New Delhi

P.H.KURIAN I.A.S.
Controller General of Patents, Designs and Trademarks

Tata Steel received the award for the 'Highest number of patents granted to an Indian Owned Private company in the last 5 years' from the Ministry of Commerce and Industry (2011).



GOVERNMENT OF INDIA.

THE PATENT OFFICE.

1, Council House Street, Calcutta.

SPECIFICATION

No. 25201. 4th May 1938.

Accepted 5th May 1939.

AN IMPROVED MACHINE OR DEVICE FOR REMOVING, REVERSING OR CAUSING CAMBER IN A METAL STRUCTURE, e.g., RAIL.

THE TATA IRON AND STEEL CO., LTD., an Indian Company of 24 Bruce Street, Fort, Bombay, British India, and NARIMAN BYRAMJI PATEL, Mechanical Engineer and General Foreman, New Rail Finishing Mill, The Tata Iron and Steel Co., Ltd., Jamshedpur, Bihar, British India, a British Indian Subject.

The following specification particularly describes and ascertains the nature of the invention and the manner in which the same is to be performed.

This invention relates as hereinafter described to a machine or device for removing, reversing or causing camber in a metal structure and particularly in a rail length.

It is the object of this invention to propose a machine or device for the purpose set forth above, which machine or device should be simple in character, effective in its application and capable of being manually operated.

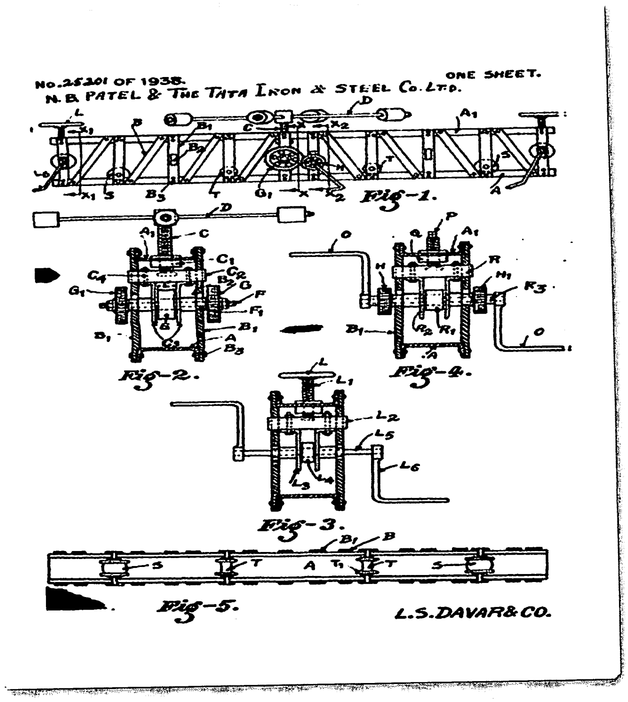
With these and other similar objects in view according to our invention the machine or device for the purpose aforesaid comprises a framework with a table, rotatable guiding and supporting rollers mounted thereon, a pressure roller mounted on a shaft, means for lowering or raising the said pressure roller and means for rotating the same, so that after the rail mounted on the guiding and supporting rollers is subjected to pressure by the pressure roller, the rail is then moved longitudinally by the pressure roller by operating the said pressure roller rotating means. Means for lowering or raising the pressure roller comprise a screwed spindle, a sliding block holding the roller shaft secured at the lower end of the said spindle, so that when the screwed spindle is rotated the roller shaft and consequently the roller can be raised or lowered.

Means for rotating the pressure roller comprise gear wheels mounted on the shaft carrying the pressure roller, said gear wheels meshing with other gear wheels mounted on another or lay shaft fitted in the frame, a handle fitted on the lay shaft so that when the handle is turned, the gear wheels on the lay shaft mesh with gear wheels on the roller shaft thereby turning the said roller shaft.

Further in accordance with this invention and in order to ascertain as to what extent should the pressure roller be depressed, the guides in which the sliding bushes of the pressure rollers move are calibrated. The guides are formed in vertical supports which connect the upper and lower channels.

25201

Price: ONE RUPEE.



First Indian Steel company to get Patent

Nowadays, an Indian company being granted a patent is no great shakes. But back in 1939, Tata Steel, then known as The Tata Iron and Steel Co. Ltd. (TISCO), earned a mark of distinction by becoming the first Indian steel company to be granted a patent. It was filed as Specification No. 25201 on 4th May 1938 on behalf of TISCO and Noriman Byramji Patel by their attorneys, L.S.Davar & Co. Mr. Patel was the Mechanical Engineer and General Foreman of the New Rail Finishing Mill. The patent was accepted by the Kolkata – based Patent Office of the then Government of India on the 5th of May 1939.

The patent was for "An improved machine or device for removing, reversing or causing camber in a metal structure, e.g., rail". Basically, it was a new rail straightening device that was described accordingly:

"This invention relates as hereinafter described to a machine or device for removing, reversing or causing camber in a metal structure and particularly in a rail length. The device comprises a framework with a table, rotatable guiding and supporting rollers mounted thereon, a pressure roller mounted on a shaft, means for lowering or raising the said pressure roller and means for rotating the same, so that after the rail mounted on the guiding and supporting rollers is subjected to pressure by the pressure roller, the rail is then moved longitudinally by the pressure roller by operating the said pressure roller rotating means. Means for lowering or raising the pressure roller comprise a screwed spindle, a sliding block holding the roller shaft secured at the lower end of the aid spindle, so that when the screwed spindle is rotated the roller shaft and consequently the roller can be raised or lowered."

The patent document then proceeds by detailing the means for rotating the pressure roller, their calibration and many more technicalities. The document also provided 5 detailed drawings of the different parts of the machine along with textual descriptions.

Three major steps were taken during 2001-2008 under the leadership of the then Chief R&D and Scientific Services Dr. D Bhattacharjee, First, a Patent Cell was created that was manned by Senior Manager Patents, Mr. B K Bhuyan. This Cell helped execute a large number of initiatives aimed at spreading awareness of the importance of intellectual property, the ways to protect new developments and the relevant rules and restrictions. Initiatives included a newsletter, posters, leaflets and company-wide courses. These were tailored to suit employees at different levels and were conducted both in Hindi and English. An IPR consultant, Mr. Subramaniam Vutha, was the main architect of these courses.

Alongside, changes to R&D's quality system were made. Project notebooks were introduced to improve research documentation in accordance to IP documentation rules and it became compulsory for researchers to carry out a patent search at the start of a project. These search facilities were provided through specialised internet search engines and external IP service providers. "Patents searches are a great support to ensure effective R&D", says Bhuyan. "Those who wish to start a project or file a patent application can now simply check the novelty of their ideas."

During these initial years, the momentum picked up gradually and annual patent filings grew to 20 in 2004. People came forward with hardcopies of documents detailing their inventions and how it could benefit the company. The difficulty was that either they had to post the documents or personally come to the IP Cell located at R&D in Jamshedpur, both of which entailed delays.

To overcome this obstacle, an electronic IP filing system was launched. This enabled the inventor to answer a questionnaire after which the Senior Manager Patents could scrutinise to assess if it met the requirements for a patent filing. Subsequently, documents were provided to the patent attorney for further processing and to file the patent at the Indian Patent Office in Kolkata.

A second major step was the launch of R&D Thrust Areas for the development of strategic technology with a large potential of competitive advantage. These projects target the development of world-first technology that can be protected by patents. In 2005, six such Thrust Areas were launched. This number was subsequently extended to nine; examples are a new technology to produce 8% ash coal from high-ash Indian coal, new technology for the beneficiation of ultrafine iron ore tailings, new technology for energy-efficient ferro chrome production and new advanced high-strength steels to make cars lighter and safer.

The third major step by 2005 was to strengthen the governance mechanism on Intellectual Property by the creation of two committees. One was the 'IP Executive Committee' headed by the Managing Director and consisting of Vice Presidents of all divisions. This focussed on policy making and review. The second, known as 'Team IP', was chaired by the Chief of R&D and Scientific Services. Its role was to drive initiatives aimed at promoting IP best practices and to further boost IP awareness throughout the company through visits, courses and seminars. The result of these initiatives has been a dramatic rise in the patent filings, which have averaged 47 per year since 2005.

In order to own the market of the future, Tata Steel needs to carry out research in areas not covered by prior art. This involves exhaustive and continuous patent search and commitment to research

\- Dr. Debashish Bhattacharjee

Herbal treatment of chromite concentrates

Approximately 65% of globally mined chromite ore contains 0.2 to 0.4 parts per million of hexavalent chromium, which is carcinogenic. The conventional remediation method reduces toxic hexavalent chromium into non-toxic trivalent chromium using inorganic reductants such as ferrous sulphate. This method is costly, environmentally unfriendly and adds impurities to the chromite and to effluent water.

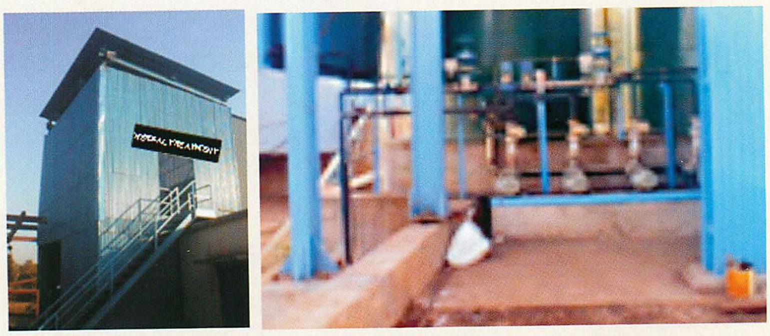
Tata Steel's R&D and Sukinda Chromite mines, in collaboration with the Central Leather Research Institute in Chennai, have successfully developed and commercialised an alternative process that reduces the hexavalent chromium to trace levels. This novel process uses an organic reductant known as Myrobalam extract. Myrobalam is a dried fruit of an Indian tree known as kasafal in Hindi (Terminalia Chebula) and contains 40-60% tannins. These are phenolic compounds consisting of poly-hydroxy phenyl groups with a high affinity for heavy metals such as chromium.

Dr. Debashish Bhattacharjee of Tata Steel receiving the DSIR award from Prof. S K Bramhachari, Director General-Council of Scientific and Industrial Research, Government of India (2007)

This herbal remediation process was implemented at Tata Steel's chrome ore beneficiation plant in Sukinda and produces green coarse chromite concentrates that are preferred by overseas customers. The process is eco-friendly and cost-effective. It saves 1.4 crore rupees and 95 million litres of water every year.

This new technology is patented in India and abroad. For this development Tata Steel was awarded a National Award from the Department of Scientific and Industrial Research on 15th November 2007.

Nuts of terminalia chebula



Hexavalent chromium removal treatment setup at the chrome ore beneficiation plant, in Sukinda (Odisha)

The R&D department at Tata Steel is the major source of patent filings. From 2009 till today R&D has seen its highest number of filings averaging 50 per year. Under the leadership of Mark B. Denys, Chief R&D and Scientific Services, the department strengthened its practices on sharing intellectual property with partners and introduced procedures to formalise the terms of collaboration projects with technology partners through non-disclosure agreements, memorandums of understanding and other contracts.

Tata Steel R&D pursues numerous projects in collaboration with partners throughout India and abroad. There are three types of collaborations: external research projects, collaborative research projects and external technical services. In the first case, an entire project is outsourced based on a partner's specific expertise and capability. In the second case only a part of an R&D project is outsourced and, finally, in the third case a partner is engaged to perform predefined technical services in support an R&D project, for example sample analysis through transmission electron microscopy.

The first two types of projects can generate substantial new knowledge and intellectual property. For example, Tata Steel R&D is presently developing a new Clean Coal technology to create a coal with an ash content of 8% from a typical Indian coal with an ash content of 35%. This will decrease the use of costly imported coal, will enhance energy efficiency and productivity in ironmaking.

In 2005-06 the early concepts were developed with Professor Saibal Ganguly at IIT Kharagpur. One patent was filed at this stage. In 2006, subsequent bench-scale trials were conducted in to develop the concept which resulted three patents.

At present, this technology is being scaled up by a team of researchers with important support from engineering consultants and Dr. T K Roy, a retired Joint Managing Director M N Dastur Co. and professor at BE College, Sibpur. A major pilot plant is running and produces batches of 500 kg clean coal. It is a sophisticated and impressive piece of equipment that is used to evaluate the optimum operating conditions, to test various types of coals and to fully establish the design aspects necessary for further scale-up and commercial success. During this stage of the project further 6 patents were filed.

Tata Steel's R&D in India typically has about 40 collaborative projects running at any time. Partners include universities, research institutes and other companies, both in India and abroad. Examples are most of the Indian Institutes of Technology and various institutes under the Indian Council of Scientific & Industrial Research, such as the National Metallurgical Laboratory in Jamshedpur.

Together with the four R&D centers of Tata Steel Europe, the number of technology partnerships is more than 200. This reflects a worldwide trend whereby R&D activities are no longer confined to the boundaries of the company, but increasingly take place with customers, suppliers or across entire supply chains, industries or even the virtual world. Tata Steel R&D has examples of all these practises.

These collaborative R&D practices require extra attention to IP protection and introduce new practices in the sharing of IP. In the past few years, Tata Steel made its first attempts to license out patents and copyrights. In 2010 it became the first Indian company in the Tata Group to earn royalty from a patent on a new form of 'idler', a support roller on which a conveyor belt moves.

Tata Steel has also effectively leveraged its growing patent portfolio as a ready indicator of its technological capabilities . For example, it is one of the criteria in the Prime Minister's Trophy assessment that Tata Steel won for two consecutive years in 2009 and 2010. It also received due attention during the application for the coveted Deming Prize awarded by the Japanese Union of Scientists and

Hybrid Idler - Tata Steel's first case of licensing out Intellectual Property

Conventional idler

Novel hybrid idler

In 2010, Tata Steel became the first Indian company in the Tata Group to earn royalty from a patent; a small but significant breakthrough that marks the success of its patenting initiatives.

The invention concerns a new form of idler, which is a support roller on which a conveyor belt moves. Idlers are round pipes that support the weight of both the conveyor belt and the raw materials that are transported. At the Tata Steel's sinter plants, for example, the role of the conveyor belt system is to convey the raw materials mix to the sinter machine and convey the product sinter to the blast furnace. At one sinter plant alone, the conveyor belt network is about 42 km long and uses nearly 100,000 idlers.

These conveyor belt systems need to be highly reliable. However, the wear and tear on conventional idlers implies that they have a very short operational life. At the sinter plant, the idlers had to be replaced every month resulting in system down time, extra maintenance and higher costs.

Tata Steel's Mechanical Maintenance department and a Jyoti Cero Rubber, a local supplier based in Adityapur, worked on an initiative to improve the quality and lifespan of these idlers. The result of the R&D was the creation of a new idler coated with alumina ceramic powder and polymer. The unique combination of polymer and ceramic powder is coated on the idler by casting and becomes an integral part. The resulting hybrid-idlers have a very high abrasion resistance and a very low co-efficient of friction.

The hybrid-idlers at Tata Steel have worked dramatically well: the lifespan has been extended eight to tenfold, resulting in benefits in the form of reduced cost of replacement, reduced down time and reduced maintenance.

Tata Steel applied for a patent on the Hybrid-Idler in 2008. The right to this patent is equally shared between Tata Steel and Jyoti Cero Rubber. In 2010 Tata Steel granted Jyoti Cero Rubber the rights to commercialise its share of the patent for a royalty of 3 percent of annual revenues. This income is over and above cost savings from replacing conventional idlers with the innovative hybrid idlers. Jyoti Cero Rubber can expect customer interest from a wide range of industries using conveyor belt systems.

Engineers (JUSE). In 2008, Tata Steel was the first integrated steel company in the world, outside of Japan, to win this prize for its distinctive performance improvements through the application of total quality management. This includes not just quality of products and services, but also the processes and activities that are needed to achieve quality.

Based on its patent filings Tata Steel India is now recognised as a benchmark in the Indian commercial sector. It has won the coveted Government of India Annual IP Award 2011 for 'the highest number of granted patents during the past 5 years amongst all Indian private companies'. The company also won the Thomson Reuters Innovation Award 2011 that recognises Tata Steel as 'the most innovative private company amongst hi-tech corporate India'.

There are many reasons why companies file patents: as a competitive tool to protect one's own business, as a source of additional income in the form of royalties, as a strategic tool to build alliances or as marketing to improve reputation, promote sales and motivate employees.

Thomson Reuters Innovation award (2011)

"Today IP is increasingly seen as a source of risk mitigation, new business options and competitive advantage.", explains Mark Denys, "This is why we will continue our drive to harvest and protect our intellectual assets. We also plan to develop more sophisticated practises to leverage our patents for business opportunity and to advance our reputation as the benchmark in the Indian steel industry."

Patent best practises vary wildly amongst countries, industries and companies. Reasons are the size of the markets, the varying relevance of patents amongst industry sectors and differences amongst firms and their policies to promote or discourage patenting. It is therefore not surprising that each company develops its own specific patent policies, guidelines and principles.

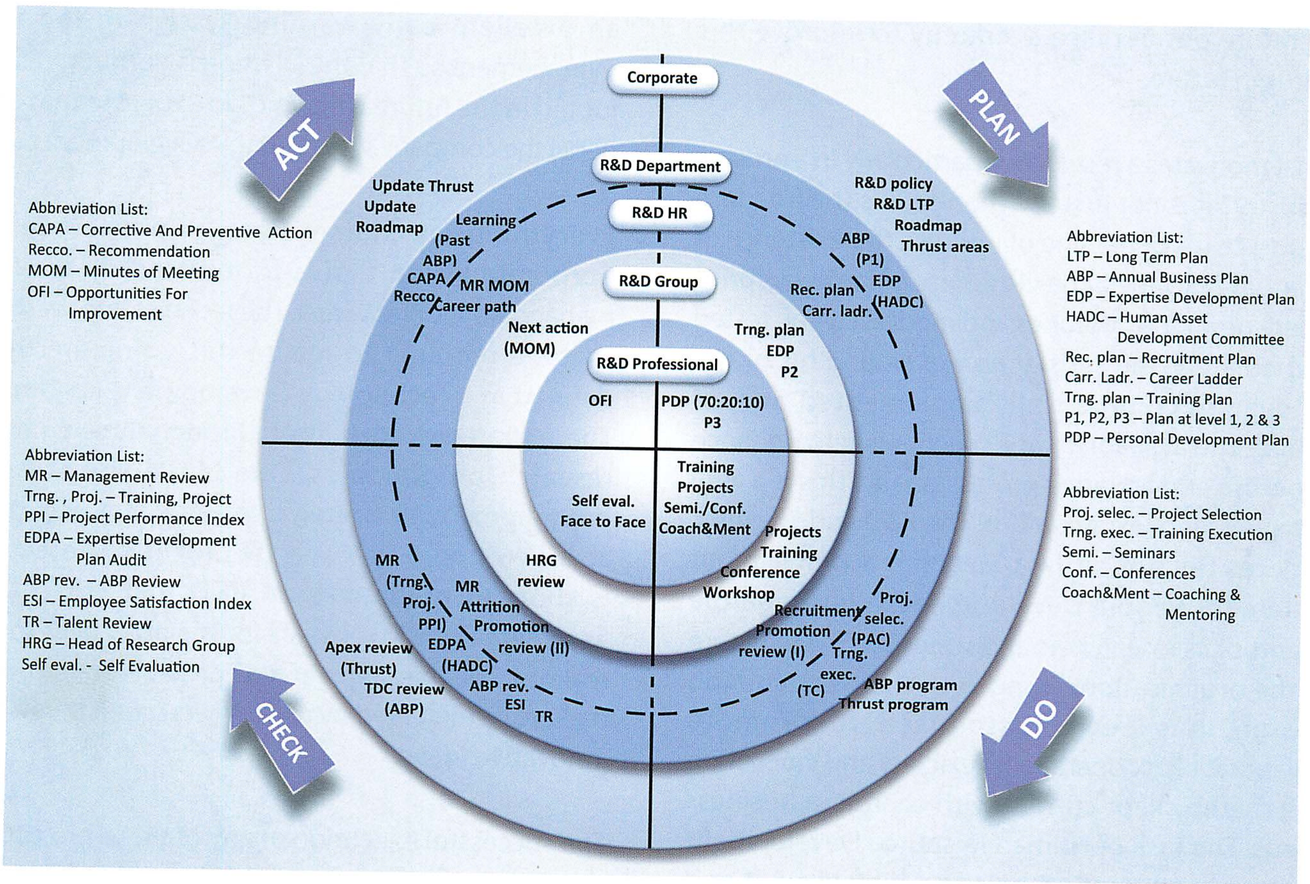
The IP accomplishments of Tata Steel are indicators of its success in capturing the inherent knowledge base and creating the potential to leverage such knowledge. In this Tata Steel has been a leader in India. Today this is taking a greater significance in the context of Tata Steel's globalisation. The challenge now is not only to grow our patent portfolio, but also to improve quality and to leverage these assets for business. Companies such as Philips, General Electric and Bosch have evolved sophisticated practices. Tata Steel is studying their approaches to learn and develop its own so that the company can derive maximum benefits for itself and its stakeholders.

"Give me a place to stand and a lever long enough, and I will move the earth."

(Archimedes of Syracuse, 287-212 BC)

An effective R&D organisation leverages the unique talents of its researchers to reach uncharted heights. This starts with the recruitment talented and well educated individuals. Unfortunately, the developments in higher education in India, especially in science and engineering, have been out of step with the requirements of the manufacturing sector. India turns out merely 9000 science, technology and engineering PhDs per year; a fraction of the output in China and the Western countries. This has resulted in an acute shortage of talent for industrial research. This paucity is a particular problem for process industries, such as steelmaking, due to the preference of students for research work in the newer industry sectors like Information Technology or Biotechnology. Process industries are also less in favour because of their often relatively remote locations, while many of today's educated youth prefer the bright lights of big cities.

Even many university academics prefer to work on the scientific frontiers in relatively unexplored areas, such as Nano materials or Space Age materials. This apparent lack of interest in process industries has become so acute that many of the prestigious educational institutions, such as the Indian Institutes of Technology, are desperately short of faculty in process engineering. On top of this, the last decade has seen a rush by a large number of multinational companies to establish research centres in India.



The people development process at Tata Steel R&D (2012)

"... the value of human assets and the power of their knowledge is the greatest assets that we have. Leveraging the intellectual capital is the key differentiator today and our success will largely depend on organisational knowledge across the company. There is ample scope for learning and sharing within and across Tata Steel Group with special focus on Intellectual Capital and Innovation.

\- H M Nerurkar

This has created extra demand for talented students who would have found their way to Indian companies instead. It is, of course, in addition to the flight of researchers abroad that has been going on for several decades.

Tata Steel has a prestigious corporate reputation and a tradition of 75 years of leadership in industrial R&D. Nevertheless, in the above mentioned environment it is a challenge to attract and retain high quality research talent. The company has therefore put in place a strategy to improve this status in future.

What motivates a researcher, particularly in a process industry? It is not just the money. It is the freedom to pursue his or her line of interest, the existence of adequate facilities, the closeness of large factories where new ideas, theories and models can be tested immediately, the satisfaction of seeing his or her innovation commercially implemented and, of course, the availability of a mechanism to enhance expertise and advance professionally. This is a very complex set of expectations. The R&D and Scientific Services Division of Tata Steel has a well laid out system for People Development to leverage the talents of its researchers and scientists. The structure of the organisation, along with the work and job design, has been customised to promote collaboration, cooperation, flexibility and innovation and thereby kept current with changing business needs. The task of Human Resource Development is directly controlled by the Chief of R&D and Scientific Services, who is assisted by Chiefs and Heads of the various departments and groups, and also by a cross-functional Human Asset Development Committee (HADC).

This Human Asset Development Committee consists of three senior Heads of R&D groups. It makes an annual expertise development audit of the Division, which brings up the gaps at each level in terms of numbers and level of expertise. It also recommends measures to deal with the same and recommends targets for expertise development. Such an audit is an excellent early warning system to the top management so that the Division is not caught flat-footed in the future with voids in expertise that can derail the company's technology development plan.

Everything, of course, starts with the overall Corporate Vision that is formulated by the top management of Tata Steel. The technical innovations that are required to realise this vision are then defined in a Technology Development Roadmap. These strategies are fulfilled through three types of research programmes. One is the Thrust Area programme with strategic projects that may take anywhere from 5 to 10 years to bear fruit. The second is short to medium-term R&D that could last anywhere from 1 to 3 years for the objectives to be realised. The third type of R&D projects are projects that are self-initiated by researchers based their own innovative ideas.

The successful execution of any of these projects is a major opportunity for professional development for any researcher. As such, 'learning on the job' comprises 70% of the total personal development activity of any researcher. Other development opportunities are created through mentoring & coaching, classroom training and conference attendance.

Based on the Technology Development Roadmap, the leading lights of R&D prepare an outline of the expertise that will be needed to successfully execute the different types of projects. The People Development System is then put in place to ensure that the expertise available with the R&D and Scientific Services Division, both in numbers as well as quality, keeps pace with the needs of research and development objectives. This is a very complex and continuous exercise.

Just like any professionals, researchers also look forward to improving their prospects and earnings by climbing up the hierarchical ladder. Researchers have three paths for career advancement. One is to become a researcher of a higher seniority level. The other is to advance into a manager of a research team, group or department. The third is to advance into other senior positions outside R&D. Through this route, the Division can take pride in many distinguished alumni. These include several past and present Managing Directors and Vice Presidents, who often have spent the very formative early years of their careers in the Division.

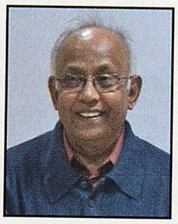
Visiting scientists

A major initiative in 2004 was the hiring of Visiting Scientists to boost research quality and performance. The personalities considered were eminent teachers and technocrats from leading engineering institutes and industries, who had superannuated from their service following a very successful career. Tenure contracts were given to Prof. A Ghosh for Steel Making, Prof. A K Lahiri for Iron & Steel Making, Prof. R K Ray for Product Development, Dr. D K Sengupta for Coating Development, Dr. T K Roy for Engineering and Pilot projects and Prof. T C Rao for Raw Materials. The major intent was to use their rich expertise in inducting new dimensions to applied industrial research by honing fundamental concepts in different technology domains. Through an interactive process they have been sharing their knowledge and advising young Researchers to execute projects in a scientific and systematic manner.

As invited members of the Project Appraisal Committee (PAC) they have supported the selection and review of projects. They also chair the Technical Project Review Committee meetings that evaluate the scientific contents of projects and provide guidance. Further, they have been providing insights to the R&D management on emerging research opportunities, particularly for formulation of Thrust Area projects. Significant benefits have been accrued with their association. A good example is the hike in publications in high impact peer reviewed journals, which has enhanced the image of Tata Steel R&D. A large number of successful implementations and pilot plant studies were possible under their guidance. Progress in reducing ash in coal, facilitating new lance design for steel making, development of automotive and coated steels were achieved with their support.


Prof A Ghosh


Prof A K Lahiri

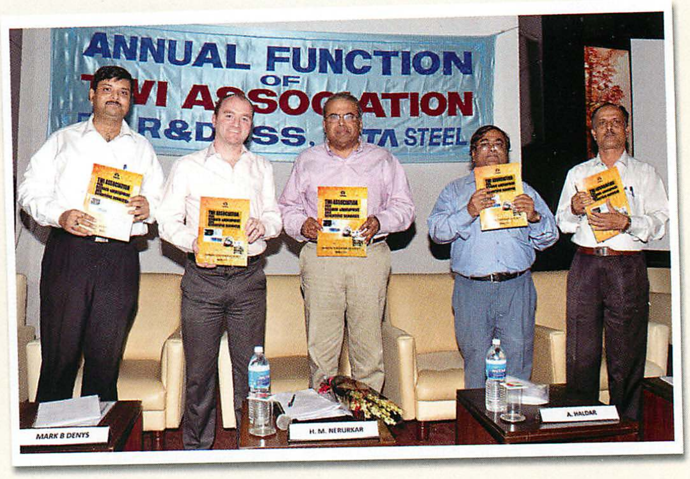

Prof R K Ray


Dr D K Sengupta


Dr T K Roy


Prof T C Rao

Training Within Industry



Launch of the Annual Souvenir 2010-11 of the TWI Association for R&D and Scientific Services

The Training Within Industry (TWI) Association for R&D and Scientific Services is a training forum for all employees, but with a particular attention to those who have not been fortunate enough to attain higher levels of education. There are currently 320 members. Started during the 1960s, it is still going strong after nearly half a century.

Throughout the year, the association organises various activities, such as technical paper presentations, quiz competitions and plant visits, both inside and outside Tata Steel. It hereby provides a forum for continual generation and sharing of knowledge, as well as the promotion of self-improvement activities.

The association finds sustenance through a subscription fee collected from all its members. Tata Steel provides a matching grant and infrastructural support.

There are six levels of seniority in the career ladder of a researcher, starting from Research Associate and ending up with Chief Researcher. Each level is defined by its role, expertise and competencies. Roles are elaborated in the form of responsibilities that get enlarged in scope at each step up the ladder. It is important to note that the competencies are not just confined to the technical capabilities, but include a wide variety of other factors such as ability to communicate, customer orientation, networking, teamwork, etc. Every researcher regularly makes a self-evaluation and is also assessed by his seniors or mentors to check his expertise status and appropriate opportunities for improvement. These are then formalised in a personal development plan that includes plans for training, higher education, coaching, attending conferences, etc. Also the 'learning on the job', by being a team leader or team member of a certain project, is consciously used as a tool for talent development.

Such researcher career advancement is administered through a transparent system of timely promotion that leaves little room for complaints about favouritism, cronyism or too much subjectivity. The promotion system was initiated by the Automation Department of Tata Steel and, adapted and advanced by the R&D and Scientific Services Division. Promotion reviews are held once a year and researchers become eligible for review after a minimum of three years in his or her present position. There are two selection committees. The Short-listing Committee is chaired by the Chief of the Division, while members include various Chiefs and Heads of R&D groups and two professionals from the central Human Resources function. Every researcher who is eligible for promotion makes a brief presentation to this committee followed by an interview session. The committee then recommends a shortlist of candidates to the Selection Committee. This committee is chaired by the Global R&D Director, while members are three Chiefs internal to R&D and three senior executives external to R&D. These three external members (one of the level of Managing Director or Vice President) take part to ensure parity and transparency towards the wider Tata Steel organisation.

Awards and Accolades

Awards and recognitions are one of the many means to gauge the expertise and quality of work from a research organisation. Several prestigious awards and recognitions conferred on professionals from the R&D and SS division over the years serve as an indicator to the rich expertise, both then and now, available with the division.

- 'National Metallurgist Award' to Dr. J J Irani (1997), Dr. T Mukherjee (2000) and Prof. R K Ray (2011) by Ministry of Steel, Govt of India
- 'Metallurgist of the Year' award to Dr. J J Irani (1974), Dr. T Mukherjee (1975), Dr. Amit Chatterjee (1977), Mr. C D Kamath (1978), Dr. M D Maheswari (1982), Mr. H M Nerurkar (1986), Dr. O N Mohanty (1989), Dr. A K Das (1991), Dr. Rameshwar Jha (1992), Mr. S K Roy (1997), Dr. Sanjay Chandra (1998), Dr. Debashish Bhattacharjee (2004), Dr. P K Banerjee (2009) and Dr. S K Ajmani (2011) by Ministry of Steel, Govt of India.
- Indo-US fellowship award to Dr. M Shome (1994) by the Department of Science and Technology, Govt. of India.
- 'Young Metallurgist' award to Mr. K P Shukla (1994), Dr. Saurabh Kundu (2004), Dr. Tapan Kumar Rout (2006) and Dr. Pratik Swarup Dash (2007) by Ministry of Steel, Govt of India.
- Corrosion Awareness Award to Dr. N Bandyopadhyay by NACE International India Section in 2006.
- National Mineral Award 2007 to Dr. A K Mukherjee by Minstry of Mines, Govt of India.
- Dr. Debashish Bhattacharjee selected as a 'Fellow of Indian National Academy of Engineers (INAE)' in 2009.
- INAE Young Engineers' Award to Dr. Sumitesh Das by the Indian National Academy of Engineers in 2006.
- 'Steel 80s' award to Dr. N Bandyopadhyay in 2010, Dr. M D Maheshwari and Mr. Indranil Chakraborty in 2003 by the Indian Institute of Metals.
- 'Refractory Technologist Award' to Mr. Atanu Ranjan Pal by the Indian Ceramic Society in 2011.
- Indian Institute of Mineral Engineers' Mineral/Coal Beneficiation award to Mr. PV T Rao (in 2001), Dr. S Mohan Rao (2007) and Dr. P K Banerjee (2008).
- 'Eminent Materials Engineer 2010' award to Dr. Arunansu Haldar by the Institution of Engineers.
- AICTE-INAE Distinguished Visiting Professorship to Dr. Debashish Bhattacharjee (2006), Dr. Sumitesh Das (2009) and Dr. Monojit Dutta (2010).







The criteria used by both committees include past performance ratings, functional performance (how well did the candidate meet the expectations of the present level) and functional orientation, knowledge and skills (how well is the candidate expected to grow and meet the expectations of the future level).

It must be pointed out that the promotion system that is detailed above relates to the six seniority levels of researchers; each with different designation, remuneration and privileges. However, in terms of hierarchy, there are only three levels in Tata Steel R&D, namely Researcher, Group Head and Chief. This is a very flat structure and tends to overload each Group Head with the administrative responsibility of managing more than 20 researchers; a large number for a knowledge intensive organisation where regular in-depth review and coaching is required. A proposal is now being mooted to introduce a third hierarchical level of Knowledge Group Leader, who will be able to oversee the work and interests of about half-a-dozen researchers.

Besides promotion, there are, of course, other reward and recognition systems in place to spur the employee to high performance and creativity. In addition to company-wide approaches such as cash awards, bonuses, special increments, suggestion

Joint Departmental Council

The Joint Departmental Council (JDC) is a welfare association that includes all officers, supervisors and workers belonging to the R&D and Scientific Services Division, Automation Department and Technology Groups of Tata Steel. This forum organises several activities throughout the year. These include blood donation camps, employee health check-up, safety awareness programs, essay writing, poster competition, etc. Family programs involving children of various age groups are also organised. Discussion sessions, career counselling and plant visits are the prime activities of such events. The JDC also conducts a large number of sport events that include team games such as football, cricket, basket ball and water polo. Also a competition for badminton and table tennis is arranged. The post of JDC chairman is alternately held by a senior executive of the division and a senior union representative.

Football teams comprising of JDC members after the Annual JDC Sports tournament (October 2010) awards, there are also special recognitions and rewards specific to the R&D and Scientific Service Division. These include sponsored study leave for a Doctoral level programme at reputed Indian and foreign universities, sponsoring participation in seminars and conferences in India and abroad, enabling study tours of foreign plants, supporting publication of research papers in prestigious journals and publication of monographs and books, deputing to reputed institutes for management development programmes, assisting in obtaining patents, etc.

One criterion for gauging the success of professional talent development in the Division is the number of researchers who are invited to participate in prestigious international technical conferences and Tata Steel has maintained a good hit rate. Also the number of publications in peer-reviewed journals is impressive. Each year the Division publishes about 60 papers in twenty selected top international journals and roughly another 60 papers in other national and international peer reviewed journals. This is approximately an average of one paper per researcher each year.

Of course, the success of the People Development system in the R&D and Scientific Services Division can also be gauged by Tata Steel's ability to leverage its unique research talents and reach uncharted heights. Here, as the stories in the previous chapters of this book reveal, the Division has done pretty well. However, there is no room for complacency. New foreign steel companies are entering India, the domestic steel industry is growing, new Indian research centres by multinational companies are being established and the flight of students to foreign universities; these are all factors that make the recruitment and retention of top researchers a continuing challenge.


TATA
TATA STEEL

Managing Ambiguity

A company has to satisfy many stakeholders. Their demands and relative importance keep changing as an industry gets buffeted by the winds of economic, political and social change. Unlike open-ended academic research, managing research & development is therefore as important as the pursuit of discovery itself.

In today's world of global competition, innovation is the key to sustained value creation. Yet, many executives worldwide still believe that their corporate R&D department is fuzzy, full of uncertainty and sometimes troublesome to manage.

Management of R&D is indeed a challenge. Apart from the idiosyncrasies of researchers and scientists, there are inherent differences in the organisational culture of the R&D department and the rest of a company. Effective R&D organisations have an informal culture where ideas are freely shared, convention is perennially challenged, directive management is usually resisted and ambiguity reigns. For example, executives want timely results, but researchers need creative freedom. Executives expect support for operational plant problems, but true innovation emerges only when one can rise above day-to-day fire fighting. Executives want quick business returns, but exploratory research is important for expertise development and sustenance of success.

The unpredictable returns on investment from R&D are another challange. Most often, there is a high uncertainty whether benefits will be realised, some benefits may never be quantifiable. It shows that the R&D department is characterised by differences, contradictions and uncertainties. It is threfore no surprise that R&D and innovation are amongst the most studied topics in management research.

Views on how R&D is best organised evolve over time and are highly dependent on country, culture, industry and company. This chapter discusses how the corporate R&D at Tata Steel has evolved into its current shape. It offers insights in how the management of R&D has responded to the prevailing trends and economic conditions both at Tata Steel, in India and the world.

Since the birth of corporate R&D in the western economies, roughly one century ago, its role has evolved as a consequence of trends in industry, economy and society. Up to the late 1950s the R&D function was often called 'corporate research'. It was a department that was dominated by scientists and managed as a traditional, hierarchical and functionally driven organisation. Researchers were given a lot of independence and scientific freedom, while the outcome of their work was largely left to serendipity. Outsiders often looked upon such an R&D department as an 'ivory tower' that had limited interaction with the larger organisation.

Undoubtedly some at Tata Steel will have seen the Control & Research Laboratory in a similar light. It was housed in its splendid that were buildings designed with the latest insights into architecture, working conditions and natural air conditioning. It was equipped with the latest instruments and staffed with well-educated Indian scholars. In the 1950s it was said that Jamshedpur housed more PhDs to the square mile than anywhere else in India!

Yet, looking at its history, there are several indications that the Control & Research Laboratory at Tata Steel was less isolated and more effective than some of its peers across the world. It suggest that its output was not left to serendipity alone, but was a result of effective management.

Ensuring safe research

Safety Campaign using the poster during early years.

A laboratory can be a hazardous place, particularly one devoted to metallurgical research that may involves with toxic and corrosive liquids, hot and molten metal, dangerous radiation such as X-rays and Gamma rays, heavy and sharp objects, sparks flame and other perilous environments. This was very much kept in mind even 75 years ago by the original designers of the R & D Centre. Special attention was paid to safe and healthy working conditions, with considerable thought given to ergonomics, light and ventilation. The position and height of the tables and benches were designed for the convenience of technicians and to avoid unnecessary movement of the workers. Fume extraction systems were installed with specially designed hoods to protect the technicians. Switch boards were kept out of the laboratories and installed in the corridors to avoid corrosion due to fumes in the chemical labs. Numerous emergency showers were provided in case of acid splashes or similar incidents.

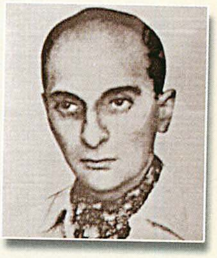
Tata Steel has always given high priority to ensuring the safety and well being of its employees and this very much includes those in its R&D and Scientific Services Division. The division strives to comply with the company-wide policies and targets, most notably its targets on *Zero fatality* a nd Lost Time Injury Frequency rate (*LTIFR*) < *0.5*.

Leaders in the division are encouraged to act as role models to promote Health and Safety behaviour through their own examples. Every member of management is made accountable for Health and Safety in their area and people under their control. In addition, proper knowledge and training of Standard Operating Procedures while carrying out their jobs is ensured among employees and contractors. Adequate arrangements are in place to ensure effective two way communication about Health and Safety throughout the division. Exceptional group and individual performance is recognised in a transparent manner. Workforce representatives meet with the management team periodically to discuss matters relating to Health and Safety and raise any concerns the workforce may have. Incidence and outcomes of investigations are appropriately communicated through the established channels across the division.

Hazard Identification and Risk Assessment (HIRA) records for each job are maintained within the division's Document Control System. Identified hazards are countered effectively to mitigate harm to human beings and property through an effective Risk Management System. A written down procedure is in place to drive the ongoing risk assessment and risk control in order to reduce Health and Safety risk to levels as low as practicable. Emergency preparedness is also given its due importance and emergency planning identifies arrangements in place to protect the workforce, customers, public, assets, environment and others in the event of any accident.

A structured approach through audit is in place to collect information on the efficiency, effectiveness and reliability of the Health and Safety Management System and plans are drawn up for corrective action in order to ensure that the organization maintains its ability to manage risks. Learning from events and observations form one of the important pillars for the whole safety management structure. Finally, the importance of our environment is embedded in the whole action plan by ensuring that its employees and contractors will comply with the existing policies on environment act.

Past Leaders



Dr. S J Vatcha Ghandy

Mr. M C Kumaraswamy

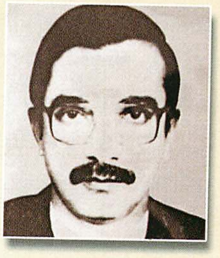
Dr. V G Paranjape

Mr. P K Chakravarty

Dr. J J Irani

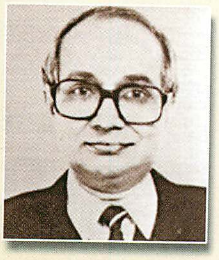
Dr. Amit Chatterjee

Dr. T Mukherjee



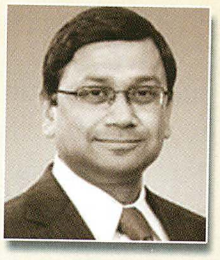
Dr. A N Mitra

Mr. Suresh Thawani

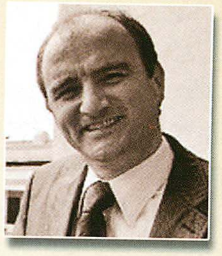


Dr. S K Mandal

Dr. O N Mahanty



Dr. Debashish Bhattacharjee



Mr. Mark B Denys

Firstly, the Laboratory had its roots in the various quality control departments on site. This meant that its researchers were well aware of the challenges in operations and favoured applied research over the pursuit of lofty scientific ambitions.

Secondly, the Control & Research building was designed with a large conference room, specifically to draw in production staff from the works and stimulate interaction. Another feature was the inclusion of a statistical office to facilitate plant process research based on routine observations; a field that was becoming more and more prominent at the time.

Thirdly, the remote location of Jamshedpur, its dependency on less than ideal local raw materials, the particular challenges posed during the second world war and the unique 'can do' spirit which enabled Tata Steel to thrive as the only large scale steelmaker in India were important factors in building bridges and nurturing a deep sense of serving a shared cause.

Finally, the laboratory has made substantial impact right from it early years. Spurred on by the specific needs for infrastructure, transport and armoured steels during the Second World War, the Control & Research department made major contributions to the story of Indian Steel, as narrated in earlier chapters.

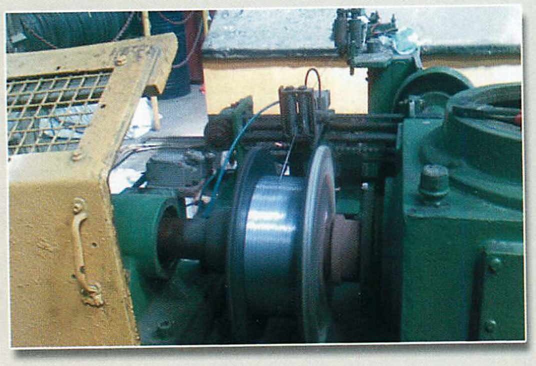
An eco-friendly wire electrode

Gas Metal Arc Welding is the most commonly used industrial welding process whereby an electric arc is formed between a consumable steel and the metal workpiece. A conventional wire electrode is coated with copper, which provides superior conductivity, smooth feeding ability and good corrosion resistance. However, the drawbacks of using copper are spatter loss, clogging of the welding nozzle and the generation of copper fumes that can be detrimental to a healthy work environment. Some countries have therefore banned the use of copper coated welding wire.

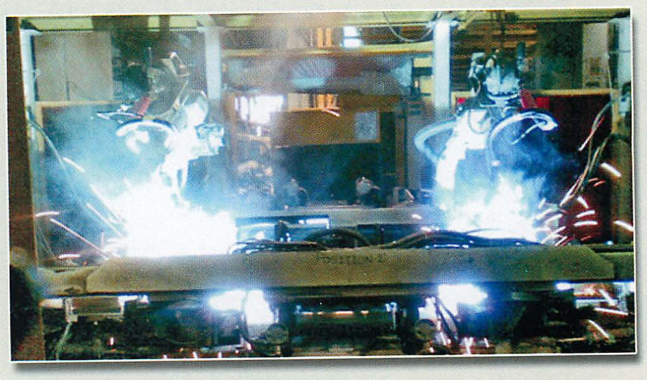
Eager to emulate these greener practices, Tata Steel's Wires Division turned to R&D for a solution. R&D, in collaboration with a partner research company, developed a novel water-based coating formulation using non hazardous metallic components. These components were chosen such that, in addition to being environment friendly, they imparted the properties required for smooth welding. The new coating is applied by dipping, similar to the practice in the existing wire production line so that its commercialisation needs minimal modifications.

This project resulted in a new wire electrode product that generates less spatter, smoother welding and less fumes, which are also non-toxic. The weld quality and bead appearance is similar and the wire electrode has a higher shelf life.

Bulk production trials were successfully completed at the Tarapur wire plant in 2011. Welding performance was subsequently evaluated using a welding robot at the premises of a customer. The superior performance of the new product was endorsed by subsidiary of Tata Motors and this new wire product was adjudged a winner in the Promising Innovations category in the regional round of Tata Innovista Awards 2011.



The new eco friendly coated wire rolling out of Tarapur wire plant



Comparative welding performance of the new coated electrode (right) and a conventional copper coated electrode (left)

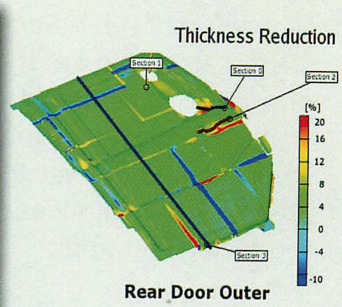
In the 1960s and 1970s, R&D departments worldwide began building more organised links to the other business functions. This new orientation recognised the importance of using combined insights for the successful initiation and completion of R&D projects. The increased cooperation, communication and interdependence brought a stronger focus on the market and the customer, resulting in more emphasis on development rather than research. This period also saw the emergence of the concept of the 'internal customer', whereby manufacturing departments and other business functions served as customers of R&D projects.

The need to strengthen market orientation arose from the many growth opportunities in the post-war period. Growing prosperity and a globally rising number of middle class families created previously unseen levels of consumption and a hunger for new products and new designs. At the time, India was somewhat shielded from these global trends as a result of the government's policies for a planned economy based on socialist principles. Still, demand for steel in India boomed and production capacity rose more than fourfold from the early 1950s till the late 1960s. Most of this new capacity was built by the fast growing public sector steel industry. The

Delighting customers with know-how

The Indian automotive market has seen phenomenal growth over the last decade. India has become a destination for all major global car manufacturers. Indian manufacturers are fast catching up by deploying the latest tools and techniques for the design of new automobiles. Hereby they are increasingly looking at their suppliers, such as Tata Steel, for specialist advice and technical support during design and production.

Review of vehicle division at the customer



Strain measurement for severity analysis on a door panel

Anticipating this trend back in 2005, Tata Steel R&D started a team of five researchers to study the use of advanced steel products in automobiles. After various projects and studies it gained experience and started offering design support to Tata Steels customers. Hereby it collaborates intensely with the experienced application research teams at Tata Steel Europe.

Apart from advanced technical support to automotive customers, the team also conducts basic research for the development of models to predict the behaviour of steel during the forming of vehicle components. For example, the team has developed one of the most advanced models for the prediction of the springback phenomenon during steel forming, which was presented in prestigious conferences abroad.

These services are highly appreciated by Tata Steel's customers such as Bajaj, TVS, Mahindra & Mahindra and Tata Motors. Value engineering studies and vehicle design studies result in significant cost savings for the customer and enable the customer to make best use of advanced steel products. Demand for these new services are expected to grow significantly and will be provided through the effective use of expert resources across the Tata Steel Group.

A new process for energy efficient ferrochrome production

Ferrochrome is an important raw material to produce steel, in particular stainless steel. It is produced through the smelting reduction of chromite ore in a Submerged Arc Furnace (SAF). For each tonne of ferrochrome this process consumes 3500 kWh electricity and 500 kg of costly low ash minerals metallurgical coke.

Tata Steel R&D has developed and patented a new process with much lower specific power and coke consumption. It is based on the discovery that pre-oxidation of chromite ores destabilises the chrome spinel structure by generating cation vacancies and pores in the ore structure. This improves the reactivity of the chromite and results in substantial energy savings when the oxidised ore is subsequently partially reduced into sponge chrome using a rotary hearth furnace or tunnel furnace.

When sponge chrome is fed into the SAF, both power and coke consumption are decreased by 20% and SAF productivity also increases. In another variant of the process, the rotary hearth furnace is used to fully metallised chromite into ferrochrome nuggets to be used directly as an alloying element during steelmaking.

Following extensive laboratory tests, Tata Steel R&D conducted various scale-up trials in an industrial tunnel furnace in Adityapur. In 2009 the team also completed a series of smelting trials using 50 kVA electric arc furnace at the National Metallurgical Laboratory in Jamshedpur and demonstrated the use of sponge chrome to produce high carbon ferrochrome. In 2011, a full material and energy balance was developed and a rotary hearth was designed for semi-commercial production. Also further viability studies are underway for the construction of a 100 ktonne per annum sponge chrome plant at Tata Steel's Ferro Alloys Plant in Bamnipal, Odisha. This process is patented in India and other ferrochrome producing countries.

Sponge chrome process trials in industrial tunnel kiln furnace

Smelt- reduction tests of sponge chrome in laboratory SAF at National Metallurgical Laboratory, Jamshedpur

resulting increased competition created a powerful incentive for new product development and process improvements for cost reduction.

Evidence that these new practices in the management of R&D were embraced by Tata Steel were given by Mr. S. Moolgaokar, then Executive Vice-President, who wrote in 1967: "At a time when the world's economy is getting extremely competitive, few products can maintain their place in the market without continual change and improvement. Not even a lipstick or fountain pen can remain static. This also applies to basic industrial commodities like steel. A steel highly acclaimed today may be superseded tomorrow by one that offers, say, improved machinability. It is therefore increasingly clear that a major portion of our country's research efforts must henceforth be expended on new and improved products. Any changes in products without market studies beforehand is extremely hazardous. A product is not something that can just be made; it must also be something that meets a market need."

From the early 1970s to the mid 1980s the world economy went through several crises. The oil crises of 1973 and 1979 and the economic crisis of the early 1980s created strong pressures to maintain profitability under difficult economic circumstances. These led company executives to concentrate on measures to maximise their returns from R&D. Practises were introduced to prevent 'wasteful R&D'; i.e. R&D with insufficient attractiveness, not directly linked to corporate strategy or with a high risk-reward ratio. This period saw the development of new ways to R&D portfolio to align with the business and maximise value potential.

R&D departments also experimented with new organisational designs, such as the matrix structure to bring the voice of the customer deep into R&D. The concept of the internal customer was taken to the extend of project costing, cost-benefit analyses and internal invoicing. As a result, many R&D departments became profit centres that could only become successful when responding effectively to the needs of the company.

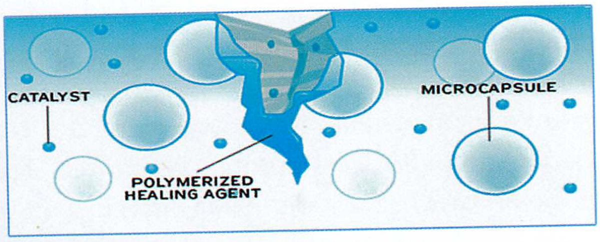
During this time, R&D at Tata Steel had less than 100 researchers, was housed in a in a single location and primarily served the integrated steel plant in Jamshedpur. This meant that complex organisational designs, like the matrix organisation, were not required to succeed in alignment. Nevertheless, the Division did undergo several initiatives to improve alignment, increase focus and curtail some of the earlier freedoms it may have enjoyed.

In these difficult economic times, Tata Steel's main concerns were to improve product quality and bring new steel products to market, despite several outdated plants and lack of capital to invest. "New wine in old bottles was the theme of the day" recalls Dr. J J Irani, who was General Manager of R&D and Scientific Services in the mid 1970s and later held the position of Managing Director of Tata Steel from 1992 till 2001. "During these years, the R&D budget was divided into two parts. A quarter of the time was given for researchers to work on 'whatever they want'. Even topics that may not be related to steel industry. The remaining 75 percent was spent on steel related research."

During Dr. Irani's tenure at R&D, several high level committees were formed to create a formal bridge between operations and research. Tata Steel also introduced an Apex R&D Committee presided by the Managing Director. This committee, which still continues today, meets once in three months to discuss major R&D policy matters, capital plans, sanction manpower and review major R&D projects.

Under the Apex Committee there were three second level committees for processes, products and coke & energy. Similar committees still exist today and are presided by the Vice Presidents in charge of Tata Steel's manufacturing divisions. To review the development of new technology and new products relevant to each division.

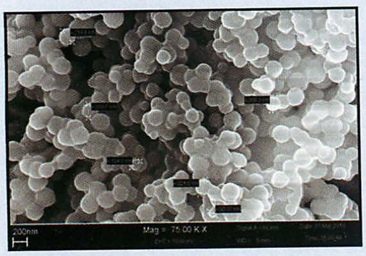
A self-healing skin



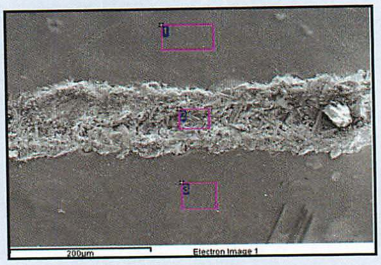
Schematic showing polymerized healing agent being released at a crack

Inspired by nature, Tata Steel R&D has developed an innovative self-healing organic coating to create superior coating resistance. A cut in the coating triggers a nature-like stimulus response and releases active repairing agents that heal the damage.

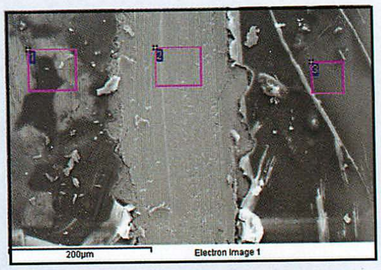
Minute capsules of 200 to 800 nanometre were synthesised in the laboratory through an intricate process of chemical emulsification. These capsules were added to a functional organic coating and applied to steel samples. Upon being scratched, the samples exhibited self-healing within three hours of damage as shown by scanning electron microscope studies. The coated samples also performed well in corrosion tests.



SEM image of nanocapsules



SEM image of fresh scratch on steel sample coated with self - heating



SEM image of self healed coating 24 hours after introduction of scratch

A pilot scale coating trial was conducted in R&D's pilot coating line in Bangalore and the results were encouraging. This coating was appreciated by Mr Ratan Tata and Mr Cyrus Mistry during the Tata Steel Innovation Exhibition in Jamshedpur on the 3rd of March 2012.

Demonstration of self healing coating to Mr. Ratan Tata, Mr. Cyrus Mistry and Mr. H M Nerurkar (2nd March 2012)

"One of the fundamental strengths of R&D in Tata Steel has been its close cooperation with operations and management." as Dr. Amit Chatterjee, then Deputy General Manager of R&D, noted in 1987. "Researchers and operators at Tata Steel think and speak in the same language. This close interaction has resulted in the smooth transition of ideas from the lab to the field. Being a storehouse of specialised knowledge, R&D conducts round the year courses for operating personnel in specific areas, particularly involving new processes and technologies."

Clearly, the success of R&D projects was not left to serendipity. The starting point for directing R&D was to define a clear mission that served as a lasting statement of R&D's purpose. During the 1980s this statement included various directives that endure till today. Examples are self-reliance on technology, optimum use of natural resources, stay ahead of competition, quality steels, customer satisfaction a nd scaling new heights in excellence.

Also a new project selection process was introduced. It took about four months and started by interactions with Manufacturing and Marketing to collect plant problems to solve or ideas for new products. These were then discussed in R&D and draft proposals and plans were prepared, including manning, financial plan and timelines. These were then reviewed at the second level committee and subsequently a full annual plan for R&D was prepared, reviewed and approved by the Apex Committee. Once approved, projects were launched and reviewed according to project management charts with clear timelines and defined responsibilities of project team members.

Abovementioned structured process for planning and reviewing R&D, which evolved in the 1970s and 1980s, was in synch with the latest ideas on R&D management abroad. Although not unique, Tata Steel seems to have been ahead of its time in India. In 1987 Dr. M N Dastur, the pioneering founder of Dasturco Ltd, also noted the same: "We are struck by Tata Steel's outstanding performance actioned against heavy odds – its high productivity, production of quality steels, technological innovations, self-reliance and swadeshi spirit, commendable work culture and forward looking management policies."

The late 1980s and early 1990s saw a worldwide economic recovery followed by renewed economic malaise. This drove a mixed response in the form of renewed entrepreneurism, but with a strong focus on cost competitiveness. The prevailing management theories therefore laid emphasis on a need for speed in innovation and leveraging core competencies. During this period, the Total Quality Management (TQM) concepts developed by American management consultants, such as W Edwards Deming, were being advanced enthusiastically in Japan. Methodologies such as the Toyota Management System, Lean Manufacturing, Six Sigma and many more, were new ways of integrating practices across all functions. Their purpose was to drive customer satisfaction, quality performance and productivity improvement using systematic practices, often based on scientific and statistical methods.

In the second half of the 1990s the world and particularly the USA experienced accelerated growth in GDP, increased employment and low inflation. Underlying reasons were the productivity benefits of the computer age and low energy prices at levels not seen since the oil crises of the early 1970s. Yet, these positive trends were hardly felt by the steelmaking fraternity. At the end of the 1990s global steel prices were historically low and overcapacity remained given an industry-wide reluctance to reduce production in a response to reduced demand.

Despite this global malaise in steel, the scenario in India was more positive. The 1990s in India were a period of economic liberalisation. Economic growth surged and doubled the GDP per capita within a decade. This laid the foundation for India to become one of the fastest growing economies during the next decade. Growth meant demand for new products, particularly in the automotive, construction and engineering sectors. Liberalisation and increasing globalisation brought new competition from foreign steelmakers seeking profitable export markets in India. Against this backdrop of 'mixed signals', including a growing domestic economy, high levels of volatility and increased competition, Tata Steel realised that business-driven R&D remained a potent long-term strategy for success.

These trends clearly reflected on the R&D management practices at Tata Steel. Under the leadership of Dr. O N Mohanty, then Chief R&D and Scientific Services, the department adopted several TQM methodologies. This included the introduction of Balanced Score Cards for senior management and

Piloting breakthrough technology to produce clean coal

Indian coals have a relatively high fraction of non-energetic minerals. This ash is preferably removed before using the coal. However, this is difficult to achieve with conventional physical techniques such as crushing and sieving, because the ash is finely dispersed in the coal. An alternative way is to leach the coal with chemicals that selectively react and dissolve the mineral matter, leaving behind a clean coal.

After encouraging results were achieved in the laboratory, the Raw Materials research group at Tata Steel R&D designed, erected and commissioned a large semi-continuous pilot plant for Leaching coal. The plant, with a capacity of 500 kg of feed coal, has a dedicated utility section, a causticiser, a chemical reagent recovery unit and is fully surrounded with a semi-automated control system. Coal slurry and reagents are prepared in tanks and are then mixed inside alkali reactors at atmospheric and elevated pressures, which are followed by treatment inside various other reactors. After the final treatment, the coal slurry is filtered and then washed with water to produce a coal that is low in ash. The filtrate is regenerated and recycled using a novel evaporator.

The first trial series were conducted in 2011 and confirmed that the ash content can be reduced substantially. Presently, a long series of continuous trials is being conducted to demonstrate that technical and operational challenges have been overcome effectively and efficiently. Examples are efficient solid-liquid separation (filtration), high levels of productivity, minimum energy requirement and maximised regeneration of the leaching chemicals.

Plan is to complete these trials in 2013 and then design, build and operate the world-first continuous demonstration plant at semi-commercial scale. This process will create cleaner coals that improve the energy efficiency and productivity the ironmaking blast furnace. It will also substantially improve the yield of clean coal from Tata Steel's mines, thereby contributing to the sustainable use nature's resources.

The 'Clean Coal' team receiving the Tata Innovista Award from Mr. Cyrus Mistry, Deputy Chairman, Tata Group (April 2012) measurable annual objectives for researchers in key result areas, such as financial impact, customer impact, improvement of internal processes, organisational and individual learning, and the positive impact on communities served by the company.

Various indices were introduced to measure the many dimensions of a successful R&D, such as an index for project compliance to plan and indices for customer interaction and customer satisfaction. Although the indices that are used today have changed, this method of driving performance is still very much alive and is based on a comprehensive set of indices with targets that is cascaded to all levels of the organisation.

These systemic approaches were underpinned by the introduction of a quality management system that attained ISO certification. This management system recognises project management as the central core process for value creation and defines a comprehensive set of supporting processes. It clearly identified the role of R&D as part of a company-wide system of value creation; a concept that strongly endures today.

Since the mid 1990s the global economy has seen enormous change and very high levels of volatility. Globalisation has brought increased competition, rapid diffusion of know-how and faster adoption of latest technologies across the globe. Entirely new information technology industries have emerged that compete through innovation, creating high incentives for speed and placing greater value on the development of breakthrough technology rather than incremental innovation.

R&D today is increasingly pursued through collaborations with suppliers, customers and even competitors. Sharing knowledge and jointly pursuing new developments decreases the cost of innovation and increases the chance of success. Sharing the burden of innovation is also no longer the exclusive domain of one-to-one partnerships, but often takes place in innovation ecosystems, with many different partners and different interests, or even in the virtual world through open innovation and crowd sourcing.

Although the information technology industries are the source of most of these trends, they have also substantially influenced R&D in other industries, including the steel industry. At Tata Steel R&D this impact is felt in three ways. It has encouraged breakthrough innovation and the protection of intellectual property. It has resulted in an increasingly rigorous process for long term planning of technology developments, and it has influenced the creation a global R&D organisation with a large number of R&D partnerships across the globe. These three themes are discussed below.

The past decade at Tata Steel R&D saw major new initiatives in strategic long-term R&D. In 2006 the Apex R&D Committee, chaired by Managing Director Mr. B Muthuraman, decided to launch nine major projects for the development of breakthrough technologies. The purpose of these 'Thrust Areas' are to realise technological breakthroughs to create new opportunities for long-term competitiveness. A few examples are the development of new technologies to drastically increase the yield of high quality raw materials from existing mines thereby maximising the sustainability of mining, the development of new technologies to reduce energy consumption and address Tata Steel's responsibility to curtail climate change, the development of new advanced high strength steel products to make automobiles lighter and stronger for increased fuel efficiency and crash safety, and the development of novel coatings to make steel more durable and functional. Examples are a self-healing organic coating that increases corrosion resistance and a low-cost photovoltaic coating to generate solar electricity from corrugated steel roofs.

From 2006 till 2009 these Thrust Area projects matured from early concepts into first working

Global Research, Development and Technology

The Global Research, Development and Technology organisation was launched in 2009. It combines the forces of all the research centres in the Tata Steel Group. Apart from the R&D and Scientific Services Division in Jamshedpur (India), it also includes the four research centres from Tata Steel Europe (formerly Corus):

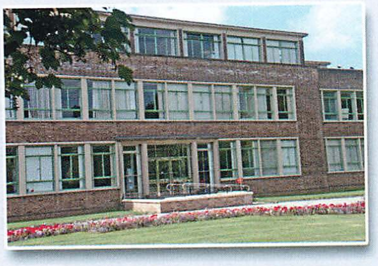
- The IJmuiden Technology Centre is located on the integrated steelmaking site of the Tata Steel in IJmuiden, Netherlands. It started as a quality-oriented investigative department in 1946, and developed to an R&D lab in the early 1990s. The present organisation with nearly 350 staff offers support to the processes for ironmaking, steelmaking and steel rolling and coating. It also has a strong focus on the automotive market through a product application centre.
- Swinden Technology Centre near Sheffield (United Kingdom) was established in 1946 by then United Steel. With approximately 270 staff, it is mainly focused on product and product application research in areas such as steel metallurgy, coated products and industrial & construction applications.
- Teesside Technology Centre (United Kingdom) was established in 1964 by the British Iron & Steel Association. The facility, with a staff of 100, has a long track record in process technology, in particular cokemaking, steelmaking and continuous casting.
- Automotive Engineering Group is located at the International Automotive Research Centre at Warwick University (United Kingdom). This group employs a team of 20 specialists with automotive industry experience in design and engineering. Its purpose is to help Tata Steel's automotive customers to exploit the full potential of advanced steel products.

The Global RD&T organisation has a single management team, chaired by Dr. Debashish Bhattacharjee, Director Global RD&T. It ensures that the activities of the different labs are coordinated and globally effective. Particular attention is given to the timely execution of a balanced and aspirational research portfolio, the management of an expertise pool that is globally effective and avoids unnecessary duplication, and the speedy implementation of innovations by cloning new technologies across the Group.

R&D and Scientific Services Division, Jamshedpur (India)

IJmuiden Technology Center

Automotive Engg Center, Warwick



Swinden Technology Center

Teeside Technology Center

prototypes of new processes or products. It involved extensive literature studies, laboratory experiments and mathematical modelling. These early stages of technology development typically result in most new inventions. Several new initiatives were therefore taken to secure these inventions through patenting. As a result, patenting at Tata Steel R&D grew to about 50 applications each year.

Building the first prototypes of an entirely new technology requires skills and capabilities that are usually not lectured in universities, but that are learned through experience from past successes and failures. Such experience was in limited supply since researchers in process technology had previously concentrated mostly on the creative indigenisation of technology.

Two new initiatives were taken to overcome this gap. Firstly, a new committee was introduced to review project plans and their resource needs, including required expertise and team composition. This Project Appraisal Committee is chaired by the Chief of R&D and Scientific Services and attended by the Heads of research groups as well as visiting scientists. It forms the central review and appraisal committee that sets direction to all proposed and running projects.

Secondly, a new strategy was launched to promote the development of technologies through effective partnerships. It has resulted in a partnership programme with around 40 running projects at any time. This number increases to well over 200 projects when Tata Steel's European R&D centres are also considered. Partners are universities, research institutes, companies throughout India and abroad as well as consultants and visiting scientists.

A special form of an enduring partnership is the formation of the Global Research, Development and Technology organisation in the Tata Steel Group, which took place in 2009. Under his banner the R&D centre in Jamshedpur has joined forces with the four research centres in Tata Steel Europe (formerly Corus ltd.). The Global RD&T organisation has a single management team to ensure that the activities of the different labs are coordinated and globally effective.

Today several Thrust Area projects are being pursued as collaborative projects, whereby a substantial part of the project is outsourced to partner companies with specific know-how or capabilities. This particularly concerns the need for specialised engineering skills; the number of collaborations with engineering partners has increased from nil in 2005 to fifteen by 2012. As a result, Tata Steel R&D has built six major pilot plants in the past five years. These pilot plants include two plants for chemical beneficiation to create high quality coal, one pilot plant for the beneficiation iron ore including a new technology to recover iron from ultrafine mine tailings, a pilot installation for ultra-fast cooling using nanofluids, a pilot plant to recover a hydrogen containing gas from by-product slags and a pilot plant for coating advanced organic coatings onto steel.

By 2011 four out of nine Thrust Area projects have created world-first technologies that are now sufficiently proven to be included in the future business plans of Tata Steel's manufacturing divisions. Each of these technologies is still undergoing further trials and development, but nevertheless, this acceptance is a pivotal moment. It means that what was once a 'wild aspiration' has matured into a new technology that is perceived to be viable.

Given the rapid diffusion of know-how in a globalised world, it is essential that any promising technology that emerges from the Thrust Areas is rapidly implemented to maximise first-mover advantage. In 2011 Tata Steel therefore introduced a new technology planning process for the ideation, stratification and prioritisation of projects and their future implementation. A key vehicle hereby is the

"With assimilation of new technology and many patents under the belt, R&D has achieved a lot. But, in my opinion, the journey has just begun, Tata Steel has changed. It is now in the forefront of the steel world, jostling for space to lead the race "

Mr. Partha Sengupta, VP RM

introduction of a corporate Technology Development Roadmap that aligns R&D projects with the technology needs of the company. This 70 page planning document identifies strategies to bridge gaps between present day capabilities and expected future needs for new products and new process technologies. These strategies include technology acquisition and technology development, both continuous improvements and breakthrough innovation in the Thrust Areas.

The Roadmap also serves as an important input into the long term plan of the R&D division in order to ensure sustenance of value creation through R&D. This entails many strategies, such as the promotion of grassroots innovation, the development of world-class experts, the development of an intellectual property portfolio, R&D collaborations, investment plans, etc.

The Roadmap was developed through a process that closely resembles the Strategic Management by Policy methodology developed by Dr Hiroshi Osada, a renowned TQM expert. It is a structured process with numerous inputs from other functions in Tata Steel and many external sources for future trends in markets, competition and society. The Roadmap therefore integrates and aligns the work of R&D with the long term needs of Tata Steel and all its business functions, so that all contribute to realise Tata Steel's corporate vision. Central in this vision statement is 'Value Creation'.

The creation of value through innovation requires a robust planning process, such as the Roadmap. It also requires a robust practice of target-setting and monitoring. In late 2009, Mr H M Nerurkar Managing Director of Tata Steel, therefore challenged the R&D and Scientific Services Division to triple its annual financial impact by 2012. The Vice Chairman of Tata Steel, Mr. B Muthuraman, also strongly advocated this initiative under the adage that "When benefits cannot be measured, this suggests benefits are not very large."

Financial impact from R&D comes in the form of reduced operating costs, increased margin on products sold or simply more revenues. In 2009, there was no such monitoring of financial impact from R&D; however, estimates indicated that benefits were roughly 3 times annual costs. Such estimates are notoriously difficult to obtain and reasons are manifold. Examples are the typical time-lag between inventions and actual commercialisation, the many agents that are involved creating dispute of ownership, and often recommendations from R&D form part of a larger improvement initiative and cannot be singled out.

Nevertheless, under the leadership of Mr M B Denys Chief R&D and Scientific Services, Tata Steel R&D introduced a financial tracker to monitor impact from completed projects. So far, the impact of 395 projects and initiatives completed from 2008 till 2012 is estimated.

The methodology that was developed is based on estimating a proxy of the net present value of annually recurring benefits. It only generates an approximate value, but is not excessively work intensive. It tracks the overall financial value created by any innovations in which R&D played a significant role and does not attempt to differentiate the contribution of R&D from the contributions of others. The philosophy is that R&D does not want a share of the credit, but wants to create visibility of the overall value of improvement initiatives in which R&D contributed significantly.

Research Policy

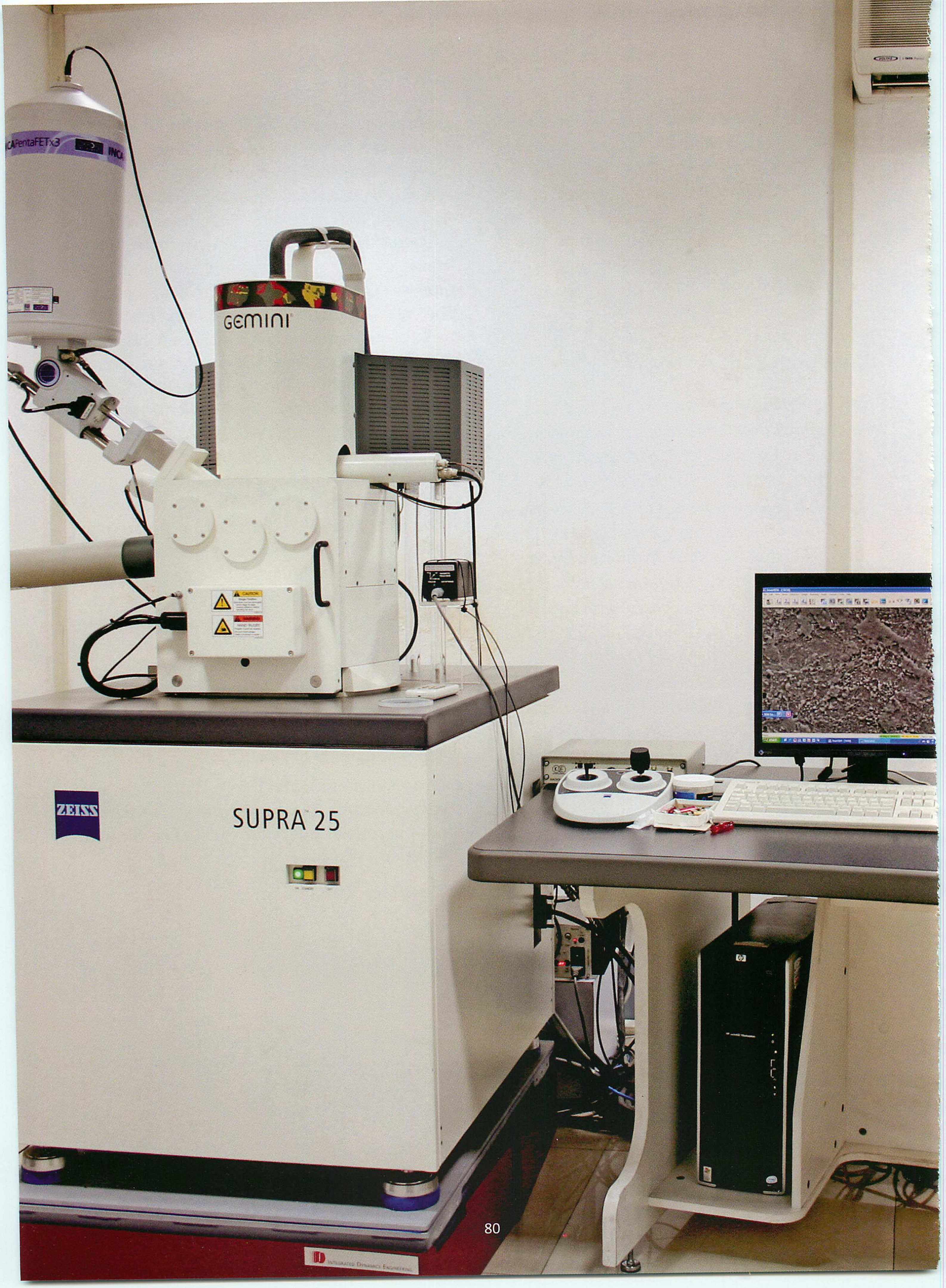
Tata Steel believes that research provides the foundation for sustained, long-term, stakeholder delight. Tata Steel shall nurture and encourage innovative research is a creative ambience to ensure that the competitive advantage in its overal business is retained and surpassed. Towards this goal, the Company commits itself to providing all necessary resources and facilities for use by motivated researchers of the highest caliber. Research in Tata Steel shall be aligned to the technological initiatives necessary to evolve and fulfil the overall business objectives of the Company.

1st October, 2009

H M Nerurkar
Managing Director, Tata Steel

These analyses have given new insights that enable R&D to more consciously prioritise highly rewarding parts of the R&D portfolio and have further stimulated the drive to implement new inventions. As a result, R&D has been able to meet the target. Its annual financial impact has risen to the tune of 9 times annual costs, which is several hundreds crore rupees each year (many tens of million US dollar). This strong growth in annual implementation benefits stems from both an increased number of implementations and an improved ability to estimate implementation value. In 2012, 29% of closed projects resulted in implementation and 62% of implemented projects were financially assessed.

Clearly, R&D at Tata Steel is an engine for value creation. It generates high and reasonably predictable financial returns on top of many non-financial benefits, such as innovations that positively impact environmental impact, customer delight and corporate social responsibility. Value creation is achieved through well-defined management practises that, throughout the past 75 years, have continuously evolved to serve the needs of Tata Steel within its economic and societal context. Management at Tata Steel has been abreast of the latest developments in other parts of the world and has readily internalised the latest concepts in how to manage an effective R&D. These strengths continue today and form a firm foundation for Tata Steel's perennial quest for excellence through innovation.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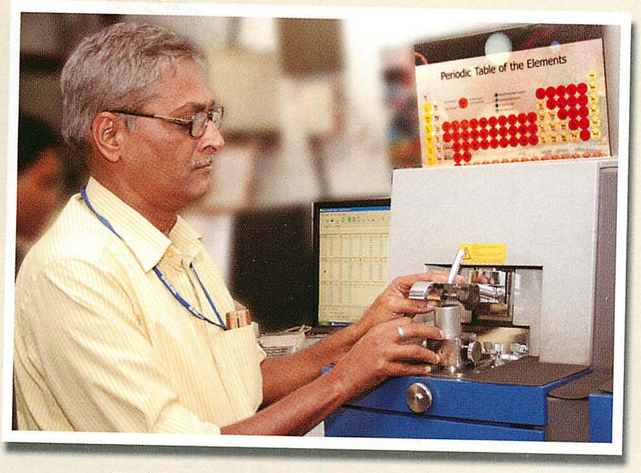
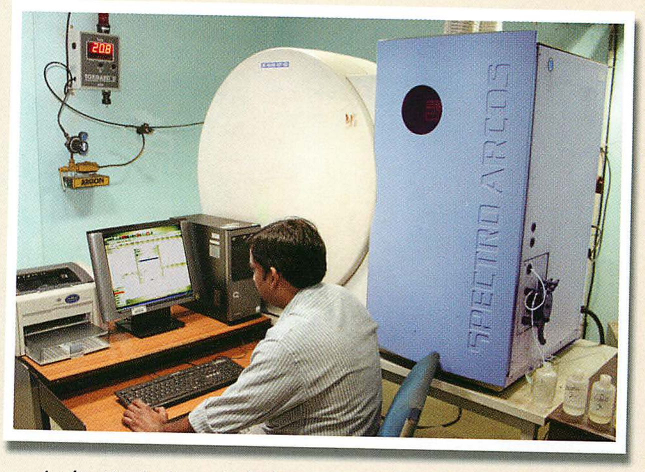


Carbon, Nitrogen and Sulphur analyzer in Chemical Laboratory



Inductively Coupled Plasma Emission Spectrometer in Chemical Laboratory

Automatic sample polishing machine in the Metallography Laboratory

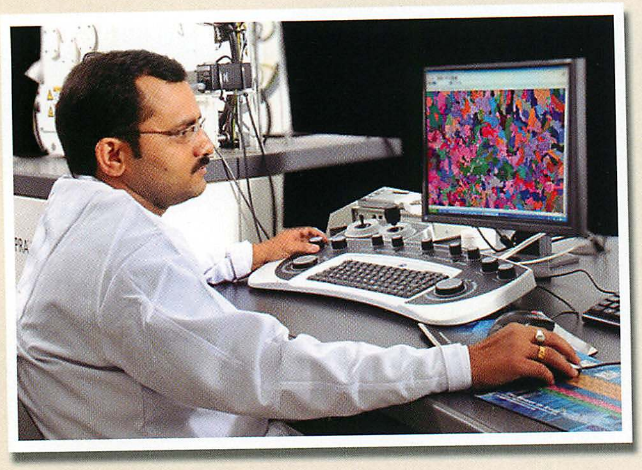
X-Ray Fluoroscence Spectrometer in Chemical Laboratories

Fourier Transform Infrared Spectroscopy in the Advanced Corrosion Laboratory

Electrochemical Impedance Spectroscopy facility in the Advanced Corrosion Laboratory

Carbon coating unit in the Metallography lab

Hot mounting press in the Metallography Laboratory



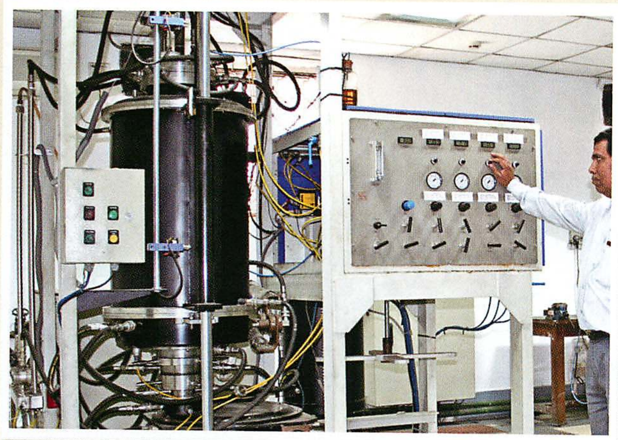
Scanning Electron Microscope

Carl Zeiss Optical Microscope equipped with high resolution camera

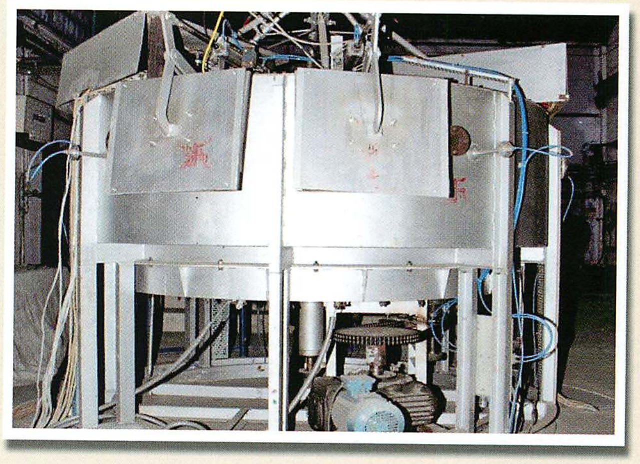
Bio-remediation Laboratory

1:10 scaled down models of Tata Steel blast furnaces equipped with bell less charging system

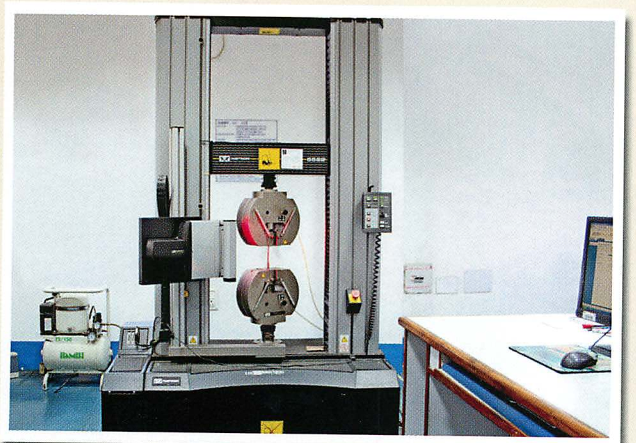
High temperature furnace



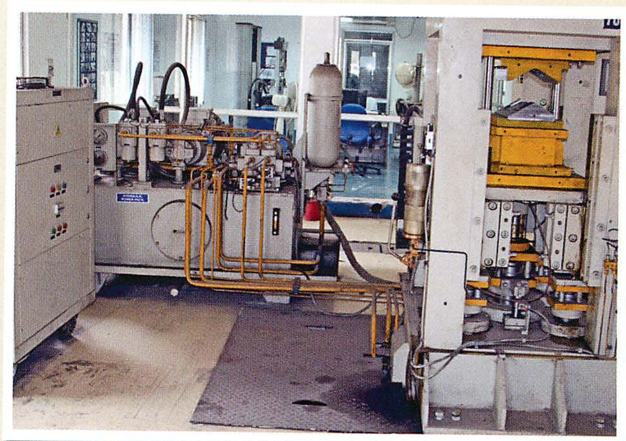
Softening-Melting equipment



Laboratory Rotary Hearth Furnace



Tensile testing machine in the Advanced Materials Characterization Laboratory



Hydroforming Press

Inauguration of fastest computer in the Tata Steel Group 'Reynolds' (2010)

Scaled down water model of the Slab Caster facility at Tata Steel

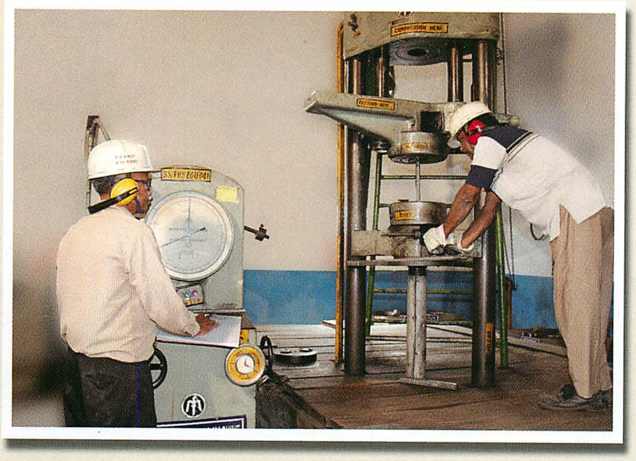
Scaled down water model of the LD Vessel

25 kg mini pilot oven for coke making

Hot Modulus of Rupture H-MUR

Compression testing machine in the Physical Laboratory

Power Saw for sample cutting at the Physical Laboratory



Universal testing machine

The Labscale cokemaking oven

Pilot scale Organo-refining facility at Kolkata

"Innovation will hold the key for success, and our R&D team should lead on the crest of technological innovation and set technological benchmarks."

Cyrus P Mistry, Deputy Chairman, Tata Sons Limited

R&D and innovation are essential for progress in all industries. The steel industry is no different. The role of R&D depends on the chosen strategy: low cost commodities or value-added premium products? It is a simple choice between a follower who buys technology or a leader who pioneers. The launch of Tata Steel's Control & Research laboratory in 1937 was the very first start of corporate R&D in all of India. Clearly, Tata Steel has always felt an urgency to pioneer.

Till the end of the 20th Century, R&D at Tata Steel was mostly driven by the need to improve existing products or to overcome process constraints that were specific to the local conditions. The overall vision was to maximise use of indigenous raw materials, develop products for the domestic market, reduce specific energy consumption and minimise the negative impact on the environment.

The onset of the 21st Century has seen significant changes in Tata Steel's internal and external environment. Several international acquisitions, culminating in the takeover of Corus in 2007, have changed the gambit. From being domestically competent and able to fulfil Indian requirements, Tata Steel has now become a global player catering to the demands of the international markets as well.

These global acquisitions have also dictated a change in Tata Steel's R&D environment. A Global R&D Board has now been established whose members are drawn from the senior-most managers in Tata Steel India and Tata Steel Europe. This Board sets global strategic direction in alignment with the overall strategy of the Tata Steel Group.

In response to this new scenario, the thrust of R&D at Tata Steel has been altered. While many of the old objectives still remain valid, the approach to them is now much more ambitious. The focus has shifted from immediate problem solving and adaptation, to the development of truly new technologies that try to change the rules of the game; not only in India, but also abroad.

R&D at Tata Steel is therefore at a juncture. The previous chapters of this book may have demonstrated that it has suitably lived up to the expectation of its founders. In particular that of Mr A R Dalal, Director of Tata Sons, who mentioned on the occasion of the laying of the foundation stone: "In the fullness of time this laboratory should play an important part in the progress and development of the steel industry in India" (6 November 1935). This final chapter argues that, although India will continue to drive the main agenda of the R&D and Scientific Services Division in Jamshedpur, the innovations that are sought today are technologies that rise above local issues and should be deployable across all of Tata Steel's global businesses.

Looking at the far future of Tata Steel in India, we can identify both challenges and opportunities that will shape its markets and its industry. India's gross domestic product is projected to continue its strong growth in the coming decades. This growth will come through large investments in industry, infrastructure, construction and transport - all of which will fuel a sharply rising demand for steel in the country. The steel industry in India is expanding rapidly to meet this growing demand.

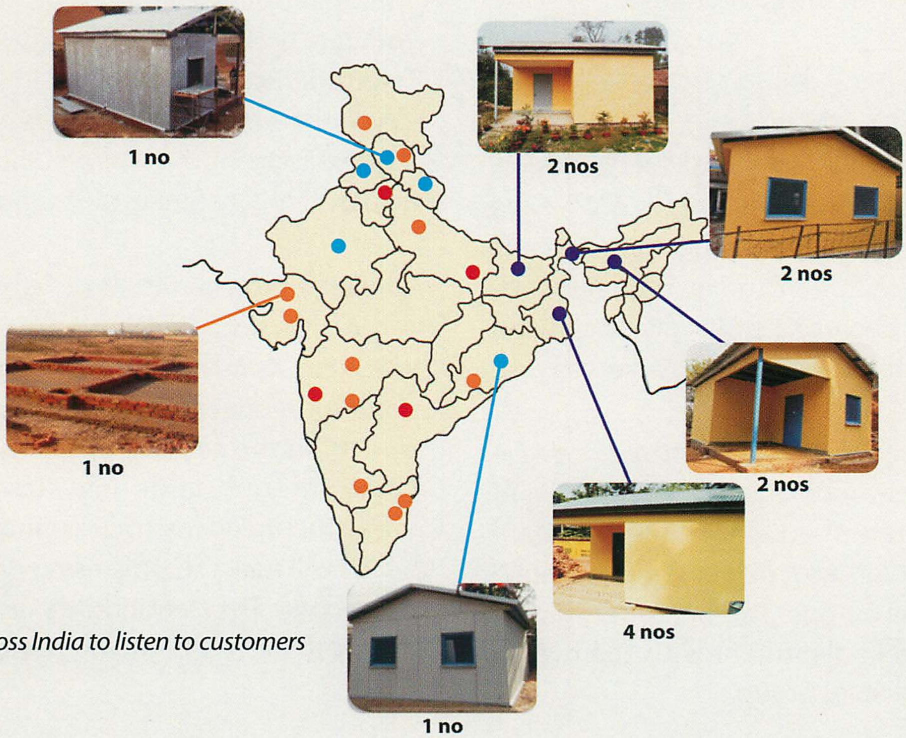
Affordable housing for rural India

Frame of the small scale prototype building in construction

Affordable and durable housing is one of the key needs in rural India. In April 2010, Tata Steel R&D and Flat Products Marketing & Sales jointly launched a project to develop a modern single family dwelling using steel, local materials and various new techniques to make it durable, easy to transport and very quick to construct, without the need for heavy equipment.

Supported by expertise in modular construction from Tata Steel Europe, a small scale prototype of 4 m^2 surface area was built. This prototype was manufactured as a 'kit of parts' in the United Kingdom and erected in Jamshedpur within just one day. This prototype used a unique combination of 60% steel and locally available natural materials. Novel floor, wall and roofing systems were used for ease of assembly and reduced work on site. Also a patented technology was used for easy assembly and fixing of steel frames.

The design of the building is flexible and can easily be adapted for residential, commercial and disaster-relief applications. In 2011 the project team conducted scaled-up trials with houses of 20 and 30 m^2 that can be built in a span of a few days. The year 2012 saw the completion of 30 pilot houses built across India to capture the voice of customers and train local construction workers. Activities are underway to market the first batch of these housing 'kits' that will be distributed through Tata Steel's wide network of dealers. Through concerted efforts of Tata Steel's Global R&D and Marketing and Sales, durable and affordable housing for rural India may soon be a reality.



30 pilots across India to listen to customers

Removal of arsenic from groundwater to create safe drinking water

Contamination of groundwater by naturally occurring arsenic is a serious problem in many parts of the world. Drinking such water causes severe chronic health problems. It is estimated that more than 100 million people in West Bengal (India) and in Bangladesh are exposed to water containing arsenic concentration of more than 50 ppb, while WHO recommends values below 10 ppb.

R&D at Tata Steel has developed and patented a very low cost solution for the removal of arsenic and the other hazardous materials from contaminated groundwater. It is based on using nanosized iron oxide particles that are generated as a by-product during steelmaking. The fineness of these particles increases the surface area and thereby the arsenic adsorption capacity. During laboratory experiments these by-product fines have already shown to effectively remove arsenic and other hazardous elements such as Cr, Cd, F, Fe, Cu and Ni from contaminated water.

A filter system has been designed to hold these fines into permeable filter blocks that are inserted in a water purifying system. In 2011 this system was tested with great success during a three-month field trial in the arsenic affected areas of the 24th Parganas district of West Bengal. Tata Steel is now developing the first marketable low cost arsenic removal filters in association with Tata Chemicals Ltd, the developers of the famous Tata Swach affordable water purifier.

Arsenic removal candles made of by-product fines from steel making

Arsenic removal filled study at North 24 Parganas, West Bengal (February 2011)

The past decade has seen a rapid growth of the Chinese steel industry to a gargantuan size. This has created upheaval in the availability and price of raw materials. Global growth in demand for energy and steel will continue to create substantial pressures on these natural resources, creating opportunities and threats for the Indian steel industry. Accessible coal, iron ore and other mineral resources are increasingly costly. Trade in these commodities is dominated by a handful of global players, suggesting that the present high prices are less likely to fall for as long as the Asian engines of the world economy continue their path of growth.

This incentivises continued investment in the efficient use of Tata Steel's captive mines, the development of new technologies to enable the use of low grade raw materials, the improvement of energy efficiency and the use of alternative energy sources. Earlier chapters discussed various examples of how Tata Steel R&D is developing new solutions to these challenges. Two new chemical beneficiation technologies are being developed that may double the yield of high quality coking coal from its existing mines. Novel ore beneficiation techniques to recover iron values from ultra-fine mine tailings are also being piloted.

In the coming two decades, India's energy consumption per capita is predicted to grow five-fold. This necessitates substantial investments for energy transport, power generation and transmission. Given the already tight supply in oil and gas, new alternative energy sources and supply routes will have to be developed. These include less accessible fossil energy sources, such as coal bed methane, as well as renewable energy such as biomass, solar, wind and geothermal energy.

Tata Steel R&D is also active in this field. Examples are the development of a technology to recover a hydrogen-rich gas from the waste energy contained in steelmaking slag and also the development of a photovoltaic coating applied onto steel products to create a low-cost mass produced solar cell.

Such new sources of energy are expected to grow into a significant part of India's future energy mix. Particularly the recent discoveries of abundant shale gas show large potential. As these energy sources mature, they will trigger specific demands for steel for the construction of extensive gas networks, liquefaction, storage and sea transport. Tata Steel R&D is working on the development of several new steel grades to meet the needs of these markets. These products are expected to be introduced along with the ramping up of Tata Steel's new Kalinganagar steel plant in Odisha. This plant is presently under construction and will have a production capacity of 6 million tonnes per annum. It will include the latest technology to produce premium flat products such as API, Dual Phase, TRIP and other advanced steels under development at Tata Steel's R&D.

Climate change is another challenge that will shape the future steel industry. Given a general lack in global comprehensive action to address climate change, it is likely that the world will see a substantial further rise in atmospheric CO_2. This means that countries may face much more expensive consequences beyond 2050; India included.

In 20 to 30 years, India is expected to become the second largest emitter of CO_2 after China. This will bring threats and opportunities to the steel industry. Examples are the early write-off of less energy efficient production facilities and the new products and markets arising from increased investment in energy efficient and carbon-lean equipment and infrastructure.

The global steel industry emits about 2 billion tonnes of carbon dioxide each year. This is about 4% of total man-made emissions. It is a substantial carbon footprint for one industry sector alone. This does not mean that the steel industry is wasteful or careless; quite the opposite.

Ultra-fast cooling using nanofluids

Water containing nano particles (nano fluid) is known to be a better coolant than pure water due to its higher thermal conductivity. Industrial application of this concept was, however, limited due to concerns for safety, stability, scalability and sustainability. In 2006, a team from R&D took up the challenge of large scale production and use of nano fluids on the industrial scale.

CoolFast H2 team at the award ceremony of Tata Innovista (29 July, 2009)

Production of nano fluids was scaled up atleast 10 times through innovations such as effervescent tablets and high speed shear mixers. Use of nano fluids on the industrial scale was first demonstrated in 2008 when 20,000 liters of nano fluid was used for wire box cooling in the wire rod mill of Indian Steel and Wire Products Limited where the observed cooling rate was higher than that of water by approximately 100°C/s. Trials were also undertaken in the Cold Rolling Mill at Jamshedpur to extract heat from hydrogen used for cooling hot steel coils in a batch annealing furnace. Results from the 'CoolFast H2' trial showed that the use of nano fluids could reduce the cooling time by one to two hours which translates into an extra production of 30,000 tonnes and a reduction of 187,000 m^3 of cooling water per annum when applied to the cold rolling mill at Jamshedpur.

Hydrogen harvesting

The LD steelmaking process generates 120-150 kg of by-product slag per tonne of steel. It is cooled by granulation or quenching, which removes a significant amount of heat. In 2009, Tata Steel R&D developed a novel technology to recover part of the energy contained in the slag. This process, known as Hydrogen Harvesting (H2H), generates a hydrogen-rich gas by intimate mixing of water and slag, which forms steam and reacts with the molten slag.

H2H team receiving the Tata Innovista award (29 July, 2009)

Online demonstration of hydrogen harvesting at the ferrochrome plant in Bamnipal

After laboratory scale tests, the H2H process was first demonstrated with a batch of 10 tonnes. These trials were conducted by a cross-functional team consisting of members from R&D, Tata Steel Growth Shop and the LD#2 Steelmaking plant. Next, an online continuous pilot plant was constructed at the Ferrochrome plant in Bamnipal (Odisha). Its design was developed with inputs from Tata Research Design and Development Center and RD&T at Tata Steel Europe.

This pilot plant has demonstrated the capability to generate a product gas with up to 75% hydrogen and generated detailed understanding on productivity and how to scale-up this process. At present, studies are being conducted to assess viability and merits of commercialisation.

This novel technology has the potential to generate a hydrogen-rich gas from waste energy. Several national and international patent applications have been filed and the invention also won the coveted Tata Innovista award in the 'Promising Innovation' category in 2009.

Over the past 50 years, Tata Steel and other steelmakers across the world have developed a range of improvements to the blast furnace that have more than halved the consumption of coal per tonne of steel. The impact of this achievement is that today's steel industry is far more efficient compared to other coal-consuming industries. Still, Tata Steel is convinced that the industry needs to improve further and is therefore working on several new technologies. The R&D labs in Tata Steel Europe are leading partners in the Ultra Low CO_2 Steelmaking project, a consortium of 48 companies and institutes that develops breakthrough technologies to reduce CO_2 emissions by another 50%. This project is the largest steel industry initiative on climate change worldwide and has already spent over 470 crore rupees (85 million USD) exploring the ironmaking technologies of the future.

One such technology, HIsarna, is presently being piloted in at Tata Steel in the Netherlands. It is a very compact direct iron making process using non-coking coals and iron ore fines. The technology is based on a cyclone reactor for melting iron ore that was patented by R&D in Tata Steel Europe. This is combined with a bath smelting reduction reactor developed by Rio Tinto in Australia. This challenging technology involves high-tech engineering to manage process temperatures of up to 2500°C. However, when successful it is expected to become

Learning from Nature's little helpers

Ferrochrome is an important raw material in steelmaking. The Ferrochrome Plant of Tata Steel at Bamnipal (Odisha) produces 50,000 tonnes of ferrochrome each year through the carbothermic reduction of chromite ore in a submerged arc furnace. Chromite ore pellets are used for the production of ferrochrome. These pellets are sintered at temperatures of up to 1300°C to increase their strength. Unfortunately, due to high refractory nature of Indian chromite ore, the required strength can often not be achieved while sintering is energy intensive and costly.

One day, on the long road from Jamshedpur to Bamnipal, a researcher wondered how the termite mounds, which he saw everywhere in the forests of Odisha, could be made so strong and hard without high-temperature sintering. A literature search revealed that these mounds are made of clay particles cemented by the termite's saliva and chewed wood or cellulose. This inspired him to attempt to emulate Nature and create cold-bonded pellets.

Similar to the termite's cocktail of clay and cellulose, he developed a composite binder comprising of bentonite clay with a natural organic binder. The polymeric bonding characteristics of the organic binder and the highly dispersion and swelling nature of bentonite resulted in excellent bonding of the chromite ore. The alkalinity of bentonite, due to the presence of Na_2O, also enhances the polymerization of the organic binder thereby increasing the tendency for bonding under both tensile and compressive loads.

Successful lab scale trials showed that this new and patented cold bonding process has significant advantages over conventional high temperature sintering in terms of cost, energy and emissions. It also requires four times less processing time.

Several plant scale demonstration trials were carried out in 2012, whereby 100 tonnes of cold-bonded agglomerates were produced and successfully smelted into ferrochrome using the arc furnace. Full commercialisation of this new technology is planned next. It is estimated to decrease specific energy consumption of chromite pelletising by 70% and reduce CO_2 emissions by approximately 10,000 tonnes per year. The improved bonding of pellets is also expected to increase Chromium recovery by 7% and may also be used in manganese ore agglomeration.

Cold bonded chromite pellets

Pilot scale arc furnace smelting for ferrochrome production the world's most energy efficient iron making process, beating today's best technology by 25%. It also has various other expected benefits, such as flexibility in the quality of raw materials and lower capital and operating costs.

Apart from abovementioned challenges in raw materials, energy and climate change, the forthcoming decades will also bring very large opportunities for Tata Steel. India, as it grows its economy and increases it prosperity, will face profound shifts in consumption patterns. Already, as a result of the rapid growth in countries such as India, over half the world's population belongs to the 'middle class'. This socio-economic group is characterised by a reasonable amount of discretionary income, with over a third of income left after expenditure for food and housing. This will result in increased expenditure for leisure, comfort, luxury and other human interests. Particularly, expenditure for quality housing, mobility, white goods and electrical goods will have a noticeable impact on the demand for steel.

Tata Steel supplies approximately 40% of the steel strip required by the Indian automotive industry. The rising demand for mobility will therefore make a significant impact. The rising costs for energy will stimulate the introduction of lightweight vehicles powered by battery, hydrogen fuel cell or hybrid technologies. In the next decades this will continue to give strong incentives to further develop advanced high strength steels and associated application technologies, such as hot forming, tailored annealing, etc. Earlier chapters already discussed Tata Steel R&D's commitment to these developments.

Economists predict that, as part of India's growth, its underprivileged masses at the 'bottom of the pyramid' will also gain prosperity due to the trickle down of wealth. They will experience a rise in the standard of living, as growing global food scarcity increases the income of farming communities. It is expected to result in the introduction of more mechanised farming and agro-industry. We can therefore expect that rural India too will experience the development of its infrastructure and gain access to municipal services.

This increased prosperity amongst rural masses will first be spent on the improvement of living conditions and health, such as improved housing, access to reliable sources of clean water, modern sanitation and a general improvement of nutrition standards. The latter will raise the appetite for preserved foodstuffs to reduce seasonality in nutrition.

Here again there are three areas where Tata Steel R&D is shaping the future. In collaboration with its European R&D labs, it has access to the latest developments in packaging steels and it has also started a major initiative to develop an affordable house for rural India using steel, local materials and various new techniques to make it durable, easy to transport and very quick to construct. Tata Steel R&D has also developed and patented a low cost

"Trying out new things has long been our way of life. The search for new ideas and the willingness to accept a challenge will always remain central to a dynamic and growing Tata Steel."

Mark B Denys, Chief R&D and Scientific Services, 2009-2012 filter for the removal of arsenic from contaminated groundwater. Such naturally occurring contamination is a serious problem in many parts of the world and particularly in certain parts of rural India.

There are many future opportunities in urbanised India too. It has been predicted that by 2050 about 75% of the world's population of 9 billion will live in cities. The rise of the so called 'megacities' poses unique challenges for city life and the environment. Some scenarios assume that these conventional forms of urban growth will result in cities where half the population lives in slums with limited infrastructure, utilities or sanitation. Other scenarios describe organised development resulting in designer cities with new energy efficient mass transportation infrastructures, integrated infrastructures for energy, water and waste, systems to manage traffic congestion and a pre-eminence of electric mobility, resulting in less pollution of air and noise. Particularly the latter scenario would generate novel forms of demand for steels in construction, notably long products, tubes and wires.

Finally, today's increasingly globalised world indicates the rise of a new world order: a shift of the economic power balance from West to East, increased interdependence and connectedness across nations and heightened global awareness. We may expect that these calls for transparency and accountability of companies will continue to rise. One day, sustainability may supersede profitability as the decisive factor in business.

Tata Steel has built a certain legacy on this topic that sets it apart from many other companies. In fact, its founder Jamshetji Tata created the blueprint of a company that is responsible and sensitive to the communities and environment in which it works. His vision was also to develop the city of Jamshedpur with a high standard of living, where business flourishes and where we continue to ensure the ability of future generations to enjoy the same. Essentially he showed a path towards sustainability.

The R&D and Scientific Services Division at Tata Steel feels a particular sense of duty to remain close to his ideals. Its researchers and scientists are experts in questioning the status quo and have a profound understanding of the processes of steelmaking. This combination brings a heightened awareness that Tata Steel too needs to continue its efforts to reduce its environmental footprint and more R&D is therefore required.

The advent of the 21^{st} Century has seen Tata Steel grow from a domestic player to a multinational giant following several acquisitions outside India. While this has strengthened its R&D capability by adding several European labs, it has also thrown up the challenge to raise the bar for its research and development. The challenge today is to develop a highly innovative response to the major trends that are shaping the future of both the Indian and the global steel markets.

The many examples of R&D projects that are mentioned in this chapter reflect Tata Steel's innovative responses to these challenges and opportunities. Many examples also reflect the synergetic efforts between the five R&D labs that are today part of the Tata Steel Group. Ongoing intensifying collaboration between these labs will create a seamless international R&D organisation with an expertise pool that is globally effective, where ideas are freely shared and convention is perennially challenged.

R&D has long been an important part of Tata Steel. Questioning convention, meticulous research and the excitement of discovery will continue to engross its researchers and scientists. It will continue to inspire its leaders to challenge the status quo and stretch beyond the known. Their joint aspirations will ensure that they live up to the legacy of Tata Steel; always striving to make a lasting and positive mark anywhere it operates.

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In 1937, Tata Steel was the first Indian company to create a corporate research & development department. This book recalls its colourful history and numerous achievements. It was published in 2012 to commemorate the occasion of 75 years of research and development in Tata Steel.

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