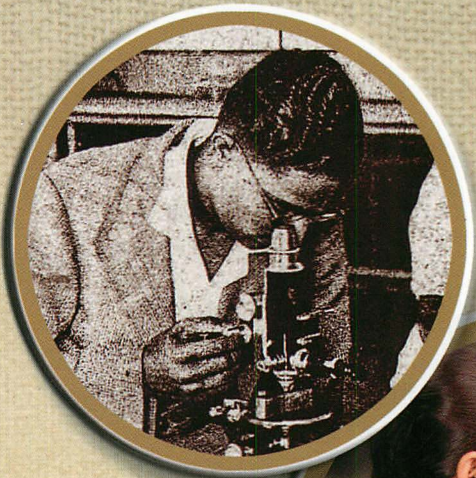
75 Pathfinders of Excellence

years of research at Tata Steel



N N Sachitanand • Mark B Denys • P K Banerjee

Pathfinders of Excellence

TATA
TATA STEEL

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75 years of research at Tata Steel

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75 years of research at Tata Steel

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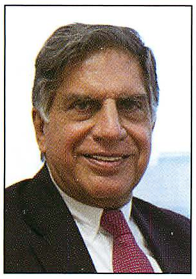
This book is dedicated to

Jamsetji Tata
Founder, Tata Group

Message

TATA



Ratan N Tata
Chairman

It was in 1937 that Tata Steel set up the Research & Development and Scientific Services Division, thereby pioneering corporate R&D in India. This book presents an engaging account of how the last 75 years of work by the division has brought innovation and excellence to Tata Steel and the Indian Steel Industry. It is a story of inspiration, imagination, hard work and great achievements by researchers, engineers and scientists.

As had been envisaged by its founders, the division has supported Tata Steel in its growth and successfully helped the company meet the ever more stringent requirements for quality products from safe and sustainable production processes.

The division's track record is truly impressive. Whilst being only a fledging laboratory in the early 1940s, the division successfully developed no less than 110 different varieties of steel, among which the well-known examples are the ballistic steel grades used in the Tatanagar armoured vehicles, the (then) new steel rails for the Indian Railways and the weather-resistant steels for the old Howrah bridge in Calcutta.

Over time, the division has pioneered many more innovations. These have contributed substantial value to Tata Steel and its stakeholders and resulted in a large number of patent applications, publications of papers in leading international journals, and national and international awards.

The story of Tata Steel's Research & Development and Scientific Services Division is also a reflection on the growth in the impact of research and sciences in all aspects of industry, both in India and overseas. The most important change this book details is how the role of research has evolved from being a fringe activity to a core activity since robust R&D is now seen as essential for sustained success in any business.

Looking ahead, the role of R&D will only gain in importance as companies seek to be more innovative in order to be more competitive. This book will inspire the present and future generations of researchers, engineers, scientists and business leaders and I am pleased to commend it to readers.

August 3, 2012

Ratan N Tata

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Message

TATA

Cyrus P Mistry
Deputy Chairman

I am delighted to know that the Research & Development and Scientific Services Division of Tata Steel will celebrate 75 years of existence this September. My compliments to the entire R&D team for what they have been able to achieve over the years that has brought glory and pride for the Division and the Company.

The coming years are full of challenges for all of us. To meet the varying demands of the discerning customers; our manufacturing practices have to embrace the passion to innovate and offer new products based on newer technologies. Innovation will hold the key for success, and our R&D team should lead on the crest of technological innovation and set technological benchmarks. These could be in the sphere of innovation of new products, process improvements and in greener technologies to reduce carbon footprint.

On this momentous occasion of its 75th year of existence, let me take this opportunity to congratulate the Research &. Development Department team of Tata Steel and wish them success in their initiatives to take Tata Steel to a more Illustrious phase going forward.

June 14, 2012

C. P. Mistry
Cyrus P Mistry

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TATA

B Muthuraman
Vice Chairman

Tata Steel was the first steel company in India and one of the earliest in the world to realize the importance of research and to establish a Research and Development Division way back in 1937. As it completes 75 years of eventful history, I wish to pay a tribute to many of its illustrious personalities of the past and present who have contributed in great measure to the success of R&D efforts and consequently of Tata Steel's success over these 75 years.

Years ago, at a time when Tata Steel did not possess adequate and proper facilities for the manufacture of specialized steels, it is the R&D division that enabled it to produce steel for armour plates, battle tanks and for cutting tools, as efforts to help India during war times. Later, steels like the high tensile steels, wear resistant steels, corrosion resistant steels, high carbon and alloy steels were all due to the efforts of R&D and were beyond the capability that existed for processing these steels.

With India's meager reserves of iron ore and poor quality of coking coals, it is only natural that the more recent efforts of R&D were focussed on mineral beneficiation and getting the best out of our mineral reserves, keeping in mind conservation and sustainability. Tata Steel is on the verge of a major breakthrough in bringing down the ash levels in-our coking coals to dramatically low levels without undue loss in yields. This is a path-breaking achievement.

Our R&D division has contributed immensely in making Tata Steel a globally competitive and sustainable enterprise. The Steel Industry is ripe for the development of a new process that will reduce emissions dramatically, that will consume less energy, that will use mineral resources in the most optimal manner and which will significantly lower the steel cost curve. It will only be fitting for Tata Steel's R&D to begin efforts to bring in such a process into commercial reality.

On its 75th year, it gives me great pleasure to congratulate the people of Tata Steel's Research & Development division and wish them continued success.

August 21, 2012

B Muthuraman

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TATA

H M Nerurkar
Managing Director

It is a matter of pride for Tata Steel that its Research & Development and Scientific Services Division has the distinction of being the first of its kind in India and is set to celebrate 75 years of its existence this year. Since its inception, the division has been actively engaged in adding value to the company in terms of quality assurance, enhancement of existing processes and the development of new products and has been a consistent driver of innovation in the Indian steel industry. I must commend the efforts of all those who contributed to the growth of the division and made it the great institution it is today.

The steel industry is today facing critical challenges in terms of rising costs, difficulties in raw material availability, increasing competition from alternate materials and a rising demand for more eco-friendliness. I am sure the division will rise to the occasion to meet these challenges and provide support and competitive advantage to the company through innovations in processes, technologies and products.

I am very pleased that the division has taken the initiative to document its long and illustrious journey in the form of this book. I am sure the book will appeal to a wide audience of scientists, engineers, managers, businessmen, students and even laymen. I take this opportunity to convey my best wishes to the staff of the Research & Development and Scientific Services Division as they prepare to tackle the many challenges in the years to come.

August 29, 2012

H M Nerurkar

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Message

Debashish Bhattacharjee
Director, Global RD&T

I am delighted that the Jamshedpur R&D centre (R&D and Scientific Services Division) is celebrating its 75th year through the publication of this commemorative volume. This chronicle of the achievements of the researchers and engineers of Tata Steel will find an important place in the annals of Indian science and technology.

In its early years, this Division of Tata Steel was obviously the hub of the company's technical discussions as seen from the comments and signatures left in the visitor's books of 1940s by many very important national and international technical, social and political leaders. During those years, this centre led the development of rail steel grades and steels for armour applications and bridge construction.

From then till the end of 1990s, the Jamshedpur R&D centre closely supported the business in improving yield at various stages of operations and in optimizing new products for the Indian market to suit the production process. Significant improvements in blast furnace performance, continuous reduction of ash in washed coal and improvement in surface quality of cold rolled products for automotive applications were achieved during the last two decades of the 20th century. The first decade of the new millennium saw a paradigm shift in R&D programme with focus on strategic imperatives such as raw materials utilization, new materials and new markets, energy and environment and step change in cost and yield.

Breakthrough projects such as attaining 8% ash without reducing yield, zero reject iron ore, 30% reduction in production cost of ferro chrome, hydrogen harvesting and steels with ultra high strength and good formability were initiated and have progressed to some maturity. These projects are potential game changers in the steel industry.

Now that the Jamshedpur R&D centre is part of a bigger global organization, its access to European technologies and expertise is easier. In the next 5 to 10 years, the Jamshedpur R&D centre, together with its sister centres in Netherlands and the UK, need to provide thought and technical leadership to the company by having a healthy technology roadmap, developing high margin products and quickly implementing significant process improvements.

I wish the team all the success.

August 24, 2012

Debashish Bhattacharjee

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Contents

JRD Tata, then Chairman of Tata Sons Ltd., being escorted into R&D Centre by Dr. J J Irani, on a visit.

The Industrial Revolution in the mid 19th century ushered in a new world economy based on manufacturing using machine power. Western Europe was the first to experience the transformation. India, as the premier colony of the British Empire, was also quick to face this trend when it established steam powered textile mills and the development of a railway network. In turn, this created a market for spares and components, mostly of iron and steel.

Jamsetji Nusserwanji Tata, a visionary textile magnate based in Bombay, realised the enormous potential of this emerging market. Towards the end of the 19th century he moved to establish a company that would manufacture steel for the country's nascent industrial economy.

The Tata Iron and Steel Company (now Tata Steel) was incorporated in 1907 and the first steel ingot was rolled in February 1912. As a pioneering steelmaking venture in India, Tata Steel faced scepticism about its ability to deploy technology that was new to India. This was compounded by various infrastructure constraints due to the plant's remote location and the less than ideal quality of locally available raw materials.

An important factor to overcome these challenges was the emphasis, right from the beginning, on research, development and quality control using scientific approaches. Initially, this focussed on meeting production and quality requirements, despite raw material inadequacies. As the company gained the confidence, stature and the trust of the market, its research and development activities also entered more complex areas, such as new product development, process innovations and even exploratory work into various world first technologies.

All this has kept Tata Steel in the forefront of the Indian steel industry and maintained its competitiveness in the world steel market. In a country where historically investment in industrial research has not been very forthcoming, Tata Steel has been an outstanding exception.

In 1937 Tata Steel was the first Indian company to create a corporate research department. Its start meant the birth of Industrial R&D in all of India. It is a tell-tale sign of the vision and enlightenment of the 'House of Tata' to set up such a then 'Western' concept in the remote township of Jamshedpur.

While a number of books have been published about the Tata Steel story, the company's glorious and gritty research and development saga was not yet documented comprehensively. This book attempts to fill that gap and is published on the occasion of the Platinum Jubilee of the company's Control and Research Laboratory, now known as the R & D and Scientific Services Division.

The first few chapters of this book recount the early efforts of the company to generate a research and development culture within the organisation and to meet the requirements of the market. This began with establishing testing and analysis facilities and procedures to meet the qualitative demands of its first customer – the Indian Railways. The painstaking efforts of Dr. Andrew McWilliam, a professor from Sheffield University contracted by the Railways as a Metallurgical Inspector, to establish the systems of quality control in the fledgling steel company has been highlighted. The onset of the First World War and the fact that Tata Steel was the only integrated steel plant in the Asian part of the British Empire gave an opportunity to the company's engineers and metallurgists to experiment with producing steel for armaments that were required by the British Forces in the Middle East. This expansion into the new products further strengthened the push for research.

The logical next step was the establishment of a R&D department and a central laboratory. That came in the latter half of the 1930s. The chapter on this central laboratory elaborates on its architecture, facilities, safety features and capabilities. This large and well-equipped R&D facility was directly able to meet the needs of the day. This is recalled by the chapter that details how Tata Steel was able to quickly develop special and alloy steels to be used in armaments for the Allied Forces during the Second World War.

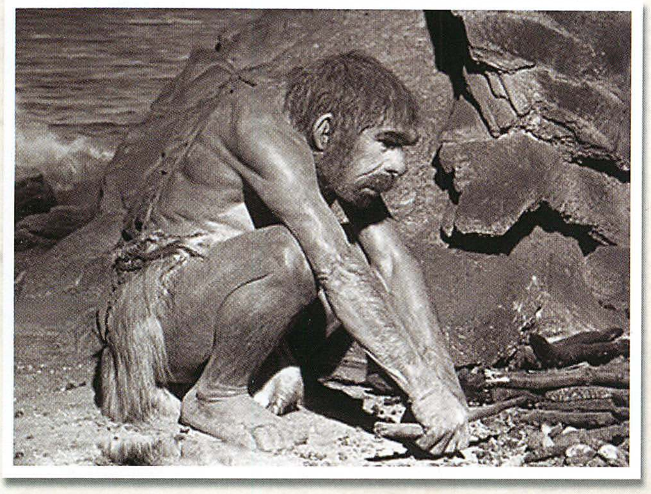
Post Independence, Tata Steel expanded its capacity and inducted new technologies to meet the growing requirements of a developing and modernising India. In this phase, the laboratory played a pivotal role in technology absorption, productivity improvement, specific energy reduction, quality enhancement, new product development, etc. In particular, it supported the company immensely to overcome the handicap of poor quality indigenous mineral resources. These efforts are detailed in the chapters devoted to hot metal, steel and products.

Research and development is not just about scientific laboratory work. It also concerns able project selection and management, human resource development and, in these days of a competitive global environment, protecting and exploiting intellectual property. How the R&D and Scientific Services Division of Tata Steel has tackled these issues is dealt with in the last few chapters of this book. Finally, the book concludes with the challenges posed to the R&D and Scientific Services Division in the 21st Century, with a particular reference to the fact that Tata Steel has become a major global steelmaking company through its recent acquisitions.

The preparation of such a book involved cooperation from large number of agencies, divisions and individuals. The editorial team would like to express their sincere appreciation towards everyone associated with the formulation of this book, including all the employees of R&D and Scientific Services Division. A special mention is necessary for Prof. O N Mohanty, Mr. U K Jha, Mr. P V T Rao and Dr. M D Maheshwari for their valuable insight into R&D's past. The technical contributions and useful suggestions from Dr. S K Ajmani, Dr. A N Bhagat, Dr. M Shome, Mr. Atanu Ranjan Pal, Dr. Sumitesh Das and Dr. Sandip Bhattacharyya are thankfully acknowledged. Throughout the writing of the book, we had received constant help and support from Ms. Jenny Shah, Mr. Swarup Sengupta and Mr. Prabhat Sharma for the historical archives of R&D. The photographs are courtesy to Mr. DAS Murthy. And finally, we sincerely thank Mr. H M Nerurkar, Managing Director of Tata Steel, for his support to this book on the occasion of 75 years of R&D in Tata Steel.

Jamshedpur,
August 31, 2012

N N Sachitanand
Mark B Denys
P K Banerjee



We commence with a story...

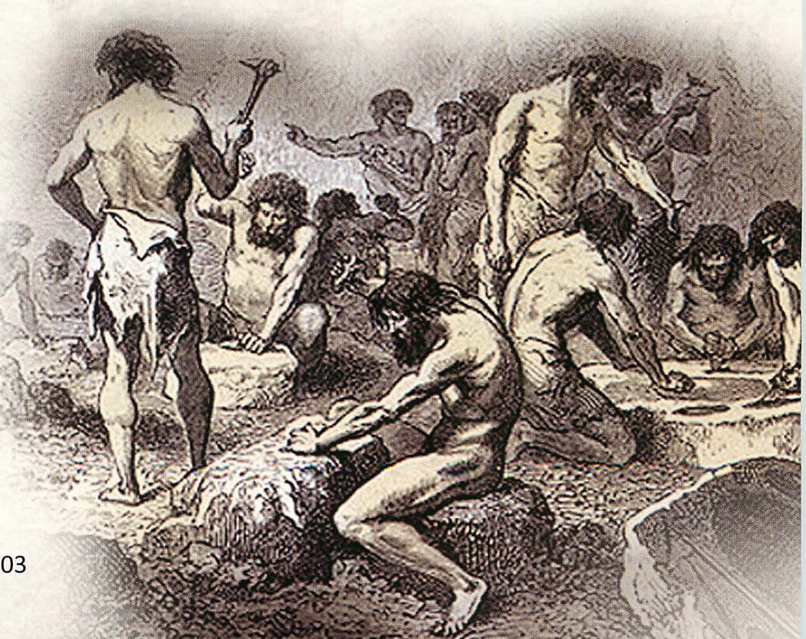
Urguk was idly flinging pebbles at a nearby rock as he basked in the morning sun. The warmth of the day was a relief after the cold night in the cave where he and his fellow tribesmen had taken refuge. Suddenly, something peculiar caught his attention. Sometimes, a bright flash of light emanated from the spot where a pebble struck the rock. The flame reminded him of the tree-devouring Red Monster that rose when the Cloud God suddenly hurled his dazzling weapon towards the earth with an ear-splitting sound.

Urguk's curiosity was aroused. The next time a pebble caused a light flash, he rose up, retrieved it and again hurled it at the rock. There was the flash again! Now he became more daring. He grasped the pebble and slashed it across the rock. Sure enough, the light flashed again! As he struck the rock again and again, one flash leapt from the rock onto the surrounding dry grass that immediately burst into flames.

At first, Urguk was unnerved. "It is the Red Monster!" he thought. He dropped the pebble, stepped back a few paces and got ready to run. But once the blades of grass were consumed, the wisp of flame died down. Emboldened, Urguk cautiously approached the rock again and looked speculatively at the blackened grass that was warm when touched. On an impulse, he plucked tufts of dry grass, put them around the rock and again started striking it with the pebble. Sure enough, one of the sparks set the grass alight.

Urguk knew he had found something special - the power to summon the Red Monster when he wished, with the help of the magic pebble. Of course he could not have realised how epochal his discovery of lighting a fire would be. Nor did he appreciate that the means to the discovery is what research is all about: observation, experimentation, analysis and conclusion. Down the ages, it is such research that has led to breakthrough discoveries - agriculture, cooking, irrigation, the wheel, free-standing structures, transport, script, astronomy, geography, metallurgy, biology, medicine and so on. All this has raised the level of human development in quantum steps.

This is also the story behind the biggest game changer in the history of human development: the Industrial Revolution. This event occurred primarily due to the development of the steam engine and the internal combustion engine, which enabled motive power in a compact form at levels not feasible with the muscle power of humans or animals.




Industrial Revolution

The Industrial Revolution radically altered the position of steel in the world. From a rare exotic material used mainly in weaponry, it became a universally available material used in a wide variety of applications. This was rendered possible by the development of large scale steelmaking processes that exploited the engines of power invented during the Industrial Revolution. The 20th century became known as the Century of Steel and the material became central to economic prosperity, political power and international prestige.

The Industrial Revolution was transplanted to colonial India in the latter half of the 19th Century. This coincided with the genesis of the movement for self-rule that became the precursor of the Independence Movement. Indian businessmen who had started as traders now turned industrialists. Instead of just exporting raw materials and importing manufactured goods, the country slowly started on the path towards large scale manufacturing.

Amongst these industrialists was Jamsetji Nusserwanji Tata, a cotton textile magnate from Bombay. Although he refused to appear on public political platforms, he was a strong nationalist and desired self-government for India through constitutional means. But he considered economic self-reliance for India to be equally important. Jamsetji's vision was of a self-supporting, strong industrial India, of ships built in India carrying goods made in India to far flung markets across the oceans.

A widely travelled person, Jamsetji had seen how the production and use of steel had led to the rapid development and empowerment of Western Europe and the USA. This motivated him to set up a modern steelworks in India. After a lot of tribulations, it finally started operations in 1907. Unfortunately Jamsetji did not live to see this dream turn to reality as he passed away in 1904.

How accurate Jamsetji was in his prediction of the importance of steel can be gauged by the following comment of Sir Thomas Holland, then Director of the Geological Survey of India. He declared in 1923 that *"without steel manufacture on a large scale and, therefore, for the near future at least without the Tata steel company, there can be no national India and all political reforms must be non-productive".*

The Industrial Revolution altered the paradigm of manufacturing from dispersed small scale to concentrated large scale. Leadership in technology became a critical agent for achieving business leadership. Those companies and countries that invested in scientific thought, research and development raced ahead.

There was a time when nations could build walls against imports and their industries could manage with outdated technologies. Globalisation and the dismantling of trade barriers have ended that. Today, enterprises have to be globally competitive. One of the fundamental means is to stay ahead to servive in research and development.

Tata Steel incorporated the spirit of research and innovation right from its inception, when the country's organised industry was still in its infancy. Jamsetji Tata was a man who appreciated the value of science. In his 1925 biography of Jamsetji, Frank Harris remarks *"The bent of Mr. Tata's mind inclined towards those who were advocating greater attention to scientific studies. He was much impressed with the progress of the rising Powers. He saw in America, Germany and Japan the prosperity,which the application of science to industry has already produced."*

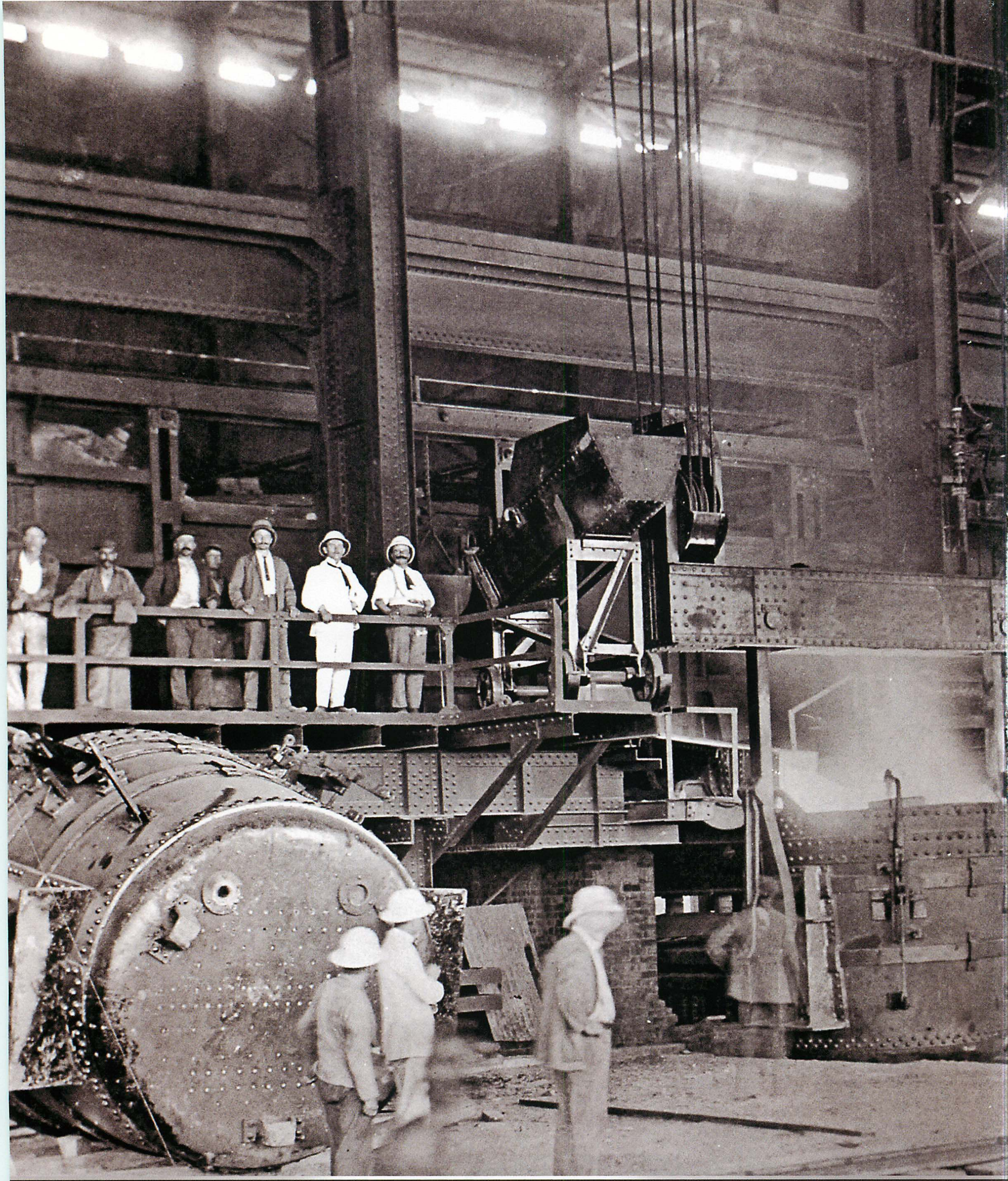
It is this application of science to industry, what is now termed Industrial Research & Development (R&D), that has played a crucial role in the shaping and growth of Tata Steel. This industrial research is rarely about "eureka" moments or paradigm-shifting innovations. The path of scientific discovery may be hacked through the jungles of the unknown by brilliant and obsessed individuals; however, industrial research works more systematically and collectively on these paths to turn them into highways of value creation.

In the public mind, innovation is what hits the news headlines with the promise of a breakthrough that may change the world. Any Industrial R&D organisation will devote part of its resources to pursue the path of such breakthrough innovation. These are the risky, costly and long-term developments that, once successful, can generate large returns.

However, this is just the iceberg of innovation. Most research and development exists out of sight. Most of the time, it is tiresome experimentation, modelling, piloting with many blind alleys from which the researcher has to backtrack. This part of industrial research is focused on continuous improvement; taking many incremental steps that are individually small but cumulatively over time become game changers for an industry.

Very few researchers in industrial research become stars of the scientific firmament, but their collective contribution can change the fortunes of a company, industry, even society. There is more to industrial research than just science. There is planning, costing, resource management, project monitoring, human resource development, motivation management, intellectual property protection and a host of other activities.

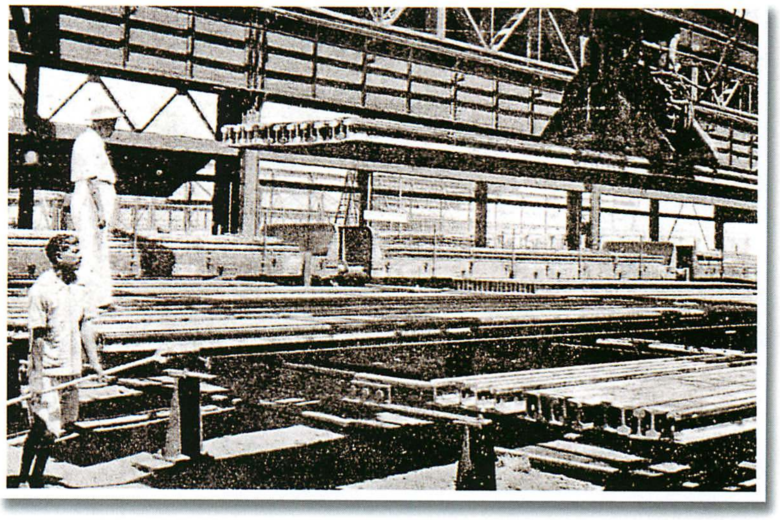
How Tata Steel has introduced, handled and polished all these facets of industrial research makes a fascinating tale. While there have been numerous books, monographs and articles written about Tata Steel and its founders, little is known about this formative role of its R&D and Scientific Services Division. This book intends to tell that story. It is also a tribute to the dedication of the numerous persons who have unobtrusively but conscientiously done their part for the welfare and success of Tata Steel.



Open Hearth Steel Furnace

"Do you mean to say that Tatas propose to make steel rails to British specifications? Why, I will undertake to eat every pound of steel rail they succeed in making."

That was the scornful remark that was reportedly made to Charles Page Perin, the American consultant to the fledgling Indian steel company, by Sir Frederick Upcott, the then Chief Commissioner for the Indian Railways. Contradicting the scepticism, the infant Tata Steel succeeded admirably in making steel rails that were acceptable to the Indian Railways. It also exported 1500 tonnes of the material to Mesopotamia to support the Allied campaign there during World War 1. Dorabji Tata, the company's first Chairman, commented dryly that if Sir Frederick had carried out his undertaking, he would have had "some slight indigestion".



Surface inspection of rails at the new Rail Finishing Mill

Dr. Andrew McWilliam

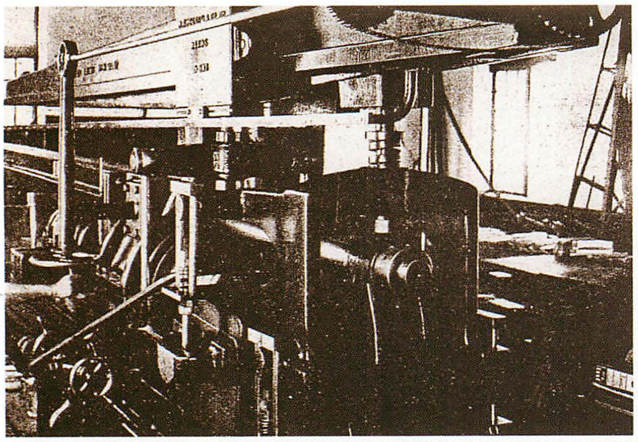
Tata Steel owed its success in producing rails, not only to the efforts of its own staff but also the valuable assistance and cooperation of Dr. Andrew McWilliam, D. Met., a renowned professor of Sheffield University. He was engaged through the India Office on a five year contract to the Railway Board, to serve as the Metallurgical Inspector at a proposed government testing laboratory located next to the steelworks.

After the construction of the laboratory, Dr. McWilliam started work at the Inspectorate when the first rail-heat was tapped out Tata Steel in February 1912. At that time, only one open hearth was running. Second furnace was added in September 1912. The first batch of rails produced by the company and passed by the Inspectorate was of 41 1/4 pounds section on an order from the Baroda State Railway. Dr. McWilliam grew very fond of Tata Steel and after the expiry of his term of office under the Government in 1918, he stayed on as a Technical Adviser to the company for another two years.

Dr. McWilliam whole-heartedly devoted himself to finding a solution for every knotty problem of steel making that was put before him. He used to be present in the works at all the stages to watch the making of heats and the rolling of steel. These rails were then cut to the required lengths in the hot saws, straightened and finished according to the specifications and then arranged in tiers for Government inspection in the yard. The Government Laboratory analysed one sample of every rail heat and one piece of every one hundred tonnes of rail.

After the rails had passed the walking and drop tests and completely analysed for their chemical composition, certificates were issued direct to the purchasers of materials from the Company. In the beginning, the charge used to be made on the tonnage of steel inspected, whether passed or rejected, to the railway for whom they were made. But, in a few years' time, at the instance of the railway companies, this procedure of debit on account of inspection of the rejected quantity was abolished by the Railway Board. This sudden change of procedure, however, did not affect the income of the Inspectorate since Tata Steel had by then a guaranteed order of 20,000 tons of rails to be supplied annually to the Railway Board for a period of 5 years at the outset.

The reputation of Tata Steel for the production of sound rail steel in India had already been established when the First World War broke out in August 1914.



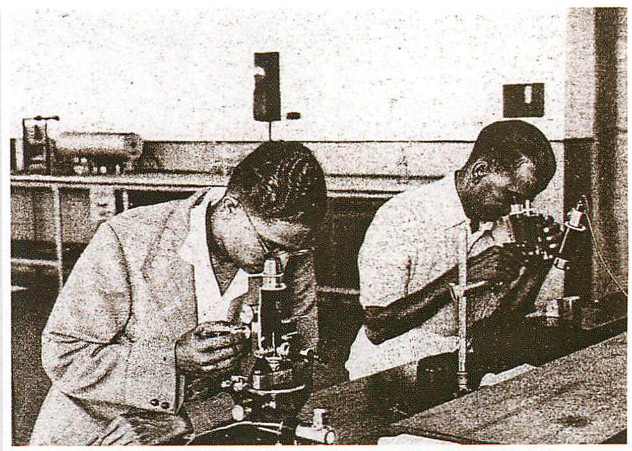
100 ton horizontal multiple lever Bucton Tensile Testing Machine at the Physical Laboratory

By then, the Company had completed a Bar Mill, increased the number of furnaces and erected a Physical Test House for tensile and other tests under the guidance of Dr. McWilliam. This could be regarded as the progenitor of in-house testing and research.

In the Bar Mill, Tata Steel had started making structural materials such as joists, bars, angles and channels of varied sections against Government and Railway orders. When the Great War broke out the company assumed great importance as it offered the only potential supply of iron and steel east of the Suez Canal. It was provided with huge orders for shell steel bar of different sizes and rails for the construction of military tracks.

The Company had only open hearth furnaces then and shell steel had never been made in such furnaces. Tata Steel did succeed in making the shells under the dogged and skilful command of its first General Manager, Temple W. Tutwiler, a veteran steelmaker from Gary, Indiana. The company did not have the means then to press the steel into shells. Tutwiler ransacked every railway and ship-building workshop that had a lathe to bore five-inch rounds into shells. They worked and saved the day in Mesopotamia for British and Indian troops. Not a single ton of Tata's shell steel was rejected. Special grades of steel for combat helmets and jerry cans were also developed and supplied.

The war effort took almost 80 per cent of the company's production. By the time the First World War was over, Tata Steel had already supplied 2,400 km of special Steel Rails and 3,00,000 tons of special grade steel for the manufacture of shells, combat helmets, jerry cans and other materials for Allied Forces for campaigns in Mesopotamia, Egypt, Salonica and East Africa.



Examination of structure of steel by Polarisation Microscope

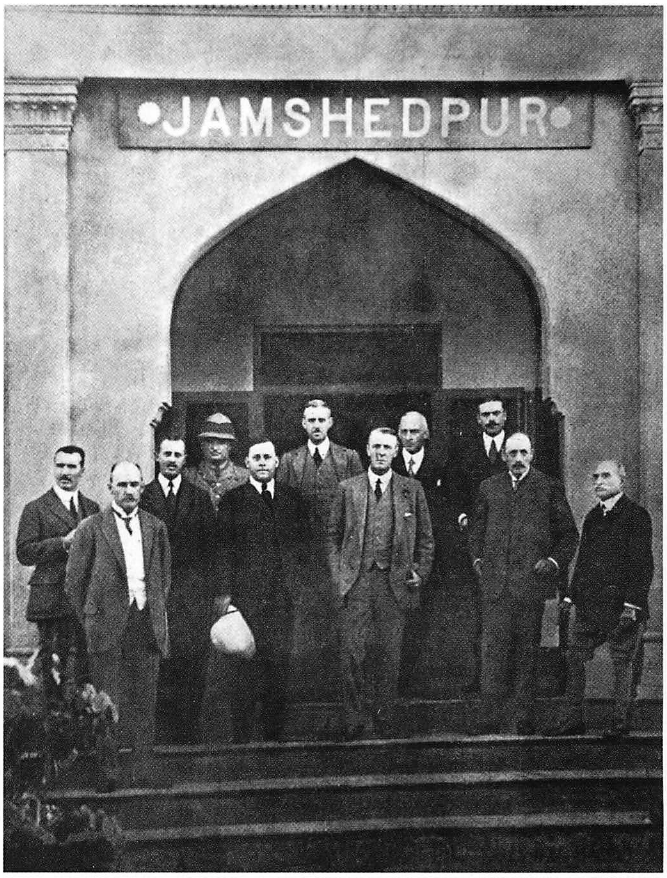
The extraordinary Mrs. McWilliam

There is an interesting aside to the dedication of Dr. McWilliam in helping Tata Steel in its infant years to achieve the required quality of rail steel. That is the role played by his wife as a true helpmeet or "ardhangini" (the other half) as the ideal Indian wife is called. In the beginning, the work in the Railway laboratory headed by Dr. McWilliam to inspect the rails from the neighbouring Tata steel works was conducted by the two chemists, Mr. Irwin and Mr. A.N.Bose. But when the company commissioned its second open hearth furnace in September 1912, the analytical work of the laboratory was greatly increased because of the frequent tapping of rail heats.

Dr. McWilliam had to often take the assistance of his wife in getting through the analysis in the laboratory. So, Mrs. William used to attend the laboratory regularly in the morning with her husband to help out in the analysis of the samples. Her work was quick and her results accurate. She made herself so indispensable that her husband had to call her to office even after lunch even in the hottest of days, when the mercury would cross 40 degrees Celsius. That was extraordinary for those colonial days when "memsahibs" spent most of the day under the room wide hand "punkah" pulled by one of the myriad servants. This went on for some time until the appointment of an engineer officer was sanctioned in 1914 to relieve Mr. Irwin to look after the analysis in the laboratory.

This contribution of Tata Steel was gratefully acknowledged by the Viceroy, Lord Chelmsford, when he came to visit the steel plant in 1919. It was on this historic occasion that the Viceroy announced the change in the name of the place of Tata Steel's factory from Sakchi to Jamshedpur, to identify it with the name of its founder, Jamsetji Tata.

The term of Dr. McWilliam with the Government expired just before the Armistice was declared in November 1918. On his returning home he was awarded the C.B.E. But, as ill luck would have it, he did not live long to enjoy this distinction for he died soon after. But Tata Steel will be eternally grateful to him for the systems and procedures of work which he laid down, particularly in inspection and testing, which laid the foundation for research and development work in the Company.



The visit of H. E. the Viceroy Lord Chelmsford (2nd January, 1919)

"In the fullness of time, this laboratory should play an important part in the progress and development of the steel industry in India and the training of an efficient body of Indian research workers in the metallurgy of iron and steel."

Mr. A. R. Dalal, Director of Tata Sons,
during the laying of the foundation stone, 6 November 1935

Tata Chemical Laboratory (1939)

The great innovators of the Industrial Revolution almost single-handedly created entire industries out of their own imagination and scientific skills. Examples are Thomas Edison with the incandescent light bulb, Alexander Bell with telecommunications and Daimler with diesel engines.

The manufacturing companies that emerged soon realised that continuing innovation was the key to remain competitive. However, the increasing complexity of new technologies meant that innovation needed dedicated teams of scientists and engineers working together in an organised manner. This lead to the birth of industrial Research & Development (R&D).

One of the world's first such industrial R&D centres was created by Philips in the Netherlands, which as early as 1914 established a research laboratory to study physical and chemical phenomena and to stimulate product innovation.

Many companies in the western world adopted this new branch of business activity. General Electric, Daimler-Benz, Bosch, Siemens and many others established large dedicated R&D centres during the first few decades of the 20th Century.

In India, Tata Steel has the distinction of being the first company to establish a composite and comprehensive corporate centre for R&D, back in 1937. This was a natural corollary to the vision of the founder, Jamsetji Tata, who foresaw an aspiring India with strong home-grown Industries, self-rule and self-reliance in technology.

Already in the late 19th century, Jamsetji Tata resolutely pursued the founding of an institute of post-graduate research in India. A bold initiative that became the Indian Institute of Science, established in Bangalore in 1909.

Swami Vivekananda

Jamsetji had been encouraged in this initiative by Swami Vivekananda, the renowned monk who was a strong advocate of the use of science for advancement of the nation. The Swami is quoted to have said *"With the help of Western science set yourself* *to dig the earth and produce foodstuffs – not by means of mean servitude of others – but by discovering new avenues of production, by your own exertions aided by Western science."*

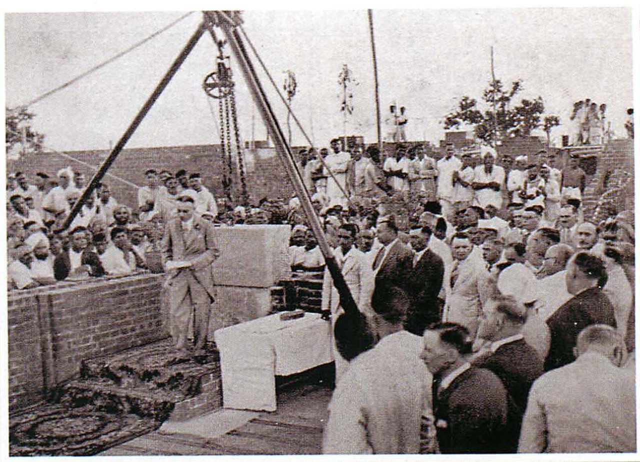
Another important founding father of R&D at Tata Steel was the eminent engineer-statesman from Mysore, Sir M. Visvesvaraya. He was a stalwart of the early years of Indian industrialisation and also a Director of Tata Steel. During a Board meeting in 1932 he pointed out that, within his experience, there was no large factory in Europe or America without provision for research. The chief object of such research was to reduce costs and increase output. Enormous sums were spent; in some cases one-tenth of the net profits of a company. Therefore, he strongly advocated that:

Sir M. Visvesvaraya

"There should be a Research Bureau maintained to carry on investigations into the methods of manufacture, costs reduction, fuel economy etc., so as to make some advance towards rationalisation. The engineers on the committee associated with research should collect material from technical journals, through foreign agents and in other ways, and constantly keep up the practice of comparing results under every phase of operation with those obtained on similar steel works abroad."

On 6th November 1935, Tata Steel saw the first physical demonstration of this vision shared by Jamsetji Tata, Swami Vivekanda and Sir Visvesvaraya. That day saw the laying of the foundation stone for Tata Steel's Control and Research Laboratory.

However, the building is popular today as Research and Control Lab and houses the R&D, Scientific Services and Refractory Technology Group (R&DSS).



Mr. A R Dalal delivering his speech on the occasion of the laying of the Foundation Stone of the R&D building (6 Nov, 1935)

The start of this Division in Tata Steel meant the very start of corporate R&D in all of India. It was a tell-tale sign of the enlightenment of the House of Tata to set up such a 'Western' concept in the then remote township of Jamshedpur.

This is illustrated in the address of Mr. A. R. Dalal, Director of Tata Sons, during the laying of the foundation stone:

"Great advances are being made in the world today in the processes of steel manufacture and no manufacturer who wishes to maintain his competitive position can afford to neglect this very important branch of his activities. In India we are labouring under a very special difficulty in this matter. No research institution on a national scale is possible in India at the present stage of development of its steel manufacture. As the only manufacturer of steel we have to provide for our own research."

On 14th September, 1937 the new research centre was formally opened by Sir Nowroji Saklatwala, then Chairman of the Tata Group.

It was designed by the firm Ballardie, Thompson & Mathews, leading architects at the time in conjunction with the Chief Metallurgist and Chief Chemist of the company. The building was constructed by the Hindustan Construction Company Ltd. With an elegant facade in the Art Deco style, it dominated the Jamshedpur landscape and made a grand statement to the trust in science and innovation. Even today this building remains a striking piece of architecture and can be classed amongst the most beautiful buildings in Jamshedpur.

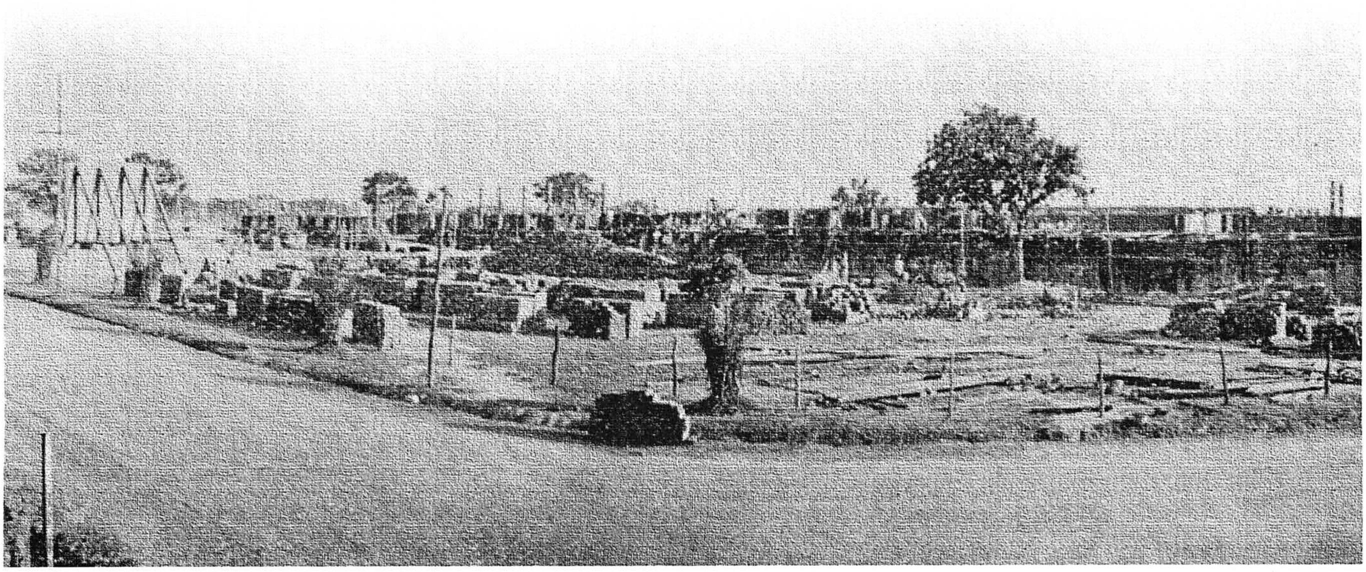
Around 400 tonnes of steel, 3000 tonnes of cement and 5 million bricks went into its construction. The estimated total cost was Rs 9 lakhs, a huge amount in those days. Still today it is colloquially known in Jamshedpur as the *"Nau Lakhi"* building.

The new Control and Research Laboratory was designed to deal with matters relating to research work in addition to routine work under the following heads:

1. Control of raw materials, involving analytical and chemical problems, for purposes of selection or investigation.
2. The study, observation and supervision of all metallurgical operations carried out within the steel plant.
3. The properties of special irons and steels.
4. Refractory materials.
5. Corrosion problems.
6. Development of new steels and new products of all kinds.
7. Fuel laboratory.

It was built on three sides of a square of 335 feet. The central entrance leads to a waiting hall with a large domed ceiling that is topped by an 80 feet high tower. The central Administrative Block contained offices, a Conference Room and a large Technical Library along the main corridor with easy access from all sides.

There were three main sections in the research centre Metallurgy, Chemistry and Refractories. The Metallurgical Section was provided with rooms and equipments for mechanical testing, heat treatment, physical and corrosion testing, dark rooms for metallography, etc. The Chemical section had facilities for wet analysis, gas analysis, colorimetry, electro-chemistry and specimen preparation rooms. The Refractory section, occupying 6,000 square feet, had dust-proof pulverising rooms, furnaces for



A view of the new Control and Research Laboratory at Jamshedpur under construction

Scientific Services today

Sampling, testing and analysis are the essential activities for steelmaking production control, quality assurance and research & development. Facilities for these activities were installed during the early founding days of Tata Steel. These included laboratories for chemical analysis and physical characterisation of raw materials (coal, iron ore, fluxes, etc.), intermediate products (agglomerates, iron and steel chemistry), by-products (slag, gases), supporting materials (refractories, plant components), fuels and finished steel products.

During the early years, these activities and facilities were distributed amongst the various production units as per the need for proximity. In 1937, when the company established its main Control and Research Laboratory, these analytical services were centralised. In the course of time, the activities of the central laboratory were bifurcated into two separate departments for Research & Development (R&D) and Scientific Services (SS) under the central leadership of the Chief R&D and Scientific Services.

The activities of the early Scientific Services department primarily involved ceramics and refractories, chemistry, metallurgical services and quality assurance. Metallurgical services included a host of responsibilities such as process and quality control at various production centres as well as analytical work in the Metallography Laboratory and Physical Laboratory.

Following a company-wide reorganisation in 2001, the process and quality control responsibility was taken out of the purview of Metallurgical Services and placed with the manufacturing units. However, the responsibility for accurate and timely analyses to support process and quality control remained. In addition, the R&D and SS departments merged and the Refractory Technology Group was added to form the R&D and SS Division. This centralised all laboratories into a single division for the effective management of these facilities and their associated know-how.

The R&D and Scientific Services departments are individually ISO certified for quality assurance and all laboratories under Scientific Services are NABL accredited units for stipulated metallurgical, mechanical and chemical tests.

The Scientific Services department consists of four Chemical Laboratories, a Physical Laboratory, a Metallography Laboratory, a Plant Metallurgical Inspection Group and Central Raw Material Testing Laboratory. It also provides various facility management services to the R&D and Scientific Services Division.

The department operates in close collaboration with the production plants. It generates and analyses product quality data for raw materials, chemical analysis for process control, mechanical properties for certain product certifications and also conducts failure investigations related to plant components and customer complaints. Many of these activities are conducted around the clock.

The laboratory is also involved in various improvement projects for life enhancement of engineering components, process and product improvements. Each year the officers of the Scientific Services department conduct approximately 20 such improvement projects and thereby develop and demonstrate their progress in solving difficult plant problems.

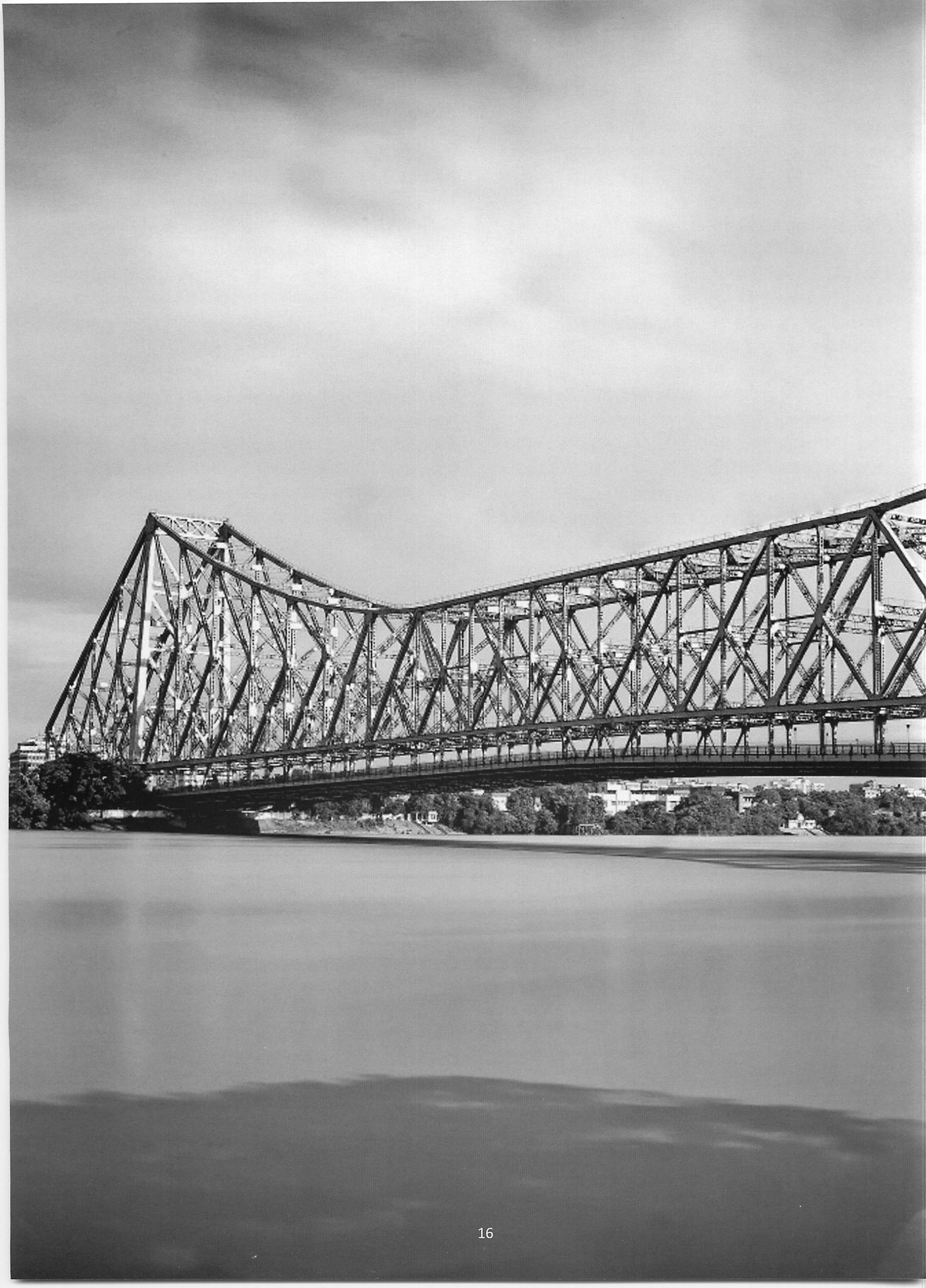
Today the Scientific Services department has a payroll of 264 persons, amongst these are 44 officers.

spalling, fusion, load and slag tests, a brick making room, electric furnaces and a special microscope room.

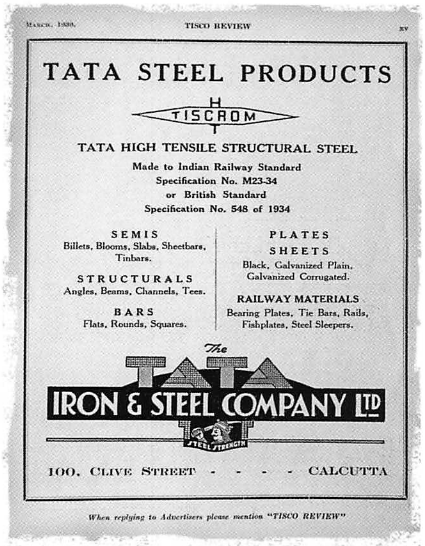
The building was designed to offer efficiency, comfort and flexibility. Rooms were laid out to provide a straight line flow of work and were connected by wide corridors. The working tables and benches were designed and constructed to be easily dismantled, added to or modified, with detachable cupboards and drawers. All services, including gas, water, power and vacuum were supplied through a duct running below the floor so that maintenance access was easy and the walls were kept free of piping and cabling.

Special attention was paid to safe and healthy working conditions, with considerable thought given to ergonomics, lighting and ventilation. The positions and heights of the tables and benches were designed for convenience of the technicians and to avoid unnecessary movement of the workers. Fume extraction systems were installed with specially designed hoods to protect the technicians. Switchboards 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.

The building was planned to meet the research requirements of the steel company for at least the next 20 years. That it still accommodates the enhanced R&D requirements of the company, 75 years later, is a testimony to the far-sightedness of the designers and builders of its designers.



The silvery steel lattice of the Howrah Bridge towers over the Hooghly River in Kolkata. It is recognised world over as the symbol of this Indian metropolis. Not many people know that in the early 1940's Tata Steel supplied most of its 26,500 tonnes of steel.



Producing steel for the Howrah Bridge was a major challenge to Tata Steel, since it had not yet ventured into low alloy structural steels. The specifications of the steel to be used called for a tensile strength of 37 to 43 tons per square inch. Developing this grade became the major focus of its new in-house research centre, that was opened just a few years ago.

At the time, an Electric Arc Furnace and a 0.5 tonne High Frequency Induction Furnace were just installed in the steel melting shop and were used to produce the alloy steel. In the beginning, certain difficulties were experienced in the rolling of sections. The degree of spread in this steel under the rolls was found to be different from that of plain carbon steel. Engineers had to modify the pass designs to enable it to roll sections in special alloy steel as well as plain carbon steel on the same roll setting.

Another difficulty was the removal of the tightly adhering oxide scale that formed due to the alloying elements used. This was addressed by introducing high pressure water on every pass to break off the scale. The presence of copper, to enhance corrosion resistance, also caused a peculiar problem of surface cracking. Ultimately, the researchers and engineers of Tata Steel were able to overcome all these challenges and the new steel product they created was christened 'Tiscrom'.

However, before this steel could be accepted by the Howrah Bridge construction engineers, Tata Steel needed to contest patent suit that tried to uphold the need to use imported high tensile steel. A great deal of public opinion was aroused in favour of the indigenously developed Tiscrom and the suit was finally decided in favour of Tata Steel. The success of building the Howrah Bridge with Tiscrom enabled the winning of contracts as far away as Burma, where the same material was used to build the bridge over the Irrawady and to lay the pipe lines near Rangoon.

Tiscrom and other early types of high tensile steel were quarternary steels with alloy additions of chromium, manganese and copper. They were not amenable to welding, since the heat generated by welding tended to produce brittle zones adjacent to the weld. This is the reason why today Howrah Bridge stands out as a totally riveted structure.

Tata Steel's researchers therefore also started developing a high strength structural steel that was amenable to welding. They came up with 'Tiscor', a quinary steel containing chromium, copper, silicon and phosphorus. Carbon conveys the greatest degree of hardenability in steel. This element was therefore maintained at a very low level for good weldability, while the higher yield strength was obtained through a balanced combination of the aforementioned alloying elements.

Tiscor's high yield strength enabled its use in thinner sections, while its weldability promoted its use in freight cars, ships, trams, and various other vehicles. Tiscor was also found to be more corrosion resistant than plain carbon structural steel.

While Tiscrom and Tiscor admirably catered to the steel requirements of the civilian sector, one of Tata Steel's finest hours in creativity and innovativeness came during the Second World War. As Dr. Amit Chatterjee, points out in 1980s monograph 'Glimpses of R&D at Tata Steel':

A wagon from Tiscor steel plates

"The outbreak of World War 2 found the country dependent on Britain for the supplies of certain types of steel products, particularly those required for ordnance products. With the increased pressure on Britain for war supplies, the growing dearth of shipping, the intensification of submarine warfare and the closing of the Mediterranean route to the East, the discovery of indigenous sources of supply became essential, if India was to play her rightful role in the provision of the ammunition of war to the British armies in the East.

Naturally, the Government of India turned for such supplies to Tata Steel, which was the only commercial unit in the country having the necessary experienced personnel, equipment and research organisation, to carry out development work. During the war, as a result of elaborate R&D work, Tata Steel was able to manufacture and supply new types of alloy steel grades such as Die Steel and Bullet Proof Armour Plate."

During the five years of the war, researchers at Tata Steel managed to develop as many as 110 different varieties of steel. The most outstanding achievement was the development and production of a bullet-proof armour plate.

The first call to make this grade was made on Tata Steel in early 1940. Having no prior experience in producing such a class of ordnance steel and no sources for guidance, the company had to literally start development of the material from first principles.

To start with, the composition and class of steel to be made were selected corresponding to the facilities and equipment available in the plant. Steels that required oil and water for hardening were ruled out, as these required new large quenching and straightening installations. Efforts were therefore directed towards making air-hardening alloy steels.

After several experiments with various compositions, an air-hardening steel containing nickel, chromium and molybdenum was produced in a 34 kg Induction Furnace in the Research and Control Laboratory at Jamshedpur. After rolling into plates and normalising followed by tempering at a low temperature, the plates were subjected to severe ballistic tests.

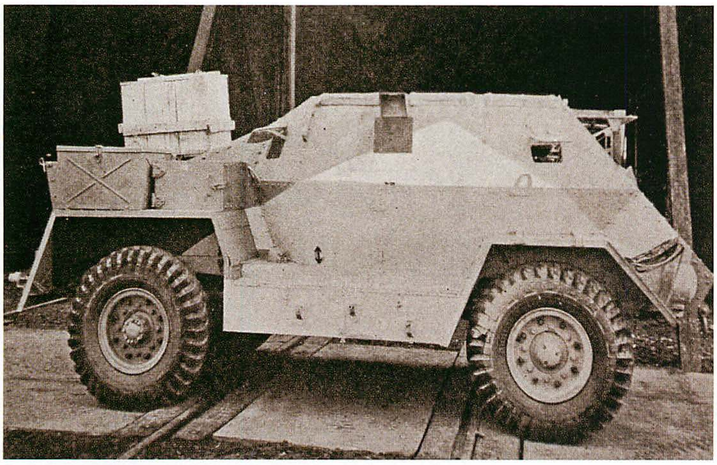
It was a tribute to the researchers at Tata Steel that the Master General of Ordnance Branch, Simla, remarked that the company's armour plate was "Excellent and up to Home Specifications". Even more creditable was the fact that this research of such magnitude and novelty was carried out in the short space of just three months.

Initially, the commercial production of this armour plate steel took place in the Electric Arc Furnace. Later, with experience gained, production was shifted to the Open Hearths. The furnaces for heat treatment were produced locally and very soon the plant was able to churn out 800 to 1,000 tons of annealed plates per month. One peculiar difficulty was this steel's extreme sensitivity to heating and cooling and its tendency to "flake". This was overcome by rigorously controlling the heating and cooling cycles at the different stages of production.

This new bullet-proof armour plate was first used for armoured vehicles that were fabricated by riveting. Special research was undertaken to also develop a bullet-proof steel for these rivets that had to be driven in hot. As it would not be possible to temper the rivets after driving, an air-hardening alloy steel was needed that retained sufficient ductility without tempering. This development was successfully accomplished by duplicating the armour plate composition with lower carbon and chromium content.

These armoured vehicles were called 'Tatanagars' and were used extensively by the British Army engaged on the North African front. A press item in the 1940's with the headline "India-made Armoured Cars Praised" mentioned:

'Safer than slit trenches during a bombing raid' was a gunnery officer's tribute to the cars during service in the 8th Army. An officer goes on to describe how a 75 mm shell burst on one side of the Tatanagar. "The metal plates were buckled but nowhere pierced. The four occupants of the car emerged unscathed. Units possessing the Tatanagar swear by them."



The Tatanagar, a light armoured vehicle built at Jamshedpur by Tata Steel using know-how developed in-house. (1940)

During the war years, researchers faced many other challenges. For example, at a crucial time during the war, nickel, an essential ingredient in armour plating steel, was in short supply. Tata Steel's researchers therefore developed a new alloy with the similar good ballistic properties but with only a third of the nickel. They also succeeded in making magnetic steel bars and high speed tool steels.

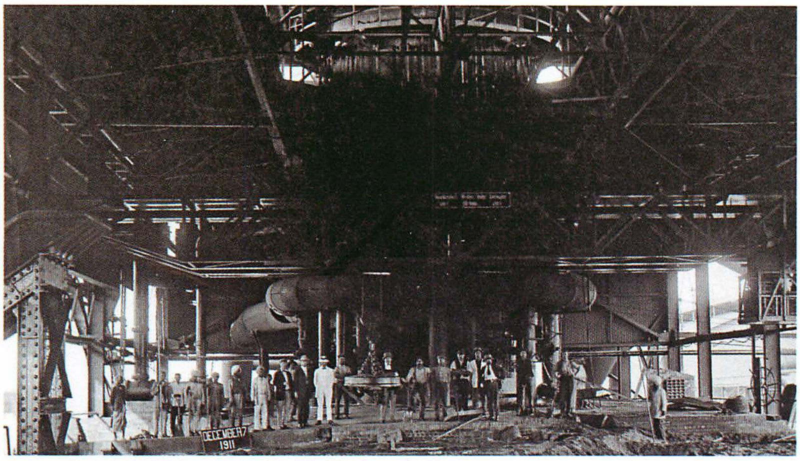
Verrier Elwin

According to Verrier Elwin in his 1958 book, "The Story of Tata Steel", the company's achievements in the production of high-speed steel faced as much opposition as the earlier battle for the acceptance of Tiscrom for the Howrah Bridge. There is a story of a responsible technical officer of the Government, at first one of TISCO's severest critics, who put the company's high - speed steel product to a series of exacting machining tests. He was amazed at the results, repeated the tests again and again and finally became an enthusiastic advocate of the TISCO steel.

Indeed, the Second World War had triggered a tremendous spurt of creativity at Tata Steel's fledgling Control & Research Laboratory. This enabled the company to make a rich variety of vitally important alloy steels for shear blades, machine tools, parachute harness and even razor blades. An interesting side-line was the production of mint die steel. In the War days, there was a great shortage of small coins and it was decided to meet this by expanding the capacity of the Bombay Mint. Since imports of steel for the dies could not be done due to unsafe seas, Tata Steel's researchers got busy and soon produced a steel which ultimately met all requirements. This may be the first attempt at the manufacture of quality tool steel in India.

The global steel industry has become highly energy and resource efficient as a result of sustained technological improvements over many decades. Tata Steel has led the way in India. Its sustained efforts in R&D and its scientific approaches to operational excellence have created world class iron making operations, despite deficiencies in the locally available raw materials.

The logic to locate the steelworks of Tata Steel at the remote tribal outpost of Sakchi, later called Jamshedpur, was the unique proximity of abundant deposits of iron ore, coal and limestone. However, the plant also had to contend with two fundamental drawbacks: a high ash content in the coking coal and a high alumina content in the iron ore. Both are detrimental to the productivity and efficiency of the blast furnaces that produce the liquid iron or 'hot metal', as it is called in the industry.



The first blast furnace (1911)

For the past 75 years, Tata Steel's researchers, scientists and their colleagues in operations have jointly fought an inspired and committed battle on a number of fronts to overcome these deficiencies. There have been a number of ups and downs, but Tata Steel has managed to achieve a high blast furnace productivity and low hot metal cost with the available domestic raw materials.

Tata Steel's researchers first turned their attention to the quality of coke, which arguably is the most important factor in a stable blast furnace operation.

There are many ways to characterise coke quality. Though all of them are relevant in some respect, the coke strength after reaction (CSR) and the ash content in the coke are amongst the decisive factors. A high ash content and a poor CSR were seen as the key reason for low blast furnace productivity in Jamshedpur.

The ash content of coal from Tata Steel's West Bokaro mine varies from 30 to 35%. This ash content is very high. However, a washing process for the as-mined coal is now able to reduce the ash content to between 12 to 15 % and yet give a clean coal yield of 35 to 40 %. This process was not achieved overnight but was perfected through extensive research and development spread over a decade.

For example, a new dense medium cyclone was introduced to reduce ash from the coarse coal and also a floatation process was adopted for beneficiation of coal fines. This resulted in a clean coal ash level of 17% during the 1980s. Subsequent investigations were conducted to reduce the ash further, including changes in the design of dense medium cyclones, the use of better quality dense medium magnetite, the use of a viscosity modifiers in the washeries, etc. Also the organic frother in the floatation cells was replaced with an improved synthetic frother and seam-wise treatment of coals all helped to improve yield with better control of ash. Finally, a new Tata-JK Dense Medium Cyclone was developed and is being trialled for treating fine coals.

At present, the R&D division of Tata Steel is also pursuing two very novel coal washing technologies based on chemical beneficiation. These new technologies hold the promise to produce clean coal with only 8% ash at double the present yield of clean coal. The seed for these developments was sown in 2006 when Tata Steel's management, headed by then Managing Director B Muthuraman, looked for solutions to increase the productivity of captive mines amidst rising prices and demand. If successful, the technologies will bring down the need for costly imported coal and double the usable coal output from the Tata Steel's mines in West Bokaro and Jharia.

Chemical beneficiation involves the addition of various chemicals to separate ash from the rest of the coal using multiple reactors. In 2007 researchers conducted more than 100 different experiments inside the laboratories in Jamshedpur. The purpose was to find suitable chemicals using only a few grams of coal each time. Five patents were filed based on these laboratory results. The next step was to build a small working prototype in the laboratory to determine the most effective and efficient concentration of chemicals, reaction times and other process conditions. Again five patents were filed during this stage.

From these humble beginnings the project has now grown into the largest project that is presently running at Tata Steel's R&D division. It has a team of 6 researchers and 20 support staff. Important advice and guidance is regularly solicited from visiting Scientists and contracting company.

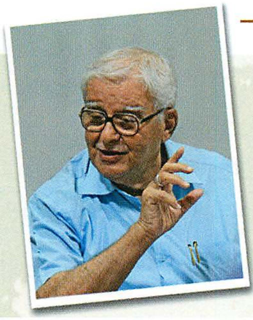
Semicontinuous pilot plant for chemical beneficiation of coal (2011)

This team has built a semi-continuous pilot plant with 500 kg batch size. It comprises of several process steps with different chemicals that selectively react with the coal. After this treatment, the coal is filtered and washed to get clean coal with low ash. This plant was commissioned in 2011 and is now operated round the clock to optimise process variables and to overcome key engineering challenges such as filtration, dewatering and regeneration of chemicals. Several unique solutions have been developed for the recycling of chemicals that have resulted in three more patents.

While chemical beneficiation is a technology that is presently still at its infancy, Tata Steel adopted another important coal technology- Stamp Charging - in the early 1980s. This technology had originally been developed in Germany and was studied, adapted and advanced in Tata Steel.

cokemaking at Tata Steel, but it was also likely to produce much better quality than the top charging process that prevails worldwide.

Based on the above findings, it was decided to progressively introduce stamp charging in the coke oven batteries at Tata Steel. The first blend used was 25% captive prime coking coal, 57.5% captive medium coking coal and 17.5% imported prime coking coal. However, this blend encountered problems with frequent hard pushes in the coke batteries. Detailed investigations in a small lab-scale coking oven concluded that the blend needed to be changed to 80% indigenous medium coking coal and 20% imported prime coking coal. This resulted in a remarkable improvement in the shrinkage behaviour of the coke mass and hard pushes were reduced considerably without adverse impact on coke quality.



" A very significant turning point in the cost of making steel in Tata Steel was the adoption of stamp charging in the coke making process."

- Dr. J J Irani, Managing Director of Tata Steel from 1992 to 2001.

Coking coal comprises only 15% of India's 200 billion tonnes of coal reserves, 80% of the coking coal reserves are of the medium coking type. During the late 1970s and early 1980s the R&D Division of Tata Steel carried out extensive tests to maximise use of domestic medium coking coal for cokemaking. They evaluated various pre-carbonisation technologies such as partial briquetting, selective crushing, pre-heating and stamp charging. A pilot plant of 600 kg capacity with state-of-the-art measurement facilities was built for carrying out studies. It was clearly demonstrated that stamp charging was not only the most appropriate pre-carbonisation technology for

Another challenge associated with stamp charging is that the stamped coal cake must have enough stability to prevent breakage during transport from the stamping machine to the coke oven chamber. Intensive studies by R&D established that it is essential to maintain a specific coal crushing fineness, moisture content and stamping energy.

During subsequent years, many further changes were made to the coal blend as part of a journey towards lower operating costs. It resulted in lowering of coke ash by 1% without impairing either the coke quality or the shrinkage characteristics of the coal cake.

Additional developments were made by incorporating lower cost non-coking coals in the blend, studying the impact on the yield of by-products such as coal tar and coke oven gas and by introducing new laboratory tests.

Pilot scale sintering facility at Tata Steel R&D

Tata Steel's strategy to adopt stamp charging for coke making in the early 1980s maximised the use of domestic coking coals and played an important role in the competitiveness of ironmaking at Jamshedpur. It has also proved to be very prescient considering today's high prices for globally traded coking coal. The impact of this technology in terms of reduction of coke rate and increase in productivity in blast furnaces has been significant and, considering the diminishing global stock of prime coking coals, we may expect that such pre-carbonisation technologies are likely to gain worldwide popularity.

When iron ore is mined it typically generates a mixture of lumpy iron ore rock and iron ore fines. Lumpy ore can be used directly in the blast furnace, while iron ore fines have to be agglomerated either in sinter plants, which fuse the fines into a single porous mass, or in pellet plants, which form small iron ore balls that are subsequently baked.

Tata Steel's association with sintermaking started in the year 1959 with the construction of India's first Sinter Plant. This plant initially produced sinter that was of such poor quality that the blast furnaces considered it as a necessary evil. The use of limestone to improve sinter quality started in 1968 and dolomite was also added in 1978. Several other developments during the mid 1980s significantly improved blast furnace productivity.

With sinter in limited supply, the proportion of sinter in the burden dropped to 30% and a need to increase the percentage of sinter was felt. However, the presence of high levels of alumina in the iron ore fines (typically 5% Al_2O_3) posed a problem to maintain the quality of sinter. When too much alumina is fed into the blast furnace, the blast furnace slag tends to become very viscous, which is detrimental to blast furnace permeability, drainage and productivity.

A vital breakthrough came in the form of 'blue dust', a material that was earlier considered to be an unusable reject. It is very fine ore that is rich in iron (67%) and low in alumina (<2%). It appeared to be ideal to be blended with high alumina iron ore fines. However, the small size of blue dust particles (35% below 0.5 mm) caused concern due its adverse impact on sinter bed permeability and productivity.

At this juncture, R&D conducted detailed pilot scale sintering experiments and concluded that up to 40% blue dust can be blended with ore fines. These results were confirmed by plant trials and, with the commissioning of the second sinter plant at Tata Steel in 1989, it was decided to use blue dust for the first time. This marked the beginning of a new era in sinter quality and, with more sinter available from both the sinter plants, the proportion of sinter in the blast furnaces increased to 50% in 1990 and 63% in 1992.

When using blue dust, the lime content in sinter had to be decreased and subsequently silica addition was also discontinued. The resulting rising sinter basicity now negatively affected the high temperature properties of the sinter. It was therefore decided to study the use of olivine, a magnesium silicate rock that was commonly used abroad. However, instead of using imported olivine these investigations concentrated on locally available dunite and pyroxenite; both are types of magnesium silicate rocks from the Dodkanya and Sukinda mines in India.

Dunite was found to be most suitable and subsequent plant scale trials at Sinter Plants #1 and #2 concluded that sinter quality and productivity were not adversely affected. Thereafter, Tata Steel completely replaced dolomite with dunite, becoming the first in India and one of the very few in the world to do so.

In the late 1990s, another special initiative titled 'P40' was undertaken in order to improve the gross sinter productivity by 50%, from 27 to 40 tons /m^2/day. As part of this project, R&D conducted several pilot scale and plant scale trials at Sinter Plant #2 to optimise the ignition intensity, to improve the granulation of sinter mix and to minimise air leakages into the sinter machine. These initiatives combined with other improvements at the sinter plant ensured that this challenging goal was met.

Keeping in line with company's environmental objectives, R&D has recently investigated ways and means to reduce solid fuel consumption and to increase the consumption of reverts and rejects during sintermaking. Pilot studies and plant trials revealed that up to 1% reduction in solid fuel usage is possible without compromising on the quality of sinter. Laboratory trials also established the technical feasibility to replace up to 20% of high quality iron ore fines by low quality and mostly unused banded hematite jasper ore.

In the same period when blue dust was adopted as a measure to reduce the alumina in sinter, various other studies were also underway to lower the

'Ultrafine beneficiation' team receiving the Tata Innovista award in the 'Promising Innovation' category (April 2010)

A recent R&D project in the field of iron ore beneficiation contributes to Tata Steel's strategy to realise complete beneficiation of all mined iron ore, and will maximise the sustainable use of iron ore deposits. This project develops a new technology to recover iron from so-called iron ore slimes; a slurry of water and ultra-fine iron particles, typically below 20 micron particle size. This slurry is presently an unused by-product of mining operations as it cannot be processed by today's beneficiation technologies. This technology won the coveted Tata Innovista award in the 'Promising Innovation' category in 2010.

alumina content of the feed ore by beneficiating the ores at the mine site. Through a series of experiments in the late 1980s and early 1990s, it was shown that the alumina content could be reduced by a combination of washing iron ore lumps and jigging iron ore fines.

The experiments conducted both at R&D and at KHD HumboldWedag in Germany showed that one percent alumina reduction with 75% iron yield was technically feasible. Based on these results, an iron ore jigging plant was installed at the Tata Steel's Noamundi ore mines. These initiatives to decrease the alumina in sinter have reduced the generation of blast furnace slag from 330 to around 280 kg/tonne of hot metal in 15 years. This has had a substantial impact on blast furnace energy efficiency and productivity.

In recent years R&D developed a novel technology to process ultra fines consists of advanced versions of a hydro cyclone, selective flocculation and flotation. After successful pilot experiments this new process is now planned to be built and commissioned at the mine site. It is expected to recover up to 50% of the ultra-fines iron ore in the form of a usable iron ore concentrate with 2% alumina.This development is part of a future trend in ironmaking technology.

Today, mechanised mining, sizing of iron ore and iron ore beneficiation are increasingly being used in India. A side effect is that more iron ore fines and ultra-fines are being generated. The ability to use such fines in sintermaking is limited and, for reasons of sustainability, it is therefore desirable to introduce processes to capture and agglomerate such fines. Pelletising is globally the most used process to agglomerate iron ore fines that cannot be used in sintering. In 2012, Tata Steel has commissioned a new 6 million tonnes per year pelletising plant using the latest technology from Outotec of Germany.

But, pelletising with Indian ores poses specific challenges. For example, their high alumina demands more energy during firing and also deteriorates pellet quality. R&D is therefore building a state-of-the-art pilot pelletising and pellet testing facility for future developments in agglomeration technology.

Besides dealing with problems related to raw materials, Tata Steel's R&D and Scientific Services has also contributed significantly to developments in other aspects of iron making. For example, Its researchers have used various scaled-down models of blast furnaces to experiment with new methods of burden distribution. A scaled down model of D blast furnace was first used in 1981 to design moveable throat armour and to optimise the radial distribution of the burden. Over 200 different trials were performed using 1500 tonne of materials. Similar models at a 1 to 10 scale were subsequently built. They were made of toughened glass allowing actual visualisation of the material flows.

The G blast furnace is Tata Steel's first large Blast Furnace and equipped with the Paul Würth bell-less rotating chute charging system. Before commissioning this furnace, R&D carried out studies using a full scale model of this furnace to gain

"The foundation of my career in Tata Steel was laid in the R&D/SS Division. As Senior Metallurgist Blast Furnaces, I got the real feel of the complexity of iron making! This helps even now. "

- Mr Anand Sen, VP
Total Quality Management and Shared Services

Toward Low Ash Coal

Tata Steel R&D is concurrently working on the development of two new technologies to remove ash from high-ash Indian coals. One development selectively dissolves and removes these non-energetic minerals using chemical leaching. The other development uses solvents to dissolve and separate the energy-rich carbonaceous part of coal.

In 2011, Tata Steel R&D demonstrated in the laboratory that the solvent route can reduce the ash content from 30% to 4% (or less) with a carbon yield of 80%. It more than doubles the performance of conventional physical beneficiation technology that uses crushing, sieving, washing, etc.

A chemical process would normally be substantially more costly. Reasons are the energy intensive regeneration of solvents using distillation and evaporation and the stringent environmental norms. However, the R&D team has discovered various innovative approaches to optimise the energy efficiency and reduce solvent loss, while further developments are underway to achieve zero solvent loss.

The R&D team presently operates a bench-scale pilot plant that processes 20 kg of coal at a time. It has again shown very encouraging results. The next phase is due to start in 2013. It will involve the construction of a continuous pilot plant with patented tailor-made equipments and a process control system according to in-house design.

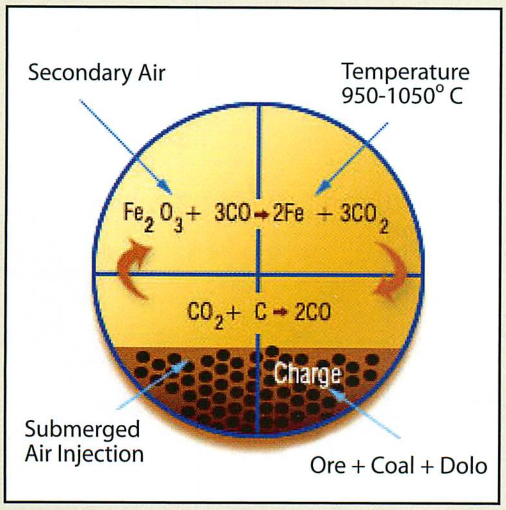
The potential of this process is not only to reduce the ash content in coke and thereby improve the efficiency and productivity of blast furnace ironmaking. The process can also be used to produce liquid fuel from coal or to create value-added carbon products, such as carbon composites, from mine tailings.

Refining evaporator and distillator in the Organo-refining pilot facility at Kolkata understanding of burden distribution and burden movement when using this new technique. Also the hearth of the G blast furnace was simulated using a scaled-down physical model. Here the impact of various hearth and taphole parameters on the drainage was established. Several of these works were complemented by mathematical models derived from first principles.

Proper charging is an essential element of stable blast furnace operation at high productivity and efficiency. On 10th December 2010, a team from R&D in Jamshedpur and Tata Steel Europe also successfully deployed an advanced trajectory probe to measure path of burden materials when being charged in the blast furnace. This new probe, an invention by researchers in Tata Steel Europe, can be regularly used even during short stops and is a clear improvement over previous measurement systems, which could only be used once during the start-up of a blast furnace.

The search for better iron making is an ongoing process. Future challenges for researchers lie in such areas as reducing the carbon footprint, smelting reduction, use of non-coking coal, full process automation, etc. Tata Steel's R & D division is gearing up to meet these new objectives.

Probing the Blast Furnace using an advanced material trajectory probe (2010)



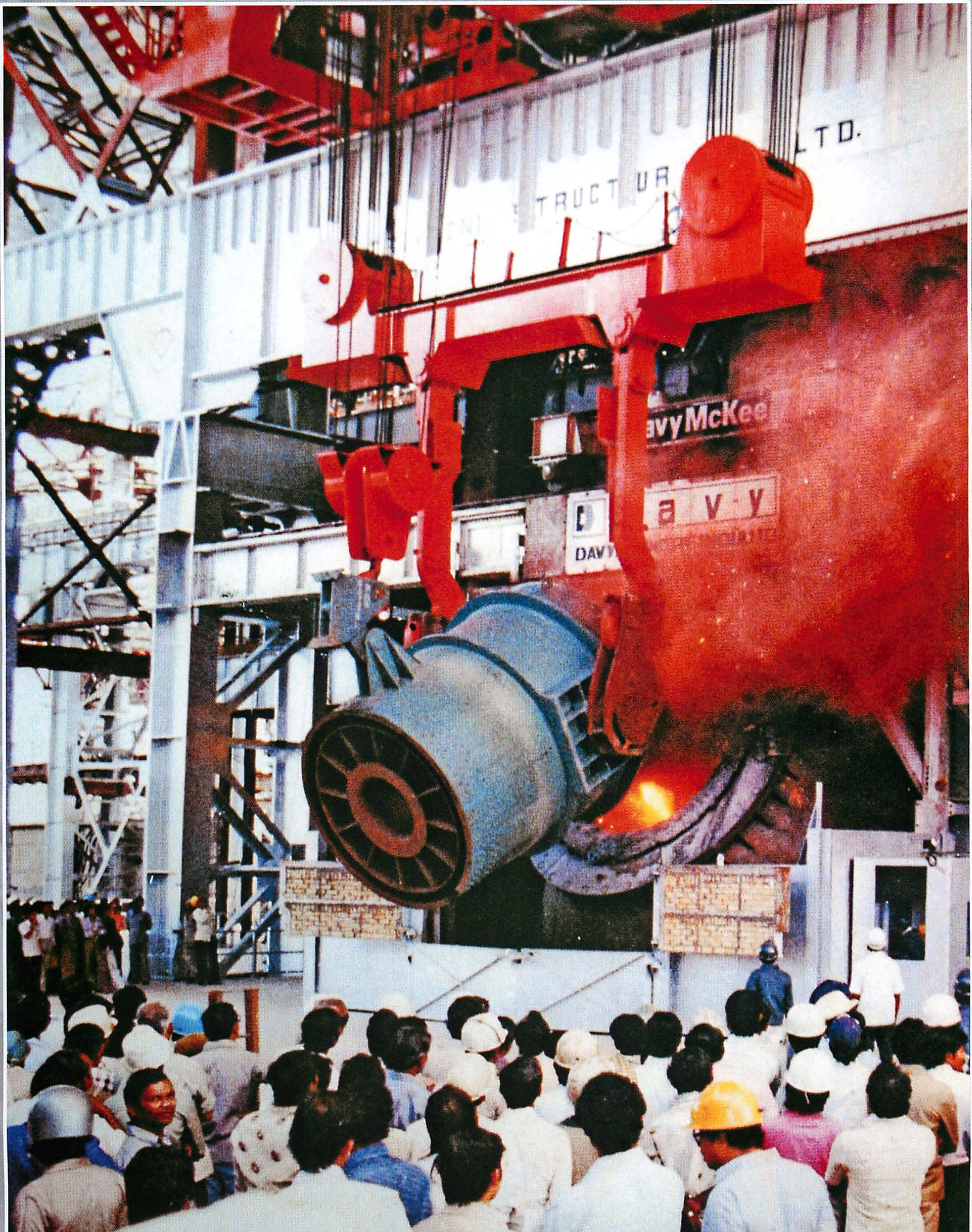
Cross-section of Rotary Kiln

TISCO Direct Reduction (TDR) Technology

In early Seventies, the mini steel plant route was envisaged to quickly escalate steel production capacity in India. Tata Steel R&D took an active interest in developing a coal-based direct reduced iron (DRI) process. The process uses an inclined rotary kiln reactor. The rotation of the kiln, coupled with the inclination, imparts a forward motion to the charge towards the discharge end. The charge, consisting of iron ore and non coking coal, while traversing the kiln length at high temperature, undergoes two simultaneous reactions, viz., gasification of the coal and reduction of the oxide ore. The oxide ore thus gradually gets converted to the lower oxides and finally, to the metallised product, DRI (90 - 95% iron). However, the hot product from the kiln also contains coal char and ash and these being nonmagnetic, are separated from the product DRI (magnetic) by magnetic separation. Before magnetic separation, the hot kiln-discharge product is cooled to about 100°C, usually in a rotary cooler, indirectly cooled by water.

Based on fundamental modelling studies, the R&D Division of Tata Steel put up a pilot plant of 10 tonnes per day of DRI. Extensive trials were conducted to optimise the process conditions and to determine the various operational issues related to the technology. All these concerted efforts led to the development of the TISCO Direct Reduction (TDR) process. Subsequently, the process was commercialized in IPITATA Sponge Iron Ltd.'s plant with 300 tpd capacity in the Keonjhar district of Orissa in 1982. The company was set up as joint venture between Tata Steel and the Industrial Promotion and Investment Corporation of Orissa (IPICOL). It became an associate company of Tata Steel in 1991 and was renamed as Tata Sponge Iron Ltd. The process won for Tata Steel, the Technology and Innovation award from the Confederation of Indian Industry in 1984 and awards galore for Dr. Amit Chatterjee, who was leading this technology development program at R&D Tata Steel.

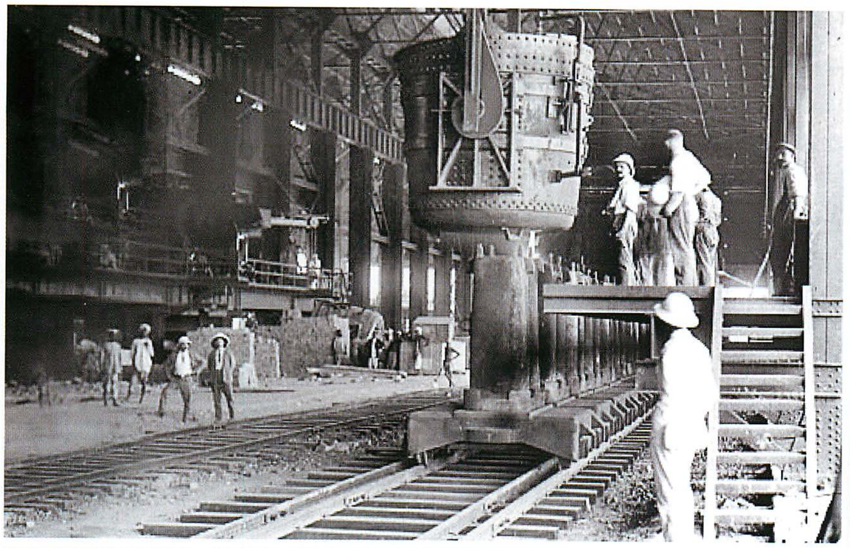
DSIR award for 'R&D efforts in Industry' in the Processing Industries Category for the TDR technology (1990)



The first LD Oxygen Steelmaking Plant in Jamshedpur (1983)

During the past 100 years of its existence, Tata Steel used a wide variety of processes for refining liquid iron into steel; and several different processes for casting Every change in process represented a major challenge, but the operations personnel succeeded in mastering the technology with the syncopated support of colleagues from the Research & Development and Scientific Services Division.

Tata Steel started its steelmaking journey with four 40 tonne stationary open hearth furnaces served by a 300 tonne hot metal mixer. In February 1912, the first steel was tapped. This enabled the company to make light rails, fishplates, rounds and flats, light angles, channels and beams.



First ingot casting steel from ladle into ingot mould, (2nd December, 1911)

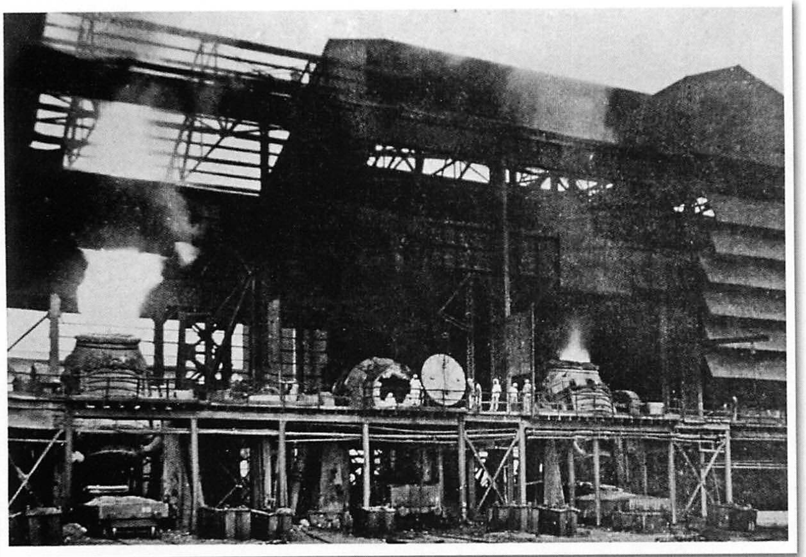
The new steel plant reached full capacity just when the First World War broke out. It caused a sudden increase in demand for steel and immediately plans were made to increase annual production to half a million tonnes of ingot steel. The company also decided for a major change in its steelmaking process.

Reports had come in of remarkable achievements by some American steel plants using a new combination of technologies. This Duplex process combined blowing hot metal in a Bessemer converter and then refining the blown metal in an open hearth furnace. While a single open hearth furnace took 10 hours for a heat of steel, this new process could do the same in just three hours.

Tata Steel decided to make the switch and adopted the Duplex process in the early 1920s. The steel grades produced with this process included medium manganese rail steel, high carbon steel, deep drawing quality steel, high tensile steel and high silicon steel.

During the early 1940s, Tata Steel's attention was drawn to the possibilities of the Perrin Process that was operated successfully by Ugine in France. It involved pouring partially refined steel into a highly oxidising basic slag and enabled rapid steel production at lower cost. Large scale experiments indicated that after some modifications the process could be employed under local Indian conditions. Steel Melting Shop 3 was designed accordingly and commissioned in 1958.

Around the same time, the Second World War broke out in Europe. It constrained imports of steel and Tata Steel was urged to produce wheels, tyres and axles to meet the requirements of the Indian Railways. The Perrin process was therefore modified to produce different steels needed for these products. The modified process was called a Triplex



A group of three Bassemer Converters at Duplex Plant (1928)

Process and involved a combination of an acid Bessemer process, a basic open hearth process and acid open hearth process. This endeavour turned out to be an outright success at the time. However, later experimentation and developments could prove that the basic open hearth process was also able to produce steels suitable for railway wheels and axles. The Triplex process was therefore abandoned in the 1950s.

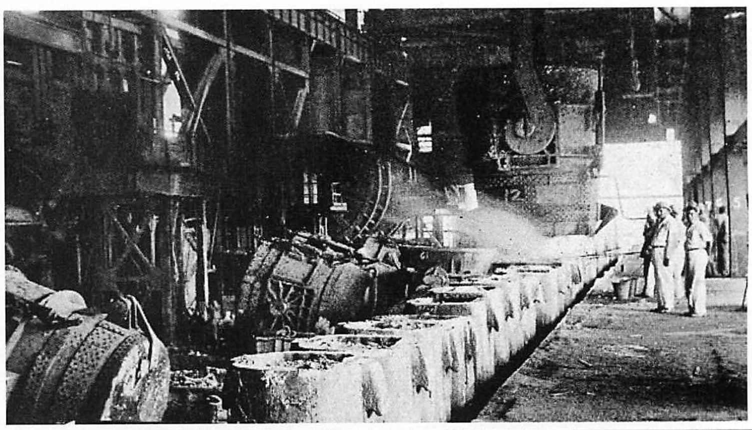
The period of the Second World War at Tata Steel was characterised by the development of a wide variety of ordnance materials and special steels for defence purposes. The central Control & Research Laboratory played a major role in these immense efforts. Today, samples of such ordnance materials can still be found in the basement of the R&D building in Jamshedpur.

This demand for urgent product diversification during the war years represented a big challenge for a Laboratory that had been established only a few years back. However, successful development projects and the investment in two small electric arc furnaces and a 500 kg high-frequency induction furnace allowed the company to produce new products, such as armour plates, alloy steels, tool steels, special steels and bars of stainless steel.

By 1956, the independent government of India launched a major industrialisation drive with its second Five Year Plan. Tata Steel was permitted to expand its annual capacity to 2 million tonnes of steel ingots. At the time, Tata Steel's management faced a major dilemma whether or not to invest in the new Linz-Donawitz (LD) oxygen steel making process, which originated from Austria. It was becoming the new technology of choice in Europe and seemed very attractive because of the lower equipment costs.

However, after actual trials at Linz in Austria, Tata Steel concluded that the process would be uneconomical in India. A key reason was that the locally available refractory materials were not expected to last long enough under the severe process conditions. Another deterrent were the specifics of Indian raw materials that result in a high phosphorous content in the liquid iron and require specific operating practices during steelmaking.

Management at Tata Steel therefore decided to continue with the Duplex process. It was a hard decision for a company that was fully aware of the technological and competitive potential of oxygen



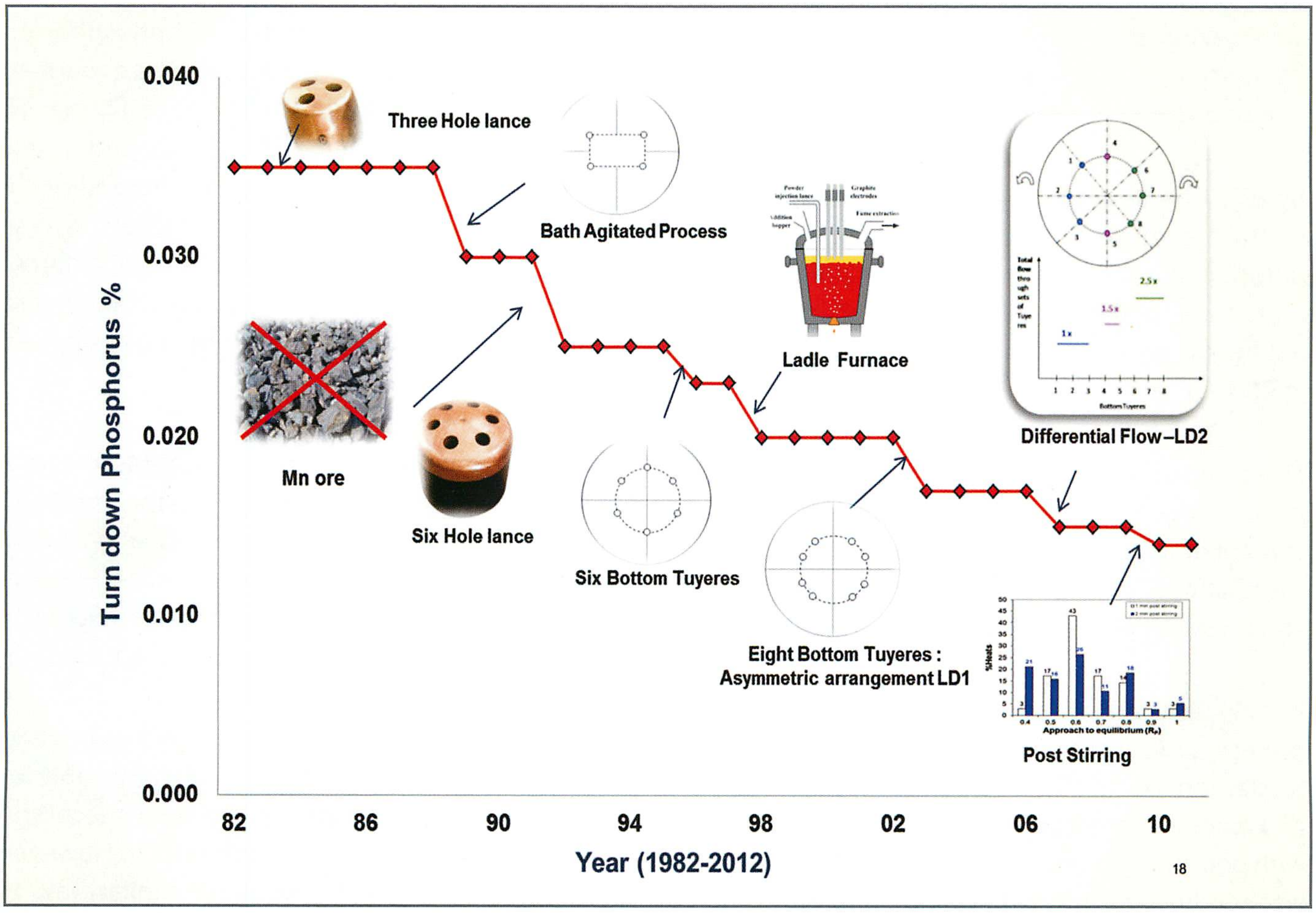
Duplex process adopted in (1928)

steel making. In the event, they proved to be right. The public sector Rourkela Steel Plant did adopt the LD steelmaking process in the 1960s, but faced enormous problems for the next 20 years, particularly regarding the life of the refractory lining of LD converters.

Ultimately, in its third expansion phase, Tata Steel did switch to oxygen steelmaking. Its first LD oxygen steelmaking plant (LD1) was commissioned in 1983 and had two LD converters of 130 tonnes capacity. LD2 was commissioned ten year later with the installation of two 130 tonne converters. One more converter was added later on.

Initially, the converters at LD1 only had an oxygen lancing facility whereby oxygen is blown from the top through a lance with a three-hole tip. This was not very suitable for the local raw materials and the resulting metal and slag. There were many problems such as higher phosphorus content in the steel (0.035 %), a higher slag volume, higher turndown temperatures, lower lining life, etc.

The Steelmaking Research Group of the R&D Division played a major role in tackling these problems. A large research programme was launched in 1990 using a water model of the LD converter. These investigations concentrated on the effects of various process parameters on the mixing and mass transfer in the converter. Researchers studied various bottom purging arrangements, such as Bath Agitated Process (BAP) and Thyssen Blowing Metallurgy (TBM), and studied their impact on productivity and steel quality. They also developed a new top lance with different holes in the lance tip. These experiments showed a need to make changes in the design of the converter and its operating practice. Two



The decades of reducing Phosphorus in liquid steel examples were the replacement of the old three-hole lance tip by a new six-hole lance and the asymmetric location of eight tuyeres at the bottom of BOF vessel at LD1.

The result was dramatic improvement. For example, the life of the converter lining in LD1 increased more that sevenfold; from 160 heats in 1983 to 1211 in 1997 and more than 2000 heats in 2002. This was a world-beating achievement for a lining made with tar bonded dolomite bricks.

At the time, conventional wisdom dictated that a highly basic steelmaking slag with 7 % MgO should be formed to protect the lining. By studying the fundamental kinetics and thermodynamics of the converter process, R&D discovered a different approach using a slag of less than 2% MgO. This new operating strategy eliminated the use of dolomite and manganese ore fluxes during steelmaking, thereby reducing production cost and creating more stable and reproducible operating conditions.

By 2005, the life of the dolomite lining life was raised further to more than 2300 heats as a result of introducing other tactics. Today the lining survives more than 5000 heats following the changeover to a different type of lining using Mag-carbon bricks in 2006.

Most Indian iron ores contain elevated levels of phosphorous. This increases the phosphorous content of liquid iron. It represents an extra challenge since phosphorous needs to be removed during steelmaking to create high quality ductile steels.

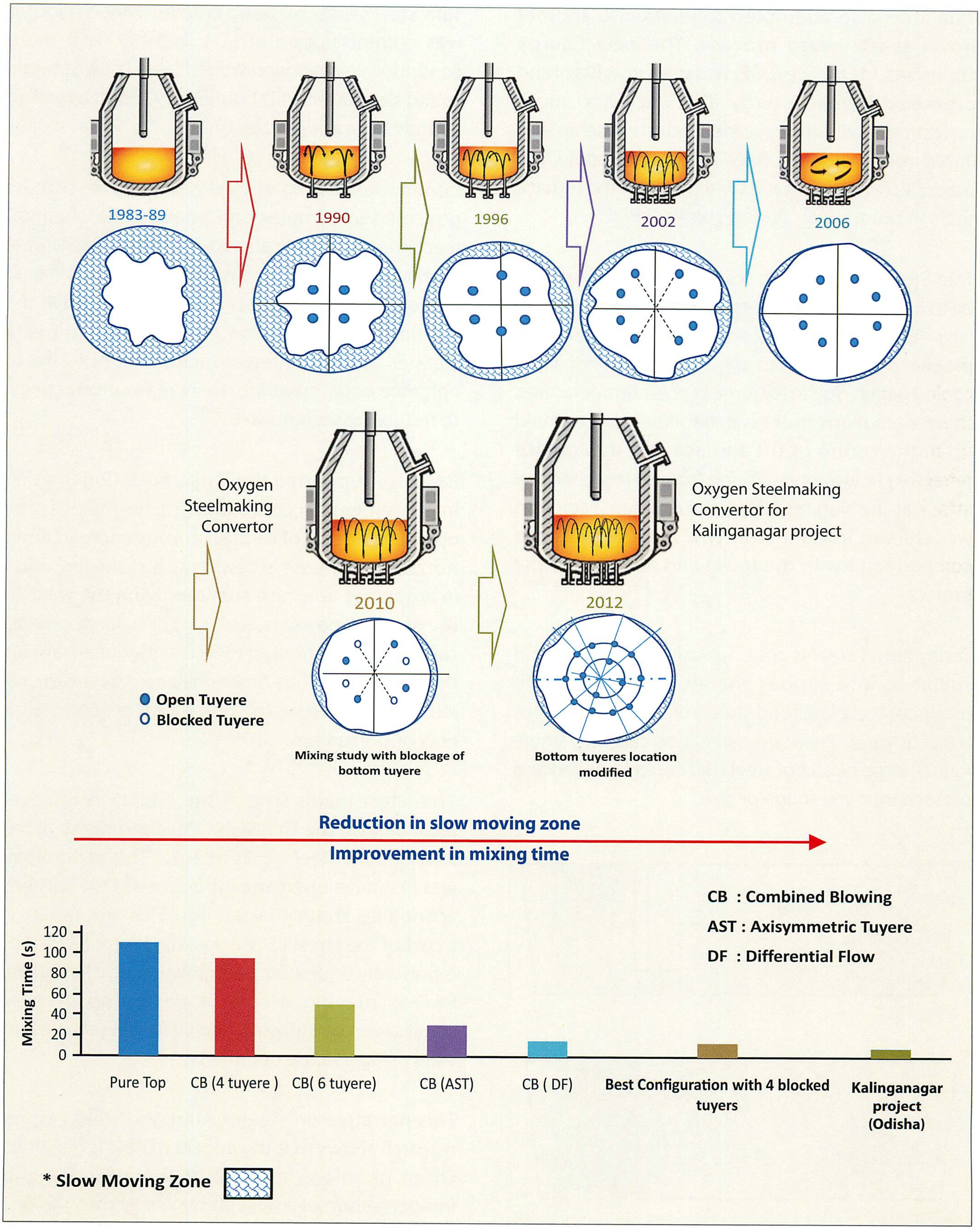
In 2004, R&D launched a new strategic development project to lower the phosphorus in steel. Its aim was to demonstrate the production of steel with a phosphorus content of below 0.015% from hot metal with phosphorus content of up to 0.22%. This project was conducted jointly with various foreign institutes and involved many colleagues in operations for conducting plant trials. New initiatives included the development and application of advanced knowledge of slag formation and the development of a novel approach for the injection of argon gas into the converter to improve the mixing of steel.

This new approach was called Differential Flow and uses non-uniform flow from eight injection points located in a symmetric pattern in the bottom of converters at LD2. A water model study showed that the differential flow of argon reduced mixing time by about 35% and increased mass transfer by 30% compared to conventional uniform flow. When implemented at the last part of a heat, differential flow also results in reduction of phosphorus content and saves consumption of costly argon gas.

Data analysis also showed that actual phosphorus partition in the LD converter is much lower than the thermodynamic equilibrium. This means that the reactions that allow the transfer of phosphorous from the steel into the slag are not fast enough to complete this task within the given time. To overcome this problem, R&D developed a new design of lance tip using water modelling in combination with computer models. These computer models allow the simulation of different process conditions and were developed by in-house specialists in advanced computational fluid dynamics.

The new lance tip has a central hole to create a subsonic oxygen jet that impinges on the steel bath. Its purpose is increase steel droplet formation during oxygen blowing to create intimate mixing of steel and slag. These new lance tips are currently undergoing trials at the LD plants in Jamshedpur.

Clearly, adoption of LD steelmaking technology and subsequent developments to make it amenable for Indian raw materials proved to be a successful indigenisation of a foreign technology. However, not all such ventures turn out in a similar way. In the mid-1980s, before putting up the LD2 steel plant,

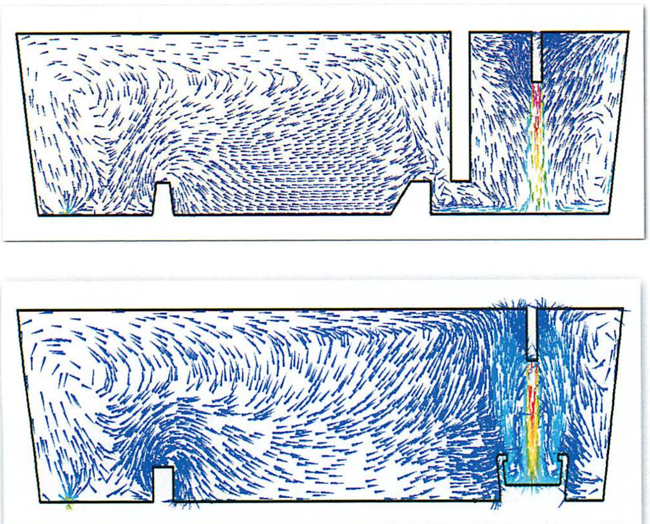


Reducing mixing time in LD Steelmaking using different bottom tuyere arrangements

Tata Steel also attempted to indigenise another novel steelmaking process. The new Energy Optimisation Furnace (EOF) was used in at Brazil and promised higher energy efficiency and more operating flexibility by using both steel scrap and liquid iron to produce steel. The furnace could also produce low phosphorus steel by tilting the furnace to flush out the slag during steelmaking.

Tata Steel attempted to scale up this process from 20 to 80 tonnes of steel per heat. Unfortunately, the large 80 tonne EOF faced too many intractable problems. Operators faced frequent failure of water cooled panels due to extreme process temperatures, there were many process instabilities due to build up in the centre of the furnace and the furnace refractory lining was suffering from severe chemical attack at the slag metal interface. When a solution was still not in sight after two years of trials, the company threw in the towel and abandoned the project.

Today liquid steel is continuously cast, cooled and solidified into various shapes, such as slabs to produce steel plates and sheets or billets to produce rebar or wires. Previously steel was cast into single ingots; large blocks of steel that could be rolled and pressed into any shape or size.



Numerical modelling of fluid flow in LD3 tundish with different flow configurations

Tata Steel's first six strand continuous billet caster was commissioned at LD1 in 1983. Two more continuous casters were added later. The first single strand slab caster at LD2 came in 1992 and two more strands were added later on.

Continuous casting of steel is an intricate process governed by complex flow phenomena, chemical reactions and solidification mechanisms. R&D at Tata Steel has carried out extensive studies to understand and optimise these processes. These included the optimisation of steel flow characteristics to create cleaner steel with fewer inclusions, but also to enhance equipment life, to increase productivity, to reduce losses, and so on.

R&D also supported the implementation of other improvements in continuous casting such as the optimum design of tundish and submerged entry nozzle, the increase in casting speed, the reduction in argon gas flow rate and improving the value in use of mould powders. Such complex developments can never be attributed to R&D only, but are always the result of various functions and teams working jointly to overcome existing problems and realise new opportunities.

The latest major step in the adoption of novel technology is the Thin Slab Caster introduced at the Jamshedpur steel works in 2012. This technology was first developed and introduced in the western economies about 10 years ago. This new facility is a part of the latest LD steelmaking plant (LD3) that is presently undergoing commissioning. Here again, R&D is playing a role in hastening process stabilisation by studying and visualising the flow of steel using a range of models.

This narrative on steelmaking and steel casting research shows that the impact of R&D is manifold. Often its role is to support the adoption and indigenisation of a novel technology that was first piloted outside India. Even then, the technical challenges are huge. Over the years, the steelmaking and casting research group of the R&D division has developed very strong modelling capabilities, both in physical water models and virtual models in the form of computational fluid dynamics. Also the chemical reactions can be predicted effectively using various types of software. With the development of ever more advanced computational models and the adoption of more accurate measuring techniques, we can expect new breakthroughs and see researchers thrive in this complex and exciting field of steelmaking.

Scaled down water model of the billet caster tundish at Tata Steel

Energy efficient ingots

Trapezoidal shaped pig iron ingot

Small and medium-sized steel foundries that have no access to captive ores are dependent on pig iron ingots that are mainly produced in mini blast furnaces. These foundries use cupola and induction furnaces to melt iron ingots. Mini blast furnaces are the main source of foundry grade ingots. Ingots that cool fast during manufacturing and melt faster in furnaces are desirable for higher productivity and help the customer to save energy. In 2010, Tata Steel R&D and Tata Metaliks, a leading company in the Indian pig iron industry with 16% market share, jointly launched a project to develop a new design of ingot that meets these requirements.

Researchers from Tata Steel R&D first used computer simulations to optimise the shape of the ingot. Through resistance network modelling and heat transfer analysis, a trapezoidal shaped ingot was found to take 25% lesser melting time than other conventional shapes. Experiments with wax ingots revealed that the new ingot design had the best packing density and a better distributed voidage compared to earlier ingot designs.

Use of this innovated ingot in an induction furnace can result in 13 minutes less melting time compare to a standard ingot, thereby substantially saving in electrical energy. In addition, product consistency at Tata Metaliks improved and spillage scrap was reduced. By re-designing the ingot, Tata Steel R&D helped Tata Metaliks to establish a new and differentiated product titled Tata eFee in a market that would otherwise driven by price alone.

In its infancy itself, Tata Steel had to focus its energies on providing a product - rails for the Indian Railways – which had never been made in India. The endeavour sowed the seeds of industrial research in the company. This interplay between meeting new market demands and R&D efforts. That has kept Tata Steel in the vanguard of steel product innovation in India.

Wire rod manufacturing at the Tata Steel Wire Rod Mill

Right from its inception, Tata Steel's primary goal was to create products that meet the requirements of customers in the Indian market. In the beginning, the nature of these products was largely dictated by the British colonial regime. In those days, being the only integrated steel plant in the East of the British Empire came with onerous expectations.

This particularly concerned steel products for the nascent Indian industry and the country's requirements for infrastructure, such as roads, bridges and railways. In fact, back in 1912 the very first products to roll out of the new steel plant were rails for the country's rapidly expanding railway network. Also the First and Second World Wars triggered a strong demand for steel. The earlier chapters in this book have already related this story in detail.

From the mid 1950s, India saw rapid and pervasive development of its infrastructure. These initiatives were led by the independent Government of India and particularly focused on the construction of dams as well as all-round industrialisation. Central themes in the government policies for Industry and Trade were technological self-reliance and import substitution dictated by the shortage of foreign exchange.

In 1960s, the Joint Plant Committee (JPC), an autonomous body constituted by the Government of India, governed the policies for pricing and distribution of steels produced in India. Unfortunately, the prices fixed by the JPC were so low that Tata Steel could barely generate enough profits to maintain its outdated equipment. Fortunately, special steels and alloy steels were kept outside the purview of JPC and their prices were determined only by market trends. This was an opportunity for an innovative company like Tata Steel, which by then had a well-established capability for research and development.

Management therefore initiated the development of new products to increase Tata Steel's profitability. This meant gradually changing the product mix to those steels with highest profit margin and also developing new special steels and low alloy steels that were not governed by JPC policies. These new developments included rimming steels with low residuals for the manufacture of wire rods for welding electrodes and also cold rolled steel strip and tubes for boiler applications. Also, various steels were identified that could still be produced with a good profit margin, despite being under the purview of JPC. Amongst these were LPG sheets, weldable steel plates, high strength billets and gothic section bars for the production of seamless tubes.

During the early 1970s, Tata Steel decided to diversify into special steel products for the engineering industry. The production facilities available then were basically suited for manufacture of mild steel grades. Several in plant operations therefore have to be modified. Examples are the augmentation of the bottom pouring facility, judicious use of hot tops, capacity expansion for controlled cooling and heat treatment, use of roller guides instead of friction guides in rolling bars and many more. New control practices were also introduced, such as rapid analysis centres at the steel melting shops. The use of the latest analytical techniques, including X-ray fluorescence, led to effective control of bath slag composition, steel de-oxidation and consistent steel quality. These laboratories are still part of the R&D and Scientific Services Division and continue to offer state of the art analyses for accurate quality control.

Under the government policy to stimulate import substitution, Tata Steel's R&D designed many new steel products and supported their successful commercialisation. The two decades from 1970 till 1990 saw a wide range of product introductions.

Low-Alloy High-Strength Structural Steels were developed and produced by quench and temper techniques using indigenously available ferroalloys. A pressure quench pilot plant was designed and built by R&D as a part of this programme. High strength steels in the range of 550 to 700 MPa with satisfactory ductility, weldability and notch toughness could be obtained using this technique.

During the mid 1970's micro-alloyed plates, sheets, strips and structural products were produced by refining the grain size of low carbon ferrite-pearlite steels with the use of small amounts of niobium and/or vanadium. Ferro-titanium, which was available in the country, was also used extensively to replace conventional imported ferroalloys. During the mid 1980s further modifications were made in the steelmaking operations, particularly the de-oxidation technology, in order to reduce the production cost of these micro-alloyed steels.

Steel tubes manufacturing at the Tata Steel Tubes Division

Extra deep drawing quality sheets were developed by treating low carbon steel with boron and titanium in order to improve formability and strain ageing characteristics. Also, cold drawn seamless tubes were developed for defence purposes. The specific process parameters were determined in close liaison with the research wings of defence establishments and about 1500 tonne of tubes were supplied.

Tata Steel also developed wear-resistant plates and closed die forged blanks. A new product called 'Tiscral' was sold in the form of plates and was the first wear-resistant steel produced in India. Close die forged blanks were designed specifically to Inter Steel Plant Standards. Tata Steel also met the requirement of the Indian Ministry of Defence for turret rings for the Vijayanta Tanks.

In addition, Tata Steel developed a wide variety of plain carbon and low alloy steel strip with a high degree of cleanliness. They were commercialised for a range of applications, such as hack saws, razor blades, springs, chains, etc. This almost completely substituted imported medium and high carbon steel strip. Other new steel products included extra low carbon steel in the form of plates and strip for applications in galvanising pots and magnetic relays.

During the 1980s, Tata Steel also attempted to develop an inexpensive lamination-grade silicon-free steel for fractional horse power motors. The steel was made with deliberate addition of manganese and phosphorus to increase electrical sensitivity. Boron was also added in order to reduce the detrimental effect of mobile nitrogen. However, because of inadequacy of the sheet and strip mills of Tata Steel, this grade could not be commercialised.

With new facilities available in Tata Steel, an array of new products was added to the basket of existing

The development of wire rod for CO_2 welding

MIG/MAG steel wire

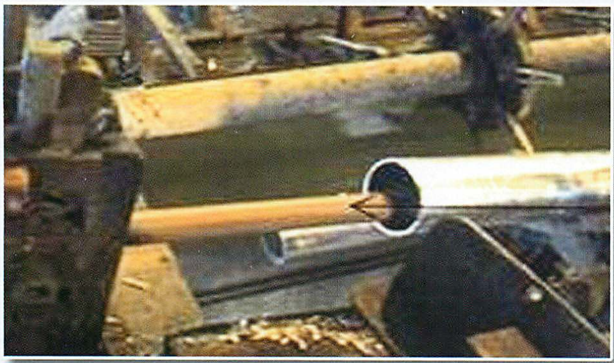
A typical example of a recent successful product development by Tata Steel R&D is the development of wire rods for direct drawing into CO_2 welding wire. At present more than 72,000 tonnes of this product is sold and this technology is protected through a patent that was granted in 2008.

The salient feature of this development was the design of a new steel with low carbon (0.07- 0.09%), high manganese (1.4 -1.8%) and a restricted nitrogen content (<50 ppm). The objective was to obtain a predominantly ferrite microstructure with suitable mechanical properties after processing through Tata Steel's wire rod mill in Jamshedpur. This chemistry enabled direct drawing from the wire rod to the final wire size without the occurrence of significant strain ageing.

Wire rod mill processing parameters like mill speed, laying-head temperature and Stelmor conveyor speed were determined by thermo-mechanical simulation experiments and deployed to attain the desired microstructure in the commercial product. The ferrite grain size was maintained at around 10 µm to meet the yield and tensile properties. Wire rods of 5.5 mm diameter were successfully drawn to 0.8 mm diameter without any intermediate operations of annealing and pickling, marking a major advancement in wire processing technology in India and resulting in lower cost and reduced environmental impact.

This example shows how a high level of expertise in steel metallurgy, lab experiments and plant trials come together to create a successful new steel product.

Reduction of zinc consumption in tube galvanising



Novel tube inner wiping system to remove excess zinc

The Tubes Division of Tata Steel manufactures high quality galvanised steel tubes whereby steel tubes are pre-treated and then dipped into a hot zinc bath. These tubes have a superior resistance against corrosion and are used in plumbing applications.

In 2010 it was noticed that the gross zinc consumption in tube galvanising was much above the benchmark value. This can be caused by non-uniform inner coating, excess dust loss or zinc dross formation. Excess consumption of zinc means a loss of a valuable raw material and results in higher costs.

A study was carried out to develop detailed understanding on zinc solidification in an industrial tube galvanising line. The entire process was simulated using computational fluid dynamics to predict zinc flow, heat transfer and the formation of a surface wave on the liquid zinc layer.

It was coneluded that zinc on the tube inner surface has already solidified along one third of the tube length before steam is blown through the tubes to remove excess zinc. The wavy coating profile that develops during steam jet blowing was also predicted and matched well with the measured profiles on actual tubes.

A solution was developed and implemented in the form of a new internal wiping system to remove excess zinc from the inner tube surface. This has generated a smoother inner tube surface and has decreased the gross zinc consumption by reducing zinc dust and zinc dross formation. The reduced zinc consumption now generates considerable cost savings each year.

products. Spring steel flats for automobiles, rolled-forged rings for the bearing industry, deep drawing quality steels in the form of strips for the cold rolling industry and the automobile industry, low alloy clean forging quality steels for crank shafts, gears and forged products for the engineering industry are some examples.

Through intensive research and very long periods of testing, creep resistant steel for use in boilers was developed and commercialised. Meanwhile, to meet the demands of railway axles in the country, the Railways had set up a Wheel and Axle plant in Bangalore. In a short span of four years, Tata Steel developed and supplied for 70% of the demand of low hydrogen steel for axles made in that unit. Tata Steel also supplied over 5000 tonnes of seamless bars to discerning customers like Bharat Heavy Electricals for the production of seamless tubes for boilers and other applications.

During these years, the product offerings from Tata Steel grew richer and richer as more and more market segments were identified. Corrosion resistant rebars, long and cross members for medium and heavy commercial vehicles, steel for automobile wheels, clean steels for the bearing industry were some relevant examples.

However, this rampant diversification of Tata Steel's product portfolio came to an abrupt end. In 1991 India was bailed out from a foreign exchange crisis and the International Monetry Fund and World Bank forced the Indian Government to open up the economy and remove a host of industrial and trade restrictions.

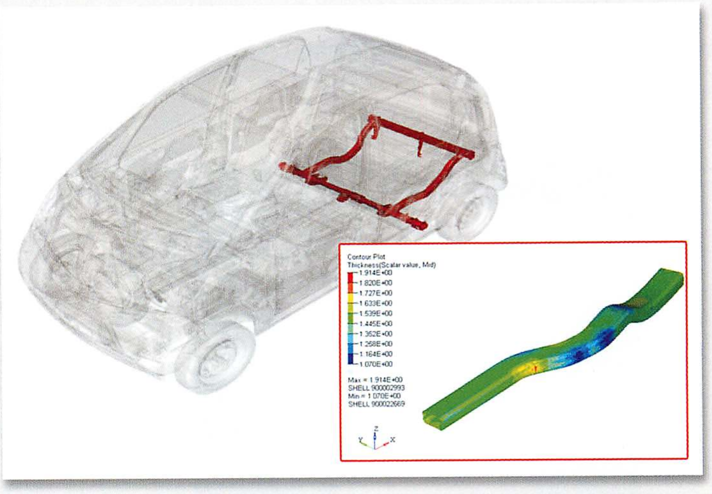
Import substitution was no longer a holy cow. For a private company like Tata Steel these new freedoms were a welcome relief in operational terms, but also a fresh challenge as it had to stand up and compete with imports from top international steelmakers. At the same time, the Government's own steel plants had become well-established and were in a position to compete keenly. All this meant that Tata Steel had to deploy new competitive strategies including a rationalisation of its wide product portfolio and a focus on core competencies in selected markets.

Changing rules for foreign direct investment resulted in the advent of multinational manufacturing giants into India, particularly in area of automobiles, auto components, electrical engineering, electronics and domestic appliances. This gave a boost to economic growth resulting in a growing population of middle class consumers with demands for the latest consumer goods.

One such newcomer was the Suzuki Motor Corporation, a major Japanese carmaker. During the 1980s it established a modern car manufacturing plant near Delhi in a joint venture enterprise with Maruti Udyog Ltd. and the Government of India. Initially, Maruti had to source steel from Japan as the Indian steel industry could not meet the quality requirements. Indian steel mills had not yet mastered the technology to make the light alloy high strength steels that the Japanese manufacturers preferred for their lightweight and energy efficient cars.

As the leading alloy and special steel producer in India, Tata Steel took up the challenge to meet

Reducing the weight of Tata Nano with hydroforming technology



One of the primary challenges in automobile design is to reduce the vehicle weight with improved structural performance, thereby improving both fuel economy and crash safety. Tube hydroforming is an advanced technology to form complex components that are structurally stiff, strong and lightweight. These are can be used in the structural parts of a vehicle body.

The process involves the use of a specialised type of die whereby high pressure hydraulic fluids are injected inside a steel tube to shape it into the desired form. It can produce complex components in one processing step, thereby preventing stamping and welding of multiple components.

However, a hydroforming component needs to be designed by specialists in order to take full advantage of the process. When Tata Motors took up a challenge to develop and produce the Tata Nano, the world's most affordable car, Tata Steel supported this initiative through design, development and manufacturing of a hydroformed engine cradle component. The design made by the joint team resulted in 26% weight reduction and 22% cost reduction compared to a cradle produced through conventional means. Tata Steel R&D now offers these hydroforming design solutions to premier automotive customers.

Maruti's needs. By then, Tata Steel had already geared up new production facilities like oxygen steel making, continuous casting and a hot strip mill that could provide the required quality of steel. It was also in the process of setting up a modern cold rolling and galvanising mill in collaboration with Nippon Steel, a major Japanese steelmaker.

While Tata Steel's R&D was investigating how to consistently produce the required steels, its sales engineers were working with Maruti's indigenisation team and provided quick and valuable feedback on the performance of the new products provided by Tata Steel. In the end Tata Steel was able to meet Maruti's needs of special steels and also that of its own sister concern, Tata Motors that had just started producing cars too.

By the time that Korean, German and American car manufacturers entered with automobile plants in India, most of their steel needs could be met by Tata Steel and a few other Indian steel producers. This successful localisation of steel supplies in an important factor creating a globally competitive car industry in India.

DSIR National award for 'R&D efforts in Industry' in the New Materials category for developing high strength steel for auto body (awarded to Tata Steel 2001)

This drive was also extended to the Indian two-wheeler and three-wheeler sectors. For example, Indian two wheeler manufacturers used to make petrol tanks with imported materials such as Terne coated and electro-galvanised steel sheets. In 2003, Tata Steel developed a corrosion resistance chromate coating on galvannealed steel sheet and replaced the above products with superior performance.

In another such instance, low carbon low alloy steel strip has been developed for Bajaj Auto. Compared to conventional grades this steel possesses more than 50% higher yield strength and 35% more tensile strength, both in welded and normalised conditions. Because of its higher strength, thinner gauge strip can be used for making tubes, which reduces tube weight by 20% and also creates superior dent and crash resistance.

Another product that was recently developed is a cold rolled batch annealed bake hardening steel. This grade undergoes a 25% increase in yield strength during commercial baking of the paint in automotive body shops. It allows a 20% decrease in thickness of car body panels, making cars lighter and more fuel efficient.

The development of such greener steel products is a strong and ongoing trend. India, as it industrialises further, has entered in the most energy-intensive phase of economic growth. This will continue to bring investments in industrial equipment, infrastructure and transportation methods for raw materials, goods, energy and people.

The steel industry in India is expanding to meet the resulting growing demand for steel. The average steel use per capita in India of 50 kg per year is presently well below international average and is set to rise substantially in the forthcoming decades. At the same time, it may be expected that Indian steel use will never rise to the consumption patterns as presently seen in some developed economies (500 kg per capita per year). Reasons being the development of new types of advanced high-strength steels that enable lighter manufacturing and construction.

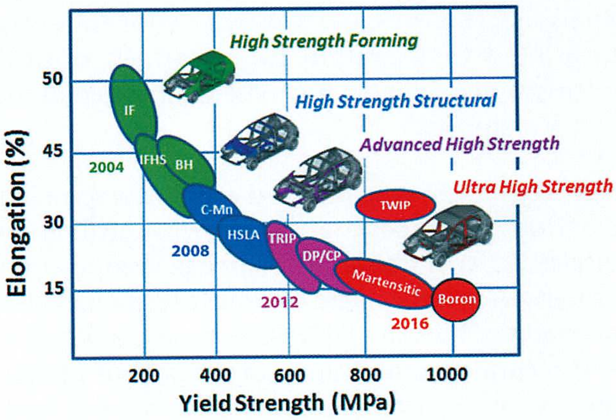
This trend is particularly evident in the development of new steels for lighter and safer car bodies; similar trends exist in light-weighting packaging, engineered equipment, buildings, etc. Tata Steel is technologically leading such trends in India and is thereby supporting India to emerge as the worldwide manufacturing hub for the ultra small and fuel efficient cars.

Tata Steel's R&D has already invented some interesting possibilities for new advanced grades, such as a high strength interstitial free steel using solid solution strengthening elements such as manganese and phosphorus, a high strength non-microalloyed galvannealed steel using carbon and manganese as strengthening elements and a new precipitation-hardened high strength hot rolled sheet with a ferrite matrix and nanometre-sized precipitates. The latter also has a high fatigue resistance and is being developed for long members of a future range of trucks produced by Tata Motors.

It is not just the automobile industry that R&D targets for its new product developments. For example, low carbon steel using boron to cause lower work hardening by causing coarse grain ferrite micro-structures developed for making ERW tubes for town water transport and replaces the more expensive FM tubes. New coatings are being developed for steel which employ polymers and nanoparticles of silica, titania and alumina to replace expensive zinc and harmful hexavalent chromium.

Developing advanced high-strength steels

Developments in automobiles are driven by four key factors: fuel efficiency, eco-friendliness, safety and cost. To meet these trends, research is underway to develop advanced steel grades with a combination of high strength and high ductility. Components made from such steels are light, strong and stiff, with a high capability to absorb energy in the event of a crash.



Development of advanced high-strength steel grades requires novel steel chemistries and very specific processing parameters so that the optimum combination of properties is achieved without adding very expensive alloying elements.

Tata Steel's R&D has defined a technology development roadmap until 2012. This plan includes the development of a high strength steel for automotive applications with a strength of 1000 MPa and 50 % elongation. Today no steel manufacturer as is able to meet this target.

As part of this development programme, R&D has already developed hot rolled steels of 600 MPa and 800 MPa strength, which have been commercialised. Further efforts are underway to develop a family of new generation high strength steels such as high strength 1200 MPa bainitic steel grade with high ductility, a ultra-high strength TRIP assisted steel for crash and structural components and several nano-precipitate strengthened steel grades with a combination of high strength, high ductility and superior weldability. Alongside, Tata Steel R&D also works on the development of durable hybrid joining techniques, so that complex car components can be formed out of multiple steel grades.

75 years of microscopy

The microscopic characteristics of steels and its raw materials, such as ore and coal, determine their macroscopic physical and chemical properties. Optical Microscopes and other microscopy systems have therefore always been important tools for material characterisation in the R&D and Scientific Services Division. Throughout its 75 years, the Division has continuously augmented its capability in this field. We hereby recall the developments in the past 20 years.

In the late 1990s there were several investments to improve the materials characterisation laboratories. An ISI 40 scanning electron microscopy system was acquired and the optical microscopy systems were enhanced with an image analyser attached with 36 mm photographic facility. These facilities provided black & white high resolution imaging, manual phase analysis and grain size measurement. Later a Zeiss Axio Plan optical microscope was also added with more sophisticated capabilities and digital image analysis. This microscope was subsequently upgraded to a system for polarized optical microscopy to identify the mineral phases present in raw materials.

Next, the old SEM was replaced with a new scanning electron microscope attached with an energy dispersive spectrometer for phase composition analysis. A manual micro-hardness tester had also been added. These facilities allowed the identification and accurate quantification of the various phases present in raw materials, sinter, refractory and steel. It allowed the operator to precisely identify the microstructure, to measure the hardness of individual phases and to digitally store images.

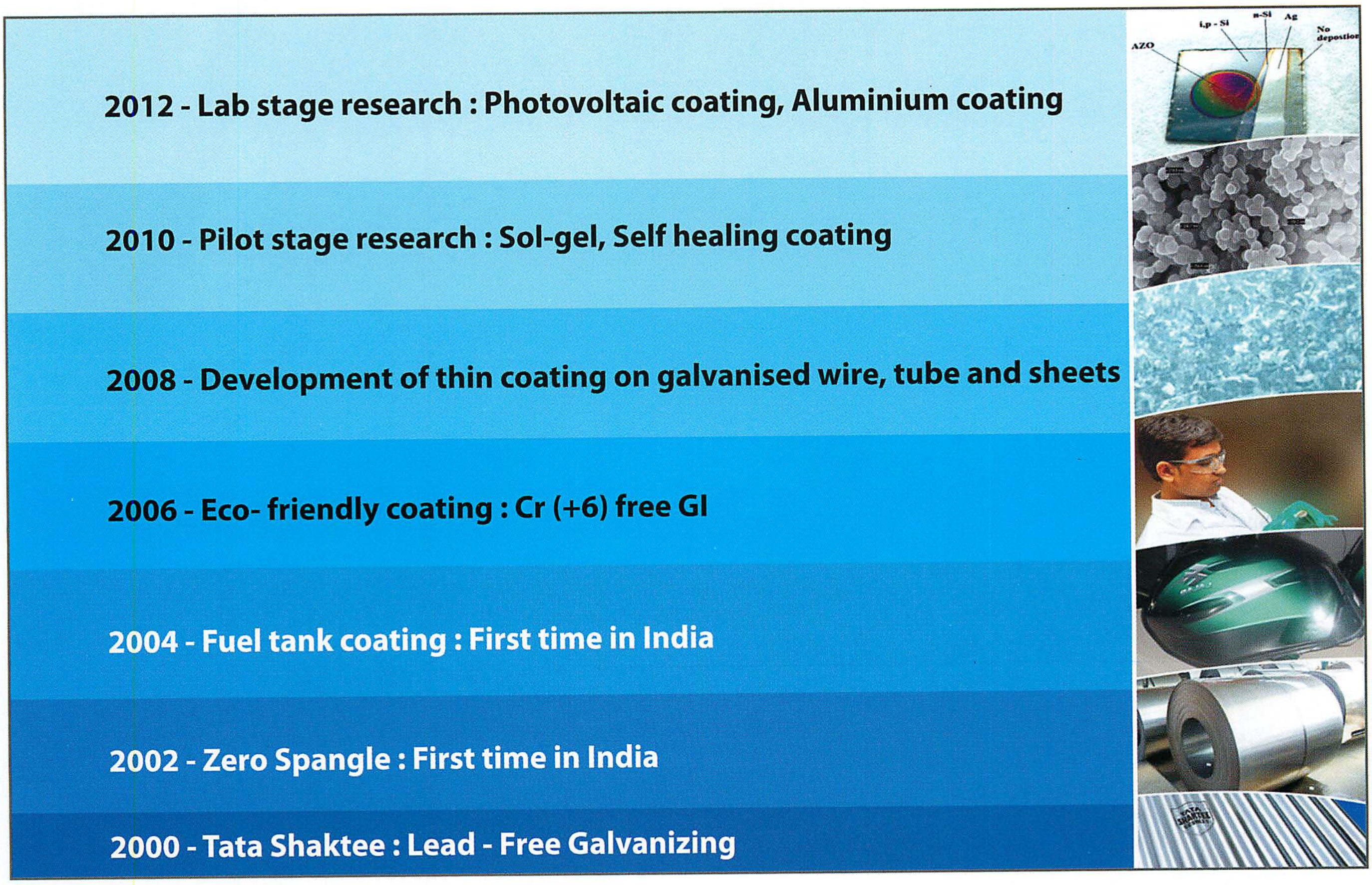
In 1999 a system for Electron Back Scatter Diffraction (EBSD) was added; a technique used to examine the crystallographic orientation of materials. It allows the researcher to predict steel properties prior to plant experiments and helps the determination of grain orientation of different phases in the steel. However, by this time the performance of the old scanning electron microscope had deteriorated and fine precipitates and microstructures could no longer be observed.

The year 2006 saw the next step-change in the metallographic laboratory. A state-of-the-art (QEMSCAN) Quantitative Evaluation of Minerals by Scanning Electron Microscopy was acquired. This automated mineralogy and petrography system, the first in India, was installed to augment raw material characterisation and support the development of raw materials beneficiation processes. Other investments included a new Field Emission Scanning Electron Microscope (FESEM) attached with facilities for both EBSD and for Energy-Dispersive X-ray spectroscopy (EDX) for the analysis of a sample. Also two X-ray diffraction facilities (XRD) were acquired (one powder XRD and another dedicated to material research) and a fully automatic optical microscopy system with image analysis software to analyse inclusions in steel. Several new equipments for sample preparation were introduced alongside.

Microstructure imaging beyond one thousand times magnification and up to 100 thousand times is now possible. It allows the observation of nano-sized precipitates in steel. In fact FESEM coupled with EBSD has generated orientation data of very small sample areas. With the help of XRD, one can now obtain information on the volumetric proportion of phases, the bulk textural relationship, the high-temperature effect on phases and also a stress analysis can now be obtained.

Using QEMSCAN and XRD, researchers are able to characterize raw materials comprehensively and generate information on phase identification, modal phase percentage, grain size distribution and liberation effectiveness during beneficiation. This information is crucial to increase the pace of developing new process flowsheets for raw materials beneficiation.

Future investment plans include a new scanning electron microscope and an advanced optical microscopy system for raw material studies to meet the growing needs stemming both from operating divisions, mine developments and R&D projects.



Development of new coatings at Tata Steel R&D

An environment-friendly coating for MIG welding wire electrodes was also developed recently. It reduces spatter and smoke during welding, resulting in a safer work environment. Thin organic coating formulations developed for galvanised products and double its corrosion resistance. This novel coating is only several microns thick and was already commercialised for superior quality steel wires and plans are in place to apply the same to steel tubes and steel sheets.

Several other advanced coatings are under development at R&D. These include a photovoltaic coating to generate solar electricity to be used on steel roofing products, and also a self-healing protective coating that has the ability to heal from scratches just like a cut in a living skin.

As India continues on its path of development an industrialisation, it will be attracting more and more high-tech industries such as wind power, solar photovoltaics, marine structures, oil gas and nuclear power. Steel in its countless avatars remains the king of all structural and construction materials. Tata Steel looks forward to meet the needs of these new customers. It will be a contest of innovation and competition. Knowing its history, we can conclude that Tata Steel with its R&D and Scientific Services Division is capable to face up to this challenge.

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

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

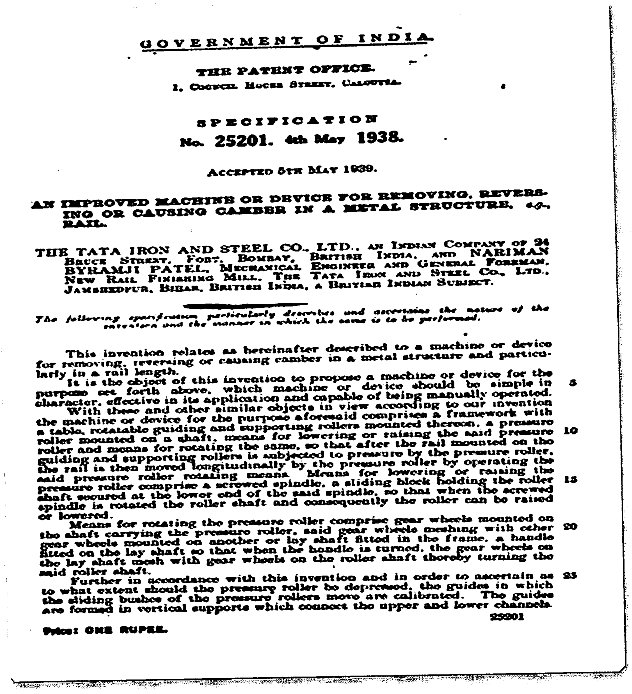
TATA STEEL LIMITED

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.

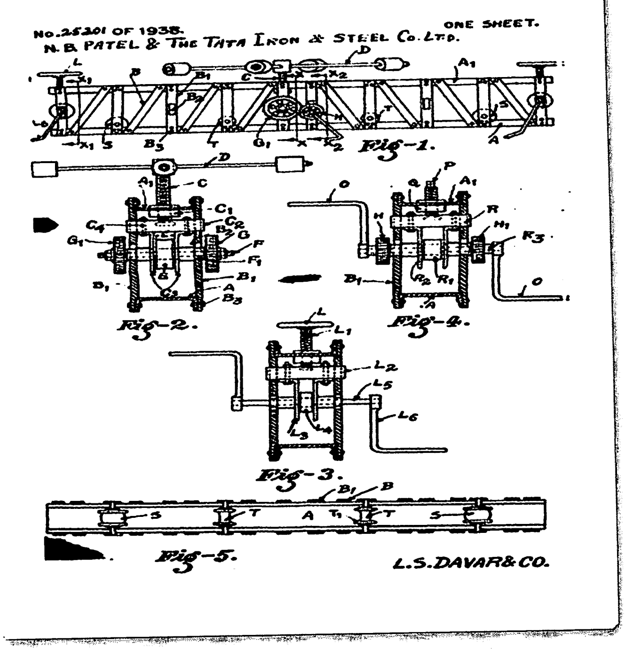
With these and other similar objects in view according to our invention the machine or device for the purpose aforesaid comprises a framework with a table, rotatable guiding and supporting rollers mounted thereon, a pressure roller mounted on a shaft, means for lowering or raising the said pressure roller 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

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)

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.

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.

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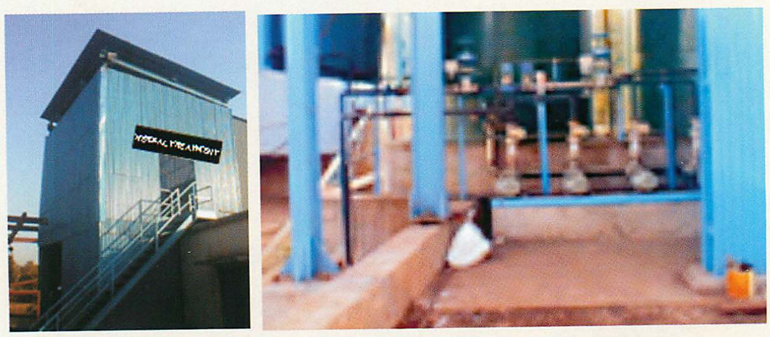


Hexavalent chromium removal treatment setup at the chrome ore beneficiation plant, in Sukinda (Odisha)

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

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.

Conventional idler

Novel hybrid idler

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.

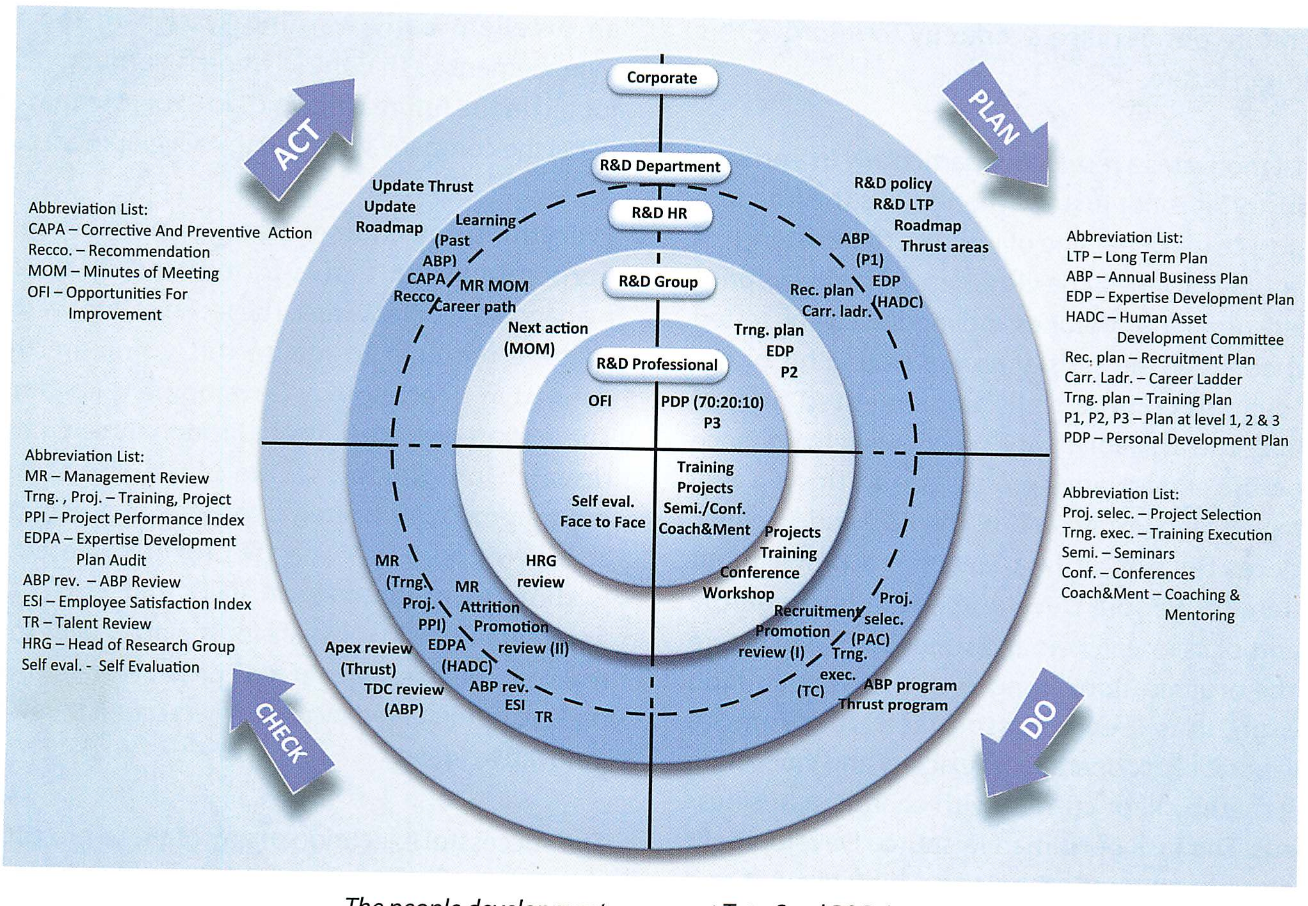
The IP accomplishments of Tata Steel are indicators of its success in capturing the inherent knowledge base and creating the potential to leverage such knowledge. In this Tata Steel has been a leader in India. Today this is taking a greater significance in the context of Tata Steel's globalisation. The 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.

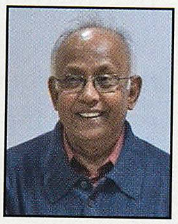
Visiting scientists

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

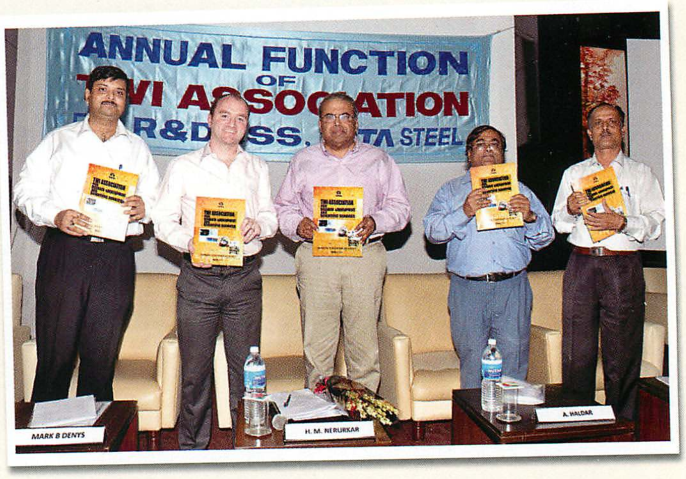

Dr D K Sengupta


Dr T K Roy


Prof T C Rao

Training Within Industry

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.



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

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

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.

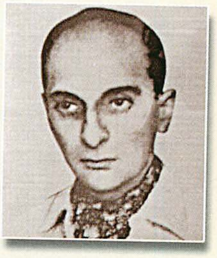
Tata Steel has always given high priority to ensuring the safety and well being of its employees and this very much includes those in its R&D and Scientific Services Division. The division strives to comply with the company-wide policies and targets, most notably its targets on *Zero fatality* a nd Lost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

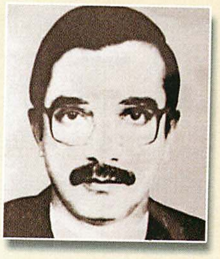

Dr. V G Paranjape


Mr. P K Chakravarty

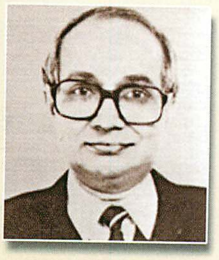

Dr. J J Irani


Dr. Amit Chatterjee

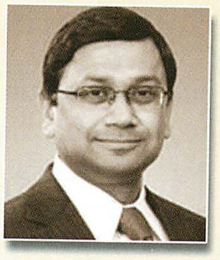

Dr. T Mukherjee


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.

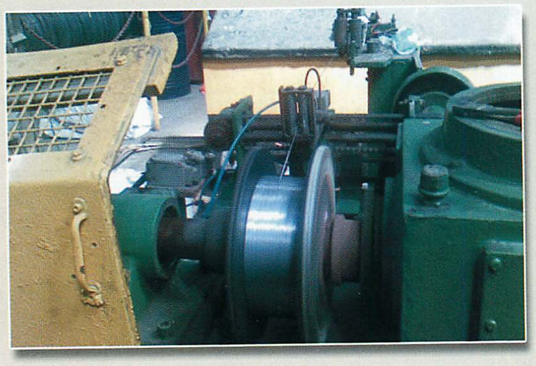
An eco-friendly wire electrode

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.

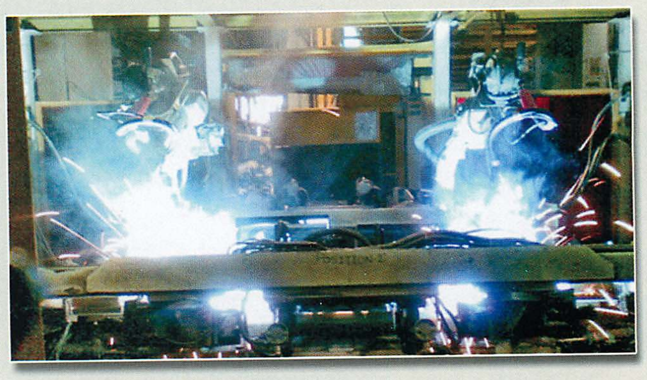
Eager to emulate these greener practices, Tata Steel's Wires Division turned to R&D for a solution. R&D, in collaboration with a partner research company, developed a novel water-based coating formulation using non hazardous metallic components. These components were chosen such that, in addition to 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)

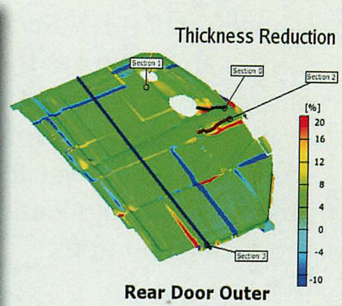
In the 1960s and 1970s, R&D departments worldwide began building more organised links to the other business functions. This new orientation recognised the importance of using combined insights for the successful initiation and completion of R&D projects. The increased cooperation, communication and interdependence 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.

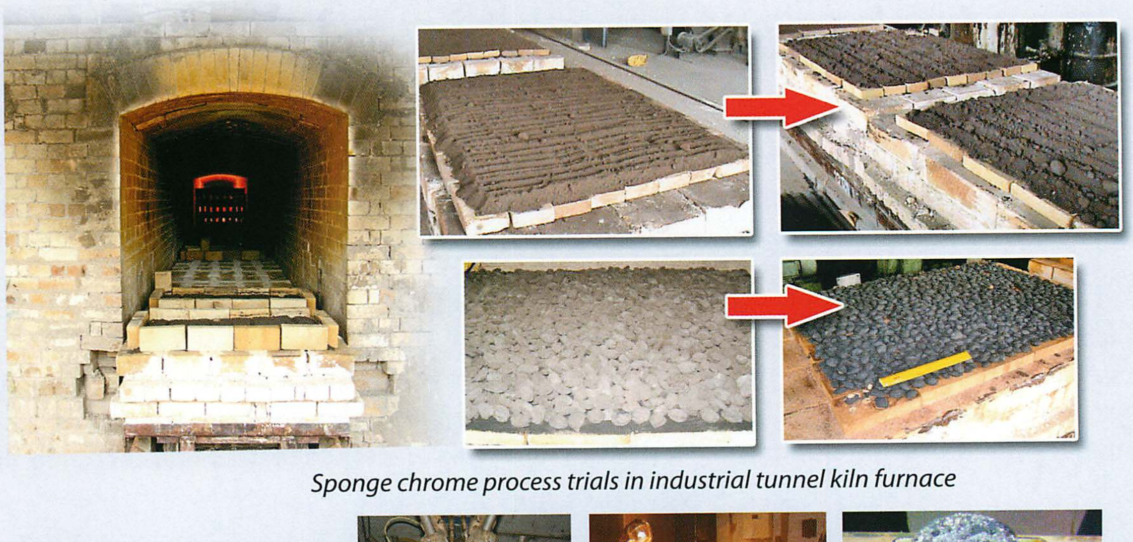
A new process for energy efficient ferrochrome production

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.

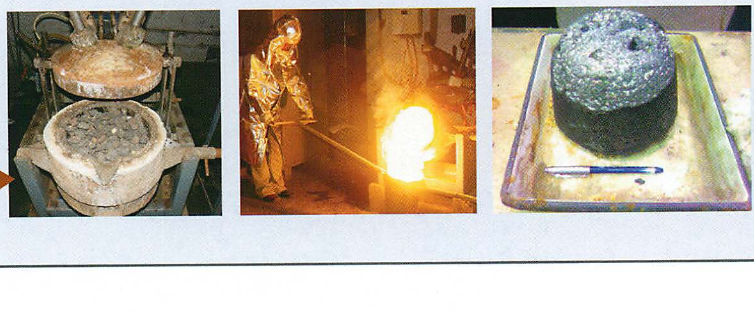
When sponge chrome is fed into the SAF, both power and coke consumption are decreased by 20% and SAF productivity also increases. In another variant of the process, the rotary hearth furnace is used to fully metallised chromite into ferrochrome nuggets to be used directly as an alloying element during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

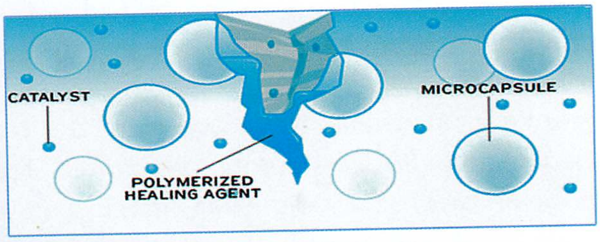
In these difficult economic times, Tata Steel's main concerns were to improve product quality and bring new steel products to market, despite several outdated plants and lack of capital to invest. "New wine in old bottles was the theme of the day" recalls Dr. J J Irani, who was General Manager of R&D 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.

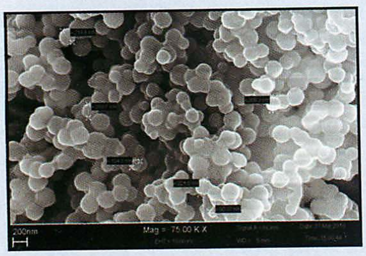
A self-healing skin

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.

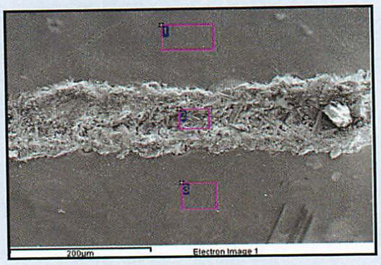


Schematic showing polymerized healing agent being released at a crack

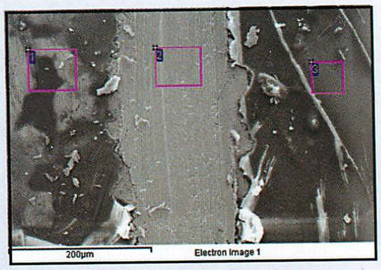
Minute capsules of 200 to 800 nanometre were synthesised in the laboratory through an intricate process of chemical emulsification. These capsules were added to a functional organic coating and applied to steel samples. Upon being scratched, the samples exhibited self-healing within three hours of damage 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):

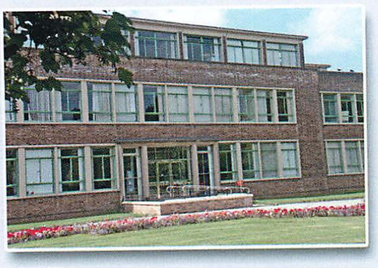
- The IJmuiden Technology Centre is located on the integrated steelmaking site of the Tata Steel in IJmuiden, Netherlands. It started as a quality-oriented investigative department in 1946, and developed to an R&D lab in the early 1990s. The present organisation with nearly 350 staff offers support to 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

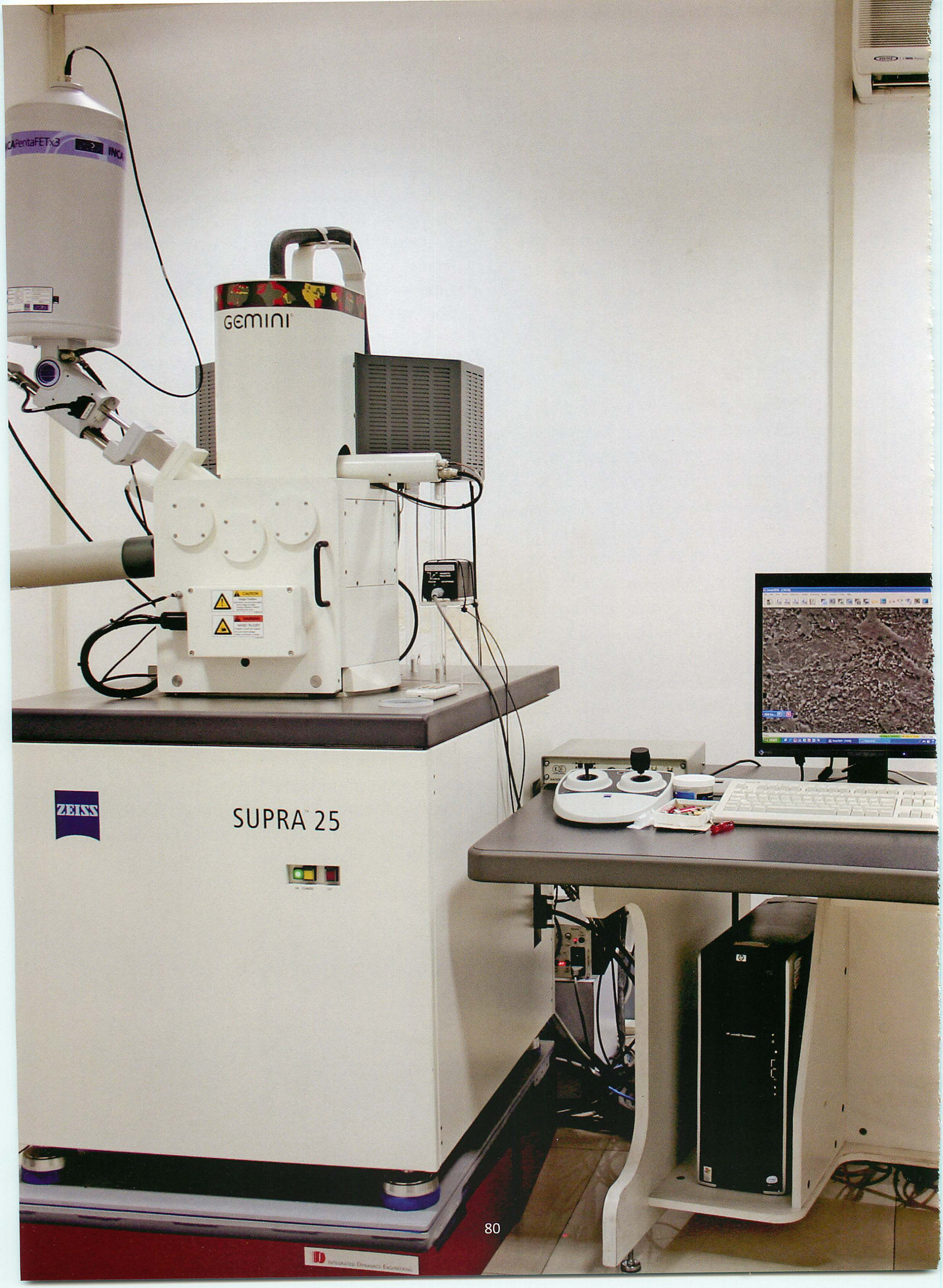
Tata Steel believes that research provides the foundation for sustained, long-term, stakeholder delight. Tata Steel shall nurture and encourage innovative research is a creative ambience to ensure that the competitive advantage in its overal business is retained and surpassed. Towards this goal, the 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.

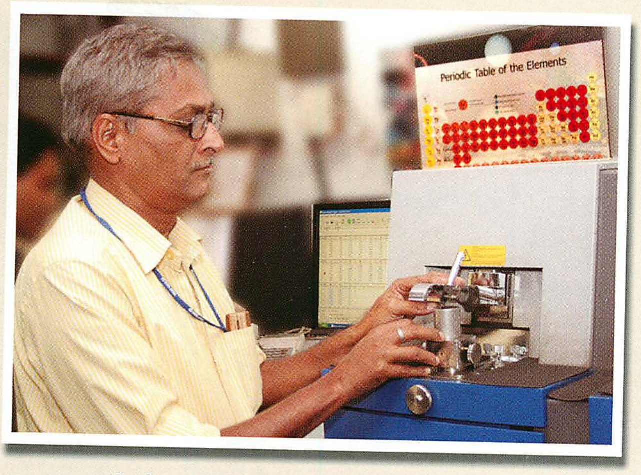
1st October, 2009

H M Nerurkar
Managing Director, Tata Steel

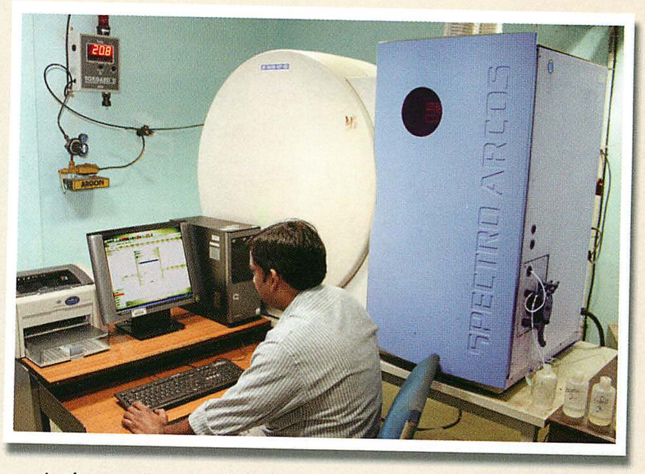
These analyses have given new insights that enable R&D to more consciously prioritise highly rewarding parts of the R&D portfolio and have further stimulated the drive to implement new inventions. As a result, R&D has been able to meet the target. Its annual financial impact has risen to the tune of 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.


GEMINI
ZEISS
SUPRA 25
INTEGRATED DYNAMICS ENGINEERING



Carbon, Nitrogen and Sulphur analyzer in Chemical Laboratory

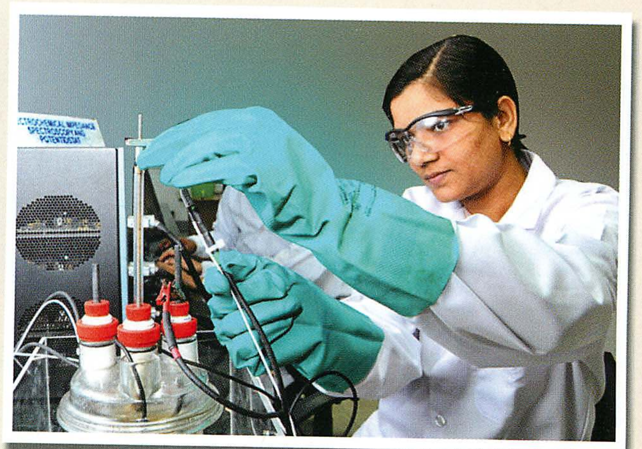


Inductively Coupled Plasma Emission Spectrometer in Chemical Laboratory

Automatic sample polishing machine in the Metallography Laboratory

X-Ray Fluoroscence Spectrometer in Chemical Laboratories

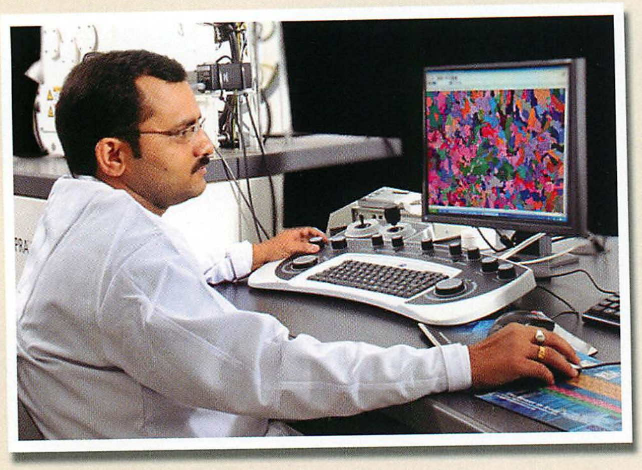
Fourier Transform Infrared Spectroscopy in the Advanced Corrosion Laboratory



Electrochemical Impedance Spectroscopy facility in the Advanced Corrosion Laboratory

Carbon coating unit in the Metallography lab

Hot mounting press in the Metallography Laboratory



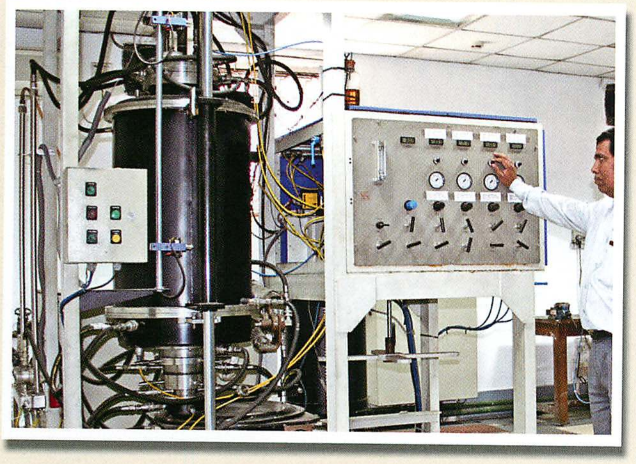
Scanning Electron Microscope

Carl Zeiss Optical Microscope equipped with high resolution camera

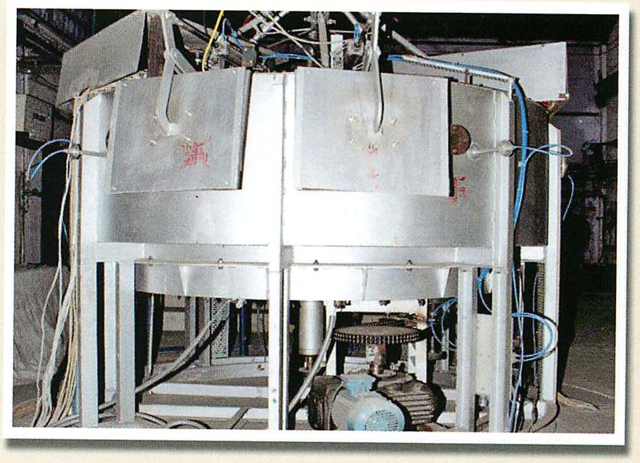
Bio-remediation Laboratory

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

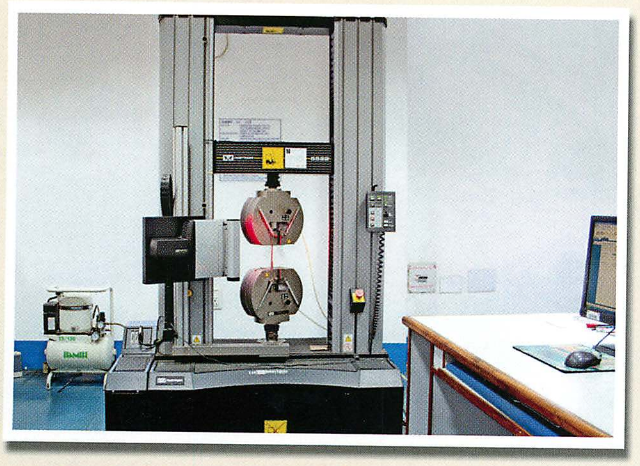
High temperature furnace



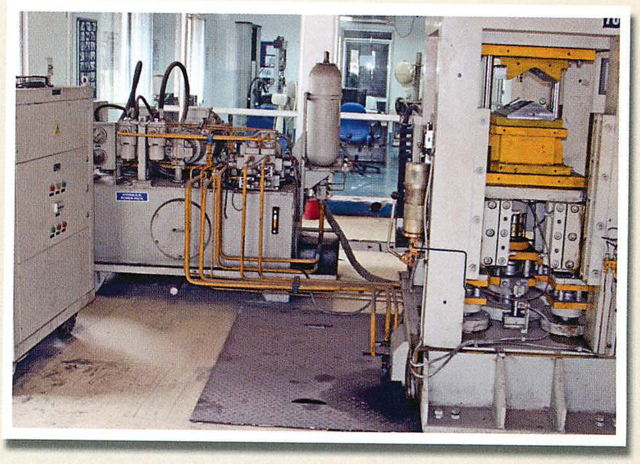
Softening-Melting equipment



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

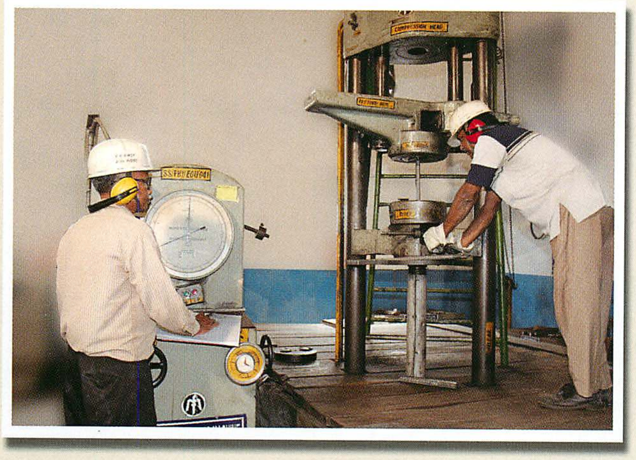
Scaled down water model of the LD Vessel

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.

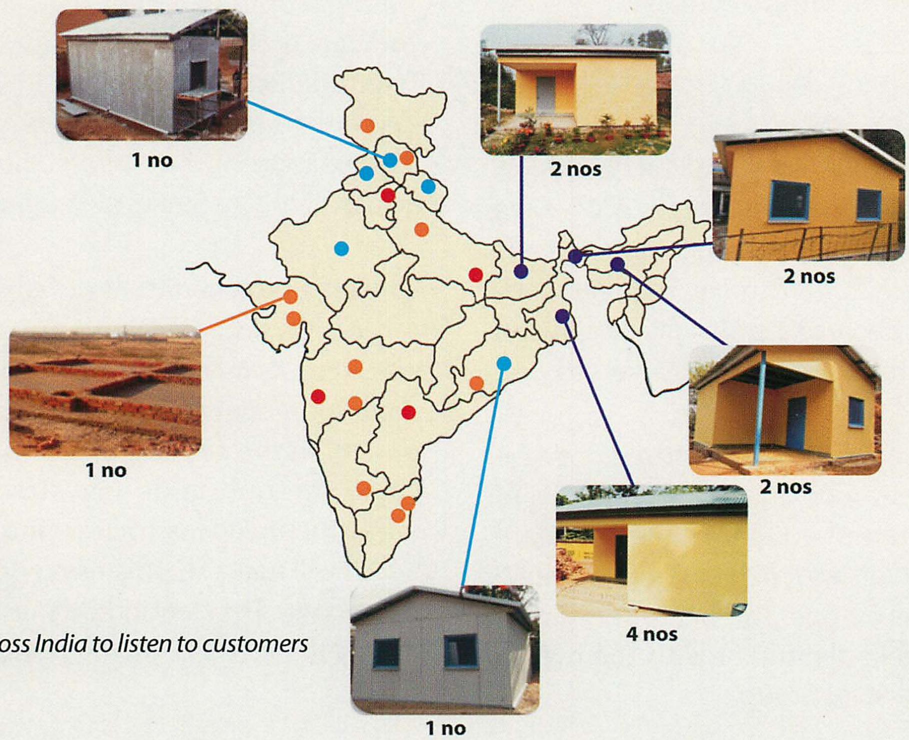
Affordable housing for rural India

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 $100^{\circ}C/s$. 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.

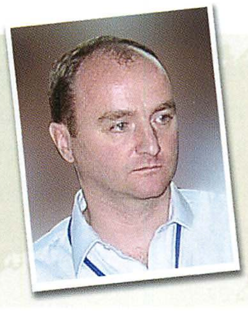
Apart from abovementioned challenges in raw materials, energy and climate change, the forthcoming decades will also bring very large opportunities for Tata Steel. India, as it grows its economy and increases it prosperity, will face profound shifts in consumption patterns. Already, as a result of the 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 21st 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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