Towards Cleaner Technologies

A process story in small-scale foundries

SDC Swiss Agency for Development and Cooperation

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Collaborating foundry association/institute

IFA (Indian Foundry Association)
IIF (The Institute of Indian Foundrymen)

Collaborating industry association(s) /institute(s)

IIF (The Institute of Indian Foundrymen)
IFA (Indian Foundry Association)
REA (Rajkot Engineering Association)
ITCOT (Industrial and Technical Consultancy Organization of Tamilnadu Ltd)
NITCON (North India Technical Consultancy Organization Ltd)
MITCON (MITCON Ltd)

Collaborating NGO for techno-social programme at Howrah

IMSE (Institute for Motivating Self Employment)

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Foreword

Very few people know that small-scale foundry units in India make the manhole covers used in Kolkata and New York City, the chassis of ABB electric motors, and several parts of the Mercedes Benz car. These are just a few examples of the range of products made by the Indian foundry industry for markets within the country and abroad.

Energy is one of the important inputs in a foundry unit. It is used for melting iron in a cupola, and constitutes about 12%–15% of the total cost of production. Hence, optimal utilization of energy is vital for the profitability of a foundry's operations. However, a majority of small-scale foundries in India use outmoded, low-efficiency cupolas that in addition generate considerable quantities of greenhouse gases and particulate emissions. Public awareness about the dangers of air pollution has greatly increased in the last few decades—particularly after the Stockholm Conference of 1972 and subsequent conferences at the global level. In response to public interest litigation, the Supreme Court of India has ordered various small-scale industries—including foundries—to meet emission norms by adopting pollution control measures, or else face closure.

TERI (The Energy and Resources Institute), with the support of SDC (Swiss Agency for Development and Cooperation) and in collaboration with Indian and international experts, has demonstrated an energy-efficient divided-blast cupola and a most effective pollution control system for Indian foundries. The demonstration unit at Howrah has yielded coke savings of 35% and reduced particulate emissions to levels far below the most stringent norms. To date, TERI has provided technical assistance to almost a dozen small-scale foundry units in different parts of the country for replicating the improved cupola. A foundry unit located in West Bengal has successfully averted the threat of closure by adopting the project's new pollution control system.

The credibility attained through these technology interventions has allowed TERI and SDC to broaden the scope of their activities beyond energy and environment issues, to include the socio-economic dimensions related to the well-being of the workforce. Rather than adopt an activist mode of social intervention, the project partners have consciously chosen a middle path that strikes a balance between technological and social dimensions. The project has been successful in creation of a worker–owner forum at Howrah so that sensitive issues such as work environment, skills-upgradation, and medical benefits for the workforce can be brought to the discussion table. The project has also promoted knowledge-sharing platforms among stakeholders, and has collaborated with the Institute of Indian Foundrymen in strengthening its website.

All these achievements have been made possible through the pooling of competence in diverse areas—foundry technology, marketing, energy management, environmental technology, and social issues. SDC has shown great flexibility during the course of the interventions carried out. This has enabled the project to adapt its action plan on an ongoing basis to overcome the challenges posed by rapid changes in the external environment and to meet the needs of the target group.

In 2005, TERI and SDC launched an initiative titled CoSMiLE (Competence Network for Small and Micro Learning Enterprises). CoSMiLE brings the various interventions by SDC and TERI in the SMiE (small and micro enterprises) sector under a common umbrella. In essence, CoSMiLE is a dynamic and informal network, comprising players bound together by a keenness to learn and share knowledge in order to bring about socio-economic development in the SMiE sector. In the years to come, efforts will be made to strengthen and extend CoSMiLE to enable widespread adoption of the improved cupola and pollution control technologies, and to bring socio-economic benefits to the foundry workforce.

R K Pachauri
Director-General, TERI

PREFACE

SDC (Swiss Agency for Development and Cooperation) has been working in India since 1961. Although a relatively small donor organization, SDC lays emphasis on building and nurturing long-term partnerships with local organizations to address both local and global concerns. In 1991, SDC established a Global Environment Programme to support developing countries in implementing measures aimed at protecting the global environment. In pursuance of this goal, SDC India, in collaboration with Indian institutions like TERI (The Energy and Resources Institute), conducted a study of the SMiE (small and micro enterprises) sector in India to identify areas in which to introduce technologies that would yield higher energy efficiency and reduce greenhouse gas emissions. Four energy-intensive areas were selected for intervention: one of them was the foundry industry.

There are about 5000 foundries in India; the majority of them are small-scale units. These units produce high-value castings that are used in a variety of industrial activities, in India and abroad. Small-scale foundries also produce a vast range of low-value castings such as manhole covers, drainage pipes, and so on that form a vital part of civic infrastructure. The small-scale foundry industry is a huge employment provider; an estimated half-a-million people find jobs as skilled, semi-skilled, or casual workers in grey iron foundry units.

Most foundries depend on cupolas that operate with low energy efficiencies and generate high levels of greenhouse gases and particulate emissions. The foundry workforce faces diverse problems—harsh working conditions, health hazards, poor wages, and contract/bonded labour.

SDC and TERI entered into partnership to address a number of issues related to the foundry industry with a focus on energy and environment.

Their work during the period 1995–2000 focused on development and demonstration of an energy-efficient divided-blast cupola and a highly effective pollution control device for small-scale foundries. Thereafter, the work has focused on laying the groundwork for widespread dissemination of these technologies, and on undertaking pilot social action initiatives to improve the lives of foundry workers in Howrah.

Working with small foundry units was not easy. Several challenges were encountered by the project team while intervening at the lower end of the industrial ladder. Accessing geographically dispersed units proved difficult, especially since no data were available regarding them and their operations. The small foundries are reluctant to consider new ideas, wary about changing their ways of doing things. Even after the improved technologies were successfully demonstrated, their acceptance was inhibited by these walls of wariness. Low priority was given to environmental issues at the unit level; this hindered replication of the pollution control system. All this was compounded by recessionary trends in the Indian foundry industry and high prices of important raw materials like pig iron and coke.

Despite these challenges, the project has been successful in replicating the divided blast cupola among several foundry units in different parts of the country. It has also promoted dialogue among different stakeholders on a various issues concerning energy efficiency, environmental improvement, and social aspects concerning the workforce.

This book is a process document: a brief, non-technical account of the process by which SDC and TERI have worked in partnership to successfully develop and demonstrate energy-efficient and environmentally-friendly technologies for the foundry industry, and the measures taken to aid replication of these technologies and to improve the socio-economic conditions of foundry workers.

The process is still continuing on. It has taken place in phases, and each phase has involved several players—among them experts and consultants from India, Switzerland and elsewhere; academic institutions; industry associations and individual foundry units; government bodies; NGOs; and others. Each player has brought unique skills and capabilities to the process; each has had a special role to play; each has worked according to an individual agenda. Yet, their combined efforts have helped move the process towards achieving the partners' common goals.

The book highlights technological problems encountered by the project staff and their resolution, as well as socio-economic issues that have had to be confronted and tackled. It describes the experiences of project teams and other stakeholders in the field, and discusses both their achievements and their setbacks—for lessons may be drawn from these by future researchers and others interested in the field.

This book is primarily intended as a guide/reference document for researchers, NGOs, academic institutions, donor organizations, policy-makers and others who might be interested in setting up projects and programmes aimed at development and dissemination of cleaner technologies in other small-scale industries sectors in India and in other developing countries.

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Introduction

Small and micro enterprises in India

In India, small and micro enterprises or SMiEs comprise a wide variety of units, ranging from tiny artisan-based cottage industries and household enterprises to small-scale manufacturing firms. There is great diversity among them—in their patterns of ownership, organizational structures, technologies, financial status, and other characteristics. However, SMiEs have a few common features as well. In general, an SMiE is managed by its owner(s) in a personalized way; it has a relatively small share of the market in financial terms; and its small and independent nature makes it relatively free from outside control in decision-making. SMiE operators and workers usually acquire their skills by tradition; these skills are transmitted through the generations with minimal change or upgradation.

SMiEs form the backbone of India's economy

The SMiE sector plays a vital role in the Indian economy. It manufactures a vast range of products, mobilizes local capital and skills, and thereby provides the impetus for growth and development, particularly in rural areas and small towns. The SMiE sector is next only to agriculture in providing employment; in 2003/04, small-scale industries alone employed around 27 million people.[1]

SMiEs are found in *clusters* all over India. There are many historical reasons for the clustering of units—availability of fuels and raw materials, access to pools of semi-skilled labour, proximity to markets, and so on. Besides an estimated 2000 artisan-based rural SMiE clusters, there are an

[1] Annual Report, 2004/05. Ministry of Small-scale Industries, Government of India.

estimated 140 clusters within or in the periphery of urban areas in India, with at least 100 registered units in each. These urban SMiE clusters vary significantly in size; some clusters are so large that they account for 70%–80% of the entire country's production of a particular item. For example, Ludhiana produces 95% of India's woollen hosiery, 85% of sewing machine components, 60% of its bicycles and bicycle-parts, and accounts for over half of Punjab's total exports. Similarly, Tirupur in Tamil Nadu has thousands of small-scale units engaged in spinning, weaving, and dyeing of cotton garments; this city alone accounts for around 60% of India's total cotton knitwear exports.[2]

In general, cost factors weigh much more for an SMiE owner than issues such as energy efficiency and pollution. Hence, an SMiE uses the cheapest fuels that are available in its locality. Because of the easy availability of biomass such as fuelwood, leaves, husks, and assorted agricultural wastes, almost all rural SMiEs burn fuelwood and other biomass for energy. For instance, each year an estimated 438 000 tonnes of fuelwood are used up for curing tobacco leaf; 250 000 tonnes for tea drying; and 100 000 tonnes for silk reeling. Urban SMiEs too burn fuelwood; about 1.72 million tonnes of fuelwood are used each year by fabric printing units.[3] Coal and petroleum-based fuels, such as kerosene and diesel, are used mainly by urban SMiEs, because these fuels are much easier to obtain in urban areas than in rural areas. SMiEs also burn highly polluting low-grade fuels such as 'spent' machine oils, lubricants, and used tyres.

Costs weigh much more for SMiEs than issues such as pollution and energy efficiency

The protected years

Recognizing the vital role played by SMiEs in production of goods and in employment generation, the Indian government took several measures from independence onwards to provide fiscal, credit, marketing, and infrastructure support to the SMiE sector—even as the nation followed a path of industrialization that emphasized the building of heavy industries, primarily in

[2] Albu M. 1997. *Technological learning and innovation in industrial clusters in the south*. Paper No. 7. Science Policy Research Unit, University of Sussex, Brighton.

[3] Kishore VVN *et al*. 2004. Biomass energy technologies for rural infrastructure and village power—opportunities and challenges in the context of global climate change concerns. *Energy Policy* **32**(2004), 801–810.

the public sector. From 1967 onwards, the government reserved certain items for exclusive manufacture by small-scale industries. Forty-seven items were reserved to start with: that number has grown over the years, and at present, there are over 500 items reserved for the small-scale industrial sector—ranging from wood and leather products to glass and ceramics; from rubber, paper, and fabric products to spices, foods, and electrical appliances. Thanks to the government's support policies, the small-scale industrial sector today forms the backbone of India's manufacturing capacity. It contributes over half of India's entire industrial production in value-addition terms, and accounts for one-third of export revenues.

But the government's policies have proved to be a mixed blessing for SMiEs. The policies were primarily intended to ensure the survival of SMiEs, to protect the jobs of those employed in them, and to increase the overall production of the sector (rather than the productivity of individual units) to cater to the demands of a growing indigenous market. Scant attention was paid by the state to improve the operating practices of units, or to help them modernize their technologies through exchange of ideas or by indigenous R&D (research and development) efforts. In the technical institutes and engineering colleges, there is a lack of interest in studying small-scale industrial processes such as drying of agro-products and food processing—even though these activities are of great socio-economic importance (in terms of revenue and employment generation), use up huge amounts of energy, and generate vast amounts of pollutants.

Protective state policies have proved to be a mixed blessing for SMiEs

On the one hand, SMiEs were insulated against healthy competition from medium and large-scale enterprises within and outside India; on the other, they were unable to access information on technological advances made elsewhere, and had neither the incentives nor the resources to conduct their own R&D. Outdated and inefficient technologies, compounded by poor management practices and declining labour productivity, steadily ate away their profits and slowed down industrial growth. By the early 1990s, the SMiE sector suffered from widespread technological obsolescence, low productivity, and an inability to access or adopt better technologies.

Liberalization challenges

In 1991, a new Industrial Policy paved the way for liberalization of the Indian economy. Since then, the market has been opened up in stages to individual/private entrepreneurs—Indian and foreign. The government is progressively withdrawing from the commercial and manufacturing sectors, even as the private sector is moving in to fill the spaces vacated. Where there was state control and state monopoly, there are now new opportunities for private players; where there were fixed prices and protected markets, there is now competition and the free play of market forces. Thus, liberalization has created new opportunities in trade, investment, and manufacturing for Indian and overseas investors.

The liberalized market favours the strong and punishes the weak

However, liberalization has considerably increased the problems of the SMiE sector. The reason is simple: the new market paradigm favours the strong and punishes the weak. For decades, the sector survived primarily because it had been shielded from the competitive currents of both indigenous and global markets. Since 1991, that protective framework has steadily been dismantled, and now SMiEs have to face competition not only from medium and large enterprises in India, but also from imports. In today's liberalized economy, the survival and growth of SMiEs depend on their ability to become competitive, that is, to improve productivity and quality of products, and to develop new products to keep up with changing demands. This in turn means that they must use better technologies and methods of operation. But these are precisely the tasks that they are incapable of doing on their own. Having functioned for five decades within an overly protective economic and industrial framework, they lack the flexibility, technical capacity, and resources to change the ways in which they function.

The environmental imperative

The SMiE sector also has to contend with a new challenge: environmental regulation. SMiEs largely use low-grade fossil fuels or biomass such as fuelwood for energy. These fuels are burned using inefficient equipment and technology, releasing pollutants that are harmful to health as well as to the earth's atmosphere. The last two decades have brought a new and growing awareness across the world about environmental pollution and its adverse effects—particularly after the United Nations Framework Convention on Climate Change or UNFCCC was signed at Rio de Janeiro in 1992. India has joined other nations in enacting laws to curb pollution. However, SMiEs do not have the technical ability or the resources to modify/change their

SMiEs do not have the technical ability or resources to modify their inefficient technologies inefficient technologies, or to install pollution control equipment to meet the standards set by the new laws. Thus, the threat of closure constantly looms large over them.

Clearly, SMiEs need help to survive in today's liberalized economy. Closure of these units would threaten the very existence of millions of people who depend on them for their livelihood, particularly in rural areas. It is against this backdrop that two organizations – SDC (Swiss Agency for Development and Cooperation) and TERI (The Energy and Resources Institute) – decided to intervene in partnership in the SMiE sector.[4]

A partnership is forged

SDC—human and institutional development

SDC is part of the Swiss Federal Department of Foreign Affairs. It focuses on poverty alleviation. Towards this mission, it supports programmes that promote good governance, helps improve working conditions, aims at solving environmental problems, and provides better health-care and educational opportunities for the most disadvantaged sections of society.

SDC has worked in India since 1963. Initially, SDC focused on the areas of livestock and animal husbandry; later, its interventions expanded to cover vocational training and SMiEs. In 1987, it began to work in the field of sericulture. From the outset, SDC's interventions paid great attention to training and teamwork, and in ensuring the participation of local people in projects to make them sustainable. In the course of its work in India, SDC has clearly outlined four areas: poverty, civil society, human rights, and sustainable use of natural resources. It recognizes that these areas are closely linked to one another; that developments in one have an impact on the other areas; and that all the areas together have a fundamental role to play in addressing the issue of sustainable development.

SDC has been particularly concerned with the effects of liberalization on the poor

From 1991 onwards, SDC became particularly concerned with the effects of liberalization on India's poor. It recognized that in an increasingly market-driven scenario, even as government withdraws from key sectors of the economy, NGOs (non-governmental organizations) and private institutions

[4] Formerly, the Tata Energy Research Institute.

play an important role in the development process. Interventions to alleviate poverty successfully, therefore, require partnerships with NGOs and other private bodies. Hence, SDC has introduced the principles of HID (human and institutional development) into all its interventions. In essence, HID aims at building strong partnerships with individuals, organizations and institutions, and in developing and enhancing partners' skills through motivation, training, access to information, and exchange of ideas.

Global Environment Programme

In 1991, the Swiss Parliament sanctioned a special grant to SDC on the occasion of Switzerland's 700th anniversary. One of the aims of the grant was to address global environmental problems. SDC accordingly set up a Global Environment Programme or GEP to support developing countries in furthering the goals of the UNFCCC. Under the grant, SDC initiated a study and cooperation programme in India for the phasing out of CFCs (chlorofluorocarbons) in the refrigeration sector. It also co-financed a market development programme for photovoltaics along with the World Bank.

SDC recognized that there existed enormous potential for energy conservation and environmental protection in the Indian small-scale industrial sector. It thereupon sought and identified two institutional partners to implement its energy–environment programmes in the country: TERI and DA (Development Alternatives). Both TERI and DA are NGOs based in Delhi.

TERI—global vision, local focus

TERI was established in 1974 through a corpus of a few Tata Group companies. Initially, TERI funded and supported research in the fields of energy efficiency and renewable energies in academic institutions. Thereafter, its activities expanded to hardware research in renewable and rural energies (first at its Field Research Unit in Pondicherry, and later at its research facility in Gual Pahari, near Delhi), and to documentation and dissemination of energy-related information. TERI works at both micro- and macro-levels. For instance, it provides environment-friendly solutions to rural energy problems; helps forest conservation efforts by local communities; promotes energy efficiency in Indian industry; shapes the development of the Indian oil and gas sector; finds ways to combat urban air pollution; and tackles issues related to global climate change.

Among other achievements, TERI has acquired considerable expertise in conducting energy audits in various industrial sectors. The institute has highly skilled human resources equipped with state-of-the-art instrumentation and software for gathering and analysing energy-related data.

TERI focuses on energy efficiency and sustainable development. . . TERI recognizes the links between poverty and depletion of natural resources

Like SDC, TERI strives to make its programmes participatory, that is, they are undertaken with the full involvement of local communities, and they tap local skills and traditional wisdom in order to ensure their adoption and success. TERI, too, lays great emphasis on training, capacity building, and education. It clearly recognizes the links between degradation and depletion of natural resources on the one hand, and increase in poverty on the other. Its activities are guided by the principle that the development process can succeed, and be made sustainable, only through the efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste.

By 1992, TERI had worked for nearly two decades in the field of energy, environment, and natural resources conservation. It was the largest developing-country institution working to move human society towards a sustainable future. It had unique skills in conducting energy audits. Above all, the model of development pursued by TERI corresponded well with the one envisaged by SDC. Thus, SDC decided to intervene in the fields of energy and environment in India in partnership with TERI.

The macro-level study

In 1992, SDC initiated a study of energy consumption patterns in the Indian SMiE sector in order to help identify areas for intervention. Pierre Jaboyedoff from Sorane SA, Switzerland, was mandated as an international consultant to assist SDC in coordinating the exercise. SDC collaborated with TERI in conducting energy sector studies in SMiE areas such as foundries, glass-making, and silk-reeling. SDC had already been working with DA in the building materials sub-sector, which included the brick-making industry.

Many SMiEs have low energy efficiencies. They are also energy-intensive: the cost of fuel makes up a large portion of production cost

The macro-level study revealed that the energy efficiency of Indian SMiEs (that is, the efficiency with which they extract and use energy from fuels) is much lower than that of their counterparts in industrialized nations. Besides having low energy efficiencies, many SMiEs are highly energy-intensive: that is, the cost of fuel makes up a large portion of production cost. Examples include foundries, food-processing units, forging units, and industries that manufacture glass, ceramics, and bricks. At the same time, SMiEs employ large numbers of workers. If these units are to remain competitive, it is essential to find ways to increase their energy efficiency and thereby reduce the burden of fuel costs.

But herein lies a challenge. To increase energy efficiency, an SMiE must make changes in its technology and operating practices. But such changes require the investment of time and money—both scarce resources in the small-scale sector! Unlike medium or large-scale units, small-scale units have limited financial and human resources, and they operate with slender profit margins. They might show willingness to adopt change—provided the change offers benefits in terms of increased productivity and profits. But they do not have the capacity or resources to initiate or invest in change.

The scope for intervention

SDC recognized this challenge faced by the SMiE sector, and saw in it an opportunity for intervention. Improving the energy efficiency of small-scale units – particularly those in energy-intensive areas – would be the best way to increase their productivity and profitability. It would also translate into reduced consumption of non-renewable fossil fuels and wood, and lower the emissions of greenhouse gases and other pollutants by the units.

How could energy efficiency be increased? The answers would vary among different SMiE sub-sectors, and indeed among units within a particular sub-sector. Better methods could be found to burn a fuel and to use its energy; alternate fuels might be identified, that were readily available and that yielded the same amount of energy at minimal or no extra cost and with less pollution; systems could be devised to recover and reuse heat and energy generated during the manufacturing process; and so on. Whatever be the mechanism, increased energy efficiency would translate into a higher yield of product for the same amount of fuel consumed, and thereby improve a unit's performance—in terms of resource consumption, environmental impact, and productivity.

SDC recognized the challenges faced by the SMiE sector, and the opportunity to intervene with improved technologies

However, it was clear that an intervention to improve energy efficiency would be sustainable only if it addressed the following imperatives:

- the SMiEs must be enabled to meet environmental laws and regulations;
- they must be made economically competitive, particularly in energy-intensive categories; and
- the quality of their products must be upgraded, and their markets must be preserved/enhanced.

Screening workshop, December 1994

To discuss the results of the macro-level study and finalize its strategy for intervention in the energy sector, SDC organized a 'Screening Workshop' on 8–9 December 1994 in New Delhi in collaboration with TERI. The workshop brought together scientists, policy-makers, government representatives, NGOs, representatives of industrial associations, and experts in diverse fields, ranging from biofuels, foundries, and forestry to renewable energy, glass-making, and silk.

The workshop adopted a unique approach. First, a total of 11 options for intervention in the energy sector were presented to an Advisory Panel, whose members represented the collective wisdom in India on policy issues related to energy. Each Panel member examined and ranked the options in order of preference. The options were: foundries (Agra); glass industries (Firozabad); silk-reeling ovens; alternate building materials; brick kilns; building energy efficiency; solar photovoltaics; solar water heaters; oil from *Jatropha curcas* ('bio-diesel'); diesel pumpsets; and biomass.

Thereafter, sectoral experts used the rankings of the Advisory Panel to discuss the options in detail, and to suggest to SDC the possible areas for action. Certain criteria were applied in order to identify the best areas for interventions. The criteria included energy intensity; potential for energy savings; potential for replication; importance of the SMiE sub-sector concerned, particularly in terms of the number of workers employed and their socio-economic status; non-duplication of efforts; techno-economic viability of measures proposed; and compatibility with SDC's India Country Programme; and potential partners, and their ability and willingness to cooperate.

Finally, based on the participants' recommendations, SDC selected the following four areas in which to intervene with technologies designed to improve energy efficiency, environmental performance, and productivity:

1 foundries;
2 sericulture (with wood gasifiers for improving thermal efficiency of silk-reeling ovens);
3 glass industries; and
4 brick manufacture.

A list of '**dos**' and '**don'ts**' suggested by the Screening Workshop for the foundries sub-sector

Dos & Don'ts—Foundries

Dos

- Provide technical assistance to foundries
- Plan for programmes with select number of units to provide effectiveness of improved measures
- Impart training to owners and supervisors
- Owners to be educated through demonstration programmes and workshops
- Convince owners that 'Unity is strength'
- Create an atmosphere that will motivate units to adopt modern methods
- Achieve compliance with statutory environmental standards
- Ensure acceptability of experts being part of the job
- Provide demonstration projects
- Support a few demonstrative methods representing the majority type of units and operation
- Demonstrate **proven** system
- Measure performance of existing plants (1)
- Implement best practice (2)
- Remeasure performance (3)
- Provide soft loans
- Low-cost technology to the existing plant must be preferred

Don'ts

- Do not invest in heavy retrofit first
- *Owners* Do not spend money on unproven ideas
- Do not believe that good performance comes from new plants
- Do not stand still
- Do not assume that consultants have all the answers

Getting started

While structuring their interventions and drawing up their work plans, the project had to consider a few vital issues.

Cluster-level intervention

At what level should the interventions be undertaken? On a national scale? Or at unit level? If so, where?

The idea to intervene at cluster-level sprang from the Screening Workshop. Units producing similar goods, and possessing great similarity in levels of technology and operating practices, are found in close proximity within a typical SMiE cluster. Therefore, it was felt that the best way to spread an improved technology would be to first demonstrate its benefits to a few representative units in a cluster. Ideally, these units should be chosen by local industrial associations. Where such formal groups did not exist, the units should be identified by other bodies familiar with the cluster profile (such as district industries centres). Once the selected units realized the advantages of the new technology and adopted it, other units in the cluster would tend to follow suit—and dissemination of the technology would be rapid and effective. Therefore, each intervention took place initially at cluster level.

Finding the right technology

Which technology is best suited for a particular sub-sector? Obviously, it should be a technology that uses less energy and results in less pollution than the existing technology. It should retain the existing quality of the product, and if possible improve upon it. Yet, the answer is not as simple as finding and importing the best technology available in the world that meets these requirements. The selected technology must be acceptable to local people; it must be easy for them to use (perhaps with training); and it must suit local conditions.

In India, unemployment is high and capital is scarce. Therefore, the new/improved technology should be affordable; and it should minimize the impact on the existing workforce in terms of loss of jobs. It should not depend on external inputs or non-local resources to function, except at the initial stages. Like existing technologies, it too should work on fuels and raw materials that are locally and readily available at affordable prices. As far as possible, it

The selected technologies must be acceptable to local people, easy to use, and suit local conditions should resemble the technology already being used in the area; for this would help make it acceptable to and easily adaptable by local people.

Therefore, in selecting a technology for intervention, existing technologies had to be evaluated – in India and elsewhere – to identify which among them could be adapted/modified to meet the standards set for energy efficiency and environmental performance. Thereafter, from among the available options, the most appropriate one, that is, the one most suited to adaptation to meet local needs and conditions, had to be selected and developed for demonstration and eventual dissemination.

Participatory technology

To succeed in the long-term, a technology should not only be appropriate. As far as possible it must build on, and be built upon, the skills and knowledge of local people; it should be adapted/developed with their full *participation*. This approach to technology development gives the beneficiaries a sense of 'ownership' over the technology; they become confident in its use. By its very nature, participatory technology is developed on the basis of collective learning, sharing of ideas and traditional wisdom, and R&D based on community needs. Since it works closely with the community and at a deep level of society, participatory technology has the potential to bring about profound social change.

To ensure the participatory development of technologies, the project teams worked closely with unit owners and workers, industry associations, local government institutions, NGOs, and other bodies at the field level.

Capacity building: key to sustainability

The success of any intervention is measured by its sustainability. This in turn depends on the *capacity* of the recipients to absorb the new/improved technology. The recipients should be able to continue to adapt and innovate the technology long after the intervention project has ended—to cope with and overcome whatever challenges the future might bring. Here, it is important to recognize that technology is not just about equipment and tools. It is a package of knowledge that enables the recipients to *use* the equipment and tools to produce specific products of specific quality.

In other words, it is not enough merely to develop a new technology and to demonstrate its benefits. Local people should be given the information and skills that they require to use the technology in the long-term. They should learn the benefits of exchanging ideas and sharing experiences, and how this would help them manage changes without depending on external sources for help. Capacity building, therefore, formed a vital component of the project's interventions.

Structuring the interventions

Having considered all the above issues, SDC and TERI structured each intervention as a package of parallel and ongoing measures that are listed below.

- Perform energy audits (Box 1). Learn, during the energy audits, about things beyond energy—such as existing operating practices, quality of fuel, and so on.
- Search for suitable solutions—to achieve the benchmarks set for energy efficiency and environmental performance.
- Develop and demonstrate an improved technology, in terms of energy and environmental performance and other parameters. Fine-tune the developed technology for wider dissemination.
- Help other units to upgrade and adapt their existing technologies as required.
- Seed the markets, that is, help make the technologies available via local suppliers; promote measures to reduce their costs and increase their uptake.
- Increase the number of partners and collaborators in the field, and strengthen their capabilities by ongoing HID so as to promote dissemination of the technology.
- Make efforts to establish a regular policy dialogue between various players in each area (industries, institutions, government bodies, etc.).
- Conduct studies on the socio-economic conditions in the clusters concerned. Devise strategies for the improvement of working conditions in the clusters.
- Identify new areas for R&D activities, for future interventions.

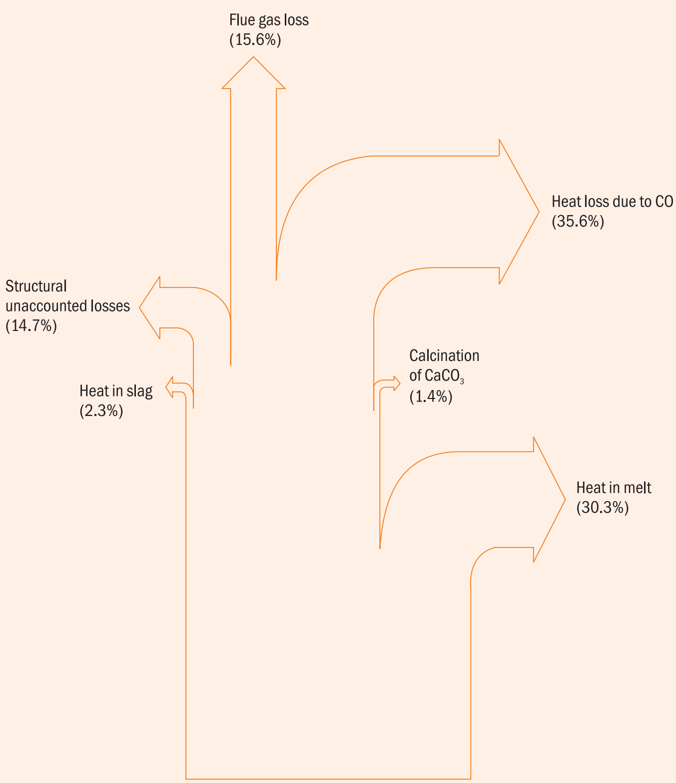
Action research

In each area, the project's work followed the dynamic and cyclic pattern of 'action research', with activities taking place in three broad and overlapping phases:

BOX 1
Energy audit and Sankey diagram

An energy audit is a kind of 'baseline' study. It examines the pattern of energy use in an existing industrial process, and provides data on certain parameters. These data are then mulled over, and some or all of them are used as yardsticks to evaluate other technological options. The Sankey diagram shows, at a glance, the amounts of input heat used in different parts of a process (Figure 1). Thus, the Sankey diagram is a simple but powerful tool to identify areas in which energy efficiency might be improved.

Figure 1
A typical Sankey diagram for a cupola melting furnace



- developing a plan of action based on reconnaissance (the 'recce' phase);
- taking actions according to that plan (the 'pilot' phase); and
- assessing results of the actions, to formulate and take further action (the 'assessment' phase).

For the sake of clarity, various activities have been described sequentially as far as possible in this book. In reality, though, action research does not take place according to a neat timeline. Action research is a dynamic framework: a process of continuous planning, experimentation, assessment, and learning that cuts across timelines, and that involves frequent and extensive interplay between different phases and the players in those phases. Action research does not achieve targets and goals by linear paths, but by a series of iterations and loops.

Competence pooling

The development of an appropriate participatory technology requires many specialized skills—in fields ranging from energy management to pollution control, from engineering and equipment design to training, market research, and market development. Therefore, each intervention took the shape of a technology package that was developed and implemented by a multi-disciplinary team, comprising experts and consultants from India and abroad, technology providers, engineers, and others (Box 2). These specialists pooled their competencies and adapted equipment designs and operating practices to local conditions and to suit the requirements of the local operators.

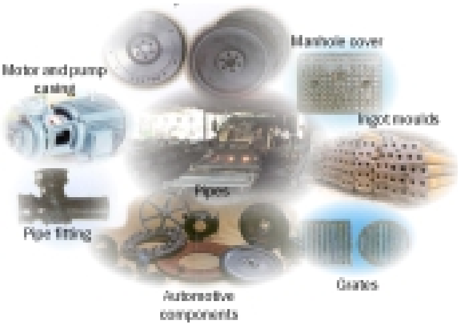
BOX 2
Competence pooling—putting the pieces together

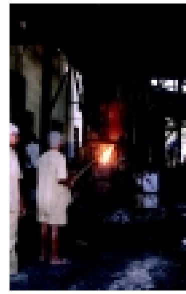
When the TERI teams started out on their interventions more than a decade ago, they did have a lot of expertise with energy audits. Most of these energy audits were focused on large and medium industries. But when the teams began analysing brick kilns, foundries, glass furnaces, and silk-reeling units, they soon realized that the complexities of these small and micro enterprises were no less than the former; often, they were even greater.

Instead of reinventing the wheel, TERI decided to call in specific experts to fill up the lack of knowledge in the many technology-related domains. This strategy – of 'competence pooling' – has proven to be very effective. Typically, technology specialists are excellent at analysing and running processes; but they are not very interested in things like energy efficiency. On the other hand, energy specialists like TERI and myself perhaps tend to underestimate some of the technology-related hurdles. By interacting closely with one another, and with the industry associations and the pilot plant unit workers, we were able to develop technologies adapted to the needs of SMiEs.

The more the different components of the intervention progressed, the more specific the demands for expertise became. The intervention process is like a puzzle. After so many years of work, it has become evident that for the successful completion of the process, the pieces of the puzzle – made up of knowledge and expertise – have to be put together in the correct way. Competence pooling is like many minds coming together to move a body in a chosen direction. The concept cuts across, indeed holds together, all the interventions by SDC and TERI in the small-scale sector.

Pierre Jaboyedoff
Sorane SA





Charting the course

Overview

Foundries can be broadly classified into ferrous and non-ferrous foundries. *Ferrous* foundries can be further divided into iron foundries and steel foundries. Iron foundries were selected for intervention in the project. Hence, foundries in this book refer to iron foundries unless stated otherwise.

Foundries make iron castings. The castings are used in a variety of applications. Some of the major end-use markets for castings are municipal castings (such as manhole covers, grates, and so on), sanitary pipes and fittings, automotive applications, and engineering components like casings for pumps, compressors, and electric motors. Figure 2 shows some products that use castings made by foundry units.

Figure 2
Some products made by foundries

There are about 5000 foundry units in the country. Almost all units are in the small-scale sector. Most foundries are homegrown units—their management, investment, and technology are largely indigenous. Collectively, they produce about four million tonnes of castings annually. While their output predominantly caters to domestic markets, a small percentage is exported. The foundry sub-sector provides direct employment to an estimated half-a-million people.

Foundry units are located in clusters, but operate largely in isolation

Foundries are located mainly in clusters. The industry is highly fragmented: that is to say, although units occur in clusters, they operate largely in isolation. While units form loose associations at the cluster level, there is little formal sharing among them of information related to technology, operating practices, and so on. The clusters vary in size: some have less than 50 units, while others have over 500 units. Some of the major foundry clusters in India are shown in Figure 3. Typically, each cluster specializes in producing castings for specific end-use markets. Profiles of a few clusters are listed below.

- The Howrah cluster has approximately 300 foundries. Most of the foundries in Howrah produce low-value-added castings such as manhole covers and sanitary pipes.
- The Coimbatore cluster consists of about 500 foundries. These units produce castings mainly for the textile and pump-set industries.
- The Belgaum cluster has around 100 foundries. They are famous for producing high-precision castings that are used by

Figure 3
Location of major foundry clusters in India

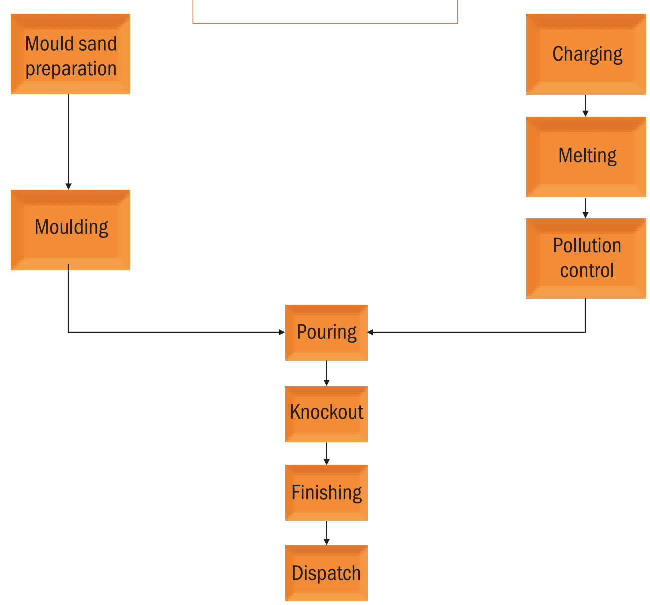
industries in Pune—to manufacture automotive parts, oil engines, electric motors, pumps, and valves.

- The Kolhapur cluster has about 250 foundries, catering mainly to the needs of local industries such as sugar mills and manufacturers of machine tools and oil engines.
- The Rajkot cluster has approximately 500 foundries. These units mainly produce grey iron castings for the local diesel engine industry. The castings are also used by automotive and textile industries, and by manufacturers of pumps, valves, and machine tools.

Technology

A foundry processes a wide range of iron-containing materials to produce iron castings of high purity. Figure 4 shows the typical operations in a foundry unit. Melting is by far the most energy-intensive stage in the operation of a foundry. It is also the stage that generates maximum pollution. Hence, it is

Figure 4
Typical operations in a foundry



during the melting process that ways must be found to improve energy efficiency and reduce pollution.

The cupola

Figure 5
Conventional cupola in operation

The conventional cupola is the most common type of melting furnace used by foundries in India. In essence, this is a hollow vertical cylindrical furnace (Figure 5). It has a single row of pipes known as tuyeres, through which air is blown in at room temperature. Such furnaces are hence called 'cold blast cupolas'. A number of iron-containing materials such as pig iron, cast iron scrap, and foundry returns (the scrap iron that circulates within the foundry; usually made up of rejected castings) are loaded into the cupola either manually or by a mechanical charging device. Limestone is added as a fluxing agent. Air is blown (blasted) into the cupola through the tuyeres. As the charge melts, the limestone combines with the impurities present to form a slag, which floats on top of the heavier molten iron beneath. The slag is removed through a slag hole; the iron is tapped through a tap hole lower down, and moulded into castings.

Cupolas use coke as fuel. A cross-section view of a cupola is shown in Figure 6.

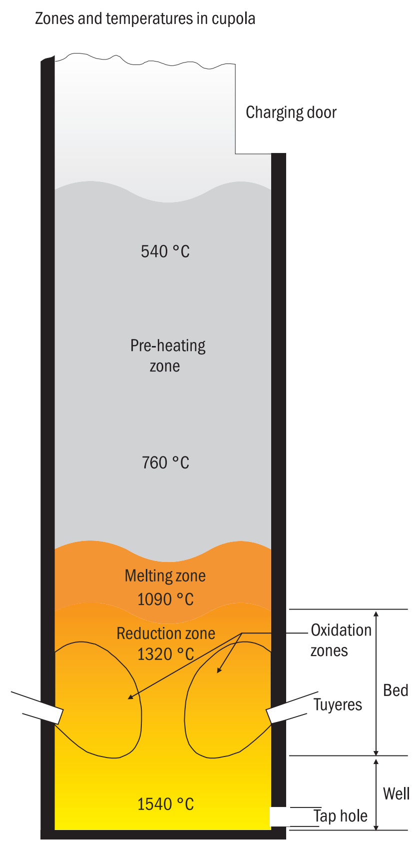
The energy efficiency of a cupola is measured in terms of the amount of metal charged/molten metal produced by one tonne of charged coke. This can be denoted either as a ratio or as a percentage, known as CFR or coke feed ratio. The lower the CFR, the more efficient is the cupola.

Emissions from cupolas

Foundries are a major source of emissions. Cupolas are charged with a wide range of ferrous materials. Many of these materials contain metallic oxides and non-metallic compounds in the form of loose particles. Within the cupola itself, the materials rub against one another and against the refractory lining of the furnace. This leads to the generation of more particulate matter.

When coke is burned in the cupola, it produces hot gases – mainly CO_2 (carbon dioxide), CO (carbon monoxide) and SO_2 (sulphur dioxide) – and leaves a residue of fine ash. CO_2 is the principal greenhouse gas that affects the earth's climate (Box 3). As the hot gases rise they pick up some of the ash, as well as the tiny particles generated by the charge materials. The particles are carried out of the cupola by the gases, and can be seen in the form of a characteristic plume above the stack. Hence, the major pollutants emitted by foundry cupolas are SPM (suspended particulate matter) and SO_2.

Figure 6
Cross-section view showing zones and temperatures in a cupola



Emission standards for cupolas

In 1990 itself, the CPCB (Central Pollution Control Board) had introduced standards for SPM emissions from foundry cupolas. The SPM emission norms for cupolas were based on their melting rates, measured in tph (tonnes per hour). The maximum allowable SPM levels were set at 450 mg/Nm^3 (milligrams per normal cubic metre) for cupolas with capacities lower than

BOX 3
Climate change and UNFCCC

In recent decades, industry has come under intense pressure to reduce environmental pollution. This is because of the growing evidence that pollution from human activity has adverse effects, not only on health but also on the earth's climate. Fossil fuels such as coal, oil, and natural gas meet most of the energy used by industry, transport, households, and also generate electricity. The burning of fossil fuels generates 'greenhouse' gases, primarily carbon dioxide. These gases slowly build up in the atmosphere and create a 'greenhouse effect', leading to a rise in average global temperatures. This phenomenon, known as global warming, is likely to bring about irreversible and destructive climate change across the planet; indeed, there is evidence that this process has already begun.

Nations across the world have recognized the threat. In June 1992, 154 countries signed the United Nations Framework Convention on Climate Change, or UNFCCC. This was an international environmental treaty produced at the United Nations Conference on Environment and Development or 'Earth Summit' held in Rio de Janeiro in 1992. While the UNFCCC recognized the threats posed by greenhouse gases, it did not make it mandatory or set targets for individual nations to reduce their greenhouse gas emissions. However, it included provisions for updates (called 'protocols') that would set mandatory emission limits. The Kyoto Protocol, adopted in 1997, is the most well-known update to the UNFCCC. A total of 162 countries have since ratified the Kyoto Protocol. This is a legally binding agreement under which, by 2012, industrialized countries must reduce their collective emissions of greenhouse gases by certain percentages below the emission levels in 1990.

3 tph, and 150 mg/Nm^3 for cupolas with capacities equal to or more than 3 tph. However, these norms have not been adhered to by most foundries, nor are they enforced strictly by the state pollution control boards.

Plan of action

Since the initial aim of the project was to improve energy efficiency of small-scale foundry units, the cupola melting process was targeted for achieving this goal.

Energy audits

In order to ascertain the causes and extent of inefficiency in energy use among foundries, TERI conducted energy audits in representative units in the Agra foundry cluster in 1993/94. Almost all of them used the conventional cupola; a few used a sub-optimal kind of divided-blast cupola or DBC. As described later, a DBC has twin rows of tuyeres, one below the other.

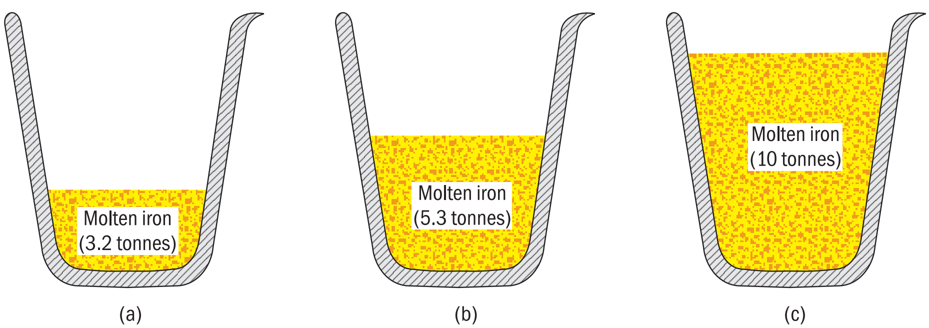
The audits revealed that the CFR was 1:3·2 (31%) in a conventional cupola, and 1 : 5·3 (19%) in a DBC. These CFRs compared poorly with the best levels achieved abroad of about 1:10 (10%). Thus, there was a large potential for improving furnace efficiency; specifically, to reduce coke consumption by almost half by proper design of the cupola and adoption of BOP (best operating practices) (Figure 7).

Causes of low energy efficiency

Poor furnace design

In general, most cupolas are poorly designed. As a result, large amounts of heat are wasted. For optimum performance, a cupola must be correctly and proportionately sized. It must also operate with the correct air blast volumes and pressures. These factors apply irrespective of whether the furnace is a conventional cupola or a DBC.

Figure 7
Amount of molten metal that can typically be produced, per tonne of coke, in (a) conventional cupola; (b) sub-optimal DBC; and (c) optimal DBC with BOP



Poor operating practices

In most foundries, instruments to monitor and regulate important process parameters such as blast volume and pressure are absent. Often, units do not maintain proper records of process data – such as amounts of coke and charge loaded, numbers of castings produced and rejected, causes for rejection, and so on – even though such data are vital to ensure operational control and efficiency. In many foundries, the charge materials are lifted manually for loading into the cupola. This is not only a physically taxing task but it also poses major hazards to workers, for they are exposed to heat and high levels of CO at the cupola charging door (Figure 8).

Non-uniform size of charge material

The charge is generally made up of metallic pieces of varying size. Very large pieces create gaps and spaces within the cupola. Hot rising gases pass too

Figure 8
Manual charging with baskets

easily – and too fast – through these spaces, preventing the proper pre-heating of charge material above the melting zone. Also, large pieces can get lodged in the cupola shaft, and prevent other charge material from descending into the melting zone. On the other hand, very small pieces tend to pack tighter, and restrict the upward passage of hot gases. This increases the internal pressure in the cupola, and restricts the blast rate. The results: low melting rate and wastage of fuel.

Exploring technological options

The energy audit results were discussed and validated by experts from Cast Metals Development Limited, UK,[5] a BCIRA (British Cast Iron Research Association) group company, and from Sorane SA, Switzerland. Potential solutions were also discussed with them. Options such as induction furnace, arc furnace, oxygen enrichment of blast air, and hot blast cupola were studied and rejected: all require installation of expensive equipment, and the first two in particular require large quantities of electric power. The DBC, therefore, emerged as the best option to improve energy efficiency at a modest investment.

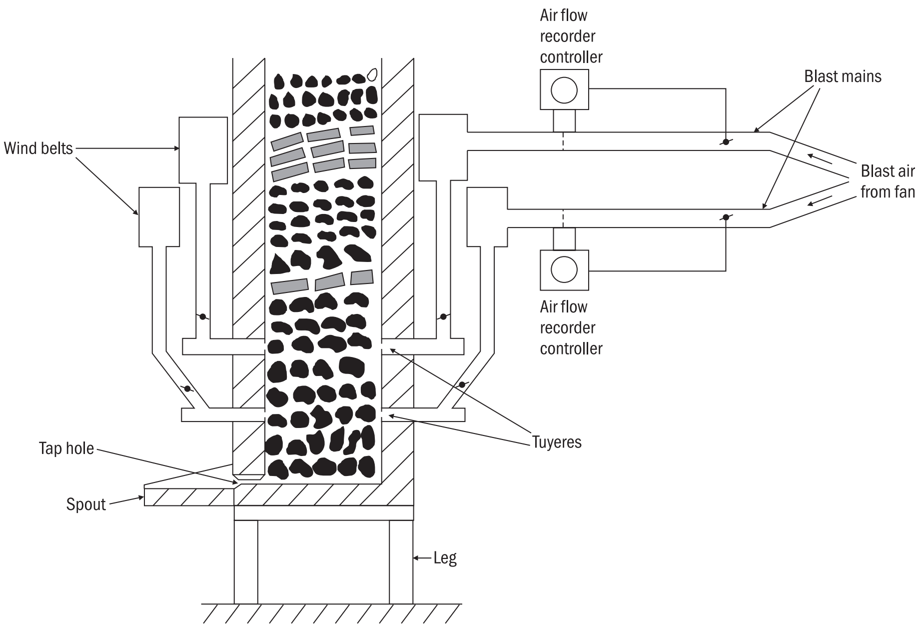
DBC: how it works

When coke is burned within a cupola, a relatively cool 'reduction zone' forms about 1 m (metre) above the tuyeres. The drop in temperature in this region is because of the combustion reaction that leads to the formation of CO. This reaction is endothermic, that is, it absorbs heat. The relative coolness of the reduction zone results in a drop in furnace core temperature, and thus lowers the efficiency of the cupola.

A DBC reduces CO formation by introducing a secondary air blast at the level of the reduction zone. Thus, a DBC has two rows of tuyeres, with the upper row located about 1 m above the lower row. This 'divided blast' system gives a DBC the following advantages over the conventional cupola.

[5] John Smith of Cast Metals Development Ltd visited Agra in 1993/94, and examined and validated the results of the energy audits that were then conducted. He also participated in the December 1994 Screening Workshop. When the project shifted its activities to Howrah, Michael ('Mike') S Brown represented Cast Metals Development Ltd. Subsequently, Mike set up his own consultancy firm – M B Associates – and continued his association with the project in this capacity.

Figure 9
Sketch of DBC, showing two rows of tuyeres



- It reduces coke consumption by about 25%.
- It increases tapping temperature by about 50 ºC.
- It increases the melting rate.

A schematic of a divided blast cupola is given in Figure 9.

Before construction of a demonstration plant based on the DBC concept, the project decided to demonstrate 'BOP' to foundry operators. Some of the areas that the project planned to cover under BOP were:

- optimization of blast rate;
- bed preparation;
- sizing the raw material; and
- charging practices.

Box 4
Pollution—monumental damage!

The 'Taj Trapezium' is an area of about 10 400 km^2 (square kilometres), covering parts of Uttar Pradesh and Rajasthan states in India. At its centre lies Agra, city of the Taj Mahal. Besides the Taj, the Trapezium is home to over 40 protected monuments including other World Heritage Sites such as Agra Fort and Fatehpur Sikri.

The Trapezium also has several SMiE (small and micro enterprises) clusters: notably, the glass industry cluster at Firozabad, and the Agra foundry cluster. From the 1970s onwards, public concern grew across the world at the damage being caused to monuments by air pollution from industries in the area, and from the Mathura oil refinery. Norms were established for control of industrial emissions in the years that followed, but enforcement was lax.

In response to a PIL (public interest litigation) filed in this regard, the Supreme Court of India delivered a landmark judgement on 30 December 1996. The Court banned the use of coke or coal in a large number of polluting units within the Trapezium. At the same time, the Court ordered GAIL (Gas Authority of India Limited) to supply natural gas to units that could adapt their technologies to use this far more environmentally benign fuel. While TERI helped glass industries in modifying their furnaces to use natural gas efficiently, almost all the foundries in the Agra cluster were forced to close down or relocate to areas outside the Trapezium.

Shift in focus to Howrah

Having identified the technology, the next step was to identify a site where it could be demonstrated. Initially, the project had decided to intervene in Agra, where it had conducted energy audits.

However, in 1995/96, the Supreme Court of India pronounced a number of landmark judgements on environmental pollution in the Agra region (Box 4). With the banning of coal and coke within the Taj Trapezium Zone, the industrial situation in the Agra cluster underwent a drastic change. Foundry-owners in the cluster were faced with the prospect of imminent closure. Many units chose to move out of the Taj Trapezium Zone. Under the circumstances, the project decided initially to concentrate on the Howrah cluster, one of the oldest and largest clusters in India.

At that time, SDC was already supporting SIDBI (Small Industries Development Bank of India) in a cluster modernization initiative in Howrah. It was felt that shifting the SDC–TERI technological intervention to Howrah would also complement the ongoing collaboration between SDC and SIDBI. However, this did not materialize. The reasons may be best understood by looking at the different approaches of the two initiatives. While the project focused on coming up with a benchmark longer-term solution, SIDBI was more concerned with helping the smaller foundries deal with the immediate challenge posed by enforcement of environmental standards.

The project itself could not develop a solution for smaller foundries as the operational culture in the typical small foundry did not match with the benchmarking approach adopted by the project.

Initially, the focus was on improving the energy efficiency of foundry units in the Howrah cluster by demonstration of BOP, and if necessary, adoption of the DBC. In early 1996, discussions were held with representatives of industry associations at Howrah. Based on the discussions, a detailed action plan was drawn up by the project. In the meanwhile, pollution control became the primary concern in Howrah as well (Box 5), with the Supreme Court stipulating deadlines for foundry units in Howrah to put up gas cleaning systems.

Under the circumstances, the project modified its plan of action to address the needs and immediate concerns of the entrepreneurs in the cluster. In order to save time, the project decided to skip the planned demonstration of BOP, and instead directly start with demonstration of an optimally designed DBC. It was felt that BOP could be clubbed along with the technology demonstration. In parallel, the project decided to begin the exercise of designing a suitable pollution control system.

Institutions and their roles

While planning the intervention at Howrah, the project contacted most of the key institutions active in the foundry cluster. This was important for forging partnerships and understanding cluster dynamics. Several institutions played an important role in the Howrah foundry cluster in 1995–97. Some of them are listed below.

- Local foundry associations: namely, IFA (Indian Foundry Association), and HFA (Howrah Foundry Association).
- IIF (The Institute of Indian Foundrymen).
- R&D laboratories/universities such as NML (National Metallurgical Laboratory, Jamshedpur) and BE College, Sibpur (Howrah).

Box 5
Situation in Howrah

In January 1996, the CPCB (Central Pollution Control Board) sent a notice to various foundry associations in India, asking them to take immediate steps to curb air pollution; specifically, to meet the emission norms set for SPM (suspended particulate matter). The WBPCB (West Bengal Pollution Control Board) issued similar notices in leading Kolkata newspapers. As mentioned earlier, the norms for SPM emissions were based on whether the cupolas melted more than or less than 3 tph (tonnes per hour). Owing to practical problems in measuring the quantity and rate of molten metal produced by a cupola, it was mutually agreed between the WBPCB and the local foundry associations that a cupola's internal diameter would be used as a yardstick to determine its melting rate.

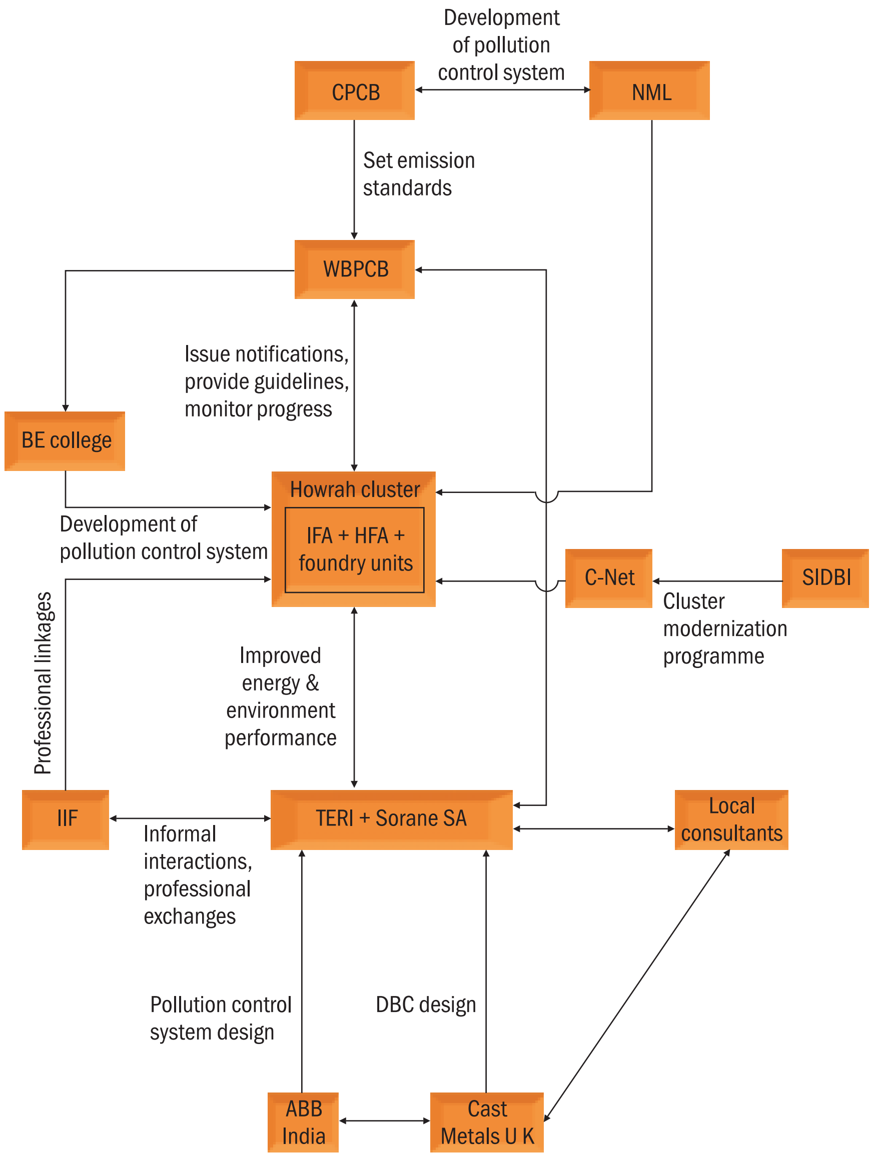
The CPCB and WBPCB stressed the need for pollution control at source (implying the use of energy-efficient technology). This led most foundries in Howrah to convert their cupolas to divided-blast operation. Many units believed that conversion of their cupolas to DBCs (divided-blast cupolas) would be adequate to meet emission norms, and save them the costs of installing pollution control systems. However, on 12 April 1996 the Supreme Court ordered the WBPCB to report on the progress made by foundries in installing permanent pollution control systems. The WBPCB conducted a series of inspections in the Howrah cluster in May–July 1996. Several units without pollution control systems were ordered to close down. This created panic in the cluster, and units rushed to install pollution control systems.

By the time the project entered the field in Howrah, many units had already converted their conventional cupolas to DBCs (of sub-optimal design). In most cupolas, the inner refractory linings had been increased to reduce the cupola diameters to between 32–34 inches, corresponding to a melting rate of 3 tph. The reason was simple: this permitted SPM emissions at the less stringent norm of 450 mg/Nm^3 (milligrams per normal metre). Also, most units had installed pollution control systems of some kind or the other.

- Financial institutions such as SIDBI.
- CPCB.
- WBPCB.
- Local consultancy firms.

The complex interactions among them, and between them and the project, are depicted in Figure 10.

Figure 10
Interactions between various players in the Howrah cluster in 1995–97



Competence pooling

The project was already working in close partnership with Sorane SA, Switzerland and Cast Metals Development Ltd, UK. In setting up the demonstration plant, the project brought together local and international experts in many disciplines—project management, foundry technology, energy management, cupola operations, and environmental technology. Pierre Jaboyedoff of Sorane SA was instrumental in arranging the technical tie-ups with Cast Metals Development Ltd. The project implementation strategy was drawn up in close consultation with him. He was also a key figure in other areas of intervention by the project: notably, the glass industry sub-sector. M S Brown, representing Cast Metals Development Ltd, brought his considerable expertise in cupola design to assist the project.

This approach – of pooling competencies – assisted considerably in overcoming the challenges and setbacks that arose, whether these were technological (as when components had to be redesigned), or procedural (such as delays caused by local suppliers and vendors).

Before building the demonstration plant at Howrah, the immediate challenges to be addressed were

- to identify a firm to design a suitable pollution control system;
- to select local consultant(s) for supervision of fabrication, installation, and commissioning activities; and
- to select site(s) for demonstration.

Pollution control system: finding a designer

The project explored various options to get the pollution control system designed by reputed institutions, both at the local level at Howrah and at the national level. Several institutions were working to develop pollution control systems. The project explored tie-ups with some of them. Towards this, dialogues were initiated with NML and C-Net (a local consultancy firm) at Howrah. However, it was found that the systems being designed by these and other institutions were aimed at meeting the less stringent emission norm of 450 mg/Nm^3 (Box 6). Instead, the project took a long-term view and decided that it would develop a pollution control system to meet the most stringent emission norm of 150 mg/Nm^3.

Towards this end, the project approached ABB to provide pollution control system design. ABB was then one of the most reputed suppliers of pollu-

Box 6
Pollution control:
other initiatives in Howrah

- NML had a field station at Howrah. The local office of the CPCB engaged NML to develop a 'cyclone' system for pollution control, and demonstrate it at Crawley & Ray—one of the most technologically progressive foundries in the Howrah cluster. Dr A C Ray was one of the directors of Crawley & Ray; he was held in high esteem by the small foundry owners, who were mainly affiliated to the Howrah Foundry Association or HFA.
- NML was also engaged by the IFA (Indian Foundry Association) to develop a suitable cyclone system for its member-foundries. NML developed and duly installed a cyclone system at Shree Uma Foundries (P) Ltd, Liluah, Howrah.
- The BE College, Sibpur, was engaged by the WBPCB to develop pollution control devices for foundries in the Howrah cluster. In December 1995, the BE College designed a 'wet scrubber' system with the assistance of the WBPCB's R&D Cell, and installed the system at Bharat Engineering Works.
- A number of other foundries in the cluster installed pollution control systems that were essentially copies of the systems installed at Crawley & Ray or at Bharat Engineering Works. In the wake of the inspections conducted by the WBPCB in May–July 1996, the IFA informed its members through a circular that the wet scrubber system was effective in meeting SPM norms. Accordingly, a large proportion of IFA-affiliated foundries installed wet scrubbers.
- About 30 members of the HFA adopted 'dry cyclone' systems for pollution control, based on a system designed by C-Net, a local consultancy firm. This design was in essence a copy of the system installed at Crawley & Ray.

tion control systems for industries in India. The project approached the senior management of ABB with a request to provide the design as a social gesture, to help the cause of protecting the environment. It was a 'special favour' that was being sought from ABB—the small-scale industrial sector is not an interesting market for the firm, because designs tend to be copied within this sector. ABB agreed to design a pollution control system for the project. The role of ABB would mainly be measurement of process parameters and design of a pollution control system. The fabrication and procurement of the equipment was the responsibility of the project.

Identifying local consultants

The project contacted local foundry institutions such as IIF, IFA, and HFA to identify local foundry consultants who could be engaged for implementation of the project. The major tasks of the local consultants would be day-to-day supervision of the fabrication and installation activities, including interaction with the entrepreneur; review and approval of bills/invoices of material purchases; and feedback on progress. After installation, the local consultants would assist in commissioning the plant and training the operators in BOP.

Initially, the project interacted with A C Ray of Crawley & Ray to discuss the possibility of engaging him as a local consultant. Ray had considerable working experience in the Howrah cluster, and the HFA foundries held him in high esteem. However, the project found that Ray's profile did not quite conform to the role envisaged by the project for a local consultant.

Subsequently, the project interacted with key office-bearers of the IIF to identify a suitable candidate. These meetings helped identify Birendra Kumar Rakshit – a mechanical engineer with several decades of experience in the foundry industry – as a local consultant. Rakshit proved invaluable during the fabrication and installation activities. Before commissioning the DBC, the project felt the need for a person with competence in refractory lining and operation of the cupola. Rakshit suggested the name of such an expert – A S Ganguli – who had acquired considerable hands-on experience in cupola operations and maintenance while working with a large-scale automotive foundry near Kolkata.

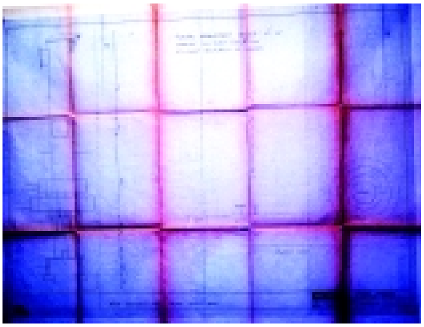
Selection of sites for demonstration

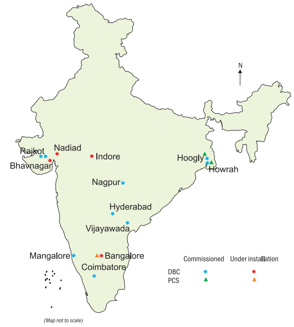
In order to maximize the involvement of local foundry owners in the development and demonstration of technology, one of the project strategies was to work closely with both the foundry associations in the Howrah cluster. Accordingly, it was decided to work with both HFA and IFA. HFA represents the very small local foundries, which are owned by second-generation Bengali entrepreneurs. On the other hand, IFA mainly represents, and is managed by, the larger and more progressive small-scale foundries in the Howrah cluster. Most of the IFA foundries are owned by first-generation entrepreneurs who came to Kolkata from other states in the 1950s–60s. Each of these foundry associations was requested to nominate one foundry from among their members in which to install and demonstrate the new technology. The units identified were

- IFA—Bharat Engineering Works; and
- HFA—Lakshmi Foundry Works.

Agreement for cooperation

To encourage the entrepreneur, the initial hardware costs of the demonstration plant were decided to be borne by the project. However, once the technology was successfully demonstrated, it was agreed that the foundry unit would buy the installed equipment and machinery at a pre-determined price. On his part, the entrepreneur agreed to allow others to visit and study the demonstration plant on a long-term basis, to help in spreading awareness.





Into the field

Pre-demonstration activity

Initially, the project's aim was to develop, install, and demonstrate the benefits of DBC technology in foundries using conventional cupolas. This decision was based on the energy audits it had conducted in the Agra cluster. However, the project found that many units in the Howrah cluster – including the two units nominated by IFA and HFA – used cupolas that already had twin rows of tuyeres, which gave the benefits of divided blast technology to a limited extent.

Energy and environmental audits

It was essential to assess the performance of the DBC design that foundries in Howrah were already using. Therefore, the project conducted energy and environmental audits of the existing DBCs in the two nominated foundries in June 1996. Assistance was taken from ABB to conduct the environmental audits and assess their results. The methodology and results of the energy audits were discussed with Mike Brown, the foundry expert from Cast Metals Development Ltd, UK.

The audits revealed that in both units, the cupolas performed below optimal level because of deficiencies in their design. For instance, the cupola at Bharat Engineering Works was found to have a CFR of 1:7·5, or 13·6%, indicating room for improvement. The SPM emissions at source (that is, before the pollution control device) varied between 1170–2200 mg/Nm^3. These measurements helped in determining DBC specifications and designing the required pollution control system for demonstration. As it turned out, the results of the audits at Lakshmi Foundry Works were skewed by

BOX 7
Two days of hard work...up in smoke!

At the start of the intervention in the Howrah foundry cluster, a baseline had to be established for environmental pollution at the two chosen foundries. It was a challenging task, requiring measurement of emissions to be taken with great accuracy.

After nearly two days of hard work at Lakshmi Foundry Works – a member of HFA, run by Sunil Kundu – we, the members of the project team, were tired but happy. The measurement results we had obtained were of good quality, and we felt that we had done a fine job.

What a surprise it was, then, when the British consultant Mike Brown came up and told us that the whole exercise was meaningless! It turned out that Kundu, the foundry owner, had decided to substitute the Indian coke normally used in his cupola, and which contains a lot of ash, with Australian coke which is much more expensive, but does not contain much ash. In doing so, Kundu had completely skewed the results of our measurements...

Pierre Jaboyedoff
Sorane SA

deviations from normal procedure made without the knowledge of the project team (Box 7).

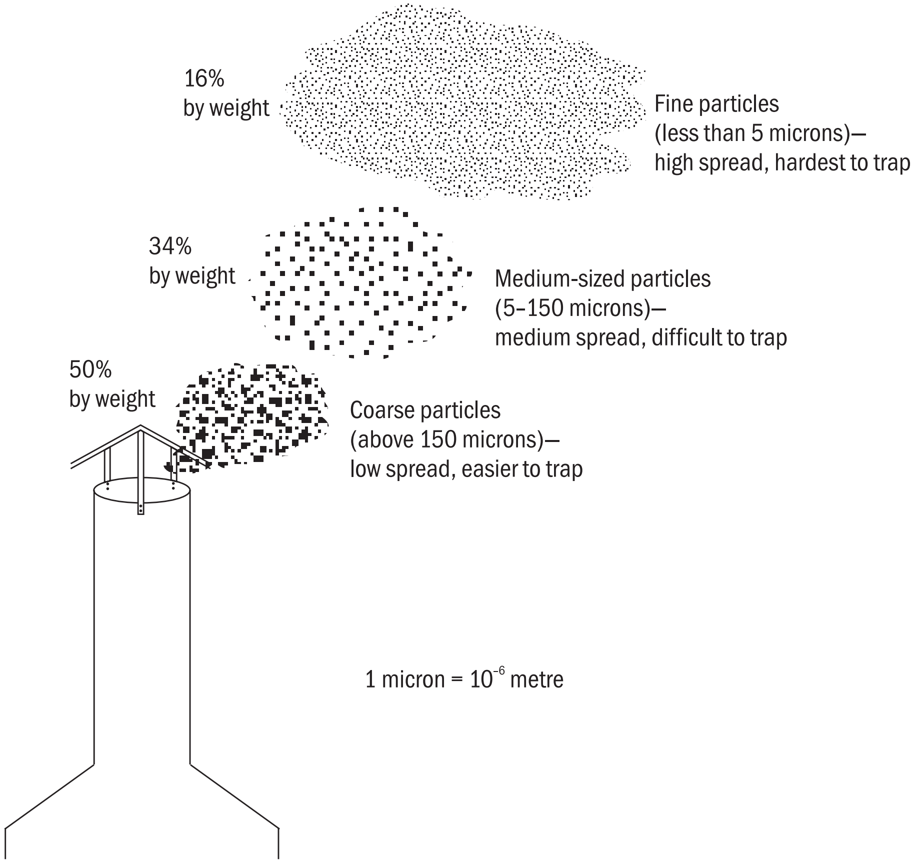
A particle size analysis of the SPM collected was done. In general, the sizes of the particulates and their distribution influence the selection of an appropriate pollution control device. The analysis revealed that a substantial percentage (about 16%) of the SPM was made up of fine particulates less than 5 microns in diameter (see Figure 11); these particles are the most harmful to health, and the most difficult to clean.

Correction of the design deficiencies in the existing cupolas would have required their extensive retrofitting. Instead, the project decided that it would be better to build a new DBC equipped with a proper pollution control system for each unit, and then demonstrate BOP.

Mechanical charging system

During the audits, it was observed that the charge materials were being lifted and loaded into the cupolas by labourers, who carried the charge

Figure 11
Particulate emissions from a typical cupola prior to cleaning in a pollution control system



material in baskets. The materials were not weighed before charging. The project decided to incorporate a mechanical charging system, known as 'skip bucket charger' (Box 8). In essence, the charge material is loaded into a bucket. The bucket is then mechanically winched up along rails and tipped to empty its contents into the cupola. This system would make weighing of charge material easier. At the same time, it would reduce the drudgery of manual loading.

BOX 8
Lessening the load

I used to work with Crawley & Ray, a well-established foundry in Howrah. We switched over to cupola melting from oil-fired reverberatory melting practice in the year 1973, after the worldwide oil crisis. We had to manage a 27-inch cupola in a small space, measuring 15 feet by 15 feet. The cupola did not have a ladder provision. We used to carry charge materials in wheelbarrows from the yard and lift the loaded wheelbarrows by electrical lift up to the loading platform. The charge material was directly fed into the cupola by tilting the wheelbarrows. This was an extremely laborious task. In the 1980s, we decided to adopt the skip bucket charging system. We adopted the design guidelines from the Wellman Incandescence Booklet. For the electrical control system, my experience in the elevator industry was of immense help.

Since then, I have been associated with design, fabrication, installation and operation of nine skip bucket charger systems. Out of these, five installations were carried out by my own organization, BBL Enterprise. I had the privilege of being associated with TERI in two such installations, at Howrah and Nagpur. My experience as a user has helped me upgrade the design from time to time to make it more user-friendly.

Niranjan Saha
BBL Enterprise

HFA withdraws from project

Unfortunately, after the initial baseline audits, HFA decided to drop out of the project (Box 9). Its nominee unit, Lakshmi Foundry Works, could not wait for the demonstration plant to be set up as it was under enormous pressure from the WBPCB to install a pollution control system on its existing cupola at an early date. Under the circumstances, the project had no choice but to set up its demonstration plant in the IFA unit alone, that is, at Bharat Engineering Works.

DBC: getting the design details right

The demonstration cupola was designed for a specific ID (internal diameter) specification, since the entrepreneur – S C Dugar, proprietor of Bharat Engineering Works – wanted a 34-inch ID cupola. The basic design of the demon-

BOX 9
An opportunity lost

From our initial interactions with the two foundry associations in Howrah – the IFA and the HFA – it was clear to us that they were very different from one another in terms of ideology, organization, management styles, knowledge of foundry technology, and environment technology.

There are a significant number of units with dual membership of both associations. However, with its centrally located office in Kolkata, IFA is much more visible to decision-makers than HFA, which operates from a dingy one-room office in Howrah.

While planning our intervention at Howrah in 1996, we decided to work with both the associations. Hence both IFA and HFA were requested to nominate a foundry unit where a demonstration plant would be set up. While IFA was quick to capitalize on the offer, HFA dilly-dallied and finally decided to opt out of the intervention. The reason given by HFA for opting out was that they could not wait for six months (the anticipated time of completion of the demonstration plant at that time). Besides, the HFA claimed, its member-units had already decided to spend 50 000 each on a cheaper pollution control system being offered by a local consulting firm, C-Net.

HFA's backing out was a great disappointment for the project team, for we had set our hearts on helping out the smaller foundries. We did approach other HFA-member units to adopt the proposed technology. However, given their small size and lack of resources, it became obvious to us that the project would have had to make many compromises in terms of quality of material and plant layout. This would have gone against the project's aim: namely, of demonstrating a technology that would set the benchmark for best energy and environmental performance.

Prosanto Pal
TERI

stration cupola was done by Mike Brown. The drawing is reproduced in Figure 12.

The DBC design paid particular attention to the following aspects.

- Specification of the blower, that is, the blast rate and pressure delivered (Figure 13).
- Dividing the supply of blast air to the top and bottom row of tuyeres in the correct proportion.
- Minimizing the pressure drop and turbulence of the combustion air

Figure 12
Mike Brown's original drawing of the demonstration DBC

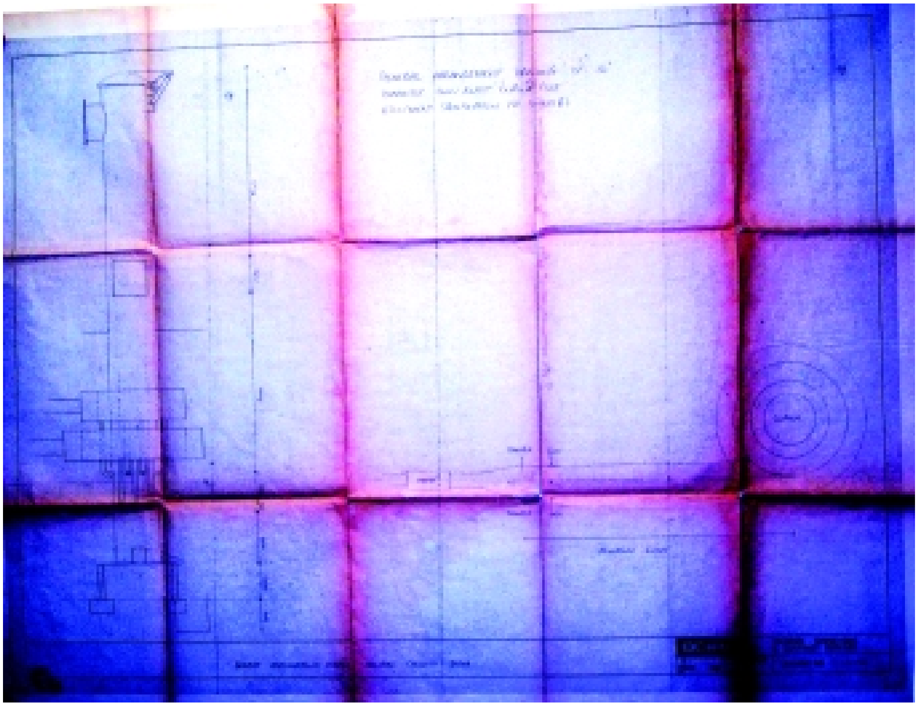
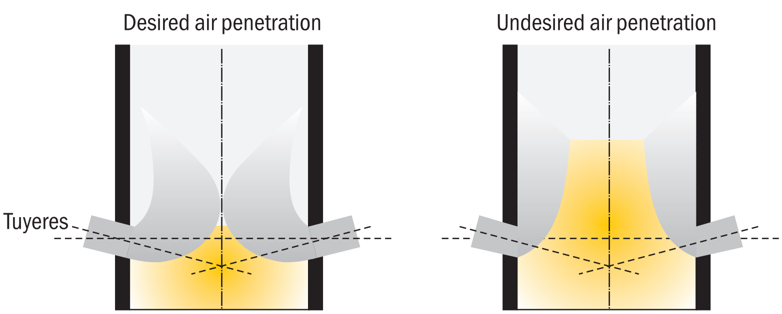


Figure 13
Desired and undesired air flow patterns in a cupola



through proper sizing and design of the blast mains, windbelt, and tuyeres.

The emphasis was to get the demonstration 'right the first time'

- Parameters like tuyere area and number of tuyeres.
- Matching the well capacity to the ladle size.
- Providing greater stack height for better heat exchange between ascending hot gases and descending charge materials.
- Material specifications, such as the thickness of mild steel plates used in cupola shell and base plates.

During fabrication, installation, and equipment selection, the emphasis was to get the demonstration 'right the first time'—for this would establish the credibility of the technology, and greatly facilitate in its eventual dissemination in the cluster and beyond. Hence, no compromise was made on design specifications or the quality of materials used in the equipment installed.

Pollution control system: selection and design

Several methods are available to clean cupola exhaust gases. These include centrifugal separators, low-energy scrubbers, fabric filters, and high-intensity scrubbers. Centrifugal separators such as 'cyclones', and low-energy scrubbers like spray towers or 'wet caps' (as they are commonly called in the local foundry industry), are not very effective in removing fine particulates less than 5 microns in size. After examining various options, the project decided to adopt a high intensity scrubber such as the 'venturi scrubber', which could meet the 150 mg/Nm^3 norm for SPM with certainty (Box 10). Although the operating principle of a venturi is simple, optimizing its design is a complex process.

Design, fabrication, and erection

To save time, it was decided to design and fabricate the DBC and the pollution control system in parallel. Ideally, the complete designs of both DBC and the pollution control system should have been ready when fabrication was taken up. While the DBC design was completed by August 1996, the venturi scrubber design was done in stages by ABB; the complete design was made available only in August 1997. As a consequence, although the cupola was ready for commissioning by early 1997, it could not be run without a pollution control system in place (Figure 15).

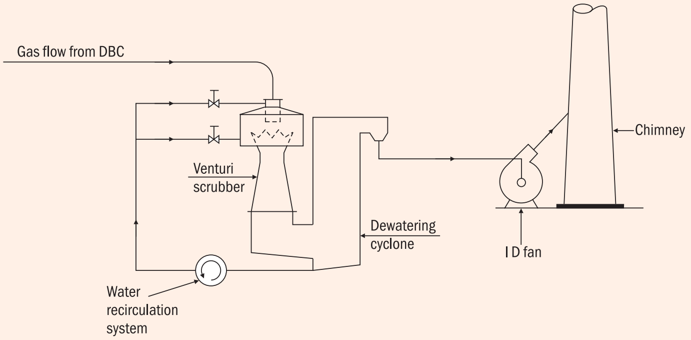
BOX 10
The venturi scrubber system

A venturi is like two funnels joined back-to-back by a narrow tube called the 'throat'. (Figure 14). Hot gas from the cupola is sucked into the venturi through the wide mouth on one side of the venturi (called the inlet). A powerful fan called an induced-draft or ID fan creates the suction. As the gas passes through the throat, its velocity increases considerably; simultaneously, it loses a great amount of pressure. Water is injected into the venturi throat. When the water meets the hot, high-velocity gas, it mixes with the gas to form a very fine, fast-moving 'mist'. So thorough is the mixing process that the tiny water droplets entrap most of the particulates in the gas.

The 'mist' exits the throat of the venturi through the wide mouth at its other end (called the diffuser). In doing so its velocity falls greatly, even as its pressure increases again. The mist is passed through a device called 'dewatering cyclone'; this device removes the water particles along with the particulates adhering to them. The remaining gas, now dry and cleaned of almost all particulate matter, is allowed to escape through the chimney.

Figure 14
(a) View of venturi scrubber system at the demonstration unit
(b) Schematic of the system

(a)



(b)

Figure 15
The demonstration DBC—ready before the pollution control system

Other unexpected delays arose in finalizing the designs and getting equipment fabricated on schedule. For instance, in May 1997, the need arose for a soil load-bearing test to be conducted for preparing the civil foundation drawings of the chimney for the pollution control system. This test could be conducted only in July 1997—at the height of the monsoon. The test report was received in August 1997, after which the civil drawings were finalized. In October 1997, excavation work began to lay a base for the chimney. However, high sub-soil water levels in the post-monsoon period hampered work. The erection of the chimney, along with other support structures and civil work, could be completed only in April 1998, and the pollution control system was finally erected in June 1998 (Box 11).

BOX 11
Business versus goodwill

Another primary reason for the delay in erection of the pollution control system was the time taken in its design by ABB India. Perhaps this was due to the fact that ABB undertook this work as a kind of goodwill gesture towards the cause of environmental protection among small-scale industries, at the instance of the project. ABB did not charge a design fee. Understandably, the firm did not accord the same priority to this assignment as they did to jobs being done on a commercial basis for their regular clientele.

At hindsight, it may have been better, and in the interests of the project, if a business/consultancy agreement had been given to ABB for the purpose of designing a pollution control device. This could have expedited the design of the system, and thereby brought forward the demonstration by at least eight to ten months.

Prosanto Pal
TERI

Demonstration: right the first time

The demonstration plant was ready for commissioning in July 1998 (Figure 16). It was decided to commission the DBC first, and ensure that it operated satisfactorily before integrating it with the pollution control system.

Trial runs of the DBC were conducted from late July 1998 onwards to fine-tune various sub-systems. The trial runs were closely and constantly supervised by the project team. In the course of each trial run, energy and environmental performances were monitored; data gathered and analysed; and operating parameters fine-tuned based on the results before conducting the next trial run.

A number of challenges were faced during the commissioning of the plant—demanding patience, ingenuity, and problem-solving skills from the project team members. One major barrier to be overcome was the widespread scepticism regarding the new cupola's capabilities, especially because the fabrication of the plant had taken an unusually long time (Box 12). There was a growing belief among workers, foundrymen, and even officials of the pollution control board that it would not function properly. In the words of a project engineer, the delay became the 'talk of the cluster' (Box 13).

Figure 16
Demonstration plant ready for commissioning

Therefore, the project team was even more elated when the trials were successfully conducted and the DBC and the pollution control system performed far better than expected (Box 14).

Energy saving and other benefits

The new DBC showed a reduction in CFR compared with the existing cupola. The CFR in the latter was 13.6% (coke:metal::1:7·5), whereas the DBC yielded a CFR of 8% (coke:metal::1:12·5). Hence, the energy saving achieved by the new plant was about 40% compared to the earlier cupola. The DBC also yielded additional benefits in terms of an increase in metal temperature and a substantial reduction in silicon and manganese losses.

BOX 12
Fabrication: from weeks to months

In August 1996, the project team met Pinaki Chakraborty, the fabricator, in Kolkata. 'This is the design for Bharat Engineering Work's new cupola,' said Mike, handing Pinaki a schematic drawing of the DBC (divided-blast cupola). 'Can you make it? And how long will the job take?'

'Yes, I can make it! And four weeks is all the time I'll take,' Pinaki promptly replied.

Only four weeks! We were relieved. But we should have known better...

The DBC that TERI offers is very different from the conventional cupolas that most foundries use, and hence, that most fabricators make. While making a conventional cupola is essentially a rolling and welding job, the TERI cupola is more than this. In TERI's design, there are cast iron parts, like the tuyere sleeves; cast iron bricks in some sections, and for the base plate; then there is the task of assembling and fitting all the sub-components and parts together, since welding of cast iron is not possible. Proper matching of the windbelts and the tuyeres is essential.

Pinaki was not able to see all this immediately. Pinaki's confidence stemmed from the fact that four weeks is normally the time taken for fabricating a conventional cupola.

Once the fabrication work began, however, Pinaki realized the challenges of the task! The entire project team – especially the project's local consultant, B K Rakshit – pitched in to help Pinaki on the job: with sketches (often hand made) that showed details of parts, and with advice on how to cast the parts and how to mark components for easier erection. The fabrication process took much more time than expected; the new cupola was finally installed only in February 1997.

N Vasudevan
TERI

On an average monthly melting of 430 tonnes, the DBC yielded an annual saving in coke of 270 tonnes, equivalent to 900 000 rupees (assuming a price of 3300 rupees per tonne for high ash Indian coke in 1998). The payback period worked out to be less than two years on the investment in the DBC alone.

Environmental performance

With the pollution control device, the average SPM emissions were brought down from over 2000 mg/Nm^3 to below 70 mg/Nm^3, which was well within

BOX 13
Size doesn't matter

TERI's new cupola shell and other components were all fabricated in the premises of Bharat Engineering Works. As the new cupola took shape, it became obvious to the factory workers that it would be smaller than their existing cupola, which had an external diameter of about 60 inches. This was enough to convince them that no useful purpose would be served by the new cupola.

'Aeta kono kajer hobe na,' they said to one another. 'This thing will be of no use.'

At last came the day of the first trial run. For a while, the workers were at a loss for words. They stood and watched, stunned into silence by the sheer quantity of molten metal that gushed out of the new cupola. Finally, one of them murmured: '*Amader chief minister to choto kintoo kota powerful*.' ('Our chief minister is small, but very powerful!') He was referring to the then chief minister of Bengal, Jyoti Basu—a dapper figure, yet a formidable politician.

S C Dugar
Bharat Engineering Works

the emission limit of 150 mg/Nm^3. Indeed, there was visible evidence that SPM emissions had been drastically reduced—because virtually no smoke was visible over the chimney when the new DBC was in operation (Figure 17). An added advantage of the venturi scrubber was that it reduced sulphur dioxide emissions to only 40 mg/Nm^3—much below the limit of 300 mg/Nm^3.

In 2001, the WBPCB revised its emission norms for foundries in the Howrah cluster by setting a single limit of 150 mg/Nm^3 for all cupolas irrespective of size. The project's venturi scrubber system comfortably met this norm. However, other units in the cluster once again came under pressure to upgrade their existing pollution control systems (which had been designed to meet the less stringent norm of 450 mg/Nm^3). This vindicated the project's long-term strategy of developing the best possible pollution control system, that is, the venturi scrubber.

BOP, and benefits of bucket charging

Indeed, the technology had been successfully demonstrated. For the project team, it was satisfying to witness the benefits the skip bucket charger

BOX 14
Teething trouble

22 July 1998. The stage was set for the demonstration run of TERI's first DBC (divided-blast cupola) furnace, with its pollution control device and energy efficient design. Personnel from TERI, a British expert, and the two local consultants of Kolkata were present on site at Bharat Engineering Works, Howrah. Ignition of the cupola bed coke was ritually carried out, and the first melt came out successfully. Everybody associated with the project breathed a sigh of relief. Little did any one apprehend the trouble that was to follow...

To start with, the cupola behaved quite normally. All of a sudden, we noticed that molten metal had entered into a couple of tuyeres. Hot spots appeared at several places on the cupola shell. There was no option but to 'drop off' the cupola, that is, to shut down the entire operation.

We realized the gravity of the situation the next day, when the cupola had to be repaired and prepared for the next run. One of the tuyere-sleeves had become completely solidified with metal. Replacement of the affected sleeve was required. No spare sleeve was available at hand, and we learnt that a spare sleeve could not be made for at least a week. The whole programme was stalled; the euphoria of the previous day's success evaporated; our pride and prestige sank to the floor.

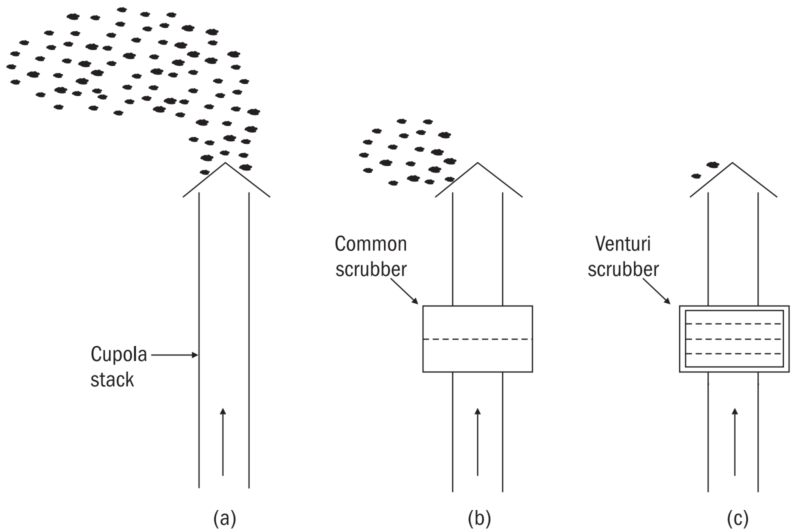
And then, out of this misery, an idea emerged like a beacon of hope! Perhaps we could procure a steel pipe, and use it to fabricate a tuyere sleeve of similar dimension? The idea worked: the clogged sleeve was replaced, and the demonstration runs were completed without any further trouble. Our pride and prestige were salvaged; the entrepreneur was happy and satisfied.

Ajit Shankar Ganguly
Local Consultant

brought, in terms of greater safety to the workers who earlier had to charge the cupola manually (Box 15). This was the appropriate stage to impart training in BOP to the furnace operators and the maintenance personnel in the unit. Team members worked alongside factory workers for several weeks to ensure that the latter understood and applied the best operating practices in the day-to-day running of the plant.

Figure 17

A comparison of particulate emission levels: (a) without any pollution control system (≈ 2000 mg/Nm^3); (b) with a commonly used pollution control system (≈ 500 mg/Nm^3); (c) with the demonstration venturi scrubber (≈ 50 mg/Nm^3)



BOX 15

A charger's blessing

I had the privilege to monitor TERI's demonstration plant for three months after its first successful test-firing. Earlier, the foundry workers would load charge into the furnace by carrying head-loads up to the feeding door. Now, the new cupola had a 'skip bucket' mechanical charger.

One fine morning a worker came up to me. His face glowed with gratitude. To my astonishment he folded his hands and said: '*Bhagwan aapka bhala karen; aap sada sukhi rahen*' ('May the Lord bless you with eternal happiness!'). When I asked him why he had blessed me, he replied: 'Sir, my name is Ram Kumar. I have been working here for several years. My duty is cupola charging. In our old cupola while I was doing the manual

Continued

BOX 15
A charger's blessing (*continued*)

charging on the platform, there was a sudden backfire through the cupola charging door. Look, you can see how my face and neck were broiled in the flames. It took me a long time to recover and to resume work.

'With the system you have installed, we now do the charging at the floor level. Our job is easier now, since we can carry the material from the yard by wheelbarrow and tilt it directly on to the skip bucket. No longer do we have to bear the material on our heads, all the way up to that 20-foot charging platform. Now there is no risk of any accident even if there is a backfire ...'

B K Rakshit
Local Consultant

Spreading the word

On 28 November 1998, a workshop was arranged in Kolkata to disseminate the results of the successful demonstration among representatives from the IIF, IFA, and financial institutions including SIDBI and State Bank of India's UPTECH programme (a programme for technology upgradation). Site visits were arranged for the participants, and presentations made and discussions held on different aspects of the technology, its benefits, and the future strategy of project partners.

A paper describing the project's work was presented by team members at the Asian Foundry Congress, held in Kolkata from 23 to 26 January 1999. The next day, about 140 delegates from the conference visited Bharat Engineering Works and witnessed the demonstration plant in operation. As luck would have it, that very day a CPCB/WBPCB surveillance squad turned up at the site to conduct a surprise check on SPM emissions from the plant. The squad found the SPM levels were well within limits, and duly announced this to the assembled delegates. Subsequently, the demonstration unit received an award from the WBPCB for its excellence in pollution control (Figure 18).

The project made efforts to motivate foundries to avail themselves of financial assistance from SIDBI; but an effective fit could not be found. Replication in the Howrah foundry cluster did not take off; as a result, collaboration with SIDBI took a back seat. At a higher level, efforts by SIDBI to

Figure 18
Certificate received by the demonstration plant for environmental excellence


Environmental Excellence Award

2000-2001

West Bengal Cleaner Production Centre

a collaborative effort of

West Bengal Pollution Control Board

Indian Chamber of Commerce

confers the Environmental Excellence Award, 2000—2001

on

M/s. Bharat Engineering Works

Kona, Howrah, West Bengal

for their proactive and appreciable environmental management practices during the year, 2000-2001

A. V. Lodha
President
Indian Chamber of Commerce

Manabendra Mukherjee
Minister-in-Charge
Environment and Information Technology
and
Chairman, West Bengal Pollution Control Board

establish an environmental cell also took time, and hence the two collaborations of SDC (with SIDBI and with the project) moved in a somewhat parallel manner.

Lessons during early replications

Providing designs 'free of cost'

To promote the demonstrated technology, the project decided to provide the designs and technical assistance free of cost to the first three units signing up for replication. In each case, the unit was required to bear only the cost of hardware.

In February 1999, a foundry unit at Kharagpur – Basu Iron and Steel Company – signed up to replicate both the DBC and pollution control system. The project spent considerable time and resources conducting the energy and environmental audits of the unit. Later, detailed design drawings were prepared. However, the foundry shelved the project, citing market recession.

To screen out non-serious foundry units, the project decided to charge a token 'commitment fee'

Soon after, the project faced a similar experience with another foundry unit at Howrah—Crescent Foundry Co. Pvt. Ltd. After initial energy audits and drawing up of cupola design, this unit too backed out from its earlier decision to invest in a new DBC. These experiences were a lesson for the project: that pitfalls lay in providing services without any financial commitment on the part of the beneficiary. Hence, in order to screen out non-serious foundry units, the project decided to charge a token 'commitment fee' for replication in future.

Quality control

Another foundry – Shree Uma Foundries in Kharagpur, West Bengal – sought help in replacing its old cupola and pollution control system with a new plant. In October 1999, the project conducted an energy and environmental audit of the unit. The unit's pollution control system, set up at great cost several years earlier, had become badly corroded and required urgent replacement. The project, therefore, drew up designs for a new pollution control system along with a new cupola.

In January 2000, the unit asked the project to make changes in cupola design—changes that would have led to reduction in the DBC's energy efficiency, and thereby negated the very purpose of the project's intervention. By March 2000, it became clear that the unit did not care about increasing energy efficiency: it only wanted to reduce costs by cutting corners. Rather than compromise on the quality of its technology, the project withdrew from the proposed scheme.

Unbundling the package

The first replication happened far away from the Howrah cluster—at Nagpur Grey Iron Castings, a small foundry located in the central Indian city of Nagpur. This foundry faced problems with its existing cupola, and was looking for a reliable and efficient cupola design. By chance, the owner heard about the project's new DBC when he attended a foundry congress held in early 2000 at Coimbatore.

In August 2000, at the owner's request, the project conducted an energy audit of the unit. Since enforcement of emission norms was virtually absent in Nagpur, this foundry did not have a pollution control system at all, nor was it interested in setting up one. It only wanted an energy-efficient DBC to be designed by the project.

This was a situation the project staff had faced, and were facing, elsewhere in the field as well. Should the new technology be provided only as a package, comprising both energy-efficient DBC and pollution control system? Or should the DBC be provided separately when requested? The project decided that while every effort would be made to provide the technology as a package, the cupola and pollution control system would be provided separately if needed—but no compromise would be made on the quality of the technology.

By December 2000, the basic design of the new DBC was completed, and the completed plant was commissioned in July 2001 (Box 16).

The cupola and venturi scrubber system would be provided separately if needed—but no compromise would be made on quality of technology

Small units are reluctant to share experiences

The replication at Nagpur resulted in a very high coke saving of 40%, and consequently translated into an attractive payback on investment for the foundry (Figure 19). The energy savings were established by conducting baseline and post-commissioning energy audits. The expectation was that the unit owner would share his positive experiences with the new technology

BOX 16
Melting barriers

I am at Nagpur – the 'orange city', centre of India – on a mission: to help commission the energy-efficient furnace set up by the project at a local foundry. Among our team are TERI engineers, an expert from England, and my colleague from Kolkata. The stage is set for the very first trial operation of the new divided blast cupola. Everyone is waiting anxiously for the first metal to roll down the spout. I stand with the foreign expert on the furnace platform, alongside the furnace operator and his helper. The furnace operator is a seasoned hand; he is sceptical of what we hope to contribute by our presence up there.

The first trickle of molten metal appears at the tap-hole. The furnace operator picks up a tap-hole poker to clear away any small coke pieces that might obstruct the flow of metal. But no! The metal has stopped flowing; it solidifies, blocking the tap-hole. This is a major problem; the blockage has to be cleared immediately, or else the cupola will have to be 'dropped off' (shut down). A commotion ensues. While everyone runs helter-skelter, flinging around ideas and suggestions, the furnace operator resorts to the traditional way to solve the problem. He grabs a crow-bar, places it on the congealed metal at the tap-hole, and directs his helper to hammer on the crow-bar to dislodge the mass. But the crow-bar itself gets stuck!

Having experienced such situations earlier, I have kept the oxygen-lancing gear available as a standby. Now I use the apparatus to blow oxygen through a metal pipe at the tap-hole, at regulated pressure. The solidified metal melts away and good fine metal gushes down the spout, much to everyone's relief.

For a while, the furnace operator stands silent, awestruck. He has never seen such a procedure before. Usually, in the event of the blockage not being cleared by hammering, the only solution familiar to him is to shut down the furnace. His earlier scepticism is gone. And my personal satisfaction is that I have been able to win over his heart, gain the trust and respect of a co-worker...

Ajit Shankar Ganguli
Local Consultant

among his peer group, and thereby influence other members of the group to adopt the same technology.

However, this did not happen. Rather, the unit showed an initial reluctance to acknowledge the benefits of the new technology. The project has learned from experience that this trait – of downplaying the benefits of a newly acquired technology – is quite common among entrepreneurs in the small-scale sector. Perhaps it stems from the intensely competitive environment in which they operate. Such entrepreneurial behaviour inhibits 'spread of the word', and is extremely detrimental from the viewpoint of disseminating a new technology.

Figure 19
A view of the Nagpur DBC

Assisting larger units has advantages

The next replication after Nagpur was at a large foundry unit named Kesoram Spun Pipes & Foundries, located in Hoogly (West Bengal). The foundry unit had three hot-blast cupolas, each melting 10 tph. Although the foundry had installed a venturi scrubber system, designed in-house, this pollution control device did not perform effectively and the unit was issued a closure notice by the WBPCB.

Towards the end of 2001, the foundry approached the project with a request to design a new DBC and pollution control system. Since the unit was a large foundry, the request sparked off an internal debate within the project on whether or not to provide technical assistance to larger units.

Larger units are torch-bearers of innovation

As replication activities were then at an initial stage, it was felt that the project should not exclude any unit merely on the basis of its size. This was especially because new technologies, which involve a higher investment, are likely to be adopted initially by medium and large-sized units. Indeed, assisting larger units would help in replicating the technology among small units later, since larger units are torch-bearers of innovation in a sector. Thus, precluding this segment of the industry from availing the benefits of the new technology would adversely affect the dissemination efforts. The project therefore decided to provide technical services to Kesoram Spun Pipes & Foundries, by charging an appropriate consultancy fee.

The unit replaced its existing hot-blast cupolas with DBCs. This resulted in substantial energy savings; for, not only did the DBCs give better melting performance, but the unit saved oil that was being consumed to pre-heat blast air for its earlier cupolas. More important, installation of the new and effective pollution control system averted the threat of closure of the foundry by pollution control authorities on account of non-compliance with emission standards (Box 17).

BOX 17
Kesoram: where DBC bettered the hot-blast cupola

Kesoram Spun Pipes & Foundries is located about 70 km (kilometres) from Kolkata. It was set up in 1965, and produces about 150 tonnes per day of grey iron spun pipes. The CFR in its existing hot-blast cupolas was about 18%, that is, a little better than 1:5.

With the conversion of its cupolas to DBCs (divided-blast cupola), the CFR (coke feed ratio) was reduced to 13% (or nearly 1:8), which translated to a saving in coke of 28% over earlier levels.[6] In monetary terms, the savings from coke alone translated to about 800 000 rupees per month (175 tonnes of coke at 4500 rupees per tonne) in the foundry. In addition, 200 000 rupees per month was saved in terms of diesel consumed earlier in the air pre-heating system. Thanks to these savings, the total investment in retrofitting the three cupolas, amounting to about 1·2 million rupees, was paid back in a little over a month's time!

[6] Two factors determine the CFR (coke feed ratio) in a cupola, apart from its design. One is the temperature at which molten metal needs to be delivered; the other is the quality of coke. In Kesoram's case, the product (spun pipes) required a higher molten metal temperature compared to Bharat Engineering Works. Hence, the difference in CFR achieved by the DBCs (divided-blast cupolas) in the two foundries.

Widening the horizon

In the initial years of the intervention, the project's activities were primarily focused on demonstration of improved technologies for energy efficiency and pollution control in the Howrah cluster and neighbouring areas. Thereafter, the project decided to expand its ambit beyond dissemination of technology alone; indeed, to use technology as an entry point to address social concerns. Towards this end, an extensive baseline study of foundry workers in the Howrah cluster was carried out during 1999–2001. Based on the results of the study, the project developed a social action plan that aims to improve the socio-economic conditions of workers in the Howrah cluster. Therefore, the project's post-demonstration activities followed two broad parallel tracks.

1 Dissemination of technology
2 Social action

Dissemination of technology

In seeking to disseminate the improved technologies beyond Howrah, the project emphasis was on studying and assessing the market potential in the foundry industry. This meant surveying various foundry clusters; understanding their needs for better technology, and the pressure on units to comply with emission norms; obtaining data on local service providers (consultants, fabricators, and so on); and identifying and establishing linkages with local-level industry associations.

The first step was to organize a brainstorming session with stakeholders to discuss possible strategies to popularize the new technology (Box 18). Participants included representatives from industry associations, state technical consultancy organizations, and local consultants. Based on the discussions, the project decided to take the steps listed below.

- Short-list five foundry clusters with high potential for replication.
- Identify local partners. Engage them to conduct studies of the short-listed clusters.
- Organize 'ice-breaking'seminars at cluster-level to establish rapport with unit owners.
- Conduct field studies with local partners, and assess the scope for the new technology.
- Analyse data collected, and follow up with foundries that show interest in the new technology.

BOX 18
Brainstorming session on dissemination

A major bottleneck to effective dissemination of technology among small-scale units is the fact that available industrial databases do not provide complete and updated information regarding the number of units, their size, their technology levels, competing technology providers, and investment priorities. In May 2002, a brainstorming session was organized at TERI to discuss the issue. Participants agreed that it was necessary to conduct market surveys of a few selected clusters to assess the potential for replication of the DBC (divided-blast cupola) and the pollution control system.

A few of the recommendations made by the session relating to cluster evaluation and marketing strategy are listed below.

- To facilitate interaction with entrepreneurs and to add credibility to the exercise, the market survey team should include a senior foundryman.
- The survey questionnaire should be brief and to-the-point.
- A basket of tools should be used to support the dissemination efforts—cluster-level seminars, articles in foundry journals, video films, networking with local experts and industry leaders, arranging visits by possible clients to working plants, and so on.
- Attempts should be made to develop innovative financial packages for the technologies—for instance, loan repayment plans based on energy savings.
- Local nodes should be developed and strengthened to disseminate the technology.
- O&M (operation and maintenance) services should be made available for a while to recipients even after commissioning of the plant(s).

Cluster studies, early results

The brainstorming session helped to identify five promising clusters: Coimbatore, Belgaum, Kolhapur, Rajkot, and Batala–Jalandhar (Punjab). The first step was to draw up TOR (terms of reference) to clearly spell out the methodology to be adopted by a firm that expressed interest in undertaking a cluster study. Soon after, the project developed a mailing list of potential regional-level organizations and invited proposals from them to undertake the studies

A comprehensive database was developed on the profile of foundries in five clusters based on the TOR. The proposals received were screened by the project, and the following organizations were selected to conduct the cluster surveys.

- ITCOT (Industrial and Technical Consultancy Organization of Tamil Nadu Ltd) for Coimbatore
- MITCON Consultancy Services Ltd for Kolhapur
- NITCON (North India Technical Consultancy Organization Ltd) for Punjab
- REA (Rajkot Engineering Association) for Rajkot
- Materials Research Centre for Belgaum

To begin with, an ice-breaking seminar was conducted in each of the five clusters (Figure 20). These seminars were organized in collaboration with the local industry associations to give the events a sense of participation, and to make them more meaningful to the local entrepreneurs. Later, surveys were carried out by the local partners. To assist in the surveys, TERI prepared an information containing detailed information about the improved DBC and pollution control system developed and demonstrated by the project. These brochures were distributed among units surveyed, to give entrepreneurs a better idea about the benefits of the new technology (Figure 21).

Figure 20
Cluster workshop in session

Figure 21
Brochure distributed to units during surveys

Based on the surveys, a comprehensive internal database was developed on the profile of foundries in each cluster. This exercise helped to identify potential client-foundries. For follow-up, interactions were held with the owners of these foundry units in each of the clusters. The interactions led to two replications in the initial stage—one each in Rajkot and Coimbatore clusters (Box 19).

Dissemination strategy

Based on the cluster-level information, the project set about formulating a large-scale dissemination strategy for the new technologies (Figure 22). A 'first-cut' strategy was formulated by the project team. As this field of work was uncharted territory for team members, it was decided to get the strategy reviewed by those experienced in the promotion and uptake of new technologies. They included senior foundrymen, industrial financiers, and academicians. Useful feedback was received from several reviewers, based on which the dissemination strategy was fine-tuned for implementation.

BOX 19
The positive influence of candour

The third replication of the DBC (divided-blast cupola) was at Shining Engineers and Founders in Rajkot (Gujarat). This foundry signed up in November 2002, soon after the cluster level workshop was organized for the Rajkot cluster. A set of two DBCs was designed for the unit. The DBCs yielded significant savings in coke consumption. Buoyed by their performance, the unit retrofitted its other operating cupolas too to DBC.

Shining Engineers and Founders is one of the most progressive units in Rajkot. Its proprietor, Mansukhbhai H Patel, is held in high esteem among the local foundry community. Successful replication of the DBC at this foundry gave a major fillip to the project's marketing efforts in the state. The news spread among local foundries, as was borne out by the large number of enquiries received from the cluster. Certainly, Mansukhbhai himself played a prominent role in spreading the word about the new technology. He openly acknowledged the benefits he had derived by adopting the DBC, and provided references to interested foundry units. The experience with Shining Engineers and Founders was indeed an eye-opener, in terms of the enormous influence that positive user-reference can have in uptake of innovations.

Prosanto Pal
TERI

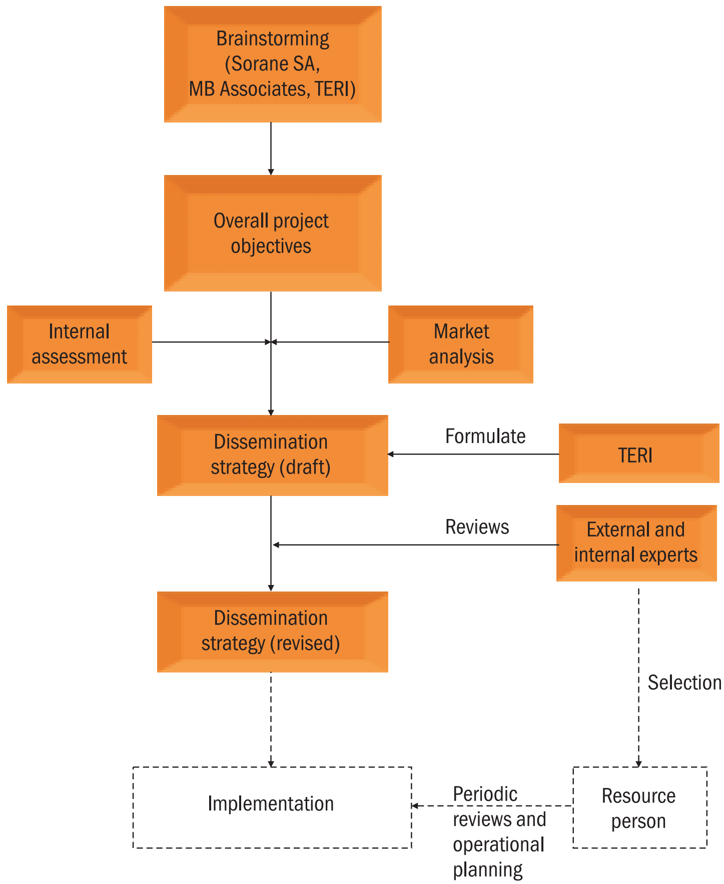
Assessing potential

Taking a conservative value of coke savings of 20% by adoption of the new DBC, the energy bill of a typical foundry unit melting 100 tonnes/month will be reduced by about 400 000 rupees (2004 prices). The capital cost of a DBC is about 800 000 rupees, inclusive of all ancillary equipment. These figures suggest a payback period of approximately two years. For a larger foundry unit melting 200 tonnes/month, similar calculations suggest a payback period of less than a year. This implies that adoption of DBC is particularly attractive for foundry units that melt 200 tonnes/month or more.

Adoption of the DBC is particularly attractive for foundries that melt 200 tonnes/month or more

Market analysis reveals that out of 5000-odd foundry units in India, about 1000 foundries operate with production levels large enough (about 200

Figure 22
Dissemination strategy formulation—
a flow chart



tonnes per month) to yield an attractive payback on an investment in a new cupola. Hence, these foundries – and among them, the more 'innovative' units in particular – comprise the potential target group for replicating the DBC technology (Box 20).

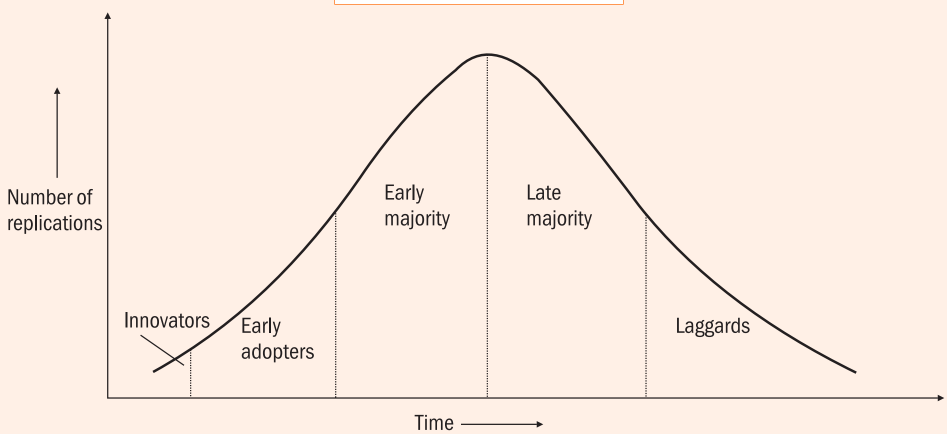
As for the pollution control system, the target group consists only of the larger foundries. Even these foundries are likely to adopt a venturi scrubber only when pollution control norms are strictly enforced and/or when community pressures force units to comply with the prevailing environmental standards.

BOX 20
The shape of replications

Adoption of a new technology by users depends a great deal on the profile of the user. According to the 'diffusion theory', adopters of an innovation or a new technology can be classified under five broad categories, according to the order in which they pick up the new technology—innovators, early adopters, early majority, later majority, and laggards (Figure 23).

Innovators comprise units that are willing to take calculated investment risks, are proactive, and generally more progressive. Hence, it was decided to identify units under this segment first, and to target them for replication of the new technology. The idea was that by developing rapport with these innovators, in the longer term they could serve as industry mentors. Successful diffusion of the technology would then depend upon managing and using the industry mentors for replication at the cluster or regional level. To identify innovators, the project sought cupola owners who had made attempts to modify their melting units to operate in a more energy-efficient manner.

Figure 23
Pattern of replication: the bell-shaped curve

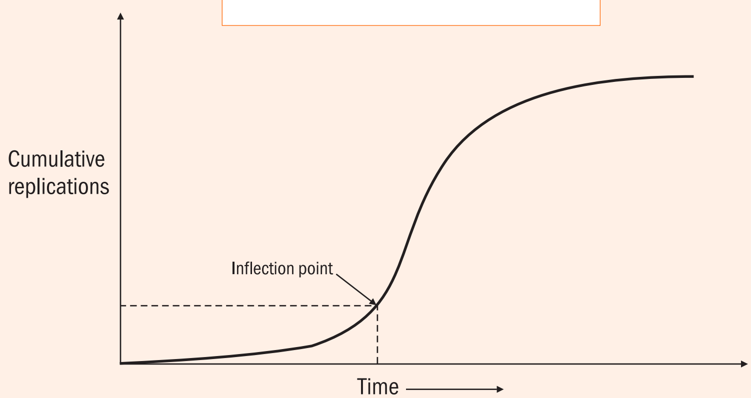


Continued...

BOX 20
The shape of replications (*continued*)

Research on diffusion of new technologies indicates that the rate of diffusion usually follows what is called the 'S-shaped curve' (Figure 24). As the figure indicates, replication initially occurs at a fairly slow rate, till a point comes where a large number of replications take place in a very short interval. This point is appropriately called the 'take-off' or inflection point. It is easy to understand why replications follow this pattern. Interpersonal networks become activated only after a certain 'critical mass' of the market (anywhere between 10% and 25% of units, according to research) has adopted the technology. It is estimated that this 'critical mass' of 10% adoption – or 100 replications – for this technology will be reached around 2015/16.

Figure 24
Rate of growth in replications: the S-curve



Marketing support

In the course of market evaluation, the project felt the need for specialized inputs from a marketing practitioner. The major challenge was to find a marketing specialist who had experience in the field of small-scale industries. In due course, three experts were identified and subjected to a screening process to identify the most suitable candidate for the role. As part of the

BOX 21
Vendor development:
influencing the delivery chain

One way of promoting the new DBC (divided-blast cupola) technology and ensuring its acceptance by foundries would be to apply the concept of vendor development. Here, the 'vendor' is a foundry that makes castings; the 'buyer' is the industry that uses those castings in its manufacturing processes. (For example, an automobile plant would be the 'buyer' of castings like brakes, flywheels, etc. from a foundry—the 'vendor'.) Essentially, vendor development means getting the buyer to influence the vendor to adopt the new (DBC) technology.

Most of the time new technologies are introduced by vendors when the buyers have needs that are not being met by the existing production facilities of the vendors. These needs could be in terms of cost, quality, quantity, or timely delivery. In the present scenario, when we want foundries to accept the new DBC technology, we should also look at the buyer expectations; the buyers too could be asked to help persuade vendor-foundries to adopt the new technology.

Rajiv R Bhatia
Marketing Consultant

screening process, each of the short-listed experts was asked to develop a small marketing plan for the DBC. Based on their responses (reports, presentations, and so on), and after further one-on-one interactions, Rajiv R Bhatia was selected to support the project in fine-tuning the marketing strategy and in its implementation (Box 21).

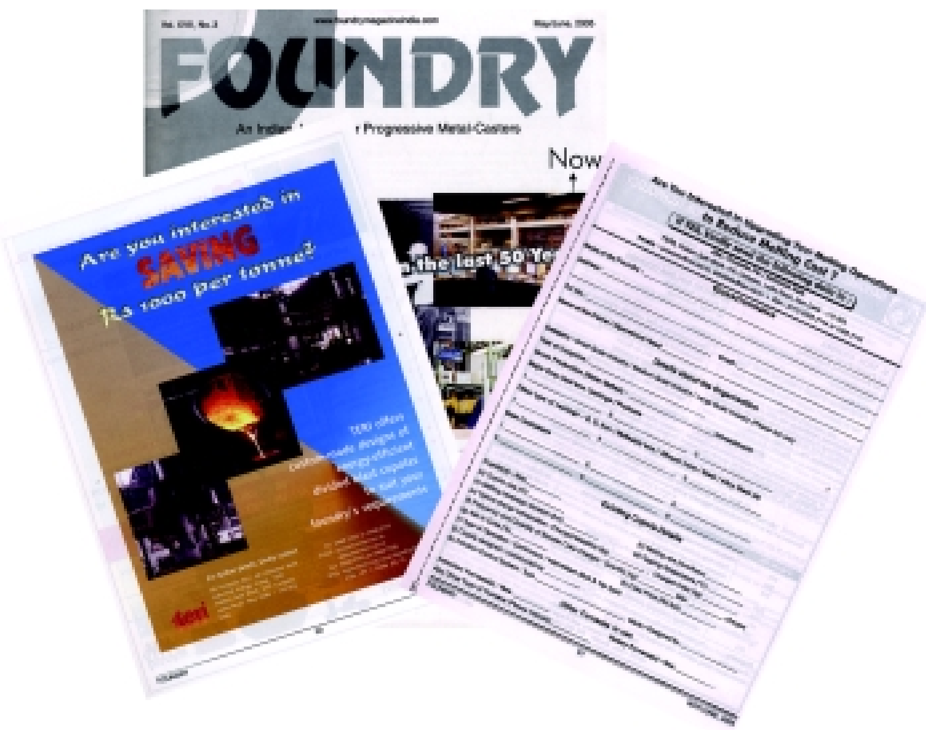
Financial attractiveness: the unique selling point

Since the bottom line for adoption of a new technology lies in its economics, it was felt that monetary savings should be the USP (unique selling point) for marketing of the DBC. A detailed exercise was carried out at Shining Engineers and Founders, Rajkot, to accurately quantify the savings (in terms of energy, materials, and reduced foundry return levels) that could be achieved through adoption of the new DBC. Based on the results, an attractive flyer was designed by the project emphasizing the DBC's monetary savings aspects.

Having developed the flyer, two strategies were followed by the project in consultation with Bhatia (Figure 25).

- The flyer was placed as a full-page advertisement in three consecutive issues of *Foundry*, the most widely circulated magazine among the foundry industry in India. The flyer was accompanied by a tear-off questionnaire that interested entrepreneurs could fill up and return to TERI. The questionnaire was simple, yet designed to provide a good profile of the foundry unit(s) and their customers.
- The flyer, along with the questionnaire, was directly mailed to potential client-foundries that were identified from the internal foundry database.

Figure 25
Reaching out to potential clients: ad-cum-questionnaire placed in *Foundry*



The advertisements in the magazine drew far more positive responses than the direct mailers. The lesson: in seeking to promote a new technology, it is far more effective to address communications to the target audience as a group than on an individual basis.

Technology delivery

As replications increase, it is desirable to have fabricators and consultants in position to deliver the technology

While setting up the demonstration plant at Howrah, much of the detailed work – drawing up designs of tuyeres, civil works, mechanical charging systems, and the like – had to be done in close coordination with the foundry. Local consultants were, therefore, hired to interact with vendors and supervise progress. However, the project realized that as the technology spreads to other units and clusters (that is, as replications increase), it would be desirable to have fabricators along with individual consultants in position to deliver the technology to interested foundries. This would also enable more effective control over the quality of the technology delivered.

Here, it is important to note that correct fabrication of the improved DBC by itself does not yield the full benefits in terms of energy efficiency. A number of specific practices must be carefully followed to ensure that the cupola performs in an optimal manner—in other words, BOP must be followed. Typically, BOP covers ways to prepare and load charge materials; methods to ignite the coke, to start the melting process, to shut down the cupola; proper maintenance and repair of cupola; and so on (Figure 26).

Therefore, in each replication that followed the demonstration at Howrah, the project closely monitored the fabrication and commissioning process, and provided technical support and training in BOP. In each case, local fabricators were trained in building DBCs, which incorporated various innovative features developed by the project. Along with them, local consultants were engaged to monitor the replication projects. In the process, these consultants obtained hands-on training from the project team in design of the new DBC, and in BOP.

To obtain optimal results from a DBC, a number of specific practices – BOP – must be followed

Efforts are now on to identify and develop more such fabricators and consultants with the assistance of industrial associations, both at national and cluster levels. This broader network of technology providers will assist in delivery of the technologies in future.

Figure 26
Demonstrating best operating practices

Exploring financial options

To assist in dissemination of the new technology, it is vital to design suitable financial packages for units that might be interested in adopting the technology, but do not have the financial resources to do so, or even know where to look for finance. There are a number of methods – classical and modern – to finance new and innovative technologies.

After exploring several classical methods of financing, albeit with limited success, the project decided to explore the possibility of financing the new technology under the 'clean development mechanism' or CDM of the Kyoto Protocol (Box 22).

Knowledge-sharing

Foundry units generally function in isolation. There is little interaction among them, especially on best practices related to technology and latest know-how. This acts as a barrier to the spread of improved technologies such as those developed by the project.

BOX 22
Clean development mechanism

The Kyoto Protocol, an international and legally binding agreement to reduce GHG (greenhouse gas) emissions worldwide, entered into force on 16 February 2005. The Protocol is a follow-up agreement to the Rio Summit of 1992. Under the Protocol, most of the developed countries have agreed to cut down their GHG emission levels before the year 2012, by at least 5% below the emission levels as of 1990. To encourage these countries to meet their emission reduction commitments, the Protocol has established three market-based mechanisms: ET (emissions trading); JI (joint implementation); and CDM (clean development mechanism).

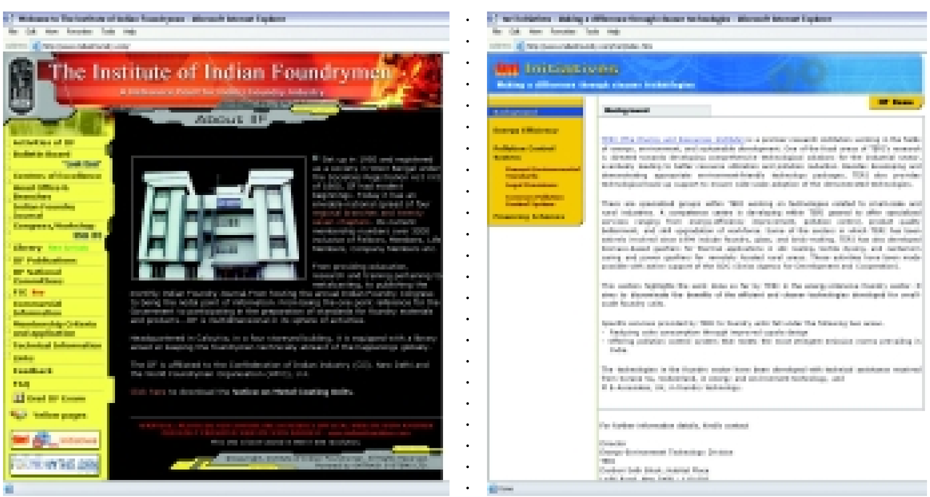
The rationale behind CDM is simple: reduction of GHG emissions in any part of the world will result in reduction in global levels of these gases. In general, it is more expensive to reduce GHG emissions in developed nations that already use advanced, low-GHG emission technologies. On the other hand, many industries in developing countries use energy-inefficient technologies that result in high GHG emissions. CDM allows a developed country to meet part of its emissions reduction targets by setting up low-GHG projects in a developing country. The arrangement is mutually beneficial: the former achieves its GHG reduction target at lower cost, while the latter benefits in the form of finance and improved technology.

The project prepared a proposal under CDM for one of the most promising foundry clusters in India—the Rajkot cluster. The process involved close interaction with the most progressive local industry association – the Rajkot Engineering Association – and drew upon data gathered by the project during its cluster-level study at Rajkot. The proposal 'bundles' reduction in emissions of carbon dioxide (the main GHG) that can be achieved by implementation of the energy-efficient DBC (divided-blast cupola) technology in 190 foundries in the Rajkot cluster. If this proposal is approved, the units concerned will benefit by obtaining access to the improved DBC technology at a lower cost. The 'bundling' approach of financing the new technology under CDM can then be replicated to cover other foundry clusters in the country. The long-term aim is to explore funding, under CDM, to support the large-scale dissemination of the new technology.

The project, therefore, decided to use the Internet to provide a space where foundries can access and share information related to the industry. Initially, the project considered setting up a separate website for the purpose. However, the project felt that the objective could be better achieved by strengthening an existing website on the Indian foundry industry. The project had interacted with the IIF from time to time; hence, their website[7] appeared to be a natural choice for the purpose.

It was a challenging process to persuade the IIF to provide space in its website for the project; a process that involved a series of consultations and interactions, and that has transformed the relationship between the project and the IIF from that of collaboration to one of strategic partnership. The website now carries several pages of information related to new energy-efficient technologies, environmental regulations and pollution control systems, financing schemes, and the like. The joint initiative has also helped to make the IIF website more 'visible' to Net users in India and abroad (Figure 27).

Figure 27
A snapshot of IIF's website, featuring foundry-related information developed in collaboration with TERI



[7] www.indianfoundry.com

Strengthening the IIF's website has in effect created a 'virtual' knowledge-sharing platform for the foundry industry. Another knowledge-sharing exercise – this one involving face-to-face interaction among key stakeholders – was a national meet arranged at the Indian Foundry Congress in January 2005 on 'Energy, Environment, and Corporate Social Responsibility.' Speakers included participants from the CPCB, WBPCB, IIF, foundry associations, and NGOs working in the fields of energy, environment, and social action. The event gave the project the opportunity to present what had been achieved, and to discuss what could still be done to benefit the foundry sector as a whole in the fields of technology, knowledge, and social action.

Assessing the results

Encouraged by the success of the demonstration at Howrah and by the early replications at Nagpur, Hoogly, and Rajkot – and assisted by the project's ongoing dissemination efforts – several more foundry units located all over India have adopted the new DBC technology. By the end of 2004, 13 DBCs were in operation. An analysis revealed that these cupolas had cumulatively saved over 4300 tonnes of coke, which translated into a reduction in carbon dioxide emissions of nearly 11 000 tonnes.

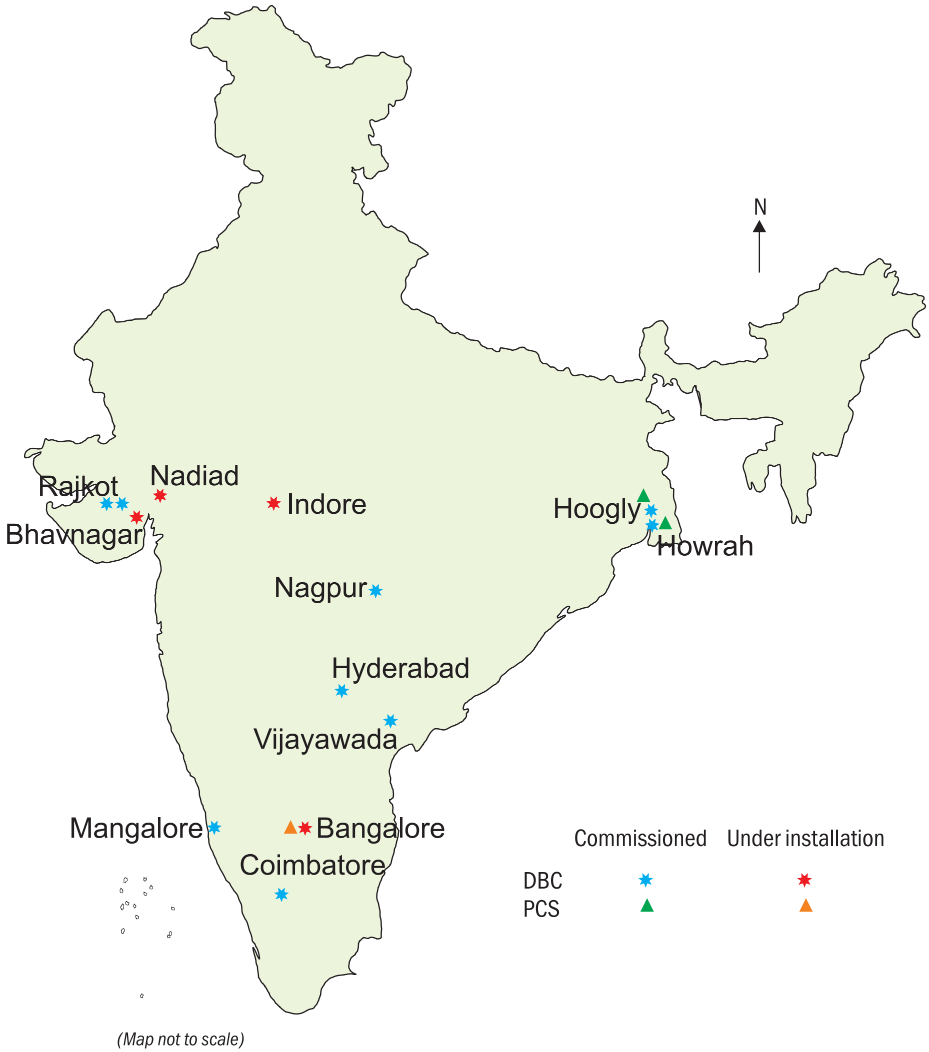
The project has not been successful in replicating the pollution control system. This is because units are reluctant to invest in expensive but effective pollution control devices (such as the demonstrated venturi scrubber) unless strict enforcement of emission standards compel them to do so.

At the end of 2005, a total of 16 DBCs and two venturi scrubber systems were in operation; eight more DBCs are under installation (Figure 28). These figures do not include a large number of 'self-replicated' DBCs and venturi scrubbers—that is, cupolas and pollution control devices whose designs are based on the project's designs, but which have been fabricated and installed without any support from the project.

Social action

As mentioned earlier, a comprehensive baseline study of foundry workers in Howrah was undertaken during 1999–2001. Based on the results of the study, the project developed a social action plan that aims to improve the socio-economic conditions of workers in the Howrah cluster. In the course of the study, the project staff interacted with the workers and their families, as well as with labour contractors and owners of foundry units in the Howrah

Figure 28
Gathering momentum: map showing replications of the DBC and pollution control system



cluster. The team met IFA office bearers; officials attached to the WBPCB, the District Industries Centre, and the Department of Environment; and researchers attached to various local institutes. In the process, the project obtained a deeper understanding of the problems workers faced within the

Figure 29
Workers carrying molten metal from cupola to moulds

foundry, as well as of the social realities that govern the workers' world beyond the foundry walls.

The factory floor

In general, operating practices in a foundry pose many hazards. Mechanization is almost absent, and workers have to bear heavy loads on their heads or carry molten metal around the factory floor (Figure 29). The SPM levels within the units are dangerously high. One key reason is the lack of proper ventilation within the units. As a consequence, respiratory ailments are common among workers. The workers are reluctant to use safety equipment such as boots, goggles, and gloves even when these are provided to them (Figure 30). They feel that such equipment impedes their movements and thereby affects their productivity.

The working environment too is difficult in foundries. Many units do not have proper toilet facilities, nor do they provide a safe supply of drinking

Figure 30
The factory floor—tough working conditions

water. Workers feel that conditions in the foundries can be made much safer and more congenial by providing better amenities; arranging more space for easy movement and operations; providing better lighting; and by providing mechanical aids in certain dangerous processes such as pouring of molten metal.

Trade unionism and contractual labour

Trade unions have always had a strong presence in West Bengal. The industrialists adopted a very conservative and static attitude in addressing the

BOX 23
Darkness—
and a flame of hope

Liluah Iron Works is a 'traditional' foundry, set up in 1946. It makes precision castings of high quality. Its owner, Amalendu Guha, is a veteran foundryman. He recalls the prosperity of the 1950s–60s, and how the foundry industry – including his own unit – was badly affected by mindless trade unionism in the 1970s.

One day in the early 1970s, the factory union leader came up to Guha and said: 'Today we will shout slogans against you, prevent you from going home after work—we will *gherao* you!' When Guha asked him why, the union leader admitted that the workers were quite happy in the factory, and did not have any grievances. 'Still, we have no option but to *gherao* you! The big trade union chiefs are applying great pressure on factory unions to agitate against their managements. So, we too have to show them we're doing something...'

'Well, if you want to prevent me from going home, you'll have to come back to the factory at 11 o'clock tonight; that's the normal time I finish work and head home,' replied Guha. The union leader's face became very thoughtful. He left and returned a while later, to say that the union had reconsidered its decision and cancelled the proposed protest.

'I knew the union leaders were all conscientious nine-to-five workers—nothing would make them stay in the factory till such an hour!' says Guha. However, things rapidly went from bad to worse. Across the state, industrial activity ground to a halt. Strikes were held over the most trivial issues; ugly scenes degenerated to violence, even murder. Many non-Bengali industrialists moved out of the state; skilled labour migrated to foundry clusters in other states; a large number of Bengali-owned foundries simply closed down. The remaining units limped along, crippled by losses. Thus, the Howrah cluster lost many of its competitive advantages.

Does Guha see any hope for the smaller, traditional foundries today? 'Yes...but the fires must not be lit in the cupolas alone. The flame of hope must be lit in the minds of owners and workers.'

basic human needs of the workers. This led to alienation of the workforce. Union activism intensified in the 1970s, leading to conflicts and severely affecting the industrial sector across the state (Box 23). Since then, many foundry owners in the Howrah cluster have turned to labour contractors to provide their workforce. This has led to further erosion of mutual trust and widened the rift between workers and owners.

Most of the workers in the Howrah cluster are impoverished migrants from rural areas of Bengal, Bihar, Orissa, and Uttar Pradesh. Almost all of them work for labour contractors. Thus, they are totally unprotected by labour laws relating to minimum wages, hours of work, provident fund, insurance, and so on. For the same reason, they have little or no attachment to the foundries in which they work.

Living from day to day

The foundry worker's toil is hardly matched by the wages he earns. On an average, a worker puts in 48 hours a week. His average income varies between 80–100 rupees per day, depending on the number of hours he works and on the level of his skills. Thus, the average monthly income of a worker is no more than 2500 rupees. A major chunk of this goes towards meeting essential family expenses—food, clothing, medicine, and rent. On an average, a family has five members, making it exceedingly difficult for them to survive on such a paltry income. To supplement their income, labourers work overtime—even taking on jobs in other foundries after completing duties for the day in their parent units. By and large, though, they continue to live at subsistence level.

Health issues

The typical foundry worker lives in a state of acute poverty. Basic essentials such as food for the family take precedence over all other concerns, including personal health. The health hazards arise not only from the working environment in the foundry. The worker and his/her family live without adequate access to even the most rudimentary health care services. Their dwellings are located in areas that lack sanitation. Water supplies are erratic and often contaminated. The combined effects of unhygienic living conditions, lack of safe drinking water, and unhealthy working environment make them particularly vulnerable to various ailments.

Frozen prospects

Most workers fall into the age group 30–40 years. The reason for this relatively high average age is simple—there is very little infusion of fresh manpower into the foundry workforce. The primary

With progressively fewer young men entering the foundry workforce, the system of traditional skills is dying out reasons are the hard labour involved; the hazardous working conditions; related health problems; and lack of any career prospects. Many among the existing workers have spent a decade or more in the cluster, and come from families traditionally engaged in metal casting. Each has learned his skills from elders: perhaps a grandfather who was an expert in pattern-making, perhaps a father engaged in moulding. With progressively fewer young men entering the workforce, this system of inherited skills is dying out.

Foundry workers in Howrah want proper medical care, housing, better wages, education for their children. . .

Most foundry workers in Howrah are men. One reason could be the arduous labour involved in many tasks. Also, traditional skills have perhaps been restricted to menfolk. However, some foundries employ local women in cleaning operations.

Almost all workers are illiterate, or dropped out of school at an early age. Lack of education and limited income inevitably gives rise to low self-esteem, and alienates the workers from the mainstream. Despite their own economic hardship and lack of education – or perhaps because of it – the majority of workers wish that their children could receive proper education. It is noteworthy that among their children, boys drop out of school far more often than girls. This is in sharp contrast to the national pattern, where usually the girl child is not sent to school, or is discouraged from continuing education beyond a point.

When asked what they would like most to improve their lives, the workers' responses are almost always the same—better wages; proper medical care and housing for their families; education for their children; and opportunities to increase their skills. All these needs are interlinked; all are equally important.

Working with workers

Interactions with foundry owners, workers, and other stakeholders in Howrah gave project staff a deep insight into the socio-economic problems faced by workers and their families, and highlighted the dire need to bring about improvement in their working environment and living conditions. In 2001/02, TERI held a series of discussions with social experts, and developed a framework for social intervention in the Howrah cluster. In December 2002, this framework was presented to representatives of industry associations, foundry owners, supervisors, and workers at a workshop held in Howrah in order to elicit their response. It was a unique initiative in the

Howrah foundry cluster; perhaps for the first time, socio-economic issues were discussed and debated in a structured manner by workers and owners on a common platform.

Thereafter, TERI asked two local NGOs – IMSE (Institute for Motivating Self-Employment), and SAVE (Society for Advancement of Village Environment) – to conduct short pilot field studies among foundry workers to evolve some actionable recommendations. The studies helped to evolve a 'Social Action Plan' which highlighted the following areas for possible intervention.

- 'Needs-assessment' camps, to assess the needs of workers and their families
- Education/awareness packages for workers
- Health camps for workers and supervisors
- Programmes to upgrade skills of workers and supervisors
- Liaison and policy dialogue with government institutions

In April 2003, TERI and IMSE organized a joint interaction with foundry owners and workers. The meeting helped to sharpen the focus of the social intervention. To ensure participatory planning, a steering group was constituted comprising foundry workers, owners, and representatives of all three industry associations—HFA, IFA, and IIF.

Establishing trust

The first and most important step was to gain the trust of the workforce, and establish a rapport with them. Towards this goal, the project assigned IMSE a short ameliorative action project. A number of health check-up and awareness camps were organized for foundry workers in Howrah (Figure 31). To sustain the process of creating awareness, a small group of workers were

Figure 31
Building trust: an awareness camp for foundry workers in Howrah

chosen to play the role of 'animators', and an education curriculum was prepared for them. The curriculum covers a wide range of issues—the foundry industry; occupational hazards and safety; first-aid training; general health and hygiene; de-addiction processes; introduction to alternative medicines and yoga; family welfare; human rights; social security schemes; and savings and credit management. The curriculum is not a rigid framework. It is flexible, and allows for ongoing amendments and changes in focus based on interactions with the beneficiaries of the social action programme.

The first and most important step was to gain the trust of workers and establish a rapport with them

Bridging the worker–owner gulf

TERI's social intervention in the Howrah cluster seeks to strengthen socially responsible behaviour among foundry owners, and to upgrade the skill-sets of workers. These measures are critical to the survival of foundries—particularly the smaller units. It is obvious that a healthy, skilled, and loyal worker will do his job much better, and thereby greatly increase productivity and profitability. However, a large number of traditional foundry owners – in Howrah and elsewhere – are unwilling to accept this simple truth. They continue to leave worker recruitment to labour contractors, and day-to-day operations to *mistrys*. Not much is done to improve working conditions in the factory, to train or provide security of tenure to workers, or to assist in the welfare of their families. Naturally, on their part the workers owe little loyalty to the units in which they serve, nor are they given any incentives to perform better (Box 24).

It is obvious that a healthy, skilled, and loyal worker will do his job much better

Indeed, for an average worker, the crushing burdens of poverty and social deprivation make each day a battle for survival; he cannot think of any change in his pattern of existence. D P Lahiri, of IMSE, expresses it in stark terms: 'The foundry labourer in Howrah lives without hope; his soul is dead.'

Issues such as medical benefits and compensation to labourers are extremely sensitive topics for foundry owners. Yet they now view TERI as a credible partner, and slowly but surely TERI and IMSE have begun to bridge the gap in understanding between the workforce and the owners (Boxes 25 and 26). The aim is to establish a 'worker–owner platform'; a forum where employers and workers can meet as partners rather than as antagonists. Such a platform would enable both sides to communicate as equals on an ongoing basis, increase mutual respect and understanding, and help resolve differences and problems (Figure 32).

BOX 24
Poor Basanta…

A project has something for everybody. So it was with the intervention in the foundry sector. For SDC and TERI it was energy savings and pollution reduction; for the entrepreneur, it was a chance to save costs and increase productivity; for me, it was an opportunity to work and see through my very first engineering project.

The Nagpur foundry replication was my first assignment. I visited the foundry quite often and got to know a number of workers there. One of them was Basanta, the furnace operator. On the day the new divided-blast cupola was commissioned, the entire project team was present at the plant—including Mike Brown, the British specialist. When the cupola was started and the molten metal began to gush out, the melting rate was so high that workers were nervous about putting the first ladle under the tapping box. Mike came to their rescue, handling the first ladle himself.

The workers already had a deep respect for Mike; he was a tough, 'hands-on' task-master. This incident increased their respect for Mike. Basanta at once asked me to take a few snaps of himself with Mike. When I asked him why, Basanta replied that he would use the snaps as proof of his experience and expertise in cupola operation, to get a better job. So, the project had something for Basanta too!

I didn't take any snaps of Basanta with Mike. I had a selfish reason not to: I didn't want a trained furnace operator such as Basanta to leave us so soon. Poor Basanta…

When I next visited the foundry, Basanta told me he was planning to start a small melting unit of his own. He proposed to convert a drum into a small cupola, melt scrap in it, and use the metal to make weights for fishing nets. I was both impressed by the idea and sorry for Basanta. Poor Basanta…

Yet it struck me later: did I have any reason, indeed any right, to regard Basanta with pity? To think of him as 'poor' Basanta? On an absolute scale, some of us may be better off than others; each one of us is involved in our own struggle, each one of us is trying to reach somewhere further in our own different way. Yet, we sink and we swim together. Each of us needs another for something, each is as important as the other.

In a flash it became clear to me that in such projects, we have to treat even the so-called 'smallest' player as an equal partner if we want the project to succeed. We should not dole out help, but extend our hands as equals in friendship and work towards our common goals. As long as Basanta is 'poor Basanta' to me, we will probably reach nowhere…

Abhishek Nath
TERI

BOX 25
Dismantling walls of mistrust

Today, the traditional Bengali-owned foundries are becoming increasingly inward-looking. The trade union cadres that destroyed these foundries over issues like bonus and raises...those very cadres now realize their mistake. Their erstwhile union leaders have long since moved ahead. There was little more they could extract out of foundry owners. On the other hand, the owners have squeezed all that they can out of their obsolete equipment. Now, they have no money even to dismantle their cupolas. Yet, their factories sit on prime land in Howrah...

There is great mistrust between the owners and workers. Often it reaches ridiculous levels...a foundry owner told me about a worker who was unwell. The owner, a kind man, told him to go home for treatment and rest. But the worker refused to leave the factory—because it was the lunch break, and the worker felt that by being asked to leave during the lunch break, he was being denied a privilege!

Yet if the units are to survive, the owners and workers must work together. This is what TERI and IMSE hope to achieve, by setting up a common platform on which both sides can meet and exchange views...

Biplab Halim
IMSE

Figure 32
Worker–owner forum meeting

BOX 26
Worker-friendly machines...

The labour-versus-machine debate has raged since the Industrial Revolution. It is particularly relevant in the context of labour-intensive industries, such as the traditional small-scale foundries in India.

Consider the skip bucket charger. For the foundry owner, the device is of course welcome. It comes at a cost; but it also saves the costs of the ladder and loading platform that are needed for the traditional manual loading of charge into the cupola. Besides, the device allows charging to be done at the factory floor level—now, the material can be easily inspected and accurately weighed. This enables tighter control over the quantity as well as quality of the charge material. This in turn translates into better quality of molten metal produced by the cupola.

For the worker, too, the device offers benefits. It spares him from the literally back-breaking task of carrying charge material in baskets up to the loading platform. Now, the charge-loader only has to bring the charge material in wheelbarrows up to the 'bucket pit' at the base of the skip bucket charger. Loading of charge at floor level also protects the worker from exposure to deadly carbon monoxide gas at the charging door, and from possible burn injuries because of 'backfire'.

A win–win situation? Not quite. Five men are needed in manual loading of charge. With the skip bucket charger, just two men will suffice. In other words, each skip bucket charger displaces three charge-loaders from their jobs. For the foundry owner, this means considerable savings in terms of manpower costs. According to an estimate made during a workshop organized by IIF, TERI, and IMSE in April 2005, a skip bucket charger enables savings of 113 400 rupees per annum in terms of reduced costs of manpower.

The question is: what happens to the three workers who have lost their erstwhile jobs as charge-loaders because of the device?

Ask foundry owners, and their replies are predictably reassuring. They claim that displaced charge-loaders are given work elsewhere in the foundry, tasks such as cleaning and material-handling that do not require special skills. Or, they say that the workers find jobs in other foundries. Such claims are hard to verify—especially in a situation where the bulk of unskilled and semi-skilled workers are hired through labour contractors. At the same time, a foundry owner can hardly be faulted for adopting a mechanical device that improves productivity and increases his profits.

In a country where levels of unemployment are very high, the prospects are indeed grim for semi-skilled or

Continued

BOX 26
Worker-friendly machines… (*Continued*)

unskilled workers suddenly deprived of their jobs. Often, they are bonded by debt to labour contractors; there are no social security schemes and no safety nets to protect them from the abyss of poverty.

What can be done in such a scenario? There is no clear-cut answer to this question. Perhaps the answer lies at a much deeper level. A level where the traditional barriers between workers and owners do not exist. A level where increased productivity because of a mechanical device translates into expansion in business, leading to more job opportunities; where a share of the increased profits is used to increase wages and improve working conditions, strengthening workers' affinity to their unit; where the owner realizes that workers who are happy with their jobs perform much better than workers who lack any affinity or loyalty to his unit.

The solution must lie in creating much greater empathy between workers and owners. This is no easy task; it requires patience, understanding, and time, and the results are not easily quantifiable. Yet the task must be done if social action is to have any real meaning. The first vital step is to create a space for the owner and worker to interact as equal partners: a 'worker–owner platform'…

Jayanta Mitra
TERI


MELTING BARRIERS
WORKER-OWNER
CHARGING PLATFORM
PATIENCE
TRUST
RESPECT
EMPATHY
HEALTHCARE
SAFETY
LOYALTY
PRODUCTIVITY

The way forward

The market for grey iron foundry castings has undergone transformation over the years, presenting both challenges and opportunities for the foundry industry. Demand for high-quality castings is rising in the international markets and from the indigenous automotive sector, even as there is reducing demand from traditional consumers like the railways and telecom sectors. Good-quality (low-ash) coke from China became available for Indian foundries at modest prices at the turn of the century; but thereafter the prices have risen sharply. At the same time, foundries face increasing pressure to comply with emission norms. In effect, there is an ever-increasing need for foundry units to improve the quality of their products and to increase the efficiency of their operations in terms of energy as well as environmental performance.

The intervention by SDC and TERI in the foundry sub-sector has led to successful replications of the DBC technology in a number of units across the country. The improved melting technology has brought about significant increase in energy efficiency, and consequently reduced greenhouse gas emissions to a large extent. In the years to come, the project's activities will focus on mainstreaming its DBC and pollution control systems. While doing so, the project will use knowledge-sharing to facilitate and catalyse change—at the technological, institutional, and social levels.

In the years to come the project will focus on mainstreaming its DBC and pollution control systems

In the course of the intervention, the project has established a large informal network of partners—workers, entrepreneurs, local consultants, international experts, industry associations, government bodies, fabricators, organizations specializing in energy and environment technology, marketing advisers, academic institutions, and NGOs. The project proposes to expand this network and strengthen its capacity through knowledge-sharing initiatives. These initiatives may assume different shapes for different recipients. For instance, training programmes in better cupola-operating practices will benefit furnace operators. On a different plane, future generations of foundry-men may be more sensitized to issues concerning energy efficiency and pollution control by strengthening and restructuring the curriculae of technical training institutes. This approach – of initiating change through knowledge-sharing processes – will greatly assist the process of mainstreaming the technologies in a sustainable manner.

The knowledge-sharing approach will also be useful in strengthening the project's efforts in the field of social action among foundry workers. The model 'worker–owner platform' established at Howrah will be used to design more such interactive forums to discuss and implement measures to increase productivity, to ensure safety on the factory floor, to introduce practices that make the workers' jobs easier, and so on. Support will continue for the ongoing dialogue between workers and owners. Initiatives such as health camps and counselling services for workers will continue to be pursued. The project will also try and network with other voluntary organizations to establish a dependable health-care system for foundry workers and their families. In due course, the experiences gained during the pilot social initiatives in the Howrah cluster can be used to design similar pilot social projects for foundry workers in other clusters.

The project will use knowledge-sharing to catalyse change

Currently, the project is undertaking policy research in areas that directly impact the Indian foundry industry and its workforce, with a view to bring about positive changes at the policy level. For instance, in recent years, the foundry industry is facing major challenges in meeting emission norms as a result of stricter enforcement of environmental laws and judicial intervention. At the root of the crisis lies a lack of awareness on environmental issues among all players. The project will continue to promote dialogue between industry, government representatives, and other stakeholders, to find innovative ways to tackle such problems. Similarly, there is a dire need to assist foundry workers, who often live and work in conditions of extreme hardship, and who lack access to social support systems. The project will pursue

Support will continue for the ongoing dialogue between workers and owners policy dialogue and advocacy with the government to influence changes for the benefit of the workforce.

In a nutshell, the project will adopt an integrated approach to address technological and social concerns of the foundry industry: both at the cluster-level and at policy-level. It will use knowledge-sharing as a mechanism by which to build bonds between various players sharing an interest in the growth and welfare of the foundry industry. This will enable mainstreaming of its clean and energy-efficient technologies; assist the growth of the industry; and bring about improvement in the lives of the foundry workers and their families. It is important to ensure the sustainability of these activities. The project will strive to anchor its various initiatives within broader institutional frameworks, such as programmes supported by government, multilateral, and bilateral institutions.

The project will strive to anchor its various initiatives within broader institutional frameworks for long-term sustainability

A step in this direction has been taken with the launch, in 2005, of an initiative named 'CoSMiLE' (Competence network for Small and Micro Learning Enterprises). In essence, CoSMiLE is a dynamic and informal network comprising players bound together by a keenness to learn and share knowledge in order to bring about socio-economic development in the Indian SMiE sector. CoSMiLE also covers other fields of intervention by SDC and TERI—namely, glass, brick, and thermal gasifier sub-sectors. This initiative could well be extended to other countries with similar socio-economic profiles.

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S Swami	IIT, Kanpur
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N Vasudevan	TERI, New Delhi
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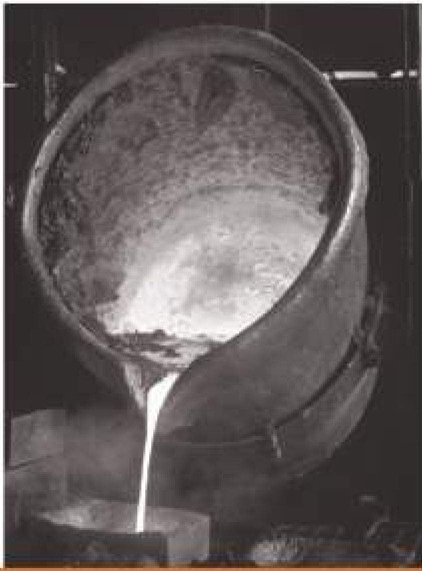
H Werner	SDC, Berne
Rakesh Yecho	NITCON, Chandigarh
K Yogeshwaran	Smithson Fountech (India) Pvt Ltd, Coimbatore
Deepak Zade	MITCON, Pune

Abbreviations

ABB	Asea Brown Boveri Ltd
APITCO	APITCO Ltd
ASCI	Administrative Staff College of India
CODISSIA	The Coimbatore District Small Industries Association
COSMAFAN	Coimbatore Tiny and Small Foundry Owners Association
CPCB	Central Pollution Control Board
HCCI	Howrah Chamber of Commerce and Industry
HFA	Howrah Foundry Association
IIT	Indian Institute of Technology
IFA	Indian Foundry Association
IIF	Institute of Indian Foundrymen
IMSE	Institute for Motivating Self-employment
IRIIM	Indian Research Institute for Integrated Medicine
ITCOT	Industrial and Technical Consultancy Organization of Tamil Nadu Ltd
MITCON	MITCON Ltd
NITCON	North India Technical Consultancy Organization Ltd
REA	Rajkot Engineering Association
SAVE	Society for Advancement of Village Environment
SDC	Swiss Agency for Development and Cooperation
SIDBI	Small Industries Development Bank of India
TERI	The Energy and Resources Institute
TISS	Tata Institute of Social Sciences
UNIDO	United Nations Industrial Development Organization
WBPCB	West Bengal Pollution Control Board



The small scale sector occupies a position of prominence in the Indian economy. In India's present liberalized economy, the survival and growth of the SMiE (small and micro enterprises) sector largely depends on the ability of units to innovate, improve operational efficiency and meet statutory emission norms.

In 1994-95, SDC (Swiss Agency for Development and Cooperation) and TERI (The Energy and Resources Institute) entered into partnership to find solutions to the energy and environmental problems of select SMiE sub-sectors through technology upgradation and human and institutional development. Four sub-sectors were selected for intervention: foundries; sericulture; glass industries; and brick manufacture.

This book deals with the foundry industry. It narrates, in a brief and simple manner, the process by which the partners developed and demonstrated an energy-efficient melting furnace and an effective pollution control system for the Indian foundry industry. It also describes the measures being taken to spread these technologies. In particular, the book highlights the experiences of project staff and other stakeholders, and the challenges faced and tackled by them in the course of their work.

This book is primarily intended as a guide for researchers, policy makers, NGOs, donor organizations and others involved in the small scale sector, particularly in developing countries. It will also be of interest to the general reader.

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