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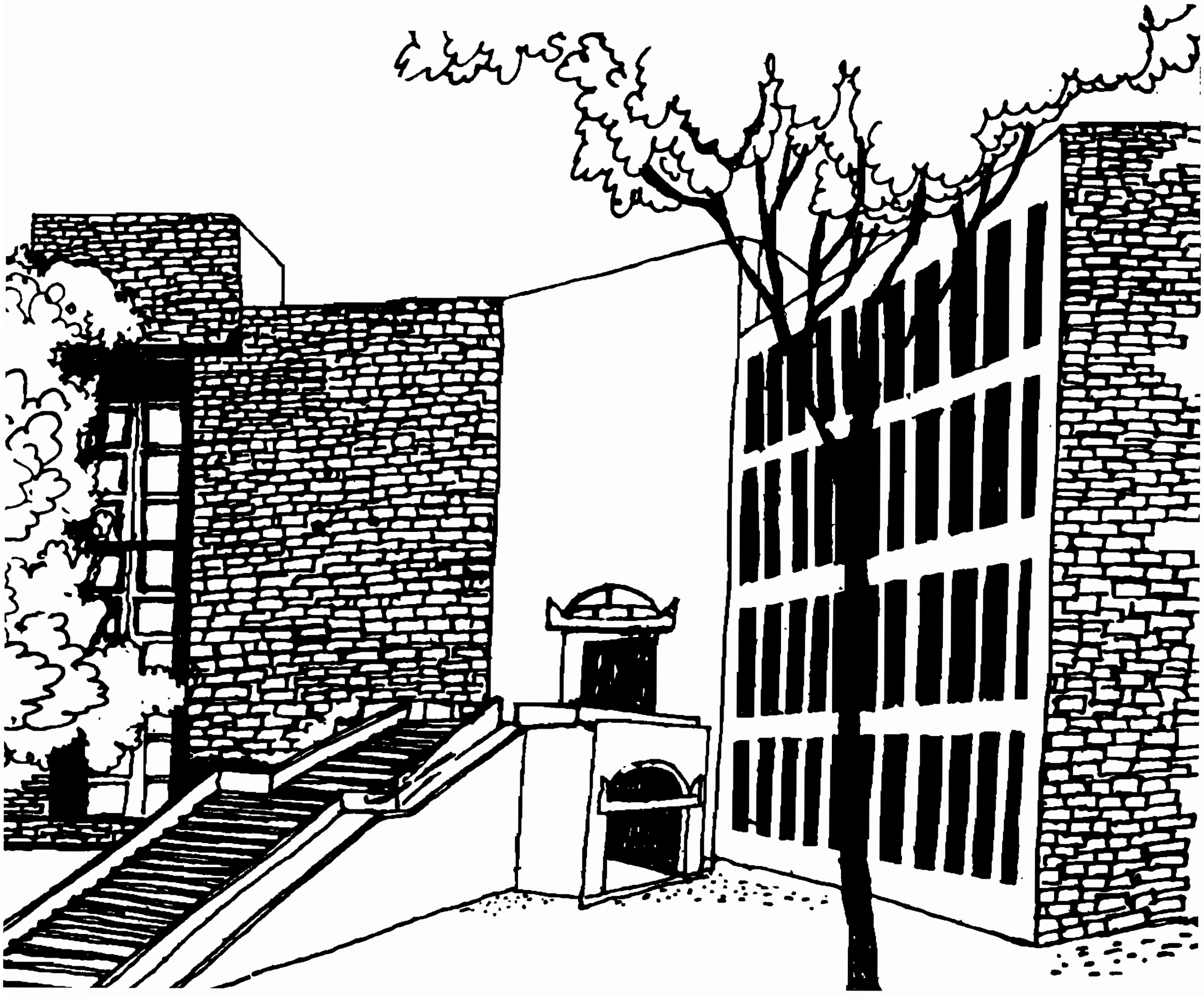

Technology Development in the Indian Foundry Industry: A Case of Choked Potential

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W.P. No. 1174
April 1994

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1. Introduction

How do foundries make product or process innovations? What role do the publicly funded technology institutions play in facilitating such changes? What are the determinants of technological dynamism of organizations? To answer these questions, a field study was conducted covering 25 foundries (Table 1 in Exhibit 1 presents the characteristics of the foundries included in the sample) and 5 technology institutions (organizations involved in education, consultancy, or research and development in the foundry industry). The sample organizations were selected from different parts of the country. A mail survey of another 25 foundries was attempted, but the response was extremely low (only 5 filled-in questionnaires were received) inspite of three rounds of mailing. The mail survey results have, therefore, not been included in the present report.

The field study included large, medium, and small firms, firms which were technologically dynamic, firms which ran stable operations, and firms which were stagnant or declining. Approximately, a day and a half was spent in each firm for collecting data. The following questions were explored with the managers:

- How technologically active is the firm? What are the information sources for the firm in the areas of existing best technological practice in the industry, or successful new technologies from other parts of the world? Have the environmental changes (liberalization, increasing market pressures, etc.) changed the technological behaviour of the firm in any way?
- To what extent does the firm have a long term perspective on technology (a strong technology culture, formal technology strategies, significant and systematic technology development, high R&D intensity, substantial new product or process development programmes etc.) as opposed to a conservative short-term approach (dependent on imported technology, evolutionary technological change, little formal organization of technological development, low status and morale of technology staff, etc.)?
- What is the nature of the firm's link with technology institutions (intermittent short-term problem solving, information provision, testing, technological assistance, product/process specifications etc.)?

A factory visit was invariably included to get a visual feel of the organization and the technology. As one took rounds of factories and held discussions with managers and technologists on how they made choices relating to their firms' technology development, certain images of technologically more dynamic and less dynamic firms and the determinants of technological dynamism developed. These images were explored further with the respondents to see how far they captured the complexity at ground level. These impressions were also tested against the subsequent observations of other units.

The study was made possible by financial support received from the Industrial Credit and Investment Corporation of India (ICICI), Bombay, and Chung-Hua Institution for Economic Research, Taipei, Taiwan. The author would like to acknowledge the support received from his colleagues on the research team -- Professors Shekhar Chaudhuri and Mukund Dixit of the Indian Institute of Management, Ahmedabad. The author is grateful to Mr. Melvin Goldman of the World Bank who was instrumental in conceptualizing the study. The author would like to convey his special thanks to Mr. Ram Mohan Rao for his research help. Needless to add, the report could not have taken shape without the support provided by the respondents from different industrial firms and technology institutions. The author would like to thank them for their help and patience.

The field study was supplemented by interviews with foundry experts in the country, and a review of the literature on the Indian foundry industry. This report is an attempt to integrate the different ideas and views obtained from these sources.

The report begins with a brief history of the industry and its present, size, form and structure. The report then presents a brief summary of a study of the Department of Scientific and Industrial Research on the technology status in the Indian ferrous foundry industry. This is followed by a description of some of the key technology institutions in the foundry sector and the problems faced by them. In the following two sections, the factors blocking technological learning and the factors contributing to technological upgradation are discussed. The report ends with a short summary and some concluding observations.

2. The Indian Foundry Industry: A Brief History

The artistic and exquisite metal casting from the civilizations of Harappa and Mohen-Jo-Daro show that Indian casting tradition dates back to around 2000 BC. During the Harappan period (2000 - 1750 BC), Indian craftsmen had mastered the skills necessary to produce cast artifacts in oxidized bronze and other non-ferrous materials. In the handling of ferrous metals also, the Indian craftsman had acquired exemplary metallurgical skills. The Ashoka Pillar in Delhi is a standing monument to India's metallurgical capabilities in those early years.

It is believed that a majority of the castings in those early years were produced on a very local basis within the village community. The Indian craftsmen practiced the metal casting techniques as village crafts. These crafts were nursed into art forms and the popular craftsman depended on the rich and the state for patronage. The popular alloys, among non-ferrous metals, used by the craftsmen in those days were bronzes and brasses.

Metallurgy of cast steel is traced to 500 BC in India. Both cast iron and steel continued to develop till 1000 AD with use of coal as a heat source, cupola as a melting unit, and cementation of iron with charcoal to produce blister steel. In all these developments of the early ages, where the foundry operations appear relatively restricted to casting art forms for decoration, and tools for specific application, clearly the artisans realized that casting was the shortest path between raw material and finished product. Advantages in alloying were recognized, whether it was bronze or steel.

Mass production of industrial castings was started in India only a hundred and fifty years back. The second half of the last century saw the emergence of the industrial mass production of castings, a direct result of the growth of the engineering industry, centred at Calcutta, during the time when India formed part of the British empire. As a result, many foundry units were established in the eastern part of the country, particularly during the late nineteenth century to produce industrial castings required by Indian Railways, and the growing textile, jute and allied industries as well as for manufacture of simple products like manhole covers, sanitary fittings and others.

The foundry industry made rapid progress in the post-independence years. This could be directly related to the industrialization programme launched through India's Five-Year Plans. Successive year plans were aimed at expanding and diversifying India's manufacturing base. There were massive outlays made to develop infrastructural facilities and rapidly expand engineering industries. This, naturally, triggered the growth of Indian foundry industry which graduated into the manufacture of complex and sophisticated castings required by power, iron and steel, fertilizer, chemical and a host of other industries. With its traditional skills, reinforced by modern technology, the industry has developed as a king-pin of the engineering sector representing a blend of the old and the new. Over the years, foundries have emerged in different parts of the country embracing a wide spectrum of non-ferrous and ferrous metals and alloys on one side to super alloys on the other. Indian foundry industry has since experienced considerable sophistication.

Today, the casting sector has the capacity to manufacture a wide range of components. Ferrous foundries are able to produce castings in grey iron, malleable iron, spheroidal-graphite iron, carbon steel, manganese steel and many high-alloy specification. There are about 5000 units in both organized and unorganized sectors with a total installed capacity of 304 million tonnes per annum. In the past five years, the industry has been growing at the rate of 4% and the same growth rate is likely to be sustained in the near future also. A number of foundries can produce a variety of special-quality castings for such demanding customers as those involved in aircraft construction, defence, the construction of nuclear power plants, and ship-building. Indian foundries can supply individual castings upto 120 tonnes in steel and upto five tonnes in copper-rich alloys. It can satisfy bulk of the domestic demand and also has the potential for meeting the export market needs.

3. The Indian Foundry Industry: An Overview

3.1 Size, Capacity and Distribution

As noted earlier, the modem Indian foundry industry has had its beginnings during 1850s when the railway network began spreading throughout the length and breadth of India. Starting from a mere 13 units in 1850, the Indian foundry industry had grown to 294 units in 1925 and around 1600 units at the time of independence in 1947. Presently, there are 6000 foundry units in the country. 90 per cent of the units are in the small scale sector. Post-independence India, under successive Five Year Plans, expanded foundry operations as part of diversifying its manufacturing base.

Based on the material used, castings may be divided into two broad categories:

i) Ferrous castings - these include grey iron, malleable iron, spheroidal graphite and steel castings.

ii) Non-ferrous castings - these have aluminum and copper as base materials. Zinc and tin may also be used. 80 per cent of the castings in India consist of cast iron, spheroidal graphite iron (S.G.I.) and malleable iron; the remaining 20 per cent is made up equally by steel and non-ferrous castings. Thus ferrous castings constitute 90 per cent of the industry.

Regionally, the castings industry in the country is concentrated in the following four locations:

South: Madras - Coimbatore region
East : West Bengal - near Calcutta
North: Parts of Punjab and Haryana - near Delhi
West : Pune - Kolhapur region

Interestingly, wide variations across these four regions exist with regard to establishment of production facilities and installed capacity. It could be noticed that India is a case of uneven development of foundry industry across states. For example, though 16% of foundry units are located in Uttar Pradesh, its share in installed capacity is only 10%. On the other hand, though West Bengal has only 10% of foundry units, it leads the country with 42% of installed capacity.

According to an official estimate the total number of foundries with an annual capacity exceeding 100 tonnes is around 4500. These can be broadly classified into three groups:

- Foundries covered by the Directorate General of Technical Development (DGTD) in the organized sector
- Captive foundries in both public and private sectors
- Small scale and tiny foundries.

The number of units registered with the DGTD were as follows:

a)	Cast iron/grey iron	145
b)	Spheroidal-graphite iron	36
c)	Malleable iron	32
d)	Steel	78

As on March 1991, the ferrous castings industry had the following capacities:

	No. of Units	Type of Ferrous Casting	Installed capacity (tonnes per annum)
Organized Sector	145	Cast Iron/grey iron	5,85,000
	36	SG Iron	50,000
	32	Malleable Iron	45,000
	78	Steel	1,96,000
Coop. Sector	450		6,00,000
Unorganized Sector	Not Available		12,50,000
Total			27,26,000

As against the total installed capacity in ferrous castings, the demand scene in 1990 was as follows:

Type of Industry	Demand (in hundred thousand tonnes)
Grey iron	8.51
SG iron	0.26
Malleable iron	0.52
Alloy iron	0.08
Steel and alloy iron	1.10
	10.47
Demand met by unorganized sector	7.50
Total	17.97

In the period 1985-90, the growth rate in demand was 4% and was likely to be maintained in the future also. The capacity utilization in ferrous foundry industry was around 45-55 per cent as against an average of 60-70 per cent abroad. India's share in the world metal castings industry was around 0.25% in 1990, which was nearly 0.47%, a decade earlier in 1980.

Grey iron castings formed the major part of the entire ferrous castings production, often as high as 70% of the whole industry. Grey iron castings were being employed as machine tool beds, motor bodies, pump castings, cylinder linings, engine blocks, heads and various other items. The automobile and machine tool sector absorbed castings made in this area. The production during 1990 was around 8,50,000 tonnes and the estimated growth rate varies from 4 to 5% (heavy engineering and industrial machinery) to 10 to 14% (textile plant, machine tools and automobiles).

S.G. iron castings were being employed as substitutes for non-ferrous castings and steel forgings. They have been found to have economic advantages in the manufacture of some heavy duty components made in small batches. S.G. iron castings accounted for nearly 7% of the total demand for iron castings in India. The automobile industry continued to be a major user of S.G. iron castings. The production in 1990 was around 25,000 tonnes.

Malleable iron castings were used for a variety of components for the automobile, railway, electrical and other industries. The capacity for this branch of the industry was around 50,000 tonnes per year.

The output of alloy iron castings was mainly absorbed by the industrial machinery and heavy engineering sectors. The capacity of this sector was around 8,300 tonnes per year. Apart from the captive capacity employed within the automobile industry in the manufacture of cylindrical blocks and cylindrical heads, more than 20 independent foundries in the organized sector supplied automotive castings.

The steel castings industry had developed rapidly in recent years. With the growth of the engineering industries, steel castings were now being manufactured indigenously in different sizes and specifications. There were 78 units functioning in this segment with a capacity of over 4,00,000 tonnes. The production of steel castings in 1990 was around 1,10,000 tonnes. The railways were the major customers of steel castings, followed by industries involved in valve manufacture and the building of refineries, petrochemical works, fertilizer plants, thermal power stations, steel works, paper factories, sugar refineries and miscellaneous activities.

3.2 Performance of Indian Foundries

The world over, the trend in the foundry industry is toward the conservation of energy and raw material consumption, improvement in quality and productivity. All these parameters are closely monitored. Compared to foundries abroad, Indian foundries consume more material, more energy but register lower labour productivity and higher rejection rates. Comparative figures can be seen in the following table.

Parameters	Foundries in India	Foundries Abroad	Comments
1. Yield	53 Steel 65 Cast Iron 53 Ductile	55 ST 76 CI (Japan) 56 Ductile	The lower yield value in Indian foundries is basically due to liberal design tolerances and gating systems.
2. Energy/Ton of Metal Melted	700-900 KWH/Ton	540 KWH (Elec. Arc.) 600 KWH (Induction) 43×10^6 (BTU/Coke) (Cupola)	The high energy consumption is mainly due to poor quality raw material, which necessitates the additional operations, lack of instrumentation on the furnace use of over capacity equipment, improper loading of furnaces, lack of recuperators, etc.
3. Tonnage/ Production per man per year	10-20	30 (Former E. Germany) 70 (Former W. Germany) 100(Japan)	The lower labour productivity in mainly due to lower automation levels and excess manpower in foundries and lack of adequate and consistent orders.
4. Rejection	7-8%	1-2%	High rejection rate is due to poor quality raw material, inadequate process control, inadequate facilities for inspection, etc.
5. Capacity utilization	45-55%	60-70%	Low capacity utilization is due to lack of consistency in orders, changes in demand for product mix and demand for type of castings not being produced.

Obviously, there is great scope for improving productivity in Indian foundries. A 5% material conservation, for example, through casting design improvement or through the practice of scientific foundry processes can result in a saving of Rs. 420 million. Similarly, a 10% energy conservation would result in a saving of Rs. 100 million.

The Indian foundry is a case of low and/or stagnant productivity because of ill-matching of demand with productive capabilities, use of obsolete equipment, methods, practices and skills, lack of quality consciousness, non-adherence to standard specifications, poor R & D efforts and ineffective use of factors of production. Any significant improvement in productivity is not feasible until and unless a whole range of changes are effected in the way systems, processes, and techniques of doing things are evolved and adhered to.

World over, the foundry industry is considered a high pollution industry mainly on account of noise and toxic waste formation and strict laws have been formulated in the European countries and also strictly implemented, whereas in India pollution laws and standards are in a formative stage. These are basically monitored by the state pollution boards. The lack of awareness coupled with a high cost of pollution control equipment in the case of foundries on the one hand and the poor and inconsistent implementation on the part of implementation agencies on the other hand has resulted in a lackadaisical approach to this important area. The very same situation is prevalent with respect to yet another critical area, i.e., safety. Barring few large units, there was a lack of awareness about safety, and safety measures especially among workers. Many times the safety gadgets were not used by the workmen and the management was also not strict enough to enforce for fear of losing production. there is an urgent need for regulatory work to be done by concerned agencies, and a strict enforcement of safety laws.

3.3 Exports

The Indian foundries are capable of exporting castings to various developed countries. Indian ferrous foundries were exporting castings to the tune of Rs. 1580 million (1992-93). But the castings were largely low value items from the eastern region. Till recently, the Indian foundry industry was not able to export more due to the raw material price, quality requirements and delivery aspects. Though the value of exports in money terms has been going up, they have been going down in terms of percentage of total world Trade in this item. A revamped export strategy of concentrating on developing countries may give a boost to Indian exports. India has also been exporting sophisticated precision castings to developed countries in small quantities. A few sophisticated foundries were involved in this process.

If proper strategy and a long-term plan is jointly worked out by the government and industry, it is believed that India could export at least 50,000 tonnes of steel and alloy steel castings per annum, over a period of half-a-decade. For such a strategy to get operationalized effectively, industry experts recommend that a *thrust group* of 20-25 foundries, already equipped with modern plant and machinery and agile management, are given incentives and facilities to enter the export field with the high quality products. The government should ensure uninterrupted supply of power and other infrastructure facilities to such units. Obviously, the future of the foundry industry lies in the efficient units concentrating on the production of castings of high quality at internationally competitive prices. Then only the enterprises in this sector can aspire to become significant players on the export front.

In this context, it is noteworthy that some of the medium size foundries had been able to upgrade themselves technologically and had become comparable to foundries abroad, although the volumes of production and productivity at the moment tended to be somewhat on the lower side. One of the heartening trends of recent times is that the Indian foundry industry has been able to absorb modern technology at an increasingly frenetic pace; many manufacturers have now acquired the competence to turn out quality equipment, very often at a cheaper cost than their foreign counterparts.

Here one can recount the indigenous development of mains frequency and medium frequency induction electric furnaces of capacities of 30 tons with capability to melt all types of metals including grey iron and ductile iron. Similarly, sand mixers are produced which can turn out sands of high strength using minimum additives. Other quality machines developed by the industry are: simultaneous jolt squeeze moulding machines of box capacities of nearly 1500 x 1000 mm. with box closing equipment; air impulse type moulding machines; special purpose shell core shooters able to manufacture cores up to 25 to 30 Kg. in weight and dimensions of 800 x 1000 mm.; hanger type shot blasting machines with high capacity output; and all types of conveying mechanisms used in mechanized operations. Even sophisticated testing and controlling equipment like digital pyrometers, thermal analysis equipment and ultrasonic fault detectors are available in the country.

With the availability of modern and state-of-the-art equipment in plenty within the country itself, it should henceforth be possible to increase the quantum and value of exports from the foundry sector manifold. Yet another positive development has been the easing of the supply-side constraint in raw materials like pig iron. India is now in a position to indigenously produce low phosphorous pig iron which hitherto was being imported. The export figures of industrial castings over the years is presented below:

Export of Industrial Castings from India

Year	Value in Rs. FOB millions
1988-89	253.6
1989-90	580.0
1990-91	950.0
1991-92	1330.0
1992-93	1580.0
Forecast	
1993-94	2800.0
1994-95	3650.0

Source: Task Force (EEPC)

3.4. New Developments and Challenges

The Indian foundry industry can become a major player in the international arena only when it displays competence and willingness to adopt new developments in technology to make the domestic industry vibrant and resilient. According to foundry experts, some of the critical requirements in technology are:

i) Production of thin walled castings for the purpose of weight reduction.
ii) Production of castings with high dimensional consistency designed for machining on mass transfer lines and SPMs.
iii) High volume production equipment like dismatic or high pressure moulding machine.
iv) Manufacture of moulds and cores using chemically bonded sands.
v) Technology which can assist in on-line monitoring and controlling various processes to minimize rejections.
vi) Computer applications like SILICA programme for monitoring sand systems, CAD/CAM for tooling development and computer aided methoding systems.

The above technological developments the Indian foundries would have to adopt as early as possible with a view to make them globally competitive. As such the foundry enterprises are in the process of going through a process of transition as far as adoption of technology is concerned: some units have already incorporated the latest developments, while a few more are in the process of doing so. The industry offers a wide range of products enabling the end user pick out a variety of moulding processes like Green Sand, CO_2, No Bake, Shell and Ceramic. For high integrity requirements where surface finish and tolerance are important, there is the investment casting process in addition to horizontal and vertical centrifugal castings.

Several of the units ensure high quality of their products through the use of sophisticated facilities such as direct-reading spectrometers, high temperature stress rupture testing equipment, tensile testing both at ambient and high temperature, metallography and microstructural analysis, non-destructive testing facilities such as Gamma and X-ray, dye penetrant, magnetic particle and ultrasonic. Most foundries meet with either Indian standards or International standards such as ASTM, DIN, BS, JIS, ISO, etc.

As we had already mentioned elsewhere in this chapter, Indian foundries produce castings in different materials from a few grams to over 100 tonnes, catering to a diversified base of industries from construction and earthmoving to nuclear power and aerospace. Most of the industrial casting exports are targeted to the industrially developed world. It is in this context that we would like to view the exciting developments which are unfolding themselves in the global arena: the formation of strategic alliances with foundries abroad. The foundries in the developed countries are on the verge of closure due to three prime problems:

a) The problem of waste disposal and highly stringent pollution control regulations.
b) Very high manpower costs.
c) Acute shortage of workmen and engineers to work in foundries.

These foreign foundries can choose to source the castings from India at more economic prices. Thus, the strategic alliances would offer Indian industry in the foundry sector easy access to the foreign markets with higher margins. But the critical prerequisite for successfully tapping these opportunities would be to gear up the foundry sector with requisite modernization in technology as well as working a range of strategic alliances with major foundry enterprises abroad. Thus the new developments and challenges also throw up exciting opportunities for the Indian foundry industry.

3.5 Technology Institutions

There is an elaborate infrastructure for Research and Development (R&D) work available within the country which is carried through at three levels: (a) industry; (b) R & D organizations; and (c) academic institutions. Some industrial enterprises have good R&D facilities. In the public sector, a number of research institutions have been in the forefront of undertaking applied and basic research in the fields of metallurgy including foundry technology. In addition, the metallurgical departments in advanced technology academic institutions spread throughout the length and breadth of the nation, also undertake R&D work. The continuous availability of skilled technical manpower is equally important and to this end institutions have been set up to impart training to aspiring professionals at different levels. These institutions have been described in detail in another section.

4. Status of Technology in Indian Foundries: An Assessment

The Department of Scientific and Industrial Research has brought out two comprehensive volumes evaluating the state of technology in the Indian ferrous foundry industry (DSIR, 1991) and in non-ferrous castings industry (DSIR, 1988). The National Productivity Council (NPC) conducted these studies, utilizing a variety of data sources. National Workshops were held to obtain inputs from a large number of experts in the field. This section utilizes the above information sources and summarizes the technology status in the ferrous foundries under the following heads: (a) pattern shop; (b) sand system and sand reclamation; (c) core making; (d) moulding; (e) melting and refining; (f) fettling; and (g) testing and quality control.

4.1 Pattern Shop

Two distinct varieties of pattern shop practices were discernible in the Indian foundry industry depending upon the size of the facility and whether it was located in the organized sector (usually large and medium foundries) or the unorganized sector (more often than not small-scale foundries). The large captive foundries alone had the pattern design and development facilities; on the other hand, the jobbing foundries, barring a few big ones, were invariably dependent on their customers for the supply of patterns; sometimes they relied on the outside agencies for the pattern design and development work. This basic dichotomy between the organized and unorganized sectors influenced the standards being adopted and followed in pattern designing work.

For example, captive and jobbing foundries in the organized sector had well-prepared company standards for pattern design and manufacture. The small and medium scale foundries, on the other hand, followed rule-of-thumb practices, resulting in the over-designed patterns with liberal tolerances/ allowances. This, in turn gave rise to higher raw material consumption, poor finish as well as high rejection rates.

The industry, across sectors, was characterized by the non-utilization of computers for the pattern design work, with the exception of a very small number of large foundries. Rest of the industry was hamstrung by the constraints of non-availability of information sources, relevant software and data systems germane to the foundry technology.

With regard to pattern usage, the large foundries, by and large, utilized match-plated patterns, in line with the advanced technologies in vogue anywhere else. Similarly, the use of expendable patterns had been introduced in Indian foundries. This usage, however, was limited to captive foundries in machine tool and automobile sectors.

Materials like pressed plywood, thermocole and wood were used in machine tool casting patterns. Thermocole/wood patterns, reinforced with metallic strips or pasted with paper, were used to improve the surface finish. These methods are used when the production quantity was one-off or just a few pieces. In industries such as automobiles, textile machinery and railways, metallic patterns were widely used since the volumes of production required were quite large.

Even with regard to machining facilities, there was wide variation in the quality of facilities available across sectors. Large captive foundries, which produced more than 6000 tonnes/annum and above, were found to be well-equipped for pattern manufacturing. Specialty machines like copy milling, jig boring and copy turning were available with these firms. In contrast, the jobbing foundries were equipped with conventional machines like lathe, milling and drilling; they invariably depended upon outside agencies with precision machining operations. Once again it was the captive foundries in automobile and defence sectors, which required precision castings, that had gone in for expensive copy milling CNC machines or 3D coordinate measuring machines. The jobbing foundries did not find it economical to install such facilities, due to high investment and low demand.

The captive foundries made use of sophisticated marking and measuring instruments such as digital height gauges and verniers which were fast and accurate enabling the pre-setting of precise tolerances/allowances. Such instruments give direct measurements, eliminating human error. The jobbing foundries, on the other hand, were found to be quite lackadaisical in their approach to precision measurement.

Similarly, in the area of pattern inspection, organized sector foundries were found to have systems for regular checks for wear and tear of patterns, core boxes, etc. Against this, the small-scale foundries were observed initiating corrective action only when high degree of rejections pinpointed to defects in patterns. Thus, except in large/captive foundries, the inspection facilities were found to be quite inadequate.

There is a need to evolve a comparative perspective by examining the developments and advances taking place in other parts of the world in the field of pattern making. The foundry industry in advanced countries avails of sophisticated databases in pattern making with a view to optimise on costs. They use computerized drafting and graphics for the design of patterns. They make near cast-to-size castings which are suitable for the machines. CAD/CAM machines are used for machining necessitating the deployment of less skilled manpower. Similarly, 3D coordinating machines with digitalised equipment is widely used for pattern inspection. Computers are also used for estimating the wear on patterns.

Patterns are salvaged with the help of wear coating or polyurethene coating. Metal and plastic inserts are used to reduce replacement time. The use of natural wood is turning out to be very uneconomical and, therefore, materials like plywood, bronze, SGI, plastics and metallised plastics are increasingly being used for pattern making. Also teflon coating is being used for metallic patterns. Polyurethene resins have become more established and have won a considerable share of the market in synthetic resin pattern making.

Special pattern coatings and paints are presently available, which offer increased scuffing resistance and better chemical resistance to very aggressive moulding and core sand binders. These developments ensure health of the worker and safety in the working area. Advanced countries make extensive use of CNC machines for pattern making. With CAD/CAM software, the milling machines enable mirror image copying, enlargement, and reduction copying, and the production of larger number of moulds from one pattern. Where it is not feasible to use CAD/CAM, marked out milling programmes can be generated on line from foil drawings by means of drafting machines and digitalisation equipment. To sum up, the Indian foundry industry has not adopted several of the sophisticated techniques and technologies in pattern making which are so widely in usage in developed nations.

Given the structure of Indian foundry industry, it may not be feasible to equip each and every facility with all the modern gadgetry - whether it be machines or skilled personnel. Foundries in the country have not made right kind of investment for integrated pattern design and manufacture, as such investment has proved to be uneconomical for any particular foundry unless it produces a wide range of castings. Moreover, the paucity of skilled manpower has also aggravated this problem.

The strategy adopted by countries like Germany, Japan and USA is interesting in this regard. Many foundries in these countries purchase quality patterns from outside pattern shops which function as centres of excellence. The DSIR Report (1991) suggests that the Government of India should set up fully-equipped pattern-design-cum-manufacturing facilities at major foundry centres in the country, as the design of proper patterns will considerably reduce the final cost of the product. Even though sophisticated patterns entail additional cost at the design stage, they would considerably reduce the overall cost of the final product by saving on energy costs, material costs, and machining costs, and also ensure low level of rejection rates.

But one of the persistent problems relating to pattern making is the shortage of skilled manpower. According to DSIR Report (1991), there is need for a concerted effort to be jointly taken up by the Government, industry, and institutions to create conducive environment for the training of personnel to take up this line. There is also need to get the hurdle of non-availability of critical material such as high density polystyrene.

In India, rejections due to pattern problems was found to be significant in most of the foundries, many of which can be attributed to wear and tear of patterns and moulding boxes. Regular in spection of patterns before moulding operation can overcome this problem.

We had already highlighted the need for increasing use of sophisticated computer system in the design work. The relevant technology institutions should develop application specific software for pattern/mould design. Apart from research and development work, these TIs should organize training programmes tailor-made to designers in the industry.

Due to high cost of imports, the industry in India is unable to afford to procure sophisticated milling machines from overseas. Unless such machines are widely used, the quality of Indian pattern making may not improve. Comprehensive strategy of local manufacture, local training, local research and local consultancy has been suggested by the DSIR to considerably enhance the pattern design and manufacturing skills in the foundry industry.

4.2 Sand System and Sand Reclamation

The Indian foundries were found to be mainly using batch type sand mullers. Since most Indian foundries operate in the small-scale with limited sand requirement, they did not use high speed sand mullers. In smaller companies where sand moulding was practiced, sand was coated, mixed, and riddled on floor for the purpose of mulling. The distribution of sand was done either by shovel or wheelbarrow in case of small units or by front-loading and overhead conveyor in case of mechanised foundries.

There are different methods for the reclamation of sand after its use in the foundry. The dry method of reclamation is used for the recovery of organic and clay-bonded sands. However, the removal of complete residual resin in organic binders or the dead clay in clay-bonded sands is rather difficult. Wet reclamation is probably the most effective attrition method for the clay-bonded and silicate bonded sands. In this process, the crystalline cleanliness and chemical purity of sand can be upgraded somewhat nearer to high quality fresh sand. However this system tends to be costlier. Wet reclamation is ineffective for organic binder and in such cases sand could be reclaimed through thermal attrition. The thermal reclamation method when used for organic binders can remove the spent binder completely but, as of now, the cost of deploying this method tends to be very high.

Currently, in most of the Indian foundries, the sand binders employed are many and the knock-out sand is, therefore, a blend of organic and inorganic binder systems. Under these circumstances, none of the recovery systems like wet thermal or dry thermal may prove to ideally suited. Though these systems transform the used up sand to near fresh sand quality, they tend to be prohibitively expensive to instal. Their high operating cost also happens to be a further deterrent.

Apart from the main reclaiming equipment, there also exist a variety of auxiliary equipment such as sand coolers, metal separators, and screen, which process sand soon after the completion of shake out operation. In India, these equipments tend to be quite rudimentary, barring a few large foundries.

More importantly, sand reclamation was done only to a very limited extent in the Indian foundries. Since clay-bonded sands is widely used, the Indian foundries need wet reclamation systems. However, in the absence of strict pollution control laws and also since the trade-off between the cost of reclaimed sand versus new sand happened to be unfavourable for reclaiming sand, most of the foundries in India did not go for any kind of reclamation. Only a few large foundries were found to be experimenting with reclamation systems.

One of the stumbling blocks in the moves towards further mechanisation of sand processing and reclamation happened to be the absence of local manufacture of the equipment. For high tech moulding, lines of continuous mixers are essential. Presently these machines are not indigenously manufactured. Similarly, sophisticated testing equipment such as automatic moisture measurement indicator is not locally available.

Another problem relates to lack of proper maintenance practices. When mullers are not properly maintained, it results in permeability problem. Small foundries were observed to have a lot of blow hole problems because of this inadequacy. DSIR report recommends the setting up of centres where specialised repair/reconditioning work can be taken up. In advanced countries some firms specialise in repair/reconditioning especially of foundry equipment.

In the prevalent circumstances many of the units appear to be reluctant to instal sand reclamation systems, as the economics of such installations tended to be unfavourable. The DSIR report (1991) has argued for the enunciation of minimum national standards for the foundries, as resin-coated sand is presently thrown out causing avoidable pollution problems.

The reclamation of used sand is feasible on a large scale only when the needed machines are manufactured in India. According to the DSIR report there is need for the manufacture of dry, wet and thermal reclamation systems at a low cost so that a variety of foundries across the board can adopt these systems.

But many a small foundry would find it prohibitively expensive to instal the reclamation system at its facility. Hence the feasibility of setting up centralised sand reclamation centres at local level to cater to nearby foundries need to be critically evaluated.

There is an accelerating demand for high silica-content sand, suitable for foundry operations, from the mushrooming house construction activity. According to the DSIR report, the government should reserve high grade sand for foundry operation, releasing the left overs for other purposes. Such a policy would go a long way in ensuring operation of foundries at high levels of efficiency.

4.3 Core Making

Most of the Indian foundry enterprises use green sand, oil sand and CO_2 cores. The jobbing foundries were found to rely on CO_2 and other conventional processes. It was observed that most jobbers could not afford to go in for core shooters or core boxes needed for shell, and hot and cold boxes. Lack of in-house facilities to make patterns and core boxes tended to aggravate this problem.

Even the machine tool related foundries in India mostly relied on CO_2 processes. The reasons for not opting for the state-of-the-art technologies were the following:

i) Difficulty in optimising various control parametres;
ii) Very high tooling cost of equipment such as core shooters, core blowers, etc.;
iii) The fear of spiralling costs and the possibility of rejection by clients on price consideration;
iv) Fear of upsetting an already well-established process and the workforce used to traditional methods.

Interestingly, most of the captive foundries attached to the automotive sector in India were observed to have hot box, shell and core box cores in varying degrees of sophistication. The reasons for the acquisition of such systems in this sector appeared to be the following:

i) The firms were able to distribute the cost of modernization and sophisticated technologies over a vast quantity of castings;
ii) The units also managed to apportion the cost of tooling and similar expenses to the final price being charged to the internal customer, and ultimately of course to the external customers.

By and large, cores were stored and supplied to moulding stations and conventional methods were preponderantly employed for core assembly and transfer. Mostly semi-mechanised core making equipment was used. India manufactures shell core shooter machines, hot box core shooter and shell sand-coating units. But the biggest problem being faced by jobbing foundries in India was acute competition, paucity of orders and low volumes of business. Given such circumstances the small and medium foundries were hesistant to adopt latest technological developments in core making.

There was the additional problem of the lack of indigenous suppliers of several resins. Imported resins were expensive as they were subjected to high customs duties. Even in the case of resins/chemicals manufactured in India, the suppliers charged high prices as compared to those charged abroad. The use of vacuum moulding eliminates the need for chemical binders altogether. But very few foundries were interested in such new techniques.

The quality and accuracy of core boxes were also not up to the mark. As a result, the quality of castings tended to suffer. This situation resulted partly from the absence of in-house facilities for making core boxes at most of the jobbing and small foundries. The DSIR study showed that there was good demand for cast-to-size castings; hence, it is necessary that cores should also be made very close to final size with the help of CAD/CAM techniques.

Though core coatings may be considered to be an insignificant part of the foundry set up, its importance cannot be overlooked because of the overall impact it can have in adding finish and quality to the final product. The DSIR report underlines the need for the use of appropriate core coatings, especially in the smaller foundries, to considerably bring down the rejection rate.

4.4 Moulding

The choice of a particular moulding machine by an enterprise depends upon a variety of factors such as those listed below:

i) weight and size of castings;
ii) saving of marginal weight in finished castings;
iii) tolerance limits;
iv) saving in machining time;
v) ability to draw pattern with minimum draft;

vi) capacity to utilize the maximum surface area;
vii) ability to produce uniform hardness throughout the height; and
viii) cycle time of the moulding machine.

Usually the cycle time of the basic moulding machine happens to be very short, ranging from 17 to 20 seconds, depending upon the design features of the machine, flask size, etc. Thus, the total output that can be generated from the system, depends upon the auxiliary times required for operations such as sand metering, sand feeding, box handling, box transfer, box closing, clamping, etc. If these operations can be matched to the machine cycle times, high output can be obtained from the line. It is with this objective in view that equipments constituting the mould handling system have been developed. The older designs created machines which occupied a good deal of space. The new generation machines are of compact design, often times combining the functions of several equipments in one machine. This has resulted in the emergence of "compact lines."

Modern automatic moulding lines are invariably computer-controlled in order to effect automatic changes in operating parameters, as and when required. Most of the systems incorporate provisions for shift pattern change, often within the cycle time. This ensures flexibility without sacrificing high production rates. There are only a select few firms in Germany, Japan and the UK which presently manufacture/supply such advanced moulding plants/lines. Now, against the backdrop of the state of the technology available, we examine the situation in the Indian foundry industry.

First, let us look at the automobile sector. The state of technology employed in the most advanced foundry shops in India was observed to lag behind by at least a decade as compared to the situation in the developed countries. For instance, the captive foundry of a leading Indian automobile manufacturer installed a machine in 1982 with the capacity of 90 moulds/hour output. On the other hand, the leading auto manufacturers abroad have been using machines of the capacity of 200-250 moulds/hour output since the early 1970s.

The jobbing foundries catering to the automobile sector have also gone in for moulding machines of lower capacity. For example, a foundry in Western India had installed a plant of 60 moulds/hour capacity in 1980. Compared to this, the prevalent norms in European firms was plants with 100-150 moulds/hour. But even at this lower capacity the Indian foundry has been making losses due to inadequate orders. The average plant utilization of this unit during the past 3 years has been less than 50 per cent. Many other jobbing foundries in the automobile sector have installed moulding machines with low capacities of 5-10 moulds/hour. Some of the relatively larger foundries have gone in for limited mechanisation. In other words, the scale of operations even in the larger Indian foundries is too low to introduce advanced high capacity machines. The largest automotive foundries have installed capacities which are at best only one third of prevalent average capacities in overseas foundries in the automotive sector.

Most of the jobbing foundries in the organized sector need to modernise their plants and introduce state-of-the-art technology. But these enterprises are reluctant to go in for modernization due to prohibitively high costs. Many of the leading moulding machine manufacturers of the world have presence in India through their representatives and thus, the Indian foundries do have access to latest technology. But their large capacity size and high prices appeared to be the limiting factors for their adoption in India.

In the Indian machine tool sector, leading corporations have large captive foundries. Large castings like Bodies, Beds, Base plates are made by the hand moulding process. There has been little mechanisation in these foundries. Even in the case of machine moulded items, none of these enterprises were found to have gone in for integrated automatic plants. The foundries listed the following constraints for introducing advanced moulding technology in this sector.

Small volume castings of a wide variety and weight range were required in the machine tool sector. While the volume was small, the accuracy requirement was very high. Given the nature of this product range, complete automation was not found to be viable. One area where advanced machines could be introduced in this sector was with respect to hand moulding operations for large castings. Here sand slingers for filling sand and moulding by large roll over machines would definitely prove advantageous.

In the electrical machinery sector in India, the leading firms have not gone in for automated plants due to limited demand. Their needs were easily met by the captive foundries or the jobbing foundries. Most of these firms had introduced some sort of selective mechanisation to increase production. The firms by and large, required moulding units of 20-40 moulds/hour capacity. This had been achieved by installing a number of individual machines. In contrast, similar firms in Germany had gone in for 120-150 moulds/hour capacity plants.

In the machinery sector that turns out industrial machines, boiler components etc., moulding machines with capacities of 20-30 moulds/hour were found suitable for the Indian needs. This was again influenced by the size of the market.

The railway system in India was one of the bulk consumers of certain type of castings. The main items were: railway sleepers, railway wedges, and items used in rolling stock. Being a bulk requirement of limited variety, one would expect excellent scope for mechanisation. But castings requirement of the Indian railways was met by a large number of jobbing foundries located at Calcutta, Bombay, Agra, Nagpur as well as railway workshops The wheel and axle plant at Bangalore was also found to cater to some of these requirements. In spite of bulk requirement of the railways, there was considerable fragmentation of orders being placed with outside firms. A large number of small firms received orders at very low prices. Since the castings quality requirement was not stringent, small-scale units had achieved a dominant position in this sector. But since the volumes of business and the margins were low, technology upgradation had not taken place in this field. Interestingly, the main hurdle to technology upgradation was the lowest price criteria of the railways which did not leave healthy profit margin with small firms to take up mechanisation. Besides, there was no guarantee about regular orders from the railways. Another more recent hurdle was the availability of substitutes like RCC sleepers which had longer life and could withstand higher dynamic loads. The fear of shrinking market prevented small jobbers from venturing in the direction of mechanisation.

Yet another sector which placed bulk orders for castings was the municipal items and pipe fittings. Items like pipe fittings, manhole covers, drainage pipes were required in bulk. The quality requirements of such items was not very high. In India , a large number of small scale units were involved in the manufacture of these items. In developed countries, automated plants, with capacity of 100-150 moulds/hour, produced such castings. But across the board comparison of technology between advanced societies and India is infructuous for the simple reason that while in the former, pipe fittings are used for the disposal of solid wastes, in the latter they are used mostly for liquid waste disposal. Similarly, the metallurgy of castings also varies widely. In tropical countries metal may be subject to hot weather, while in Europe and North America the cold climate may demand special properties to withstand cracking.

Given the status of the industry across different sectors detailed above, foundries found numerous blocks is adopting the path of mechanisation and advanced technology in moulding operations. Given the prevalent situation of small batch sizes and wide variety of castings, the moulding machines ideally suited for India were the ones with capacities of 20-30 moulds/hour.

The low productivity in Indian foundries was in no small way due to manual operation in the moulding area. A need for some degree of mechanisation exists even in the smaller foundries. Technology Institutions well versed in selective mechanisation may be able to help small foundries in enhancing productivity of their operations.

Advanced moulding machines like jolt-squeeze machines and high speed machines were available indigenously in India. However some components like timer were still being imported. Import of these items and other critical components for moulding machines also attracted heavy customs tariffs. Manufacture of the new generation moulding machines in India is not viable given the limited demand within the country at the present time.

The manufacturers in India have brought out various models of moulding machines, causing spare parts and maintenance problems. Standardisation would be helpful in giving a boost to mechanisation and enhancement in the quality of products turned out.

4.5 Melting and Refining

Before taking a critical look at the state of melting and refining systems in Indian foundry industry, we shall go through a quick survey of technological developments unfolding in other parts of the world in this field.

First about the cupola. The usage of preheated blast has considerably improved combustion efficiency in the cupola. At the same time, divided blast utilises a second row of tuyers to proportionately distribute the air between two levels to obtain improved combustion efficiency and requires less coke. Similarly, oxygen enrichment can considerably enhance the quality of combustion. The water cooling of shell and tuyeres have reduced the refractory cost and extended cupola campaigns easily to a full week and in some cases up to a month without dropping the bottom for any refractory repairs. Now it is possible to make use of computers for the following purposes:

- accurate calculation of heat costs
- recording of weights of charge components
- continuous recording of exit gas analysis and alerting of likely explosive mixtures from water leaks
- monitoring of equipment performance.

The electric arrest equipment on the melting floor has made it possible to determine the quantities of carbon and silicon within a few minutes. At the same time, it is now possible to quickly do the spectrometer analysis to determine the levels of magnesium residual in the molten flux. The quick analysis to ascertain the presence of tramp elements has made it possible to melt and remelt all varieties of scrap. Now it is possible, at least in large foundries, to transmit samples by pneumatic tubes and report the analyses back to the melting and casting floors, to take prompt corrective action. Another useful development is with regard to the injection of borings into the cupola with the help of injection attachment.

There has been considerable improvement even in the design and operation of electric induction furnace in recent years. Improved auto-control facilitates the holding of molten metal for long periods. There is also considerable improvement in refractory performance over time. Scrap preheaters have reduced power consumption. Similarly, improvements in solid state electrical equipment have reduced the cost of using higher frequency power.

There have been similar improvement in the functioning of electric arc furnace in recent times. The automatic power peak controllers have levelled power usage and reduced expensive demand charges for uncontrolled surges. Oxygen injection has reduced heat time. The water cooled sidewalls and roof have extended lining life and reduced refractory costs. Computers are being used to optimise power consumption, control melting practices and calculate alloy mixes.

There are also new state-of-the-art technologies under development. Plasma systems are being used to fire the cupola to levels which are normally not feasible through conventional heating systems. Similarly, natural gas shaft melters are being developed to avoid the pollution problems emanating from the use of coke-fired cupolas. New technologies are also being developed to reduce the consumption of graphite electrodes in electric arc furnaces. In the steel industry, ladle refining furnaces are being used in many countries.

Against the foregoing account of developments in the technology of melting and refining, let us now consider the situation obtaining in the Indian foundry industry. Around 70% of the Indian foundries are in the small scale sector. Nearly 90% of the small foundries use hard coke as the source of energy to fire the cupola. Wood and furnace oil are used for core making ovens and electricity is used for providing motive power to blast blowers, machine moulding, shot blasting, grinding and other auxiliary equipment. Fuel consumption varies widely due to differences in materials being cast, raw material quality and fuel quality.

Cupola was the most popular furnace, followed by induction furnace and electric arc furnace. Coreless induction furnaces were being used in most of the ductile iron manufacturing units. Channel induction furnace was also becoming popular due to the flexibility offered in temperature control. Electric arc furnaces were being used in steel foundries. The hot blast cupolas and allied equipment were locally manufactured and supplied to vast majority of foundries, mostly in the small scale sector.

As the Indian foundry industry consists largely of small and medium units, it could not afford the cost of electric melting. As stated above, they relied mainly on cupola for melting. The DSIR report has, therefore, emphasized the need for enhancing the quality and productivity of the cupola. The enterprises can take to latest models such as improved cold blast cupola, divided blast cupola and hot blast cupola. There should be an improvement in the metallurgical control of cupola, through direct carbon induction.

The DSIR report has also underlined the need to streamline the supply of scrap to the small and medium foundries. Presently, the system is complicated by the presence of too many middlemen.

Small and medium furnaces should be encouraged to instal boring injection attachments to feed borings directly to the melting zone. These enterprises also need to adopt energy saving devices (such as recuperators) and process control monitors. Similarly laser spectroscopy offers potential benefit in real time chemical analysis for real time metallurgical process control. The use of computers can streamline the melting operations. There is also need for perfecting ladle metallurgy with a view to reduce impurities. These methods range from simple argon bubbling to the use of refining furnaces with injection and vacuum capabilities.

The introduction of computer control systems in electric melting can enhance productivity, quality assurance and cost reduction on the melting floor. Similarly, larger foundries may like to adopt computer-guided automatic pouring systems to ensure high quality of melts. Automatic pouring is increasingly becoming attractive as it gives consistency in pouring, increases in yield, good process control and better environmental benefits.

4.6 Fettling (Dressing)

The technological changes have moved on at such an accelerated pace in this area that there is an emerging school of thought which advocates the production of castings without the need for dressing by hand. The introduction of N.C. machines could completely eliminate manual fettling. The introduction of flexible manufacturing systems and the use of robots can further eliminate the need for fettling.

But irrespective of the state-of-the-art technologies emerging in the field, the Indian foundry industry continued to make use of fettling for turning out the final product. Most of the foundries were observed to have their own fettling shops. However, some foundries sub-contracted the fettling work to outside parties.

In small foundries, fettling was done by manual breaking of runners and risers, followed by single table blasting equipment. Castings were then ground by hand grinding machines. The larger foundries had vibratory shake outs to remove cores, runners and risers. Castings were shot blasted with continuous shot blasting equipment. Grinding was done by pedestal grinder for small castings and by hand grinders for bigger castings. Excess material found on castings due to mould dilation was also ground in majority of cases in order to make castings dimensionally acceptable. But the dust and noise levels happened to be quite high in fettling shops.

The DSIR report has recommended reduction of dust and noise levels in Indian foundries, particularly in fettling shops. It has highlighted the need to mechanically move castings in the fettling shop rather than resort to manual handling. The castings were presently, moved from place to place within the fettling shop. This could lead to cracks in castings, sometimes even leading to their breakage. Material handling systems, including conveyor lines, could be helpful in getting over such problems.

The automotive foundries may find it beneficial to use manipulators for the grinding and welding operations in fettling shops. However, these steps need to be integrated into the total foundry modernization process. These steps could definitely enhance the productivity of the fettling shop.

4.7 Testing and Quality Control

In the advanced societies of Europe and North America, computer systems were increasingly being used for testing and quality control measures in the foundry industry. Sophisticated testing methods were being used to ascertain the quality of sand and the properties of clay bonded sand. Among other things, the computer packages test the following variables: moisture percentage; green permeability number; green strength; dry strength; shatter index; compatibility; wet tensile strength, weight of standard specimen; loss on ignition; volatile matter; methylene blue; and clay grade.

Statistical, quality and process control methods were increasingly becoming important in the foundry industry to reduce the rejection rate and enhance the uniformity in the castings. Computers were being used to record, monitor and control many of the important variations in cupola operations. The use of computers in foundry inspection operations was finding greater acceptance as the range and power of the hardware and software systems increased. One of the most critical determinants of casting quality in the eyes of the buyer was dimensional accuracy. In this respect, the application of computer systems in the collection and analysis of dimensional inspection data could increase the varieties of inspection and the time required to carry them out.

About the situation in India most of the conventional testing equipment relevant to the foundry industry (for sand testing, core testing, elemental analysis, molten metal temperature probe, casting quality, and crack detection, etc.) were presently being manufactured in India. But the critical area happened to be the paucity of standards germane to the needs of the industry. At present very few standards pertaining to foundry testing were available in India. The Metallurgical Engineering Division Council of the Bureau of Indian Standards had published around 17 standards under different heads like Cast Iron, Steel castings, non-destructive testing, etc. There is, however, a need for concerted effort on the part of professional associations, to evaluate these standards as well as evolve new ones.

Most of the foundries were found to be equipped with facilities for mould sand testing and core sand testing. Testing facilities for shell sand were not adequately found. Moreover, there did not appear to be uniform levels of testing facilities commensurate with the level of operations. Barring a few, most of the foundry manufacturers appeared to be bogged down with their day-to-day problems of raw material availability, thus giving inadequate attention to the testing function.

Indian foundries were producing as many as 15 categories of metal castings. Around 73% of the products had Indian Standard specifications, while the rest had no IS specifications. But quantity-wise, only 16% of Indian foundry units produced graded castings. In terms of quantity less than a quarter of the total metal castings conformed to IS standards.

It was observed that 10% of foundries had at least some basic research and development facilities. Indian captive foundries spent less than 1.5% of the Sales on R and D, but a few exceptional firms spent up to 4% of the Sales on Research and Development.

The foundry is a place where many technologies converge: pattern making, resins, sand preparation, sand reclamation, cores, binders, moulding, melting, etc. Research and Development function also needs to encompass the supply points of these materials. Such an effort can throw up alternatives in materials, technologies and processes. But as of now, such comprehensive approach to research and development function was conspicuous by its absence in the foundry industry in India.

Presently, the research and development activity relevant to foundry technology was carried on in India through a wide network of institutions and organizations: corporation, defence institutions, research laboratories, NIFFT, Indian Institutes of Technology, National Metallurgical Laboratory, Physical Research Laboratory, and so on. However, the coordination between these organizations was missing, resulting in lack of clarity, direction and vigour in the R & D efforts in this area.

5. Technology Institutions in the Foundry Sector

The technology institutions in the foundry sector in India have been set up for a range of activities: education and training, consultancy and advisory services and research and development. While some of the organizations take up an entire range of activities, others focus on a select few activities.

Only rudimentary and certificate-level training programmes in metallurgy and foundry technology were available in India during the British era. It was only during the post-independence era that the up-scaling of training programmes to graduate and post graduate level had taken place. This era also witnessed the establishment of the forums for periodical interaction of foundry professionals. The Indian Institute of Foundrymen came into being in 1951, with headquarters at Calcutta. This organization held yearly conventions which attracted foundrymen from across the nation. The yearly conferences provided the setting for foundry professionals to exchange views and notes on matters of relevance and topicality. But to carry forth the training, consultancy and research functions a plethora of specialised institutions were established all over the country.

Today, research and development is carried out at three levels:

a) R & D organizations like the National Metallurgical Laboratory, National Physical Laboratory, R & D Laboratory of the Steel Authority of India, and Defence Metallurgical Research Laboratory.

b) Academic Institutions, like the metallurgical departments in technical institutions like Indian Institutes of Technology, Indian Institute of Science, and Regional Engineering Colleges.

c) R & D centres of large foundries such as Ennore Foundries Ltd., TELCO, Heavy Engineering Corporation, Tata Steel, DCM Foundries and Mukand Ltd.

National Institute of Foundry and Forge Technology at Ranchi provided training of supervisory and technical personnel. Training was also imparted by the extension centres like Small Scale Industries Services Institutes and professional bodies like Indian Institute of Foundrymen. Process and Product Development Centre serves as technology centre for small scale foundries, particularly in the Agra area.

In the following sections, we briefly touch upon the nature of some of these organizations and the range of their activities.

5.1 Education and Training Facilities

It was during the 1950s that graduate and postgraduate education in engineering attracted the attention of the universities and the Government. A committee under the chairmanship of Prof. M.S. Thacker pointed out the need for graduate education in specific engineering disciplines and also the need for trained teachers in these fields. One of the offshoots of this committee's suggestions resulted in the starting of post-graduate (master's level) courses in foundry technology at the Indian Institute of Science (IISc.) Bangalore and the Indian Institute of technology (IIT) Kharagpur. They offered ME (Master's Degree in Engineering)/M.Tech. (Master's Degree in Technology) programmes in foundry technology. A while later, the IIT at Madras developed an M.Tech. programme in metal casting engineering. Subsequently these institutes offered the Ph.D. programmes, too, in this field.

Since foundry technology involves essentially a conversion of the metal from liquid to solid state, a number of metallurgical problems crop up in the production of castings. To fully deal with such problems, the focus in foundry technology education shifted toward metallurgical disciplines. Consequently some of the metallurgy departments in engineering colleges in India developed post-graduate programmes in foundry technology. The PSG College of Technology at Coimbatore and Maharaja Sayaji Rao University at Baroda started Master's Programme in foundry engineering. These programmes, being industry-specific, came in for commendation by the United Nations Development Programme. The students' training also involved studying and working with the foundries. This provided a strong application bias to the academic programme. Subsequently, the Bangalore University started a post-graduate programme in metal casting. During the decades of seventies and eighties many other colleges, institutes and universities designed and offered programmes in foundry technology.

5.2 Technology Institutions

As stated above, the National Institute of Foundry and Forge Technology at Ranchi offers a range of educational programmes. The Process and Product Development Centre, Agra came into being to serve the needs of the disparately organized small-scale foundry industry. The National Metallurgical Laboratory, Jamshedpur was set up under the Council of Scientific and Industrial Research (CSIR) with a mandate to serve the needs of, among other things, the foundry industry. We briefly describe these three organizations below.

5.2.1 *National Institute of Foundry & Forge Technology (NIFFT)*

NIFFT was established by the Government of India in collaboration with UNDP-UNESCO in 1966 with the objectives of organizing teaching and training programmes, conducting research and development in frontier areas pertaining to foundry and forge technology and providing consultancy, guidance and documentation services to foundry, forge and other related engineering industries.

NIFFT presently offers (i) M. Tech. Degree Programme in Foundry and Forge Technology; (ii) Post-graduate Programme in Manufacturing Engineering; (iii) Associateship Course in Manufacturing Engineering, leading to a Bachelor's Degree; (iv) Advanced Diploma course in Foundry/Forge Technology of 18 months duration; (v) a series of short term refresher courses in specialized areas; and (vi) unit-based programmes of short duration on request from industries or institutions. The institute also conducts some industrial research in foundry technology and related fields leading to the award of doctoral degree.

NIFFT offers limited consultancy services in the form of problem solving, preparation of project reports, selection and evaluation of equipment and machinery, testing of raw materials, castings, forgings and other components. Besides these services it also offers documentation and information retrieval services in foundry/forge technology and allied fields, through its library and documentation centre. The institute has well-equipped workshops for producing castings, forgings, patterns and dies; it also has laboratories for sand testing, mechanical and non-destructive testing, scanning, electron microscopy, metallography, instrumental analysis, pollution control, etc. It also has a computer centre with graphics work station for CAD, interfaced to computer-aided machining, plus a number of mini and micro-computers.

NIFFT is administered through a duly constituted Board of Governors representing foundry and forge organizations, professional bodies, education and research institutions, the Ministry of Human Resource Development and the Ministry of Industry of the Government of India. The institute functions under the academic and administrative leadership of the Director.

A quarter century after the NIFFT was set up, this premier technology institute has only 8 faculty members and 7 supporting technical staff in the foundry area to deliver the range of services listed above. Though it did not have funding problems, the procedures for the organizational planning, purchase, replenishment of equipment etc. were mired in bureaucratic tangles. For example, the Institute had been allocated Rs.1.5 million for modernization of the equipment. But key faculty members felt that the allocation was too little to make any real difference. The choice of equipments was also inappropriate, as the final decision was taken at the ministry.

The small and medium industries that could most benefit from the services of the institute did not demonstrate a proclivity to avail of the institute's facilities. The larger industrial enterprises felt that they did not need NIFFT's facilities. The Institute offered short sector-specific courses such as "Technology of Moulding and Core-making for Quality Casting", "Grey and SG Iron Practice", "Total Quality Management", and many others at very affordable rates (fees of Rs. 1600/= per participant per week). Nevertheless, the response from the foundry units from the east and north tended to be quite lukewarm. It was mostly the units with stronger interest in making improvements from the south and the west which sent supervisory and middle management participants to these programmes.

It was observed that only a few faculty were involved with consultancy activity. Though this activity was permitted, it did not receive organizational support. For example, the faculty members were expected to take leave for undertaking consultancy work, and could not use any organizational resources for the purpose. The organization had not initiated any proactive steps to upgrade teaching and research skills of professional staff.

The organizational members felt that many of the institute's equipments had become showpieces, as there were no budgets/approvals for appointment and training of technical personnel to operate the equipments or for building skills necessary for repairs and maintenance. A special problem was the frequent power breakdowns in the town, which made it difficult to operate induction furnaces.

To sum up, though the institute was initially conceived as a premier organization that would organize training and education programmes, conduct research and development in frontier areas of foundry technology, provide consultancy, trouble shooting, and documentation service, the objectives of the organization had become restricted to merely teaching and training programmes for supervisory and middle management personnel. Neither the organization had developed the strength and institutional capability required to carry out the original mission, nor was the environment favourable for the organization to play a strategic role for the foundry industry.

5.2.2 *Process and Product Development Centre (PPDC)*

This organization was set up by the government of India in collaboration with UNDP/ UNESCO as a supportive institution to foundry enterprises in the small-scale sector. PPDC is located at Agra, near Delhi. The centre's objectives are the following:

i) Providing to industry a package of technology which includes components, products, designs, inspection facilities, and standardized processes.
ii) Offering facilities for the testing of raw materials and components and products to meet national and international specification standards.
iii) Making available consultancy services to improve design, quality, productivity and adaptation of modern technology.
iv) Improving design and working operations of cupolas to reduce pollution in foundry industries.
v) Dissemination of technological information through seminars, workshops and documentation services.

In the emerging scenario of changing economic and trade policies, PPDC seeks to give greater importance to providing comprehensive technology packages to industries to make them competitive and quality producers of products with high value added content. With this purpose in view, this organization has been rendering specialized service in the following areas:

1) conversion of cupolas to efficient divided blast furnaces;
2) making of pollution abatement equipment for cupola, induction furnaces, generator sets, diesel engine test beds, reheating furnaces etc.;
3) quality and process improvements in cast/forged components;
4) defects investigation and material analysis;
5) supply of critical components in graded grey and SG iron, alloy steels, aluminum and copper alloys;
6) precision machining and die making on EDM machines; and
7) heat treatment.

With a small strength of just half a dozen foundry professionals, PPDC restricted itself largely to 200 small scale foundries located in Agra. It did not offer training programmes, but concentrated on providing some consultancy help and improving design and operations of cupola, which was used extensively by foundries in that region.

At the time of the study, the Agra foundries faced the threat of closure, as the public interest litigation filed by environmentalists was being heard in the Supreme Court on the damage caused to the Taj Mahal by the pollution caused, among other things, by the Agra foundries. A study had been done by the Nagpur-based National Engineering Environment Research Institute (NEERI), which had expertise in the field of air pollution control. The study had pointed out that the suspended particle matter (SPM) in the industrial zone near the Taj Mahal was 519 mg. per cubic metre, two-and-a-half times higher than the permitted level of 200 mg., while the sulphur dioxide level in the area had crossed 50 mg. per cubic metre when it should have been below 30. The pollution issue had attracted the attention of a host of institutions -- Environmental Management Division of the Confederation of Indian Industry (CII), NEERI, Pollution Control Research Institute, Hardwar, IIT, Delhi, National Metallurgical Laboratory, and pollution control equipment suppliers. The CII study had strongly recommended that NEERI and PPDC could work out appropriate measures in association with industries in the field of air pollution control.

Given the uncertainty facing the foundry industry in Agra, PPDC was involved in efforts to assist cupola industry in Agra region in modernizing and controlling pollution. They were working with equipment manufacturers in converting their cold blast cupola to divided blast cupola followed by venturi and wet scrubber for controlling air emissions.

5.2.3 *National Metallurgical Laboratory (NML)*

The NML was established by the Government of India at Jamshedpur, the heartland of India's steel and metallurgical industry. It is one of the national research laboratories functioning under the federal agency, the Council of Scientific and Industrial Research. NML has the following mandate to fulfil:

1) The pursuit of excellence in research in the preparation and properties of engineering materials.
2) The development of know-how for gainful utilization of natural resources of the country.
3) The development of linkages with the user organizations and utilizing the expertise generated.
3) The application of results of research for the benefit of society.

NML's R & D programme was grouped into two major categories i.e. (i) relevance-oriented and (ii) excellence-oriented. These were further classified into different categories depending upon the nature of inputs and types of the benefit derived from the project i.e. thrust area project, sponsored research project, international collaboration, sponsored investigation, interactive project, exploratory project, consultancy, technical services, etc.

NML had around 300 scientists and technical staff on its rolls, carrying out various research and consultancy projects. The institute staff had to its credit hundreds of papers published in reputed journals in India and abroad. Foundry was only one of the several fields in which NML operated.

A recent special report by the Director catalogued, among other things, certain critical problems faced by the NML:

* the flow of funds not keeping pace with the rate of inflation;
* inadequate manpower planning of scientific personnel;

- the disadvantages of being located in a region prone to breakdowns in infrastructure facilities;
- the immobilization of equipments due to inadequate maintenance.

NML was very active in the pilot plant area. It was almost a semi-industrial unit with full-scale plants to have test runs. With enormous investments in the pilot plants and a very large staff strength, the institution faced great pressure when there was inadequate work. This was much more so in the current environment, when there was decline in budgetary support, push for commercialization and generation of revenues.

At the time of the study, the organization was involved in an effort to transform itself to become more responsive to market needs, become more proactive in managing the interface with the industry and enhance its speed of response and quality of its technological support. The organizational members listed the following initiatives taken by the laboratory:

- It has upgraded its facilities, particularly for creep deformation studies, component integrity evaluation, and obtained soft loans and industry sponsorships from a wide range of organizations, such as the World Bank, Department of Atomic Energy, Steel Authority of India, Tata Steel, Bharat Petroleum, Indian Oil etc. It had developed linkages with research laboratories of other organizations such as Space Research Agency and Defence.
- It had created the technoeconomics group and built a databank on costs. The scientists received help from this group, and the technoeconomics of the process was strengthened.
- In the technology transfer fee, a travel budget was included so that scientists could keep in touch with the firm and obtain feedback on the functioning of the technology and take necessary corrective actions, wherever necessary.
- Testing services were provided at reasonable rates to build bridges with the industry, and innovative pricing mechanisms (annual contracts, obtaining a percentage of savings as fees) were initiated.
- Efforts were strengthened to anticipate technology requirements of the industry through a variety of processes and mechanisms.
- Awards were instituted for not only the best technical paper published, but also the best technology transfer achieved.

In the words of the Director, the laboratory was trying to get away from first-aid research (trying to assist the industrial firms when they were 'bleeding' as a result of their technological problems) to anticipatory research.

5.3 Summary of Problems faced by TIs

To sum up, India has a wide range of educational, training, and research institutions to cater to the needs of the foundry industry. But their impact has been minimal in terms of bringing about technological improvements and innovations (Please see Table 3 and Table 4 in Exhibit 1). There have been very few examples of significant collaboration between industrial firm and technology institution which resulted in important product or process innovation. The key problems facing the TIs have been summarised below:

Figure: Problems Faced by Technology Institutions

- Fragmented Institutions working in isolation, each with limited resources. Low intensity of focused research effort.
- Strategic Drift. Absence of marketing orientation and bold, imaginative planning. Absence of participative fora to set challenging and worthwhile technological goals, in consultation with industry.
- Bureaucratic work methods (particularly with respect to resource allocation, manpower planning, recruitment, and purchase decision). Weak renewal processes within the organization.
- Absence of improvement orientation in the industry. Remoteness from small firms and lack of credibility with large firms.

- Underutilization of the resources of technology institutions. Lack of collaborative partnerships with industrial firms to make technological improvements.

5.3.1 *Fragmented Institutions of sub-critical size*

There were a large number of institutions, but these institutions worked in isolation. Each institution possessed limited resources and only a small number of competent researchers. The intensity of research effort in each institution was too little to achieve any important breakthrough or to make any significant improvements. Given the fragmented efforts in homeopathic doses, the technology development process stopped at best with publication of a few papers.

A positive reference was made by some respondents to the initiative taken during 1985-1990 to coordinate national projects in the area of iron and steel. The Research & Development personnel of Steel Authority of India Limited (SAIL), Tata Steel, National Metallurgical Laboratory, and the Indian Institute of Technology came together regularly to identify thrust areas, coordinate research efforts, and monitor progress. It appeared that even this effort had lost momentum as a result of leadership changes in the different institutions.

5.3.2 *Strategic Drift*

Given the small size of the TIs and the enormity of the challenges facing the industry, the institutions seemed to be disinclined to look at the larger picture. There was absence of marketing orientation and bold, imaginative planning to anticipate the shape of things to come in the industry, and create participative forums to develop appropriate action plans. The TIs instead, chose a comfortable groove to operate in (routine training programmes, publication of papers as per the norms set by the journals of the Western world etc.). There was hardly any effort to proactively define challenging goals and objectives.

5.3.3 *Bureaucratic Work Methods and Absence of Renewal Processes*

A large number of the TIs were a part of the governmental system. According to some of the scientists, the government officials seemed to operate on the assumption that there was little to be gained by contributing to a large number of these institutions. Some of the institutions were found languishing without even proper organizational leaders. The organizations appeared to be tied up in knots and procedural wrangles relating to manpower planning, recruitment, purchase decisions etc. Decentralization, even when attempted, was never carried out through to its logical end. As a result, functionaries down the line in hierarchy experienced a sense of powerlessness and failure. The managerial systems to monitor the progress of projects tended to be either very weak or totally absent.

The organization structure exuded an atmosphere of stagnation. Very few attempts were made to create an atmosphere conducive to the promotion of change, freedom and creativity. No attention was given to making work a rich source of meaning for personnel at different levels.

5.3.4 *Absence of Improvement Orientation in the Industry*

There was no question of the TIs receiving support and encouragement from industry. Many of the industrial firms were hardly dynamic enterprises which would push the TIs to provide them support. In any case, The leading firms did not view TIs as credible sources for providing new technologies. When new technologies were needed, they went abroad for collaborations.

The promotors and sponsors of the TIs set up review committees from time to time to study the problems being faced by them and recommend ameliorative measures. But more often than not it took a long time for meaningful corrective actions to be taken. There was lack of cooperation, collective deliberation and collaborative action despite all the best intentions, perhaps due to inadequate interaction among various agencies. Consequently, the resources specially created to serve the industry remained underutilized.

6. Factors Blocking Technological Learning in Indian Foundry

In a number of firms, one could see the coexistence of a range of technologies from the very primitive to the most advanced. For example, in the foundry sector, there were a few foundries where raw materials were being brought in bullock carts; large scrap pieces were being broken manually with heavy hammers before being carried on the head by individuals to the top of the cupola for charging; melting, moulding and fettling operations were done manually with primitive tools; and there were practically no safety or protective equipment for the workers. Not far from such a primitive unit was a sophisticated foundry. In between the two extremes were several units on the continuum of technological sophistication. The presence of such a wide range of companies makes it virtually impossible to make general propositions that cut across all contexts. But one could see age-old methods still being widely used, lack of proper control, no instrumentation, and no efforts in energy conservation, leading to low levels of productivity and quality.

A detailed study was sponsored in 1958 by the National Productivity Council to identify key issues in the Indian foundry industry. A ten-member team visited leading foundries in Sweden, USA, and Japan and identified important areas for improvement (see Box for details). Their recommendation continue to remain valid after 35 years. It would appear that the industry has not travelled much on the technological path during the last 35 years.

In 1958, the National Productivity Council of India sponsored a ten-member Productivity Team to visit some important foundries in Sweden, USA and Japan with a view to studying the principal factors contributing to high productivity in steel, grey iron, and malleable iron foundries in those countries. Large, medium and small foundries were included in the visit. Prior to the visit, the team undertook a series of trips within India covering nearly 60 foundries and allied units in the Eastern, Southern, Western and Northern zones. From what the members saw during the in-country visits and from the discussions the team had with foundry executives, government officials and those connected with the industry, the problems facing the foundry industry were broadly summarized as follows:

* Lack of adequate and regular supplies of essential raw materials such as foundry pig iron, and graded scrap for steel melting.
* Lack of adequate supply of processed raw materials like high quality silica sand, bonding materials, core oil and binders.
* The high ash content of coke which necessitates the employment of high fuel ratio as well as the difficulties experienced in getting adequate supplies of coke in different regions of the country.
* Lack of adequate pattern making capacity, especially metal patterns and core boxes for mechanized foundries for mass-produced items.
* Lack of easy availability of foundry equipment and machinery from indigenous sources.
* Lack of adequate testing facilities.
* Lack of proper incentives based on well-planned schemes by which wages can be linked up with production.
* The general average deficiency in application and control of process details.
* Lack of proper understanding between management and labour towards the objective of striving to increase productivity.

Many of the above concerns are valid even today.

6.1 Environment for Technology Development

Two major external factors were identified by respondents as creating disincentives for technological orientation : perceived absence of connection between technological sophistication and commercial success, and high costs of modernization.

- *In one foundry, the owner manager was trying to obtain certification from an 'expert', that molten metal was not a saleable commodity for excise purposes. He felt agitated that he was required to waste time on such meaningless activities.*

Control-oriented and excessively bureaucratic procedures of the past had created a set of 'success factors' (such as cornering certain permits and licenses) that did not create strong incentives for technological orientation. Of course, the recent wave of liberalization is changing the rules of the game for several units.

There was also a strong feeling, particularly among the foundry managers, that higher quality did not always translate into higher prices. Where government was the major buyer, the 'lowest quotation' principle tended to equate technologically sophisticated manufacturers with technologically unsophisticated manufacturers of low-quality products. The respondents felt that they had, therefore, little incentive to invest in upgrading and modernizing their facilities and adding to their costs. Even non-government customers were perceived to be interested more in lower prices than higher quality. When there was not much competition, pressure for upgrading technology did not exist. Another disincentive was high cost of capital and high level of import duties. Thus, technological upgradation was perceived to be a risky proposition providing doubtful returns.

When firms did not see clear connection between investments in technology and commercial success, they did not see any necessity for becoming more technologically oriented. Interestingly, proactive managers with high internal standards of excellence alone put technological concerns on their agenda for the future.

6.2 Limitation of Size and Capability

No firm in the sample was found making very high investments in research and development to be a world leader in technology. This strategy would require firms to have large, global operations and pursue frontier areas of research actively. Indian firms are generally smaller in size than their counterparts in advanced countries, have not pursued globalization strategy, and have limited ability to commit resources for technology development. Firms mostly obtained new technologies through foreign collaborations, and pursued assimilation of technology and adaptation for local conditions or local volumes, as part of their technology development efforts.

A number of respondents mentioned that they could not effectively utilize technologically advanced equipments from developed countries, because these had been primarily designed for a much larger scale of operations.

> *A foundry manager mentioned that his firm (which would be considered large by Indian standards) had reviewed a list of secondhand equipments that would help it upgrade its technology. Invariably however, the capacities were much higher than the firm's*

requirements. The manager, therefore, felt that it would be a great help if Indian technology institutions could work on downscaling such equipments, so that those technologies could be adopted by Indian firms.

- *Two firms had brought in equipments from abroad with very high capacities. But they did not develop effective marketing units, which could ensure that the firms had enough orders to operate at breakeven level. Consequently, both firms were running in losses in spite of their ability to produce high quality products.*

Thus, investments in technology development have to be complemented by investments in market development. If firms try to go full gear on the route of obtaining advanced equipment and machinery without simultaneously building their marketing muscle, their survival could be in jeopardy.

There were several small firms in the sample which had a static view of the market. They, therefore, felt that the market would not be able to support any major technology investment. They expressed interest only in small, incremental improvements. They found themselves entrenched in their strategy of running a low technology, low cost (and often low margin) operation that catered to a narrow market. The nature of technology environment and technology problems faced by the foundries are illustrated by the following caselets.

- *A foundry felt that the quality of its castings could be improved only by improving its melting and refining methods. It had a small storage space for scrap which could barely accommodate two days' requirement of scrap. No segregation of scrap was possible in the limited space, and the composition of the charge remained was unknown to the melters. As a result, the final composition did not always meet the specifications, but the testing reports were manipulated and the castings were passed. No learning occured as a result, till its customers started cutting down on the orders and placing orders on Korean foundries. At the time of the study, the foundry was considering three proposals: making moulds and getting them poured in a neighbouring foundry with better metallurgical control; improving scrap storage; and setting up a small furnace for carrying out trials without interrupting the production.*

- *The technical personnel in another foundry considered R&D assignments as punishment postings, and dead-end jobs, till the Chief Executive assigned three bright enginers to R&D and gave them certain challenging assignments. The Chief Executive also strengthened the interaction between R&D and operations.*

Thus a few firms in our sample were found to have consciously chosen to pursue significant technological changes and create new markets.

- *For example, a foundry group set up a new unit to manufacture high quality investment castings. The new unit made all the necessary investments to run a high quality operation, and recruited qualified professionals to staff the various positions. Initially, the unit had great problems in selling its products as customers were unwilling to pay a higher price. It made losses for seven years, before it succeeded in educating customers about the value that its higher quality product could add. The unit is now highly profitable. At the time of the field study, it was planning to move into frontier areas of technology.*

6.3 Variability of Quality of Inputs

Absence of reliable quality inputs and infrastructure forces many managers to remain mired in routine, survival concerns and prevents them from undertaking technological improvement and innovation. For example, a foundry manager found it difficult to get scrap of assured quality. Similarly, the quality of sand, fluxes, alloying elements, etc. may not be as per specifications. Testing all the inputs was not always feasible. Assured timely supplies of inputs was not a luxury the foundry manager enjoyed.

- *A foundry manager mentioned regarding his visit to a foundry in the United Kingdom. When he met the works manager of that foundry, he asked him what his specifications were for a specific raw material, whose quality was a constant source of problems in India. The works manager replied that his only specification was the name of the firm supplying that material. He added that he did not ever face the need of drawing up specifications or testing the incoming material. In rare cases when the raw material quality was not up to the mark, he could simply call up the supplier on phone, and the material would be promptly replaced.*

The higher the technological sophistication of the process, the smaller the permitted variance in inputs. When input variance remains very high, firms are forced to settle for a less sophisticated process that can accommodate the vagaries of input variability. Consequently, there is lower efficiency.

7. Factors Contributing to Technological Upgradation

What motivates some managers to make consistent efforts to draw on new technology developments, adapt these to local conditions, initiate process innovations and improvements to adapt technologies to local volumes, and develop markets so that technical decisions lead to commercial success? How is it that, while some managers invest time, energy, and effort in such technical areas, other managers operating in the same environment shun risk-taking and persist with the status quo? As we examined technological behaviour of dynamic and stagnant firms to explore these questions, certain interesting patterns emerged which have been discussed below.

7.1 Inclusion of Technological Aspects in Management Agenda

We noticed that a number of key managers were unable to respond to questions relating to organizational plans for the future with respect to technology. When asked as to what support they would need from technology institutions, they could not identify what services would be the most useful for their firms. It appeared that they had not done sufficient thinking on these aspects.

Some of these firms did not have to work hard for their success. They were able to produce acceptable goods, and make good profits. Many of these firms had got stuck in this approach and had, therefore, no technology strategy of any kind.

An ancient Chinese proverb goes: "People do, not what the boss expects, but what the boss inspects." Management attention is a scarce resource in any organization, and if technology does not appear on the management agenda there is a strong likelihood that technology development efforts would receive little or no support.

- *A company had technical collaboration for five years with a world leader in technology. But during these five years, hardly any improvements resulted in the working of the unit because the company was going through difficult industrial relations problems, and all improvements and innovations were put on hold. Now the company does not have the collaboration, but is making substantial improvements on the basis of the insights gained earlier. The industrial relations climate of the unit has improved substantially, and management is attending to technical improvements with renewed commitment to retrieve lost ground.*

7.2 Performance Pressures from Customers

Some of the progressive foundries reported changes in the customer expectations in terms of quality.

- *For example, a foundry reported greater pressures from coal mines and power stations for better quality castings for pulverizing coal. There were enhanced expectations with respect to the number of hours the castings should 'run' before being replaced. The standards were influenced by the quality of castings obtained from overseas.*

The foundry, in turn, was tightening its own specifications for raw materials and putting pressure on suppliers for better quality and consistency.

- *Another foundry also reported having improved its operations as a result of having entered the export market. But the technical personnel reported that one part of the foundry which was catering to the export market had been upgraded, while no change was made in the rest of the organization, as the name of the game for survival in the local market (in this case, Railway castings) was keeping the cost low. The Railways tended to place their orders on the tender system. If there were a dozen companies bidding for the tender, only 3 or 4 organizations were larger foundries with more modern facilities. But they were governed by the prices indicated by the 8 or 9 smaller foundries, and no premium was available for quality.*

7.3 Processes and Mechanisms for Technological Innovation

Management attention to technology development also translates into organizational systems, mechanisms, and processes which are oriented to technology development and diffusion.

- *For example, an organization had instituted a system of developing short term, medium term, and long term plans for technological improvement. It had defined short term plan to include changes and improvements that would take less than six months for implementation; medium term plan included those which would take 6 to 18 months for implementation; and long term plans would take over 18 months. Towards the end of every year, the chief executive sent a note to all technical personnel in the organization to send their suggestions in a specified format. These were consolidated by the research and development department and discussed to finalize the technology agenda for the company. This company had made substantial progress over the years in upgrading and modernizing its works.*

- *Another company had constituted an advisory committee consisting of well known experts in related technologies.*

  The committee not only provided broad directions, but also supervised the review and monitoring of R&D plans.

7.4 Exposure to Global Market

Exposure to global market appeared to serve as a powerful trigger for technological learning.

> *A large steel foundry is presently exporting 10 per cent of its production and aims to increase this to 75 per cent in five years' time. It has been having a number of visitors who have had exposure to excellent foundries elsewhere. Interactions with these visitors have been giving the foundry personnel ideas on how costs, quality and delivery could be improved. The foundry exported 27,000 castings to a firm in Japan. One of these castings failed, and the foundry was surprised when it was squarely criticized even for this solitary failure. According to a senior executive of the foundry, this experience has prompted the foundry to raise questions on how it can change its approach and upgrade its technology. The R&D department of the foundry now regularly monitors market feedback and investigates failures.*
>
> *When the foundry approached Ford Motor Company for orders, it was given a 80-page self-assessment questionnaire on the various technological systems and controls. The company's overall self-rating was 83%. It invited a foundry specialist from Korea who made an independent assessment and gave an overall rating of 80%. But in certain areas, the foundry received as low as 60%. The assessment revealed that while the foundry had excellent metallurgical skills, it needed to improve its moulding practices, and introduce on-line testing methods (say, for sand quality, hardness of mould at different levels) to get quicker feedback to be able to initiate prompt corrective actions. At the time of the study, the company was involved with five major changes: upgradation of moulding machines (bigger sizes with greater automation) and resin-bonded sand for greater dimensional control and easy collapsibility; core shooters to reduce costs and improve quality; fuel-efficient heat treatment furnaces with better controls to minimize temperature variations among different zones in the furnace; shot blasting instead of sand blasting for better surface finish; and CAD for methoding of castings.*
>
> *The company personnel visited the Hanover Fair. During the trip, they met a German foundry expert who had specialized knowledge in the processing of castings. In the new liberalized environment, it was easy to invite him to visit the foundry and spend a fortnight. According to the technical personnel, this visit was extremely useful because the foundry personnel were able to exchange notes and*

information on how some specific problems could be tackled. In one or two cases, the expert was able to demonstrate how the improvement could be made. The external support from an "expert" also assisted the foundry personnel in obtaining quick management approvals for changes.

The foundry had initiated 26 quality circles in the previous 18 months. It had trained 50% of its workforce on quality circles concepts. It had also strengthened technical training. Each employee was expected to have a minimum of 1 1/2 days' training in a year. The training department of the company also organized regular factory visits to progressive engineering companies for their employees.

* *The technical chief of an automotive foundry visited several foundries in Japan, Germany, Italy and England as a team member of the Confederation of Indian Industry. As the automobile industry was undergoing rapid changes in India, the technical chief drew up a plan for technical upgradation. The foundry had gone for CAD/CAM technology for pattern making, CNC milling machines for dimensional accuracy of patterns, installation of advanced moulding machines which had already increased consistency and reproducibility, and a multi-cooler system for sand cooling. It had also initiated in-house efforts to strengthen core making and fettling.*

We found that innovative firms had several such fora and processes to channelize attention to technological concerns. They encouraged their employees to visit other companies and learn from their innovative practices. They considered it important to attend trade fairs and exhibitions, and followed it up with meetings to see what new ideas could be implemented. These organizations had mechanisms to facilitate interaction among different functions so that good ideas did not become victims of the 'management-by-objections' system.

7.5 'Workshop' Rather than 'Shop' Mind Set

Vast differences were found among firms in terms of their efforts to keep upgrading the capability of their employees. Capability upgradation does not merely refer to employee training, but includes several important facets of people management: assignment of growthful roles to technical people, induction and socialization programmes, performance planning and appraisal, transfers, compensation, career planning etc. Even relatively junior personnel in innovative firms had significant responsibilities and freedom to act, while even senior managers felt powerless in mechanistic non-innovative organizations.

On a visit to an industry association which conducts regular training programmes, we noticed that participants were largely from progressive companies. Paradoxically, the firms which were low on technological sophistication and which needed the training programmes the most were the ones which were least likely to attend.

- *In a few cases, some foundries demonstrated willingness to undertake the risk of experiencing with newer methods. A steel foundry developed the track shoes for a tank entirely through in-house efforts. The initial rejection rate was as high as 80% and it took 4 years of losses before the company mastered the technology.*

- *A small non-ferrous foundry supplying precision die cast components in Zinc alloy used hot chamber pressure die casting machine. These were tiny castings requiring high level of precision (2 to 10 microns) and were required for electronic industry. The castings went directly to the assembly line in the electronics company and so quality was very important. The order quantities were large (of the order of 1 million).*

  The large electronics company which required these castings used to get them from certain castings used to get them from certain castings manufacturers, who were essentially traders. They had obtained know-how from certain overseas collaborators who had given them a set of drawings. But the companies had not learnt the correct techniques, ad consequently the rejection rates were around 30%. This slowed down the assembly line in the electronics company, and sometimes the assembly line had to be stopped because of non-availability of these components. The castings manufacturers survived (and even thrived) in the market inspite of higher costs and lower quality, by resorting to certain unethical practices (for example, selling at premium prices certain 'controlled' items which they obtained as a result of being manufacturers of these items). There was little incentive for them to improve.

  A technocrat working in another medium-sized company operating in a related business, decided to set up a factory when the electronics company approached him and assured him of orders. He found out that he had to buy a hot chamber machine. A machine from Taiwan cost him Rs. 1.4 million. He wanted to buy a German or Swiss machine, but could not afford the landed price of Rs. 7.5 million. He made certain modifications in his machine to suit his specific needs and felt that he had understood enough about the machine to build *one himself. He approached a machine manufacturer from Aligarh and built two machines, which cost him about 0.15 million each.*

He built up technical expertise largely through interactions with technical friends and colleagues, references to journals and experimenting with the die casting facility and tool making. He obtained some information from Zinc and Lead die casting association, but he found the information too general to be of any use. He set up an organization with 6 engineers and tool makers and 12 workers, and was able to produce castings of the right quality and costs in six months. The rejection rate was 0%. Now the entire order from the electronics company came to him. He spent all his time on the shop floor and did not have to go out for getting orders. At the time of the study, he had developed a wide variety of castings, and was seriously considering the proposal of buying a German machine, which he felt could give him an unbeatable edge in the market.

- *A foundry making values approached the Indian Institute of Science to assist it in changing the layout of the foundry and introducing greater flexibility in manufacturing. As a part of the assignment, the faculty of IISc. developed a computer based information system which provided detailed information on different aspects of the manufacturing process. The foundry personnel were able to use the data base and obtain technical insights by analyzing the different problems. They were successful in cutting down the design cycle time by 80%.*

- *The son of a foundry owner in Agra attended a 6-week training programme in Japan. As a part of the programme, he visited over a hundred industrial units, and this motivated him to join his father and upgrade their foundry. While Agra foundries were known largely for making cheap, general castings, he decided to make high quality SG Iron castings. He approached the Process and Product Development Centre (PPDC) Agra who provided consultancy assistance for making S.G. Iron. The foundry also took advantage of PPDC's testing facilities and developed SG Iron castings in 2 years' time. He also mechanized the foundry, and went for core shooters and shell moulding machines. As electric power was extremely expensive, the foundry had to make high quality castings to survive. The company hardly made any effort to procure orders and still it was overbooked in terms of orders. It had not experienced the need for even preparing a brochure on the range castings it manufactured. The*

> *owner's son, who managed the technical affairs, reported that he visited a number of foundries in the western and southern parts of the country to exchange notes and get new ideas for improvement.*

7.6 New and Exciting Strategies for the Organization

Another interesting observation was that firms which had developed difficult and exciting goals and objectives were the ones which were concerned about technology development. Organizations with short term orientation were interested primarily in catering to a local market and therefore had no technological orientation.

Among the progressive firms that we visited, several had plans to obtain ISO 9000 certification. Some of these firms had outside experts evaluate their strengths and weaknesses in technological capabilities. They had studied the export market, and were aware of the technology and quality gaps that needed to be overcome. They had plans to tie up with foreign collaborators to bring in new technologies. They had plans for growth and diversification. These were the firms which felt excited about economic liberalization and had concrete technology plans.

- *A foundry which was interested in developing the export market went for ISO 9000 certification. The National Productivity Council assisted the foundry in this process. According to a senior technical executive, the process acted as a trigger for undertaking a number of improvements: the organization reviewed its systems, the testing facilities required to ensure quality, and prepared manuals; the training of the personnel at the operations level was taken up, which it had ignored earlier; during training workshops, the senior technical personnel realized that many workers did not known why certain activities had to be carried out, though they may have know what had to be done. The senior executive felt that the documentation and training efforts had enhanced the technological capability of the organization.*

- *A foundry had tied up a collaborative arrangement for five years with a German firm which was the sub-licencee of an American foundry which had pioneered investment castings. The company had sent a number of its engineers to Germany for training and felt that the collaboration had taught them finer points required for making quality castings. The company had not approached any TI because the TIs could not give them a guarantee of exclusive relationship, which was very important to the firm given the competitive market situation that they faced. But they approached individual faculty members from the IIT, Madras and the IISc., Bangalore and these faculty members provided consulting help to the foundry.*

7.7 Top Management Orientation and Philosophy

Several respondents were asked to list the factors that made firms technologically oriented. Many concluded that top management orientation and philosophy was probably at the heart of the technological innovation process. A dynamic top management was more likely to have well defined corporate plan, which could serve as a framework for technology plan. An enlightened top management was more likely to institute systems, processes, and mechanisms to channelize attention to technological issues. It was more likely to concern itself with capability building, not only through appropriate human resource management interventions, but also through a strategy of networking with collaborators, technology institutions, and progressive firms in industry. They were more likely to institutionalize a culture where technologists and managers go beyond day-to-day survival issues and concern themselves with innovation and improvement issues.

- *A company whose top management was strongly committed to technology had instituted a system for attending to complaints received from customers. When a complaint was received, it sent its engineers to study the problem. The engineers felt that the problem had arisen owing to the processing operation at the customer's end. To test this hypothesis, it asked the customer for certain records. Since the company had a good reputation for its responsiveness and its technological capabilities, the customer made available all the records of the further processing carried out on the company's product. This made it possible for the engineers to identify the problem and advise the customer how the processing work should be done. Once those steps were instituted, the problem did not surface again.*

In the above example, a free and frank exchange of views had occurred only because the company had approached the situation with an orientation of solving a technological problem rather than with a defensive posture of avoiding any penalties associated with product failure. The engineers were aware of their company's long term commitment to technological leadership and did not hesitate to make the investments required for problem solving. In the end, the company also gained in terms of experience and customer loyalty.

7.8 Summary

To sum up, several organizational characteristics contribute to technological dynamism:

a) Well defined technological goals and investment in time, energy, and efforts to pursue these goals.

b) Good systems for selection and training of people; creating a work organization in which members find challenging roles; providing members exposure to good technological practices through visits, collaborations, etc.

c) Challenging organizational missions and objectives.

d) Instituting systems, processes, and mechanisms for scanning the environment for new ideas and concepts, willingness to experiment, taking risks, and institutionalizing changes.

e) Networking with technology institutions, suppliers, customers, industry associations, etc.

8. Summary and Concluding Observations

The present research study conducted across the length and breadth of India brings into sharp focus two distinct patterns in the way enterprises approach technology issues, the kind of orientation they have toward the market place, and the way they perceive services from the technology institutions. These patterns have been presented in figures 1 and 2.

Figure 1 highlights the situation prevalent in the old-fashioned and traditional foundry sector. With a highly fragmented structure, this sector epitomizes the ills afflicting technologically stagnant enterprises: low value, often low volume output; primitive technologies of production; absence of marketing; reluctance to upgrade the skills of manpower; mired in mundane day-to-day concerns; inability to deal effectively with the regulatory environment; and the near-absence of interaction with technology institutions.

Figure 1

- Fragmented structure of the Indian foundry industry; Proliferation of small scale units with low volume operations.
- Market expectation largely restricted to having "an acceptable foundry at the doorstep", which can supply castings at " rock bottom prices"; insufficient premium for quality.
- "Shop" rather than "workshop" orientation among foundry owners.
- Poor availability of proper quality of raw materials; Absence of standards; Unreliable electricity supply; Poor infrastructural facilities for transportation, communication, etc.
- Excessive procedural orientation and corruption in the administration of regulatory system (say, for pollution control, safety, factory inspection, labour laws, excise etc.)
- Insufficient and irregular demands from major engineering industries; Absence of enlightened self-interest on the part of large firms to develop good foundries as suppliers.
- High cost of finance; Limited ability of small firms to raise resources.
- High psychological (and also sometimes physical) distance between firms requiring technological services and technology institutions with expertise in foundry matters.

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- Lack of interest in technological issues (absence of in-process quality control; little standardization of raw materials and other inputs; lack of interest in improving work methods, training people or attending to environmental pollution control; little upgradation of machinery, equipment and technology).
- Stagnation in the industry; Low quality, productivity and capacity utilization.

A major block for technological development was found to be the short-term planning horizons of industrial firms. A possible reason for this could be that several Indian entrepreneurs have come out of "shop" (trading) and not "workshop" (manufacturing) background. Consequently, they have traditionally sought commercial success through selling and accounting route, and have not bothered much about technological issues.

Nevertheless, our field experience also indicates that a new generation of entrepreneurs and enterprises exist which is markedly different in its orientation, given its exposure and background. These more modern enterprises were observed to have much greater appreciation of technology and were found willing to accord primacy to manufacturing excellence. They had longer term planning horizons and were ready to invest in sophisticated technologies and manufacturing processes.

Thus we have a new scenario consolidating itself to an appreciable extent in the foundry sector. The enterprises in this sector are increasingly realizing that it would be futile to build one's strategic game plan solely on the basis of the so-called advantage of low-cost manpower.

This segment is characterized by an acute awareness of the winds of change blowing in the global market; a willingness to adopt the latest technologies to turn the firms into dynamic and vibrant enterprises; willingness to enter into strategic alliances with leading overseas foundries; and acceptance of the importance of technology development in the emerging world. These firms also believed that the interaction between the industry and technology institutions should intensify for mutual benefit. Figure 2 presents the emerging, more optimistic scenario.

Figure 2

- High level of foundry expertise and experience present in the country in firms and technology institutions.
- Presence of industrial firms with sophisticated facilities and technological orientations.
- Economic liberalization. Widespread awareness and acceptance of the need to modernize technology and improve quality and productivity.
- Greater competitive pressures from the global market. Enhanced customer expectation.
- Easing of certain constraints in raw materials and other inputs.
- Developed countries inclined to source their castings from developing countries. Greater opportunities for strategic alliances.

Technological improvements in progressive foundries, leading to better quality, productivity and exports.

As mentioned by a senior technical executive of a leading foundry"If one wants to just remain a follower, technology is irrelevant. It is only if one wants to excel that one needs research and technology, and the yen for innovation and experimentation."

The managers in the more modern sector were found to be characterized by high level of initiative in thought and action. They were neither victims of a mind-set that only looked at past solutions to present problems, nor did they rely solely on rote learning. At the time of the study, these managers were concerned with how they could strengthen entrepreneurial risk taking in their organizations and create a sense of urgency about implementing significant changes to generate the right kind of technological temper in the enterprise.

All said and done, what happens at the ground level in countless firms would set the tone for technological efflorescence even in this emerging modern sector. While macro policies are certainly important to create climate for technological excellence, it is the micro initiatives of individual firms and the roles of senior managers which truly provide the thrust and momentum to technological upgradation in an industry. By focusing the organizational energies on challenging goals and paying attention to linkage, integration and mobilization , effective managers create technologically dynamic firms. And the environment in the foundry sector is pregnant with such opportunities.

References

01 Building up SSI Foundry Units for Global Competitiveness, Ravi Kapoor, IIF Transactions, 1994.

02 CII-IDRC Industry Mission on Pollution Control in Foundries: A Report, Environment Management Division, Confederation of Indian Industry, New Delhi, November 27, 1993.

03 Challenges of Export, Dr. R.H.G. Rau, Presentation to Annual Meeting of Institute of Indian Foundrymen, Bombay, August 17, 1989.

04 Emerging Trends in Foundry Technology, Dr. R.H.G. Rau, Shantikumar Purshottamdas Kedia Memorial Lecture, IIF, Bombay Chapter, April 12, 1990.

05 Exports - Need of the Day, Bapty Seshasayee, Indian Institute of Foundrymen, 1987.

06 Foundry Industry - Current and Future Profile, K.R. Santhanam and S Srinivasan, Indian Institute of Foundrymen, 1987.

07 Foundry Industry in Sweden, USA and Japan, NPC Report No.14, National Productivity Council, New Delhi, 1961.

08 Foundry Technology - The changing scenario, H.Md.Roshan, Indian Foundry Journal, February 1991.

09 Globalization Through Modern Technology, Dr. P.N. Bhagwati, Times of India, Ahmedabad, January 29, 1994.

10 Industrial Castings - the Indian Connection: ICEG Report, 1993.

11 Kothari's Industrial Directory, 1992.

12 Metal Casting - A Perspective, Dr. R.H.G Rau, Financial Express, Bombay, December 27, 1990.

13 Modern Technology Toward Globalization, Henry Rowan, Presentation to the Indian Institute of Foundrymen, Ahmedabad, January 29, 1994.

14 Modern Technology Toward Globalization, Nanubhai Amin, Presentation to the Indian Institute of Foundrymen, Ahmedabad, January 29, 1994.

15 New Tools for Foundrymen, D. Vasudeva Rao, Indian Institute of Foundrymen, 1987.

16 Postgraduate Education in Foundry Technology in India, G. Varadaraj, Indian Institute of Foundrymen, 1987.

17 Productivity of Indian Foundry, V Govindarajulu and R.M. Pillai, Indian Foundry Journal, April 1988.

18 TIFAC Recommendations on Indian Industry (focus on small scale sector); January, 1992.

19 Technology Evaluation in Ferrous Foundry Industry-DSIR, Government of India, March 1991.

20 Technology Evaluation in Non-ferrous Castings Industry-DSIR, Government of India, September 1988.

EXHIBIT - 1

Table 1
Characteristics of the Sample

A. Size of the Foundries			
Large Firms	Medium Firms	Small Firms	Total
9 (36%)	7 (28%)	9 (36%)	25 (100%)

B. Age of the Foundries (in years)					
Less than 5	5-10	10-25	25-50	More than 50	Total
2 (8%)	3 (12%)	7 (28%)	10 (40%)	3 (12%)	25 (100%)

C. Ownership					
Family Owned	Publicly Sold in Stock Market			Nationally Owned	Total
	No dominant shareholder	With Dominant Shareholder	Part of Conglomerate		
9 (36%)	4 (16%)	7 (28%)	3 (12%)	2 (8%)	25 (100%)

D. Sales Growth				
Declining	Negligible Growth	Moderate Growth	Rapid Growth	Total
3 (12%)	11 (44%)	7 (28%)	4 (16%)	25 (100%)

E. Share in Domestic Market			
Insignificant	Small	Important	Total
7 (28%)	9 (36%)	9 (36%)	25 (100%)

F. Technological Dynamism (Extent of Product or Process Changes)				
Stagnant	Slow	Moderate	Rapid	Total
9 (36%)	6 (24%)	9 (36%)	1 (4%)	25 (100%)

Table 2
Competition in Domestic Market

Extent of Competition	Number of Firms (Percentage)
Low or Moderate	7 (28%)
High or Very High	18 (72%)
Total	25 (100%)

Table 3
Role of Technology Institutions (TI) in Facilitating Product/Process Innovations in Firms

Did TI Contribute to Product/Process Changes ?	Number of Firms (Percentage)	Quality of TI Contribution as perceived by firm
Yes	5 (20%)	Low to Very Low
No	20 (80%)	Not Applicable
Total	25 (100%)	

Table 4
Services of Technology Institutions (TI) Used by Industrial Firms

	Service	Mean Rating of Usage by firm (1 - Not at all to 5 - Extensively used)	
1.	Information Services	1.64	(Little)
2.	Problem Solving/ Trouble Shooting	1.64	(Little)
3.	Standards/Testing	1.20	(Very Little)
4.	Education/Training	1.68	(Little)
5.	Applied R & D	1.04	(Not at all)
6.	Strategic R & D	1.00	(Not at all)
7.	Engineering Services	1.00	(Not at all)
8.	Manufacturing Products	1.00	(Not at all)
9.	Commercial Advice	1.00	(Not at all)