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Role of R&D in Local Production of Spare Parts

By

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ROLE OF R&D IN LOCAL PRODUCTION OF SPARE PARTS

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1. INTRODUCTION

Foundries are critical to developing countries industrial progress. They supply key inputs to various industrial sectors as well as sustain and generate employment and income at the small and medium size enterprises level. A major volume of the spare parts used in different industrial sectors is solely manufactured by or at least passes through the casting process through its production cycle. These castings usually have strict requirements of dimensional accuracy, surface finish, soundness and metallurgical characteristics and these requirements vary from one application to another. Small and medium size foundries in developing countries share the problems of :

- absence of advanced foundry technology.
- access to adequate and affordable raw materials.
- shortage of well trained and skilled personnel.
- inevitable result of poor quality high cost output.

After a recent study on the status of the foundry industry in Egypt carried out by CMRDI foundry group with the contribution of the General Organization for Industrialization (GOFI) and the Egyptian Foundrymen Society (EFS) and sponsored by the Egyptian Academy of Science and Technology, the casting industry in Egypt comprises about 20 public sector foundries and an estimated of 300 small and medium foundries in the private sector, scattered all over the country.

The available castings production capacity of these foundries exceeds 300,000 t/year, whereas the actual production never exceeded 200,000 t/year. In spite of the rather poor capacity utilization of most of these foundries, the casting imports by different industrial sectors reach about 80-100 thousands t/year. The major part of those imported castings are high quality castings required as spare parts for different engineering, mining, metallurgical, chemical, ... etc. industries, which usually should be of special quality. This simply indicates that the local consumers of quality and sophisticated castings still do not rely on the local foundries to meet their demands of spare parts.

2. CENTERS OF EXCELLENCE AT CMRDI

The foundry group of CMRDI (FG/CMRDI) was established in 1972 as a laboratory at the National Research Center (NRC), before CMRDI became an independent institute at 1977. Since its establishment, the foundry group started to establish links with the foundry industry in Egypt in the form of training programs or small R&D projects aiming at identification and remedy of some casting defects or recommending quality control programs. The development of those efforts into sizable at effective R&D projects was to great extent hampered by the lack of research facilities, unaffordable within CMRDI's limited budget.

To strengthen the research capabilities and overcome the associated funding problems, CMRDI has adopted, over the past decade, the policy of establishing centers of excellence through proper twinning arrangements with partner institutions from developed countries. Currently, the following centers of excellence (COE) are operating at CMRDI.

COE	***Partner Institutions***	***Sponsor***
Foundry	MI/TNO	Netherlands
Metal Cutting	IPL/TNO	Netherlands
Welding	JICA	Japan
Precision Casting	STC/ASRT	US-AID

These centers cover the main manufacturing techniques of spare parts. The objective of these centers is to transfer technologies from those developed countries to the Egyptian industry and the following chart illustrates the contribution of CMRDI and the partner institutions in the structure of those centers.

In the following discussion, the efforts made at the foundry-COE to upgrade the foundry industry in the country and to produce new castings that can successfully replace the imported spare parts are indicated.

3. FOUNDRY CENTER OF EXCELLENCE

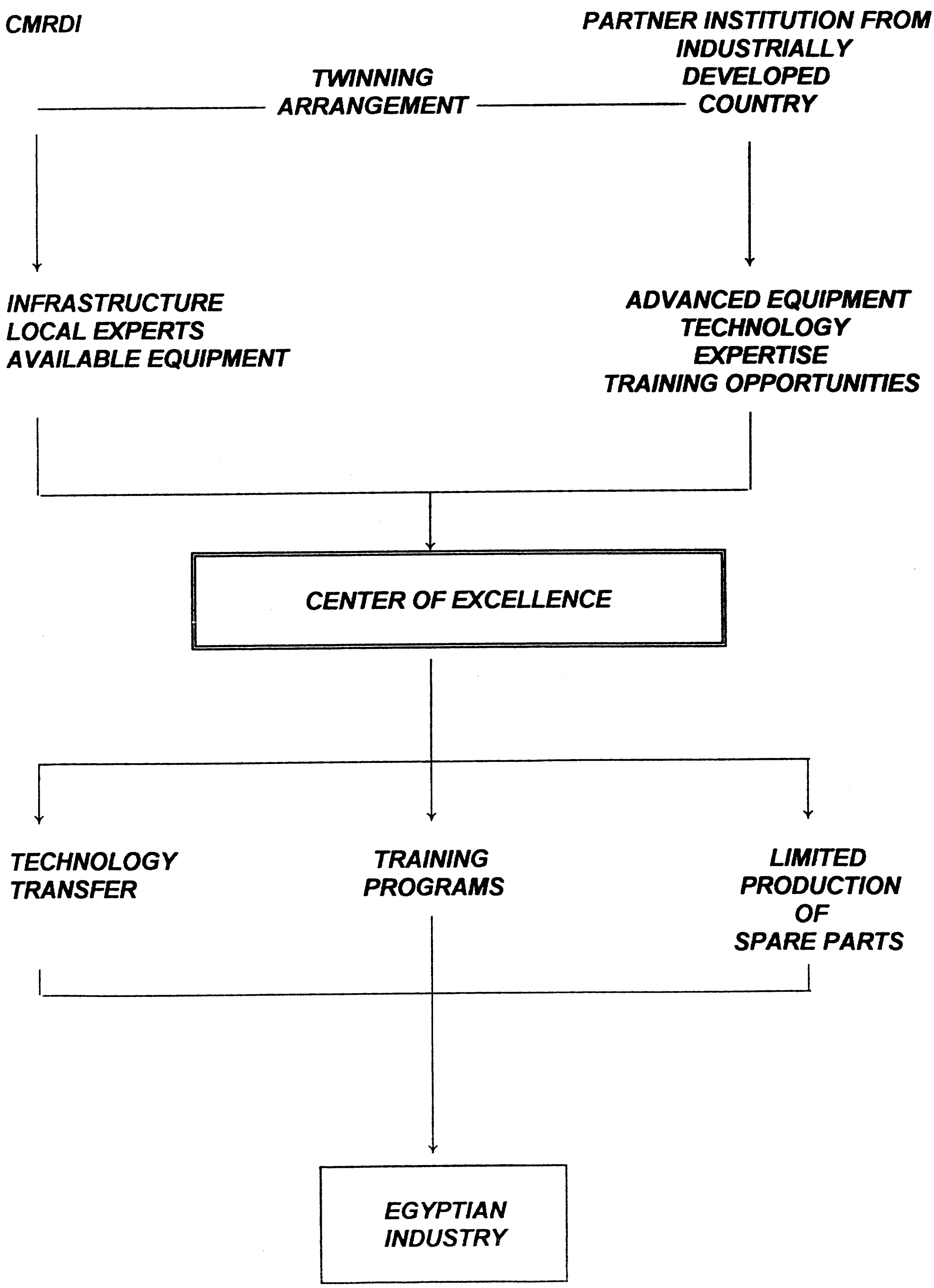
Over the past few years, the foundry COE at CMRDI has played a remarkable role in introducing new technologies for the production of higher quality castings to the Egyptian foundry industry with the following objectives in mind :

i. higher degree of utilization of the foundries capacity and hence enhanced productivity.

ii. production of quality spare parts castings involves more added value and, hence, more profitability.

iii. less dependence on imports of quality castings used by the different industrial plants, leading to savings of scarce hard currency and reduction of stoppage time caused by the lack of imported spare parts or by the use of locally produced low-quality castings.

CENTERS OF EXCELLENCE AT CMRDI
FOUNDRY - METAL CUTTING - WELDING



3.1. Facilities

The Foundry COE is backed by an experimental foundry of melting capacity of 1000 tons per year. This foundry has been established over the past five years with a generous help of the Netherlands's Government as a part of the technical cooperation program between the Netherlands and Egypt. The following is a list of the most important equipment available at the experimental foundry used for melting, melt treatment, moulding and quality assurance of the produced castings. The next three pages show photographs of some of these equipment.

3.1.i. Melting and melt treatment

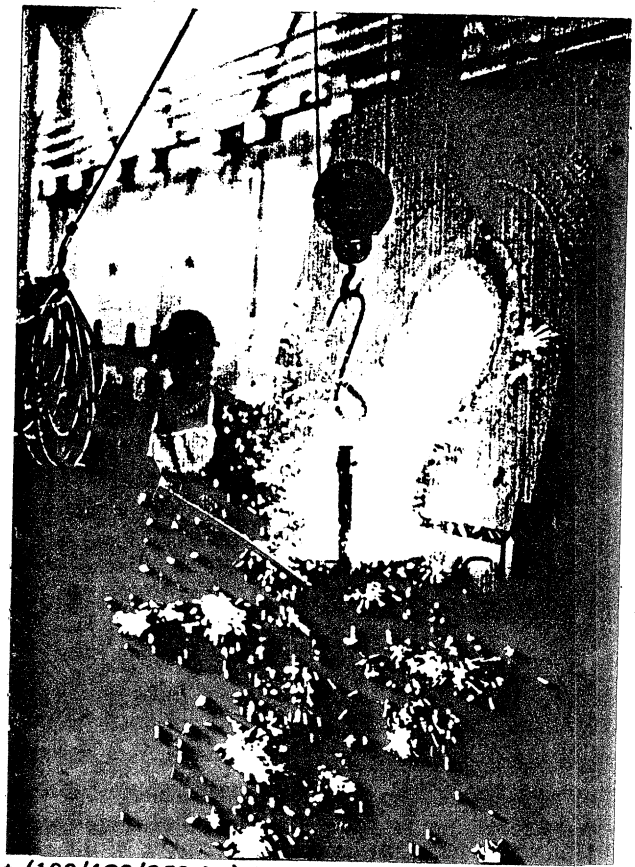
4 induction furnaces for ferrous metals, ladle capacities from 1-400 kg, total melting rate 0.5 t/hr.
1 induction vacuum furnace, ladle capacity 40 kg
1 induction melting furnace for non-ferrous metals, ladle capacity 150 kg copper
1 experimental cupola 0.75 t/hr
1 electroslag melting and permanent mould casting unit 200 tons press for squeeze casting and metal-matrix composites
Vortex unit for magnesium-treatment of ductile cast iron

3.1.ii. Moulding

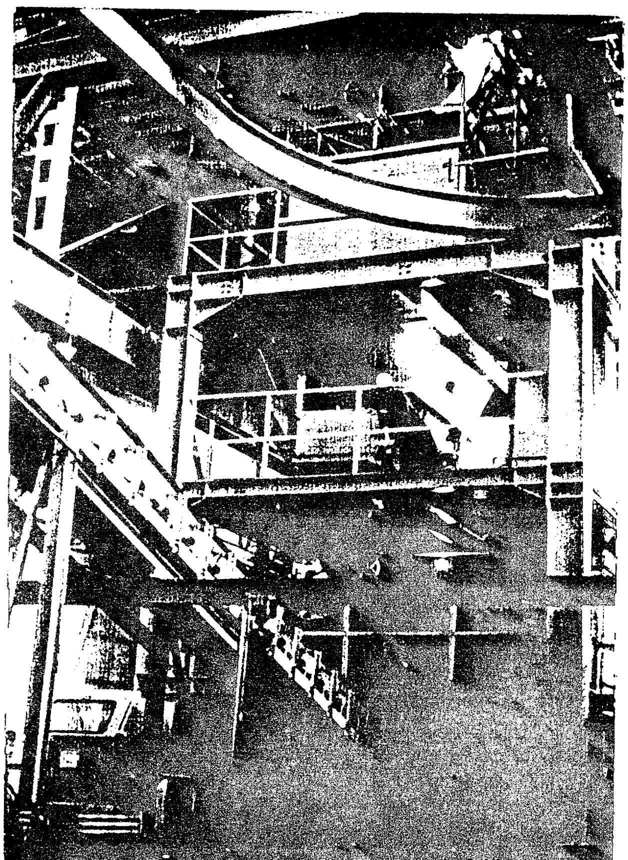
2 pairs of Jolt/squeeze moulding machines
Mechanized sand plant 8 t/hr
Core blower, 2.5 lit.
Core sand mixer, 60 lit
Continuous mixer for chemically bonded sands, 2 t/hr
Investment casting unit for precision casting
Shell moulding machine
Shot-blast fettling machine

3.1.iii. Quality Control

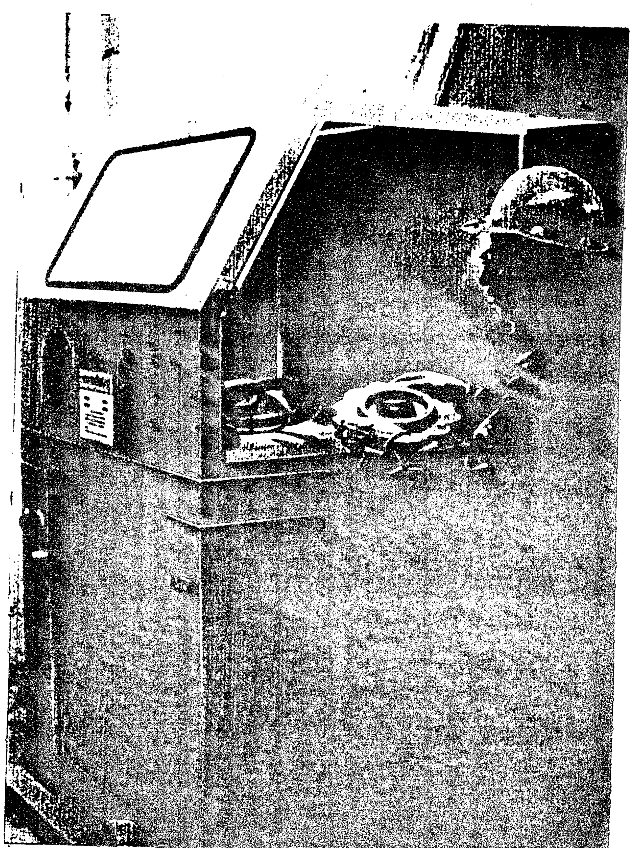
- Complete sand testing laboratory for green sand and shell moulding sands
- Sequential emission spectrometer for instantaneous chemical analysis
- Thermal analysis for shop floor determination of carbon and silicon contents of molten iron
- Modern tribometer for measurement of abrasion resistance of casting alloys.
- Complete metallographic and non-destructive testing facilities.
- Heat-treatment furnaces



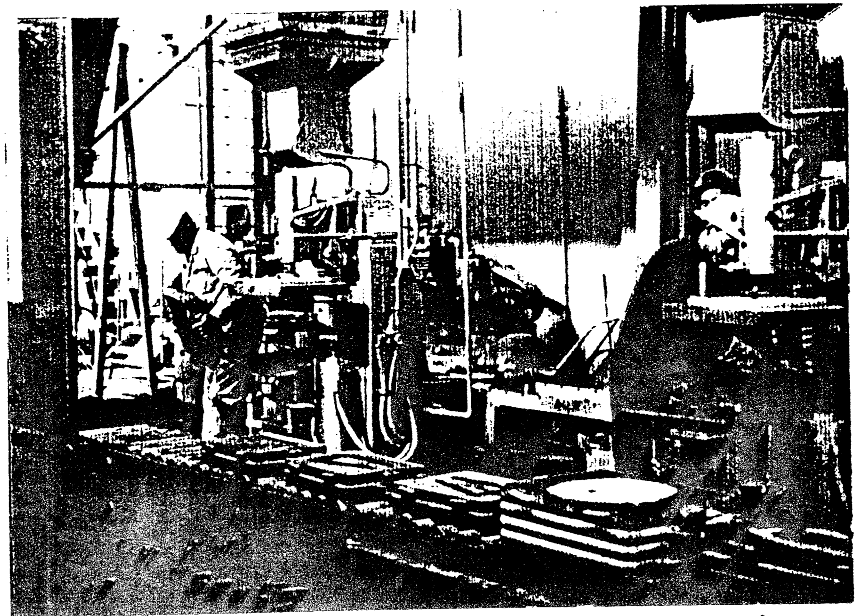
Melting plant (100/120/350 kg) induction medium frequency furnace.

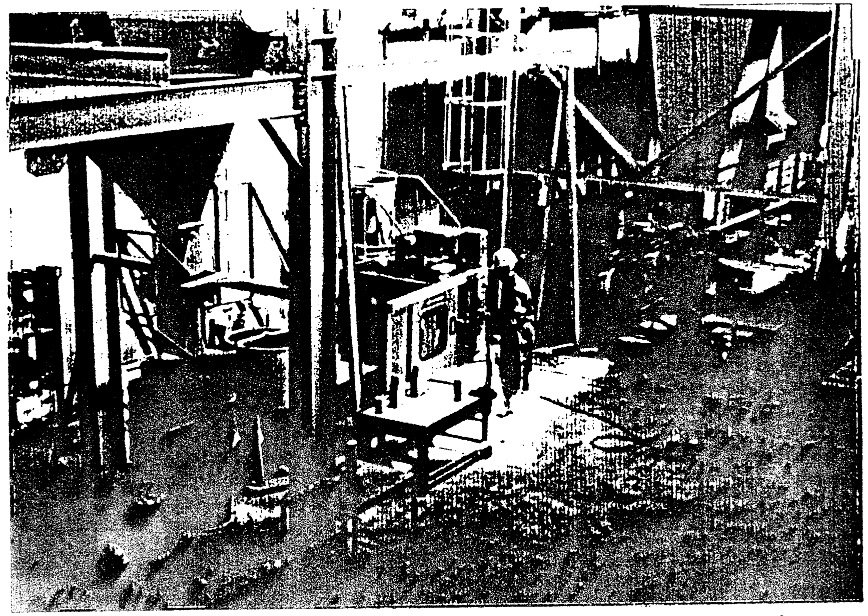


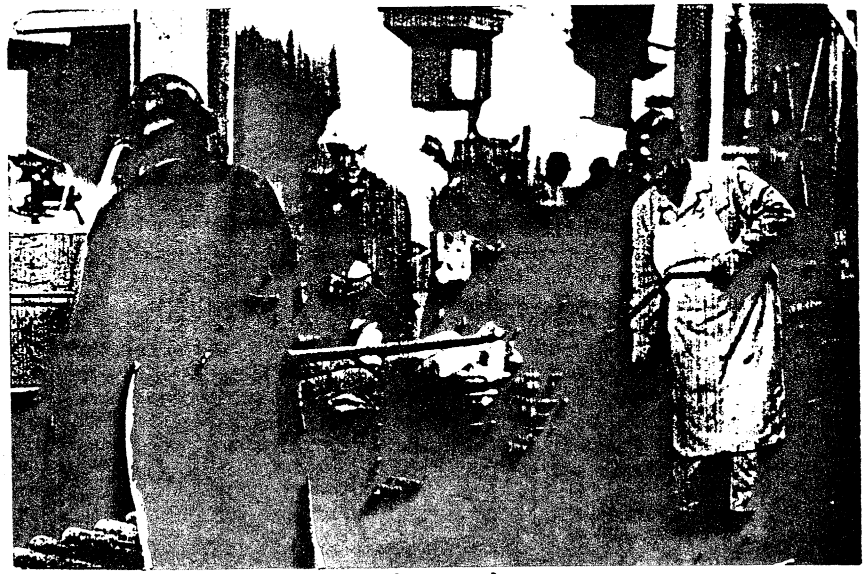
Mechanized sand preparation plant (8 t/hr)

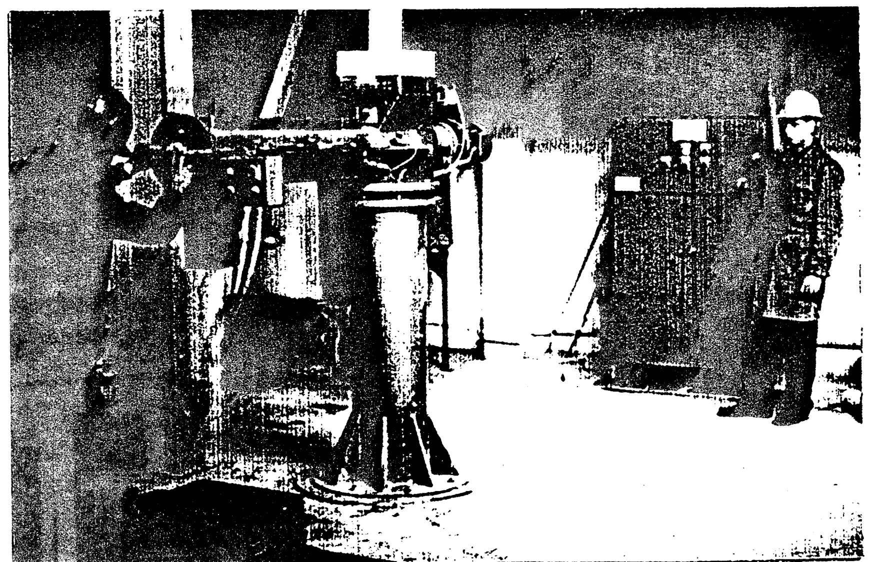


Shot-blast fettling of castings.

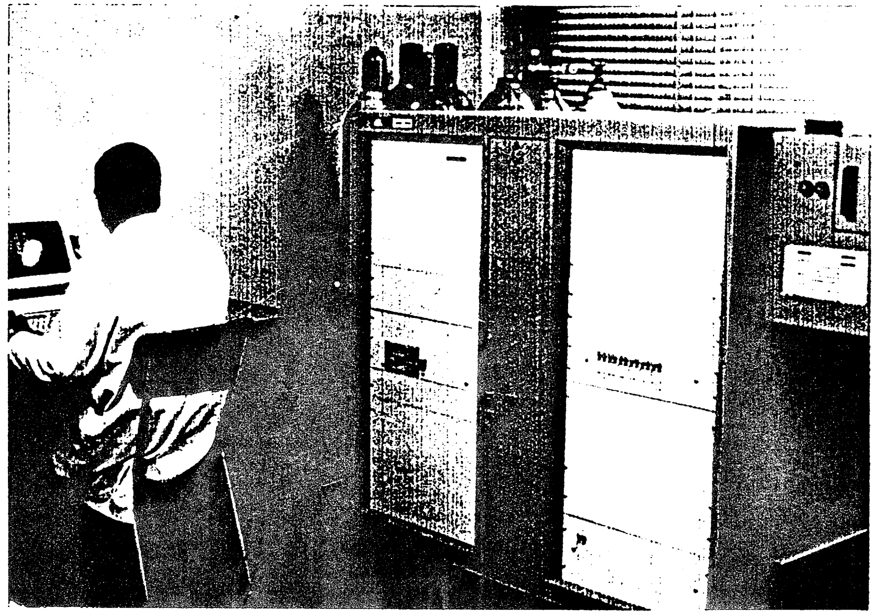

Molding line (2 pairs of jolt/squeeze molding machines).


Core shop (60 lit-core and mixer and 2.5 lit core blower)

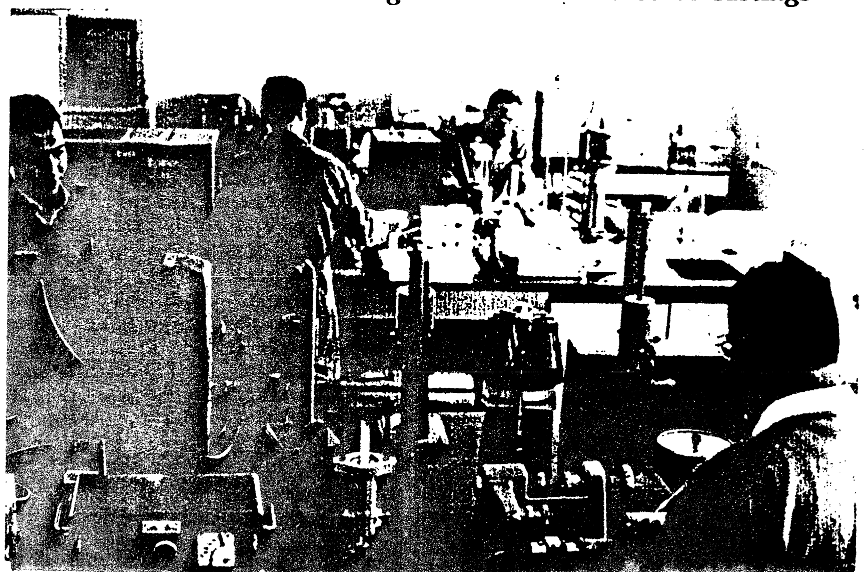

Pouring station


Continuous mixer for chemically bonded sands.

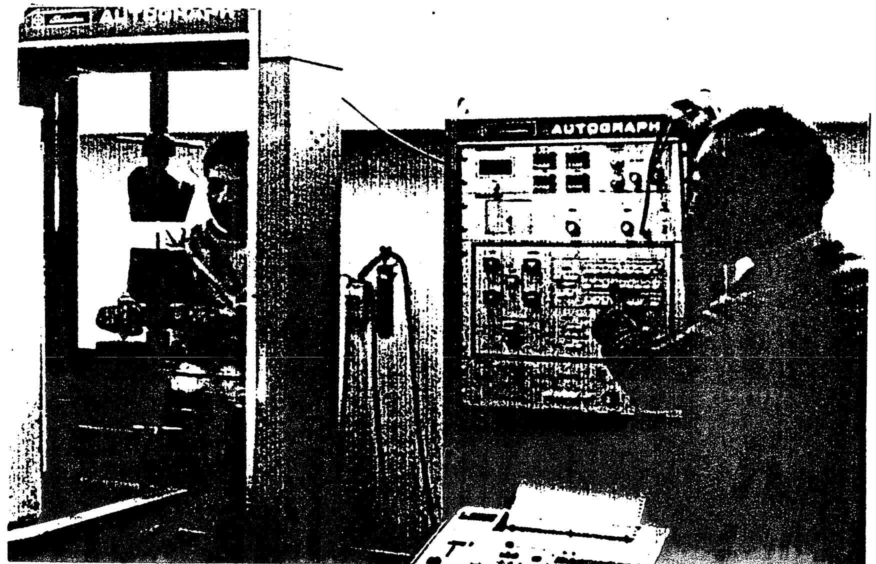
Tribometer for measuring the wear resistance of castings



Sequential emission spectrometer for rapid chemical analysis.



Testing of the properties of foundry sands.



Testing of the mechanical properties of castings.

3.2. Objectives and Activities

The activities carried out at the Foundry COE may be classified to the following main groups :

3.2.i. Production of prototype castings

With its rather versatile and flexible melting and moulding equipment, the experimental foundry is an ideal place for the commercial foundries to use for the production trials of a new casting before transferring the optimum conditions to the industrial scale. Such service offered by the Foundry COE certainly saves those foundries from stopping a complete production line to produce the first sample of a new casting.

3.2.ii. Training

Training programs developed at the Foundry COE may be either standard or tailor-made. Both types of training may be carried out at CMRDI premises or on-spot in the foundries, for periods ranging from one week to 3 months. The longest program was given to foundry engineers and technician from Khartoum Central Foundry (KCF) in Sudan sponsored by the Netherlands Government. Practical as well as theoretical training courses extended over two years were specially designed to qualify the foundry personnel working in that foundry, which was built in the frame of technical assistance program from the Netherlands.

A new system for training on R&D techniques is now under development where a "research engineer" from a foundry will spend 1-3 months in the foundry laboratories and pilot plant to carry out a short-term research program aiming at solving a specific problem encountering the production in his foundry. The benefit here is certainly mutual; the "research engineer" will get acquainted with the modern research techniques at CMRDI and in the same time some of his practical experience will be transferred to the personnel working in the experimental foundry of CMRDI.

Standard training foundry programs available at CMRDI cover the following topics :

1. Quality control in foundries.
2. Metallurgical principles of iron castings.
3. Greensand moulding technology.
4. Production and quality control of ductile iron castings.
5. Special purpose casting alloys.
6. Melting of casting alloys (cupola, induction and arc-furnaces)
7. Casting design.
8. Diagnosis, causes and prevention of casting defects.

9. Special casting techniques.
10. Heat treatment of casting alloys (ferrous and non-ferrous).

3.2.iii. R&D projects

The projects carried out at the foundry COE are financed on a contractual basis by the end users; most of them fall in the category of intermediate users, who adopt the research results and develop it further and put it to work. Within these intermediate users, two types of companies may be distinguished among the clients of the Foundry COE :

(1) Commercial uses - who perceives the potential application of research results in meeting its needs and solving production problems. The contracted research may be oriented towards improving product, change the raw material input or develop new products.

(2) Potential - investor users - who respond to economic opportunities identified by research and may support the preliminary development of new products.

Most of the R&D projects, carried out at the Foundry COE at CMRDI are contracted with commercial users (CU) and few of them are related to potential-investor users (PIU) as will be seen from the following list of R&D projects contracted by the Foundry Center over the last five years. The projects listed are more or less restricted to those concerned with the production and development of spare parts castings.

(a) Projects for development of new manufacturing processes :

a.1. production of ductile iron using the Vortex process.
a.2. electroslag melting and permanent-mould casting of high alloyed steel scrap.

(b) Projects for development of new products :

b.1. production of ductile iron rolls for steel rolling mills (PIU).
b.2. production of ductile iron spare parts for textile machinery (CU).

(c) Projects for development of new alloys :

c.1. modified Ni-hard (Ni-Cr alloyed cast iron) for casting of superior quality rolls (spare parts in metallurgical industries)
c.2. austempered ductile iron (ADI) for optimum combination of strength and wear-resistance; and ideal for gear manufacturing (spare parts in engineering industries).
c.3. compacted-vermicular (C/V) cast irons with optimum thermal shock resistance and best alloy for casting of ingot moulds (spare parts in

metallurgical industries.

c.4. high aluminium-alloyed cast iron for spare parts used under elevated temperature service conditions.

c.5. high Cr- and Mo-alloyed irons and steels castings used as spare parts working under different abrasion - conditions such as grinding media and earth-moving parts.

c.6. high Ni-alloyed ductile iron Ni-resist for ports operating in severe corrosive environments.

(d) Projects for utilization of indigenous raw materials :

d.1. Production of ductile iron castings using the locally produced sponge iron as a replacement of the rather expensive imported special pig iron.

Projects falling under different categories may be fully integrated. For example, from the previous list, project (a.1) led to the introduction of an efficient and reliable method for ductile iron production. The projects (b.1) and (b.2) utilized this method for production of very important items, whereas project (c.1) tried to optimize the performance of such product. Apart from the evident strategic importance of project (d.1), it proved that this product could be produced at more competitive price using the locally available and cheaper sponge iron.

More details about the economic impact of these five projects will be elaborated in the following case studies.

3.3. Case Studies

3.3.i. Production of ductile iron using the Vortex process

The turning point in the development of the Foundry COE was in 1979 when the group started its contacts with the Metal Institute (MI/TNO) of the Netherlands. The Dutch institute had just developed a new simple and efficient process for the production of the so-called ductile iron, an alloy which combines the excellent foundry and thermal properties of the conventional gray cast iron and the rather high strength and ductility properties of steels; a combination that renders this alloy very prospective for manufacturing of different spare parts. Such radical changes of the properties of the usually weak and brittle gray cast iron take place due to the transformation of graphite morphology in cast iron microstructure from the flaky to the spheroidal form.

As ductile iron was still not produced in any of the Egyptian foundries, a joint CMRDI/TNO project looked very attractive. The project passed through the following phases :

- techno-economical feasibility study for ductile iron production in Egypt
- evaluation and selection of foundries for implementation
- training of personnel from CMRDI and selected foundries
- pilot experiments at CMRDI
- industrial implementation at two selected foundries

In three years, the project was concluded with remarkable technological and economical benefits. Ductile iron production became a routine production in two foundries and new products such as ductile iron ingot moulds and permanent moulds used for steel and aluminium teeming were produced for the first time in the country with rather improved service life compared with items manufactured from traditional grey iron. Replacement of grey iron ingot moulds with ductile iron ones resulted in savings of 1.8 million pounds in Delta Steel Mills in 1987 as consumption was reduced to 15%.

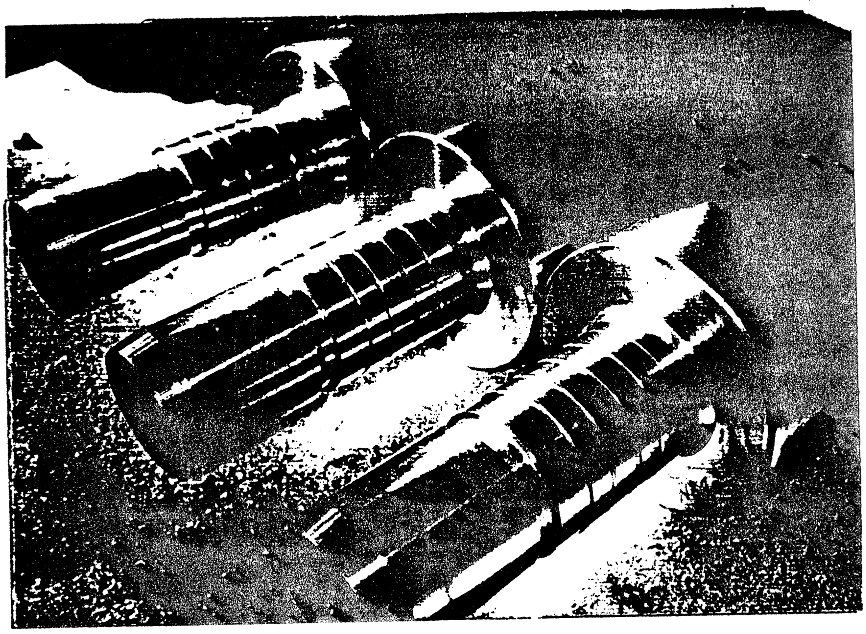
After the completion of the project in 1986, specialists of CMRDI were able to widen the scope of implementation of project results and, nowadays, there are 8 Vortex units completely manufactured at CMRDI and in operation in Egyptian foundries. The following two projects may give some indication about the impact that project had and is still having on the economics of the concerned plants :

3.3.ii. <u>Spare parts for textile machinery</u>

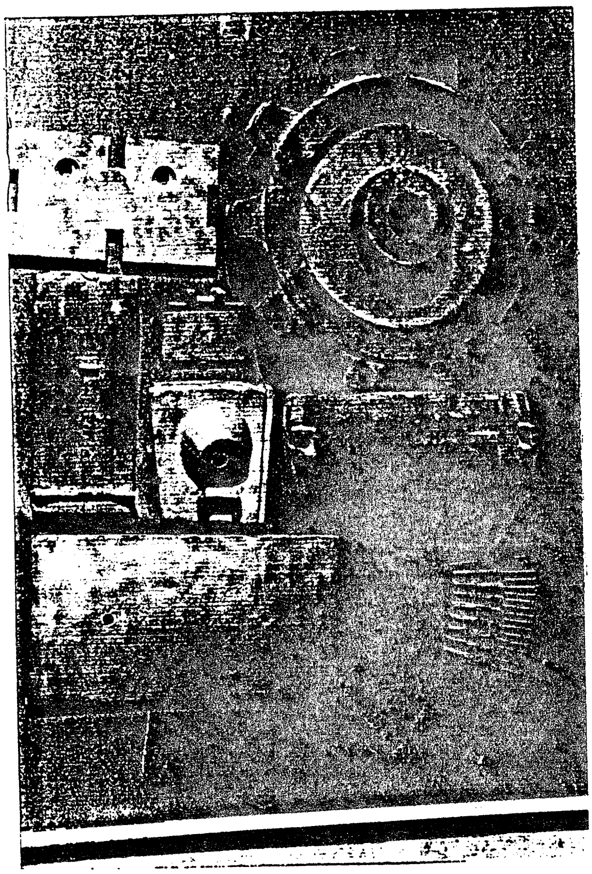
Misr Spinning and Weaving Co. (MSW) at Mahalla-El-Kobra in the middle of the Nile Delta is one of the biggest integrated textile plants in the world, employing about 32,000 workers. The castings spare parts demand reached about 3 million pounds/year of imported ductile iron and steel castings. The different trials to manufacture these parts from grey iron in the company's small jobbing foundry were met with low degrees of success. In 1986, CMRDI won an international tender issued by the company to introduce a simple, efficient and most important fire-safe technology for the production of ductile iron spare parts. The Vortex technique apparently was the most satisfactory technology required by the company. Over one year, a joint CMRDI/MSW team worked hand in hand and finally, the company's team was able to produce all the plant needs from castings spare parts. According to the company's reports, the spare parts were produced at 10-15% of the import price, with very comparable performance data. Nowadays, the small foundry at MSW can provide other sister companies in the sector of textile industry with high quality ductile iron spare parts.

3.3.iii. <u>Ductile iron rolls</u>

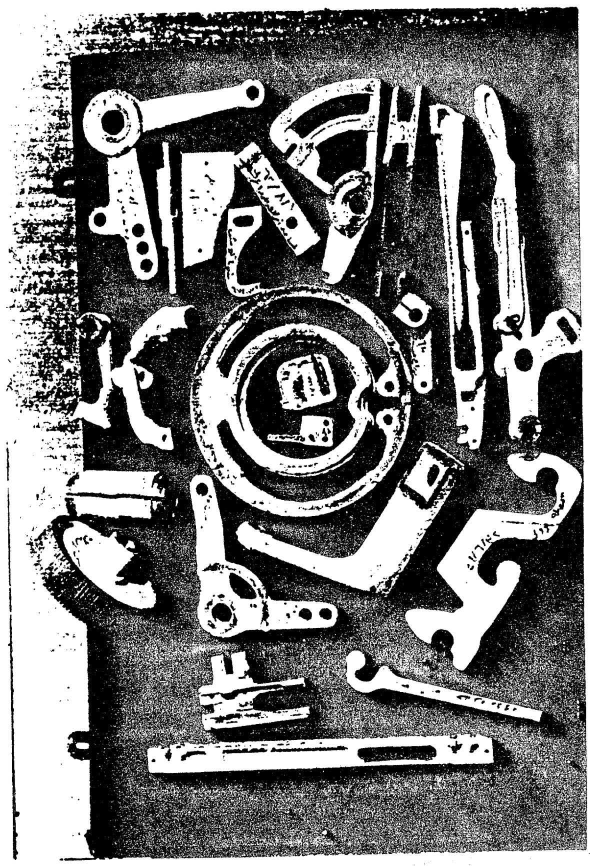
Rolls are the most important tools of metal forming, by which metal ingots or billets can be rolled into sheets, sections, bars or rods. According to UNIDO reports, the steel industry in some African countries came almost to a standstill due to shortage of rolls because of the absence of local production possibilities and/or scarcity of hard currency needed for importation of rolls.



Double-poured (chilled/ductile) iron rolls
produced at Egyptalum after CMRDI's technology



Special wear resistant spare parts
produced at CMRDI's pilot foundry
for different industrial sectors



Ductile iron spare parts for textile
machinery at Misr Spinning and
Weaving Co.

The Egyptian steel industry consumed about 5000 tons of rolls in 1989 and almost every roll was imported from industrialized countries as Germany, Japan, U.K., etc. Ductile iron rolls are rather sophisticated castings to produce since the roll specifications should be very closely controlled according to the position of the roll in the rolling train. Moreover, the same roll should have contradictory properties in different places of the roll; whereas the working surface of the roll barrel should have higher predetermined values of hardness, abrasion resistance and thermal shock resistance, the supporting roll necks should be of sufficient toughness to resist breakage in case of overloading. In the year 1989, CMRDI developed local technology of ductile iron rolls production and the results were implemented in the foundries of Egyptalum, Egyptian Copper Works and El-Nasr Casting Companies. Knowing that one ton of ductile iron rolls may cost up to 5-6 thousand U.S. dollars, one can calculate the enormous savings resulting from the local production of rolls.

Nowadays, different types of ductile iron rolls are produced as daily routine in the above mentioned foundries and a proper royalty is paid to CMRDI. The locally produced rolls are successfully replacing imported rolls. It is hopeful that by the end of 1994, about 50% of the local needs of rolls will be supplied by Egyptian foundries.

The Foundry COE at CMRDI has signed a new contract with the Aluminium Co. of Egypt for the development of a new type of the Ni-hard alloy; which is a Ni-Cr alloyed cast iron used for casting of the outer shell of double-poured rolls. The latter are high performance rolls cast from two different irons; a very hard and abrasion resistant (Ni-hard) in the outer shell and more ductile and tough iron in the roll core and necks.

3.3.iv. Use of sponge iron in foundries

The production of ductile cast iron relies mainly on imported high purity pig iron, very low in sulphur, phosphorus and manganese, imported at about 1000 L.E./ton. To increase the competitiveness of locally produced ductile iron castings, a local source of suitable raw material has to be found.

Three years ago, the Foundry COE at CMRDI started a research project financed by the International Development Research Center (IDRC) from Canada; with the objective of using the locally produced sponge iron as a main charge constituent for melting ductile iron. The sponge iron can be purchased at 500 L.E./ton and, therefore, the price difference is in favour of using it as a replacement of the imported pig iron. The project has proved that about 30-35% savings could be achieved with the new raw material and the results have been successfully implemented in two large foundries.

A second phase of the same project is about to start, which is concerned with widespread application and commercialization of the technology resulted from the first phase in small at medium size foundries in Egypt and other developing foundries.

4. METAL CUTTING COE AT CMRDI

Most of castings are subject to different cutting and machining operations, e.g., turning, milling, drilling, etc., before being used as spare parts. The experience accumulated over years at the Foundry COE of producing special spare parts of rather hard alloys, showed that the machining of many of such alloys needs optimization. Hard finishing rolls with hardness values up to 60 Rc are the most striking case.

A technical assessment of different machining operations carried out at production plants of engineering and metallurgical industries, revealed that many of them share similar machining problems.

A new Metal Cutting COE was, therefore, established in 1992 again with the kind assistance of TNO - The Netherlands. The main objective of the centre is to provide know-how required to create a controllable and consequently, predictable cutting process by following systematic approach, that guarantees reproducibility and reliability of the process parameters as well as cost reduction.

Activities of the Metal Cutting COE may cover :

i. transfer of modern cutting technologies
ii. R&D programs oriented to upgrade cutting operations
iii. theoretical and practical training programs aiming at improving skills, broadening experience and, hence, optimum use of machine capacity and cutting tools
iv. short-series production

The extensive range of equipment available in the centre covers both traditional cutting technologies as well as the CNC (Computer Numerically Controlled) equipment. The main features of already available equipment are :

1. CNC lathe - 40 kW.
2. CNC milling machine.
3. Conventional lathe, max. length 2000 mm, diameter 630 mm
4. Universal milling machine
5. Drilling machine, holes from 1-40 mm
6. Mechanical saw, max. cut diameter 400 mm
7. Small lathe for precision turning
8. Tool grinding machine
9. Presetting machine
10. Measuring instruments, such as :

- Set of dynamometers for measurement of cutting forces during turning, milling and drilling
- Surface roughness measurement
- Stereo-microscope for measurement of tool wear

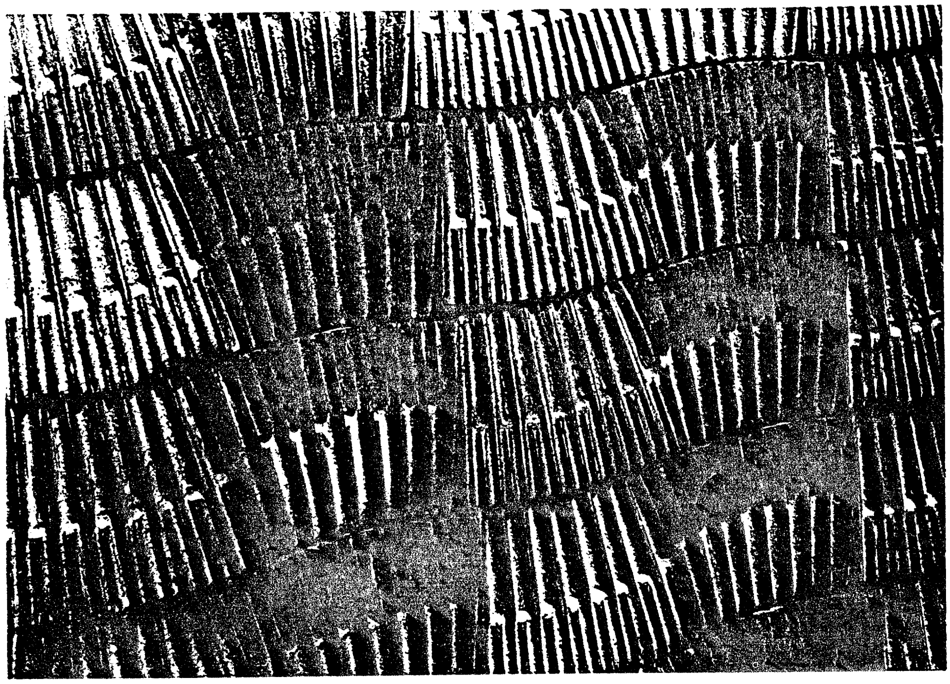
5. SPARE PARTS PRODUCTION AT CMRDI

One of the important factors behind the rather high volume of imported spare parts castings is that very wide variety of these castings are needed in rather small amounts which renders their local commercial manufacturing unfeasible.

The experimental foundry at CMRDI, with its flexible melting aggregate is very well qualified for the production of castings needed in limited quantities but with special quality requirements. The production of new castings is often preceded by a short-term R&D program to secure the required properties in a specific spare part, e.g., corrosion, abrasion, or oxidation resistance. As a good part of spare parts ordered from this foundry are supposed to operate under severe conditions of abrasions such as grinding media and earth-moving equipment, a special laboratory was established within the foundry COE for tribological measurements. Any abrasion circumstances could be simulated in this laboratory and special alloys could be designed for production in the experimental foundry. Production of grinding segments used for grinding of clays used for the production of stoneware pipes at one of the leading Egyptian plants may shed some light on the ultimate economic viability of parts produced at the experimental foundry of CMRDI. The company used to import about 20 sets/year of those grinding segments at 65000 DM/set, manufactured of steel with built-in tungsten carbide and cobalt teeth.

The frequent damage of those teeth added to delay in production resulting from shortage of segments due to import difficulties forced the company to look for a local substitute. The special chromium and molybdenum steel castings developed at CMRDI with special heat treatment could replace the imported segments with 80-90% of the life-time of the latter. The local segments shown in the next figure are sold at 7000 L.E./set, i.e. at about 5% of the import price and this price can still be very profitable for CMRDI.

The experimental foundry at CMRDI has become specialised in the production of special casting spare parts required in quantities unfeasible for commercial production. It can nowadays cover the spare parts needs of several plants in different industrial sectors, but more efforts will have to be made for complete utilization of the foundry's capacity. The recently started collaboration with the STC-program may very effectively contribute to the fulfillment of this target.



Clay Grinding Segments Produced at the Experimental Foundry of CMRDI.

6. STC PROGRAM AND FOUNDRY COE

A relatively new project at the Foundry COE has been contracted with the STC program (Science and Technology Cooperation Program) which is a collaborative effort between the US Agency for International Development (US AID) and the Egyptian Academy of Scientific Research and Technology. The STC is considered a new practice in Egypt S&T community.

The project which has been under execution for more than one year was designed to introduce the special casting techniques; used to produce precision castings, to the small and medium scale foundries in Egypt. Special casting techniques such as shell moulding and investment castings are mainly used to produce spare parts demanding high degrees of dimensional precision and excellent surface quality.

The project is conducted in five consequent phases; three of them have already been completed :

QUESTIONNAIRE

Company :

Department :

Address :

Authorized Persons; name and post :

Telephone/Fax No. :

Spare Part Casting (Please state the name in Arabic and English)	Weight, Kgs	Average Consumption Pieces/ Month	Source		Average Life-Time	Importance of Precision (1)			Degree of Intricacy, (2)			Mode of Failure (3)					Stoppage Time Due To Shortage of Spare Parts (4)	Last Price L.E or $ per Piece	Remarks
			Local %	Import %		a	b	c	a	b	c	a	b	c	d	e			

(1) Importance of casting precision : (a) the only solution for design problems, (b) to reduce machining cost, (c) not important.
(2) Degree of casting intricacy : (a) highly intricate, (b) medium intricate, (c) simple casting.
(3) Mode of spare part failure in service : (a) wear, (b) corrosion, (c) oxidation, (d) breakage, (e) others.
(4) Stoppage time evaluated as % of the whole working time.

Phase I : Market survey of the spare parts castings demand of different industrial sectors has resulted in the selection of 25 castings covering wide spectrum of properties and service conditions. The survey was based on a specially designed questionnaire shown in the following page.

Phase II : Pilot production of these castings has been conducted at the experimental foundry of CMRDI. The capabilities of this foundry have been strengthened by adding an investment casting unit as well as a shell moulding machine to the available foundry equipment.

Phase III : The quality and properties of the castings, produced have been evaluated in CMRDI's laboratories. The properties evaluated depend on the specific application of the casting and service conditions. This evaluation is now being followed by in-service performance assessment in the castings consuming plants and the life time is compared with that of the imported parts.

Phase IV : Techno-economic feasibility study will be carried out by a joint team from CMRDI and end-user companies.

Phase V : A manual will be issued listing the master technology of production of the selected spare parts. After evaluation of the technical capabilities of some selected foundries, recommendations will be made for the possibilities of producing specific castings in the different foundries.

Apart from developing the technological production know-how of high quality castings used as spare parts, this project may increase the degree of utilization and hence improve the economics of small and medium size foundries. Production of local substitutes for imported spare part castings will certainly decrease the dependency on import and create new potentials for investment in small size foundries and hence, new job opportunities.

7. REGIONAL FOUNDRY R&D NETWORK

The spare part problem is a common one between almost all developing countries. Purchase of spare parts by those countries always represents a continuous bleed of hard-currency, which is a real scarcity in all developing countries. The availability of local resources of spare parts, especially those needed by basic life activities as agriculture, irrigation, rural industries, textile, ... etc. will certainly have a tremendous impact, both economically and strategically.

Individual efforts by those countries are often insufficient and uneffective and some sort of linkage and integration is inevitable. As foundry is considered to be the basic technology used for manufacturing spare parts, it may be proposed to set up a foundry R&D network between some developing countries under the umbrella of an international funding organization such as UNIDO. If successful, the foundry network may be followed by others dealing with metal-cutting, welding and so on. The network may be based on south-south or north-south-south cooperation with the following main objectives :

(a) To promote scientific and technological research on key problem issues facing the small-medium scale foundry industry distinguishing between :

- major/fundamental problems which require substantial resources to address

- the more minor problems which could be directly dealt with within the context of the network.

(b) To support small R&D projects to address priorities problems in the industry. There are two types of mini-project area envisaged for support :

- generic projects - of importance to most members of the regional network

- company specific interests but perhaps involving university/research institute groups

(c) To coordinate and organize training activities between countries, which should be related to existing/proposed R&D projects or to help - overcome an existing industrial problem.

(d) To disseminate information on industry needs, technologies available, being developed, research and training activities and industrial opportunities. A newsletter may be set up to disseminate information required.

(e) To determine the information needs within the network and study the existing information resources and information exchange mechanisms in order to design the information exchange network.

(f) To develop and promote methods to enhance technology transfer to industry.

(g) To provide effective liaison between foundry scientists/engineers and industry at three levels: national, regional and international.

The required sponsorship for the proposed network is for a maximum of two years. Long term support of the regional network could arise as follows :

(a) Membership of the network should provide confidence to state organizations to provide continuing support as a result of a national awareness of the importance of the foundry industry to socio-industrial development.

(b) Training schemes, after being proved for (say) 2-3 years, could be self-supporting by charging for attendance.

(c) Projects initiated to meet particular industrial needs (as described by a company or companies) could be paid for in full or in-part by the industries concerned.

(d) Industrial membership of the network which would provide access to technical information would be by way of an annual fee.