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TECHNOLOGY PROFILE ON MINI FOUNDRIES

Prepared for
INTIB - THE INDUSTRIAL AND TECHNOLOGICAL INFORMATION BANK

by

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Introductory words to the "mini" series

Technical and Industrial Information available today is vast and very broad in scope. It concerns not only technological or technical information but also information required for industrial development, such as market information, socio-economic data etc. Ultimate users of industrial and technological information are mostly enterpreneurs, industrial planners and policy makers at both the large and small level aiming to establish a new or modernize an existing facility.

In advanced countries, the ultimate users in general know what information they need, and how to go about getting it. On the other hand, in developing countries, in general, users are less capable of defining their problems, searching for them and then benefitting from them.

The United Nations Industrial Development Organization (UNIDO) promotes the use of industrial information in developing countries by several means.

As one of the means the Industrial and Technological Information Bank (INTIB) compiles technology profiles on selected sectors of manufacturing industries of primary concern to developing countries and responding to the requests from mini-, small- and medium enterprises in these countries. The present profile, dealing with mini-foundries belongs also to the series of INTIB - Technology Profiles on mini scale production units. A list of the technology profiles published todate appears at the end of this profile.

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Dr. F. J. Tanaka	(Sectoral Studies Branch).

Last but not least the author wishes to express his thanks to

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Sources of Reference for Figures and Tables

Chapter 5: (cont.)

Chapter 6: Patterns, moulding and coremaking, gating and pouring

Chapter 6: (cont.)

Chapter 7: Castings

Appendix J	Source: UNIDO; Vienna International Centre Library
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1. Introduction

The production of castings is essential to the industrial development of a country. The manufacture of machine parts and components used in transportation, farming, construction and mining, and in water supply and sanitation is dependent on castings.

Various stages in the growth of the foundry industry in developing the economy of a country demonstrate the interdependence of manufacturing industries on the availability of supplies of cast-to-shape products and the foundry industry for a proper market for products. Although castings comprise a minor portion of metal consumed in an industrially developed country (around 15%), they are, however, mainstay of the mechanical and electrical engineering. Considering the end use of castings, it could be observed that in industrialized countries the major consumer is the mechanical and machine-building industries, dominated by the automotive industry. There is hardly any economic sector which does not depend, either directly or indirectly on cast products. Tables A.0/1 & A.0/2 in the Appendix A.0 provide data for economic indicators of high and low castings intensity for selected industrialized and developing countries.

The foundries in the developed countries can be classified according to the following four groups:

1) Heavy foundries - original parts for machine builders
   replacement parts for above
2) Automotive foundries
3) Specialized foundries - investment, vacuum, etc.
4) Jobbing service foundries

The last case is generally the survivor in the developed countries, because the larger and higher technical units are more vulnerable to competition because their activities are financially interesting to private investors in developing countries and the production volume can support qualified technical and administration staff.

The jobbing or service foundries tend to survive in the developed countries precisely because they provide a convenient - corner shop-type of service to local industry. Their prices are high because they are required to keep highly qualified staff, with a low total production volume. However, their market is one where the availability, rather than the cost of the casting is the important factor; the opportunity cost of the slow supply of a spare part, or too large a distance between engineering development offices and the foundry, is too great to permit the purchasing or engineering department to closely examine prices. Those who do, frequently find themselves in great trouble.

The structure of the casting industry varies from country to country but some features of the industrialized countries and the developing countries as a group emerge from the analysis of production and such data as is available, on the number of foundries, employment and size of establishments. Data on these is limited and can often be contradictory. The difference is often attributable to the coverage, particularly due to smaller units. However, these data could provide a reasonable indication of structural features and trends. An analysis of the employment profile for the ferrous industry as indicated by the Figure A.0/1 shows clearly that on average, one quarter of the ferrous foundry in the industrialized counties consists of foundries employing less than 20 people. Only the top 15% of foundries could be considered to be large with a work force of more than 250 each. By comparison, the structure of ferrous foundry industry in developing countries is more dominated by the small scale establishments, see Figure A.0/2 in Appendix A.0. The technology adopted by many developing countries to a large extent depends more on the nature of the market or lack of investment funds. In small foundries producing less than 100 tonnes per month, technoques and skills of labour are of greatest significance. In these units, the target has to be set in terms of consistently adequate quality rather than on quantity. The establishment in developing countries of low volume foundry plant producing castings of adequate quality can be seen in a similar light as indicated for the jobbing foundry in developed countries. For product quality and company growth, technical ability and management experience must be available. such personnel are not easily obtained and are in fact the heart of this type of industrial operation. A small foundry can disappear if the key individual leaves; it is thus most adviseable when considering and offering financial support for the establisnment of a foundry, to ensure that key personnel will be strong share holders or very well paid, with strong incentives to remain.

The market must be approached with caution and the initial clients selected on the basis of the real benefits which will accrue to them by having a good, small foundry on their 'doorsteps'. The requirement for the foundry to move gently up the learning curve must also be most clearly appreciated. It is of the greatest importance to analyze the market and to present the findings, discriminated into groups, each reflecting the technological and capital input requirements.

Such a discrimination will allow the investors to prepare such feasibility studies as may be required, covering an investment programme which will be related to the progress of the personnel along learning curves, and thus to a realistic projection of the progressive penetration of the 'more technologically demanding' market.

The requirements for studying a business must be remembered, as being in order of importance: (a) to make a profit; (b) to be able to operate, - obtain/train personnel; (c) to obtain finances. If (a) & (b) can be clearly shown, (c) will generally be obtained.

It is obvious that, successful purchase of foundry products from developing countries very much depends on the level of confidence the vendors enjoy in terms of quality, productivity, price and delivery schedule. Though adequate quality control at all stages is essential, too much of it may be as bad as too little. The degree of quality assurance has to be related to the type of products, their functions and the buyers real needs rather than wants. Many small -mainly jobbing- foundries need to be upgraded to produce good quality castings through technology improvement, good maintenance programmes and simple but effective management system.

Appropriate incentives may have to be built in for technology development, upgrading, application and adaptation of new technologies. One main constraint on technology adaptability is that constituted by the nature and size of the market in the developing countries and, to a certain extent, the availability of funds for investment. The product mix of an average foundry in a developing country is much wider than that found in industrialized countries and calls, therefore, for more generalized and flexible equipment. For the developing countries the essential need is to adapt technology to suit their demands and capabilities.

Part of the INTIB work programme of 1987 was the preparation and presentation of this technology profile with the purpose to make available to developing countries the necessary technological, economic and other information about the small scale foundry route envisaging the formulation for proper approach to the mini-foundry concept. This approach has been extensively elaborated in the chapter 3 of this profile. The rest chapters and the Appendices serve as explanatory and complementary ones covering the whole range of operational and economic characteristics of importance to the foundry industry, its establishment and/or development. It is to be hoped that this contribution will facilitate planning the development of the foundry industry integrated with other sectors of the economy and the selection of suitable technological options that will permit this type of development.

Note: The author is indebted to Mr. A. Buckle (Metallurgical Industries Branch, Department of Industrial operations, UNIDO) for permission to incorporate useful and illustartive thoughts into the introduction, as well as into the chapters 3.4 and 7.

2. The new directions of the foundry industry and its link with the economy

The art of metal csting has been, and mostly continues to be, an essential part of the industrialisation process. The products of the early foundries made a major contribution to the development of civilised society, ranging from the heating stoves to the vast quantities of pipe used to provide services to the growing manufacturing townships. The post-war growth of the automobile and aircraft industries provided new stimuli for cast products and casting technology and promoted the process of rationalisation and specialisation and particularly in the case of the tied foundry in a ve cally integrated company. Clearly, the demand for rationalisation is part of the requirement to cut costs. This requirement undergoes an additional pressure due to the growing economic competitiviness of other -new- materials and/or -new- processes.

The above outlined nature of change can be restricted to four basic elements regarding its impact (of the change) on the foundry industry.

First element: In the industrialised type civilisation growth as one has previously understood it, has peaked. With the resulting stability, demand drops.

Second element: Whilst the "market cake" is getting smaller, industry of every country is suffering increasingly from import competition.

Third element: A similar sort of development that has taken place in Japan (see Table 2.1) can already be seen starting to occur in the developing countries in the westrn pacific basin and other major geographical areas. It has started with footwear and clothing and is now moving through the full manufacturing range. The so called "off shore" developments basedon the latest in technology and equipment and exploiting cheap labour can be seen. Countries such as Korea (Republic of), the Philippines, Indonesia, Malaysia and Brazil are obvious examples.

Fourth element: This is defined by the industrialised countries and emerges from the shrinkage of their own internal markets. Because of the competition for a slice of the smaller "market cake" both from local industry and imports there could be a tendency for more and more industrialised countries to seek export opportunities.

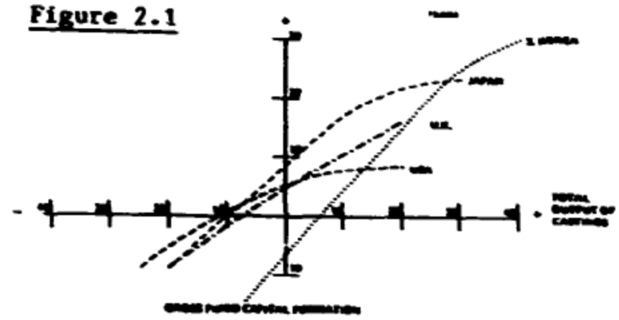
If it is accepted that the four assumptions outlined above are

Table 2.1

Age of machine tools

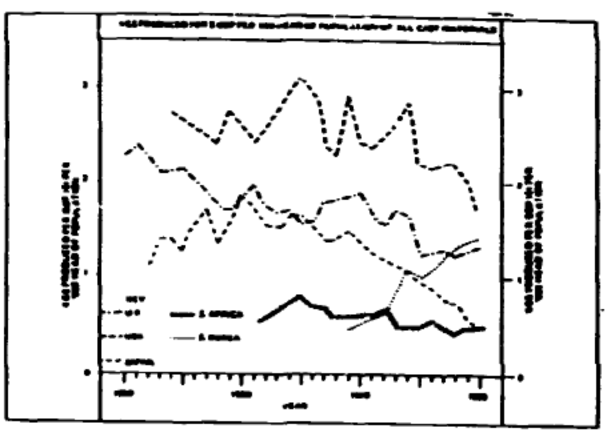
Country	Japan	Germany	U.S.A.	U.K.	Australia
Machine tools less than 10 years old % of equipment in plant	62%	56%	39%	38%	25%
Expenditure on new plant and equipment. % of gross product value	37%	28%	16%	17%	10%

Figure 2.1



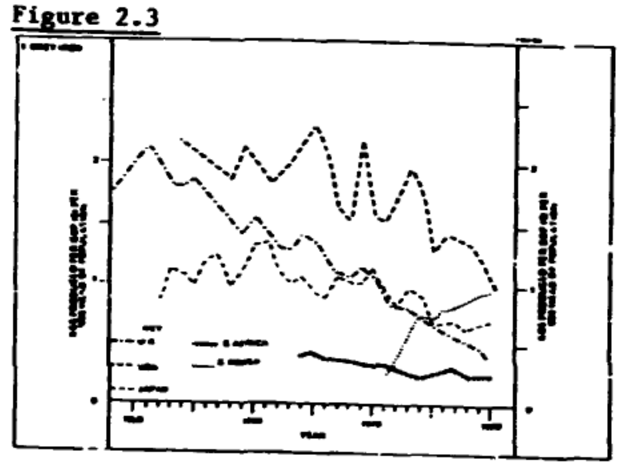
General relationships between gross fixed capital formation and castings output for countries shown.

Figure 2.2



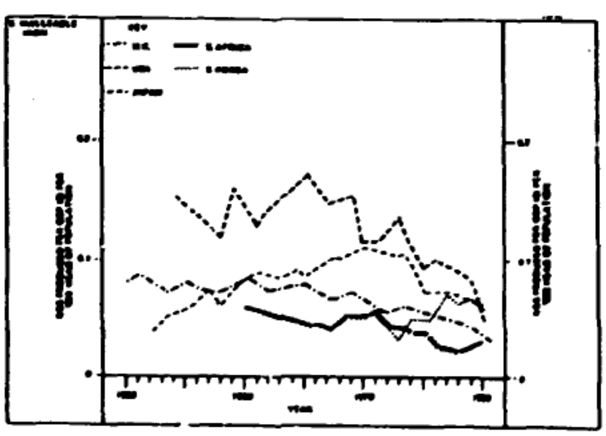
Total castings output per unit of wealth (1950-1980).

Figure 2.3



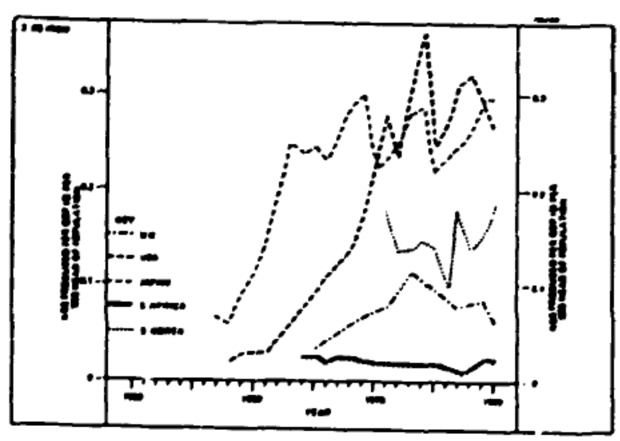
Grey iron output per unit of wealth (1950-1980).

Figure 2.4



Malleable iron output per unit of wealth (1950-1980).

Figure 2.5



SG iron output per unit of wealth (1960-1980).

valid some questions are raised about the future of casting technology in the industrialised countries. The concepts of "technological migration" are too well known to need expounding, but the basic point rests on perhaps two broad hypotheses:

(i) as industrialisation process proceeds in the industialised countries of the world, wealth creation will depend less on castings than hitherto;

(ii) where cstings are required they will tend to be made in the developing countries of the world.

To what extent the facts support these hypotheses the reader may be referred to the following Figures 2.1 to 2.9.

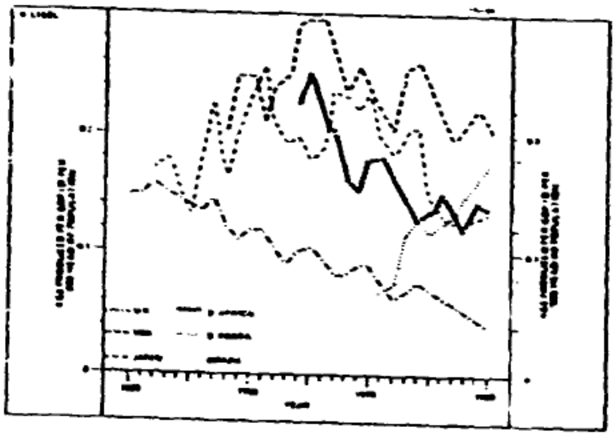
The analysis of different aspects of the international foundry industry, obtained by means of the Figures 2.1 to 2.9, probably raises more questions than it answers, but in many respects it seems to lend weight to the widespread feeling that the two hypotheses formulated earlier provide a qualitatively reasonable indication of past situation and present trends.

At this time, the future of castings seems to lie in the balance, with great technological, innovative and economic possibilities counterbalanced by questions of productivity, labour and the environment. The foundry industry is , by its very nature, dirty and noisy and it consumes buildings, plants and equipment - and people at a frightening rate. The industry therefore pays due attention to new and emerging legislation, such as the acts on consumer protection (product liability), air pollution control, health and safety at work and control of substances hazardous to health. These legislative demands can be met with increase in revenue and profit supported by the better product quality.

As the data bank increases and as control engineering techniques involving the 'Total Quality Concept' improve, this should facilitate the advancement of design technology with respect to castings of ever more complex shape and tighter specification. A model that demonstrates the possible economies arising out of a 'properly planned quality strategy' is shown in Figure 2.10.

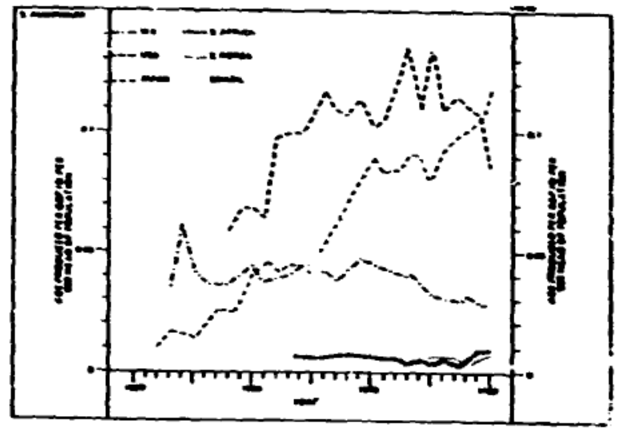
Note referring to Figure 2.1: Gross Domestic Fixed Capital Formation is defined as expenditure on fixed assets either for replacement or addition to existing fixed assets; expenditure on maintenance and repair is excluded. Nett transactions in land and existing buildings are included in the gross domestic fixed capital formation by sector.

Figure 2.6



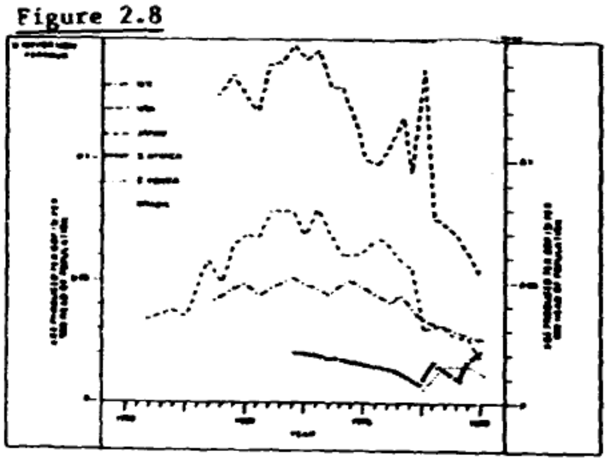
Steel castings output per unit of wealth (1950-1980).

Figure 2.7



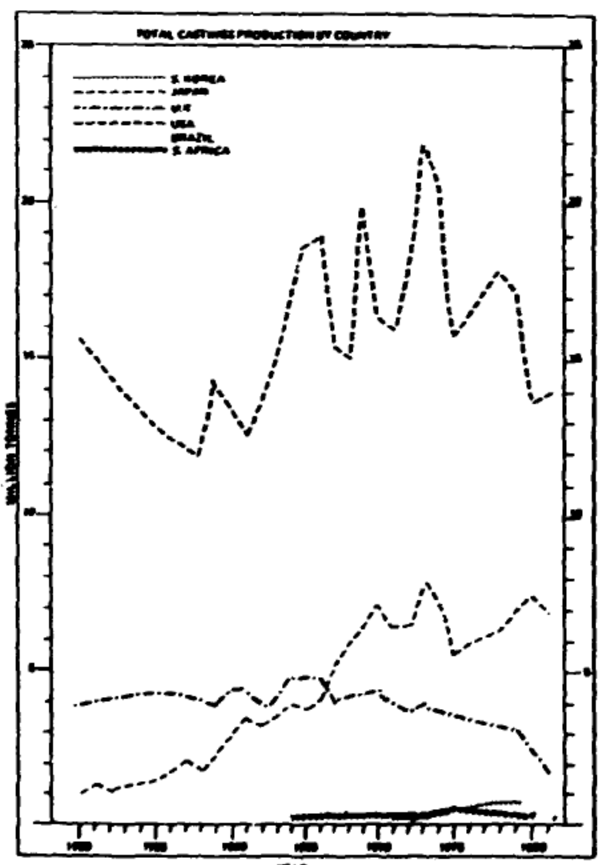
Aluminium castings output per unit of wealth (1950-1980).

Figure 2.8



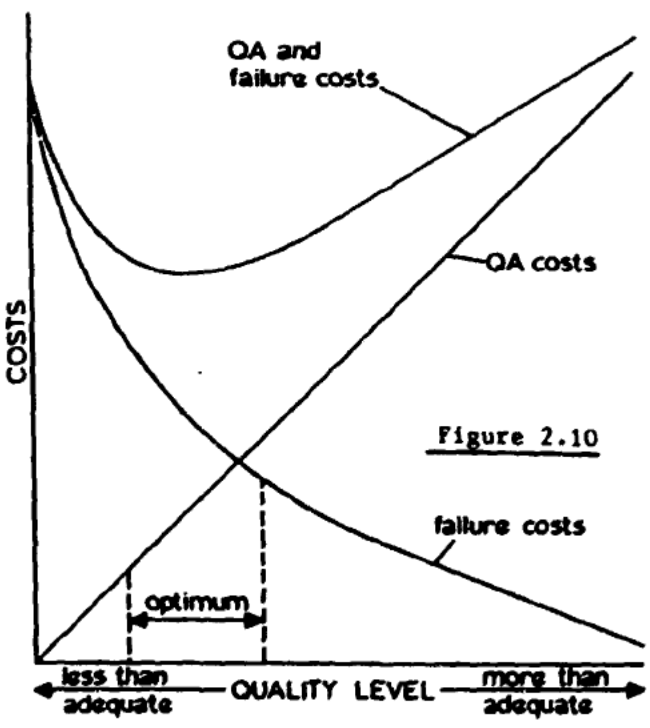
Other non-ferrous castings output per unit of wealth (1950-1980).

Figure 2.9



Total castings production by country, 1950-1980.

Figure 2.10



(A) Properly planned quality strategy.

3. Foundries and developing countries

3.1 Brief outline of the situation

As stated in the previous chapter the steady growth of an economy requires further development of the foundry and casting industry as being the principal main -and/or service- supplier of important areas, such as construction, mining, transportation, agro-based and machinery industries, etc. The basic needs of the foundry industry can broadly be grouped under materials, manufacturing techniques, management and markets. On the other hand, the problems of the foundry industry can be grouped as external and internal ones. Without adequate external support services and a good techno-economic infrastructure, it will be difficult to match high rates of expansion of facilities with adequate markets. In many developing countries a supporting infrastructure is needed not only for technology assimilation and diffusion, but also for training shop floor operatives, managers and owners to adapt to changing conditions.

The castings production in many developing countries is still at a low level, compared with the per capita output in industrialised countries. Table 3.1 presents the per capita production of all types of castings in selected developing countries. In industrialised countries the per capita output can be 40 times higher and even more than that in most developing countries. The pattern of metal castings consumption varies from country to country. Its structure and sectoral breakdown, respectively in individual countries, depends not only on the economicsituation but also on related structures of local industries. In least developed countries the bulk of castings is consumed by household goods and spare parts production. The product mix ranges from cast iron pots and pans to spare parts for agricultural machineries, man-hole covers, etc. The future of foundry and casting industry in least developed countries is mainly connected with the development of such sectors as construction, transportation, agro-based industries and minig. On the other hand, without reliable and viable foundry business serious constraints could be placed on further industrial growth. In the absence of an appropriate foundry sector some manufacturers

Table 3.1 Production and per capita production of castings in selected countries of the ESCAP region

Country	Year	Ferrous castings	Non-ferrous castings	Total	Per capita production
		in 1000 tonnes			in kg
India	1978	856	55	911	1.3
Indonesia	1980	29.7	3.2	32.9	.2
Japan	1979	6260	708.7	6968.7	60.0
Rep. of Korea	1978	660	12.4	672.4	17.7
Pakistan	1980	90	5.2	95.2	0.2
Philippines	1976	93.2	6.0	99.2	2.2
Singapore	1979	30	3.1	33.1	1.4
Sri Lanka	1980	10	2.5	12.5	.9
Nepal	1980	.4	-	.4	.0....

For Table 3.2, see next page!

Table 3.3 Some of the more commonly required types of castings which might be produced by small scale foundries

Cast Iron Castings	Aluminium Castings	Brass and Bronze Castings
Stoves	Levers and handles	Valves and taps for corrosive liquids
Pulleys	Fan and motor housings	Bearings and bushes
Manhole covers	Cooking pots and kitchen tools	Boat parts and propellers
Pipe fittings	Portable pump bodies	Pumps: bodies and impellers
Pumps	Pulleys	Ornamental and decorative castings
Fire bars	Irrigation pipe fittings	Door furniture
Brake drums	Light fittings	Machinery spare parts for all types of equipment
Vehicle Spares	Door furniture	
Bearing blocks	Machinery spare parts for all types of equipment	
Valves		
Machinery spares		

Table 3.2

Area Country	Technical	Economic	Training
Hong Kong	1. Primitive production methods with obsolete equipment used. 2. Poor capability for producing complicated high quality engineering load bearing castings 3. Lack proper environmental control facilities	1. High land cost and shortage of land. 2. Relatively high wages for and shortage of skilled workers. 3. Vicious circle development - insufficient demand for local high quality engineering castings to stimulate investment in more sophisticated machinery and equipment to upgrade foundry technology and efficiency.	1. Lack of new recruits to join the trade 2. Too few well trained professionals 3. Unwillingness on the part of students in technical institutes to be trained as craftsmen and operatives in the foundry industry
India	1. High coke ash percentage 2. High electric melting cost 3. Absence of accepted standards for castings to be machined to dimensional tolerances	1. Low production & consequent high unit cost 2. Disparities in wage scale in different sectors 3. High cost of finance and inadequate resources	1. Small foundry owners too averse to training 2. Traditional practice inhibits training among illiterate [illegible] skilled) 3. Dearth of trainers because such a profession is not sufficiently remunerative, compared to being in a foundry
Indonesia	1. Absence of a standard manual of foundry practice 2. Casting rejection rate of 30% 3. Absence of skill in small foundries	1. High cost of raw materials except steel scrap 2. Market not well developed	1. Absence of adequate training facilities 2. Large foundries not interested for training 3. Foundry manager training needed particularly in non-technical sectors
Rep. of Korea	1. Lack of [illegible] of facilities 2. Need for rationalization of management system 3. Shortage of foundry statistics	1. Price of castings going up too fast because of high cost of labour 2. Strict working environment and pollution control laws 3. Long delivery of imported raw materials	1. Need to do research work on optimization of local resources and energy
Nepal	1. Inputs: a. Coke with high ash % b. Pig iron is of poor quality c. Lack of technical information 2. Lack of standards and appreciation of the value of high price but good quality castings 3. The low level of technology gives rise to low productivity and sub-standard castings	1. High price of raw materials of poor quality 2. Too low a wage scale to attract and retain good work force 3. Poor management 4. Virtually no market research	1. Pattern making 2. Supervisor level shop floor training in general foundry practice 3. Melting practices
Pakistan	1. Need standardization of raw materials and other inputs 2. Need better in-process quality control 3. Major problem of translating product casting specifications into relevant process control specifications.	1. Cost of inputs too high because of import duties 2. Safety expenses by companies should be subsidized by the government 3. Need for country-wise analysis of cost factor which form the element of value added	1. Need training of 1) foundry engineers 2) foremen and job leaders 3) foundry managers
Philippines	1. Need more effective in-process quality control to meet quality casting requirements 2. Need more modern foundry process technology and equipment 3. Need standardization of casting products	1. High cost of imported raw materials 2. Shortage of skilled foundry workers 3. Low productivity	1. Foundry managers need more management training 2. Shortage of pattern makers 3. Need more training for foundry technicians
Singapore	1. Need further improvement to existing cupola efficiency 2. Need better foundry practice techniques and quality control to meet international customer demands 3. Lack of individual foundry or national technical (foundry & metallurgical)) support	1. High cost of raw material and freight charges when quantity requirement is not high. 2. Environmental pollution which gives no return on investment, but, in turn, lack of attention [illegible] labour force from the industry	1. Technician needs most urgent local and overseas training 2. Existing skilled worker needs through local training by trained technician Pattern making technique (in conventional green sand moulding) 3. Management needs overseas training and regional seminars
Sri Lanka	1. Equipment modification to suit to local conditions 2. Electric melting should be more widely used. 3. More process quality control and testing should be set up	1. Import of expensive raw materials 2. High cost of equipment and machinery 3. Products made locally suffer from technical inexperience	1. Training [illegible] order of priority 1) operatives and workers 2) quality control technicians 3) managers
Thailand	1. Lack of general knowledge of metallurgy and inefficient cupola operation 2. Lack of standard specifications for products and a high rejection rate 3. Lack of know-how on job simplification	1. Marketing. There is a lack of support from related industries to create mass production 2. High tax on imported raw material used in foundry and high cost of inventory of imported raw materials 3. Inter-company competition without relating prices to real costs	1. Need for a basic training school for foundry workers 2. The rapid migration of skilled labour 3. Need for training of foundry owners

and fabricators have to design their products with a minimum use of casting. The result is a considerable increase of cost. For example in Nepal, simple wheels were reported to be fabricated out of steel sheets exceeding by more than five times the cost of castings. In developing countries with higher level of development the major industrial users of metal castings are transportation and transport equipment, construction, mining and metal manufacturing.

3.2 The role of the ferrous foundries within the overall development pattern

Among types of cast metals the numeric relative importance, globaly seen, is that of ferrous castings with 90% versus 10% for non-ferrous castings. Among the ferrous castings the dominant role belongs to grey iron castings due to its easy adaptability with around 60% of total metal castings production followed by 15% for ductile iron, 5% for malleable iron and 10% for steel.

The above general mentioned, important and complex role of ferrous foundries if projected onto the plane of the developing countries it still maintains its significance. However, it would be easier to present this complex role by considering groups of countries at the various levels of development as roughly indicated below:

Group I: Areasonably well-developed range of products, capable of satisfying to a large extent of domestic demand and often with capability for exports: Argentina, Brazil, China, India, Mexico, Turkey, etc.

Group II: A smaller range of products, greater dependance on imported equipments, restricted capability and few exports: Chile, Colombia, Egypt, Indonesia, Pakistan, Tunisia, etc.

Group III: Generally characterized by import industry, often with specialization of few types of products: Bangladesh, Bolivia, Ghana, Uruguay, etc.

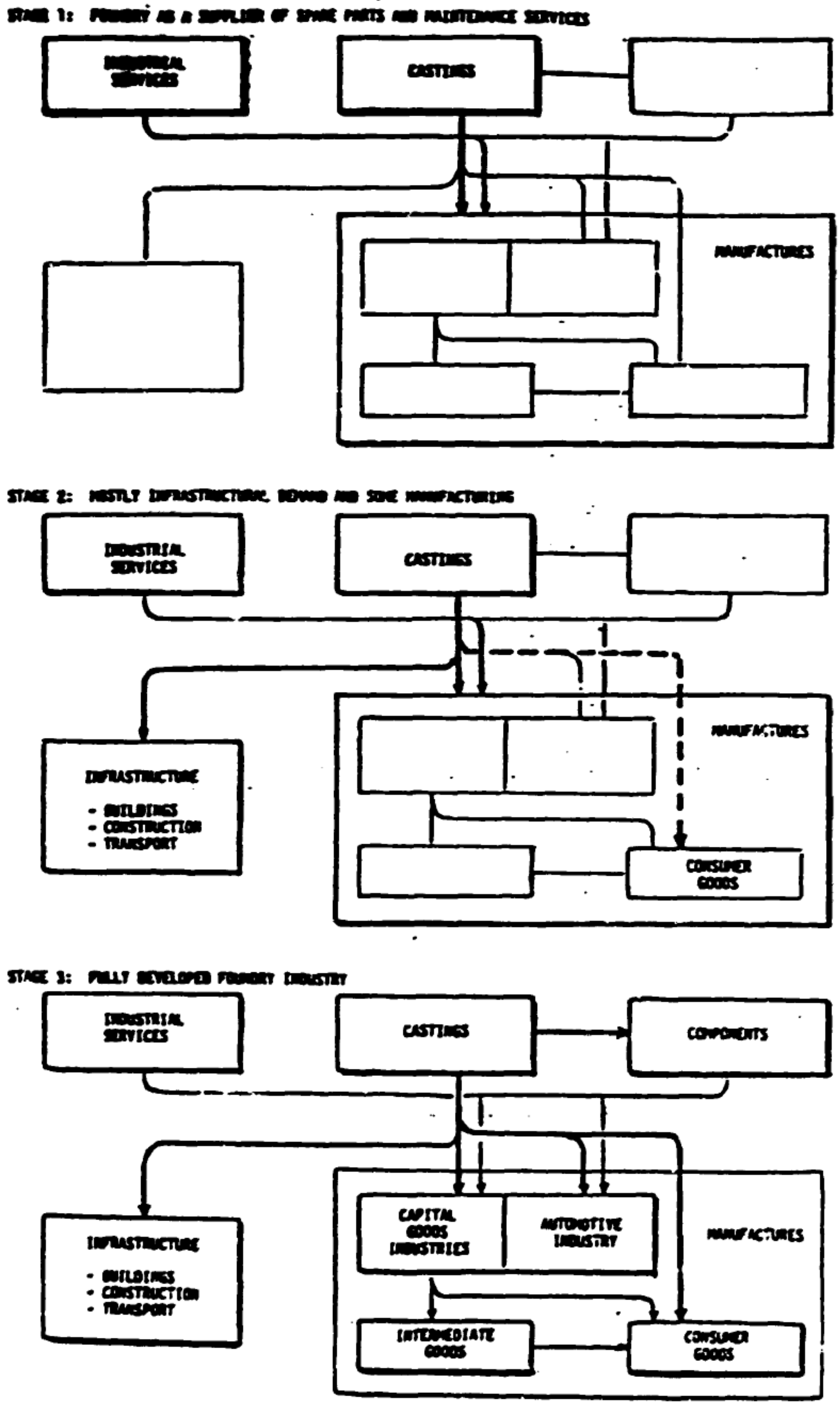
Group IV: Very little end item manufacturing capability per se, mainly repair shops and spare parts, Central America, Caribbean, Sub-Saharan Africa, Paraguay etc.

The groupings are a way of indicating that the problems of the engineering industries in general and foundry in particular differ substantially among the countries.

The foregoing outline of foundry developments appropriate to the various stages of industrialisation, illustrates the role of foundries which are essential to development of engineering industries, once again. The linkages between castings and other components and the industrial infrastructure and the user industries are shown schematically in Figure 3.1. for example to facilitate the development of the agricultural machinery and implement industries in addition to ferrous foundry development of engineering workshops with toolroom and manufacturing facilities, electrical, hydraulic and pneumatic component manufacturing plants and metal finishing plants would be needed. With the development of these supporting industries, the infrastructure would become better and would provide further opportunities to develop capital goods and consumable durable industries.

3.3 Factors affecting development and concealing problems

The difficulties and constraints encountered by the foundry industry are numerous, and though some of the problems are specific to a given country, many difficulties tend to be common to most of the developing countries. Establishments in the small and medium scale sector can suffer from these more severly than larger units if they cannot secure technically qualified personnel and cannot afford to get the necessary technical assistance. The general major problems could be attributed to technical related problems, economic/management related problems and manpower/training related problems. Difficulties in connection with the availability and proper quality of raw materials are to be considered in the group of technical problems. Table 3.2 presents important problems faced by the Foundry Industry in several Asean countries. Another constraint often faced by foundries in developing countries is their remoteness from any organization with accumulated data and technical expertise on foundry matters.



LINKAGES AT VARIOUS STAGES OF DEVELOPMENT

Figure 3.1

3.4 The problem of the capacity utilization

In spite of reported growing demand for the cast products in developing countries capacity utilization in the foundry industry is a matter of serious concern both from the point of view of its viability and close inter-relationwith all sectors of the engineering industry. In Singapore, for example, the ratio of foundry capacities as against available market was 6:1 and 2:1 for steel and cast iron accordingly at the early 1980's. Under-utilization of almost 50% of the jobbing foundries was reported in India.

Both reviewing of the basic difficulties in attaining full or nearly full capacity utilization and then formulation of course of action, on a short and on a long term basis, are important intermediate steps. Some basic reasons for under-utilization of capacities in the foundry industry are:

(i) existing, locally unsatisfied market is of a technological level above that of the local foundries,
(ii) insufficient and irregular demands from major engineering industries,
(iii) capacity originally designed for a particular product-mix having lost its relevance in a radically altered situation over a period of time,
(iv) lack of innovation and technological inputs,
(v) organizational problems conected with finance, management and/or industrial relations.

To cope with problems of under-utilization a careful assessment of domestic and external market for metal castings should be undertaken by governmental agencies and the industry*) itself. It is of special importance to try to estimate demand patterns of castings by linking it to growth estimates and plan projections of various key industries. This accurate and detailed information is basis for planning foundry industry development, extension and/or modernization of existing or erection of new foundries and, as a result, for matching the capacity of foundries to the actual demand.

Continuous industrial development of the developing countries will stimulate an increasing demand for cast products of high quality. Such attainment can be easier realized by large or medium scale foundries. Small scale are thought to produce more commonly required types of castings (see Table 3.3).

*) It is often found that even if there are local foundries which are capable of supplying a part of this market, they are unaware of its existence.

Small scale and/or small jobbing foundries often have to operate in the market influenced by external factors such as economic situation, competitor's activities, changes in governmental policy and consumer behaviour and are beyond their control. Under these circumstances the technologies employed must prove flexibility in order to pace rapidly with clients changing requirements, and this without causing additional investments. Moreover, the technology ought to be simple in view of handling, and at the same time ensure operational reliability. Nevertheless, even for the foundry with a high degree of flexibility the period of the introduction of new production consumes considerable effort and cost. Basically, if changes in the product-mix occur too frequently, because of shifting demand patterns, the rate of production is bound to be affected. It is obvious that a repeated jobbing order is more profitable and allows to use accumulated skill for maintaining quality and improving productivity. Table 3.4 summarizes the main competitive factors showing those areas where developing countries may have competitive advantage.

3.5 Production capability, technology level and "mini" concept together with the significant planning and lay-out criteria

The general level of production capability can be evaluated from

- type of metal
- casting product
- dimension accuracy and product uniformity
- weight of product.

The choice of the production means and scales refers to machine features as well as to the aspects of the foundry production programme. The choices can result from general market investigations in the countries under development and can produce a guidance programme for foundry activities, which could also be modified from current design practice to better suit the labor capital and material resources of the area. This requires an understanding regarding the applicability and reliability of the alternate techniques available which accomplish the same tasks with a different mix of economic resources. A systematic presentation

Structural Factors of Competition

Competitive Factors	Position of Developing Countries Relative to Industrialized Countries
Raw material Costs	Disadvantage
Energy costs	Advantage for some countries
Labor costs	Advantage for all countries
Cost of capital	Advantage for some countries
Productivity	Disadvantage
Marketing	Disadvantage
Pricing	Advantage
Production technology	Disadvantage
Product performance	Disadvantage
Customers service	Disadvantage
Government aid	Advantage for some countries

Table 3.4

of technological alternatives in conjunction with the respective basic activities employed in foundry operation can serve as an approach for the definition of technology levels with respect to the scale; Table 3.5 illustrates the technology levels for foundries. Level I (Table 3.5) corresponds to small scale foundry industry with respect to the simplicity of the parameters involved. By means of the classification done in Tables 3.5 and 3.6 the origination of the mini foundry concept can be placed within the frame corresponding to level I. A cross reference in the whole range of the levels I to IV signifies the operational importance of melting. Moulding rates depend on the rates at which liquid metal can be produced. Hence, the two operations must be efficiently synchronized, an important consideration in selecting the type and size of melting equipment. The establishment of a foundry with technology features of level I would take place within the frame of simple operational conditions area:

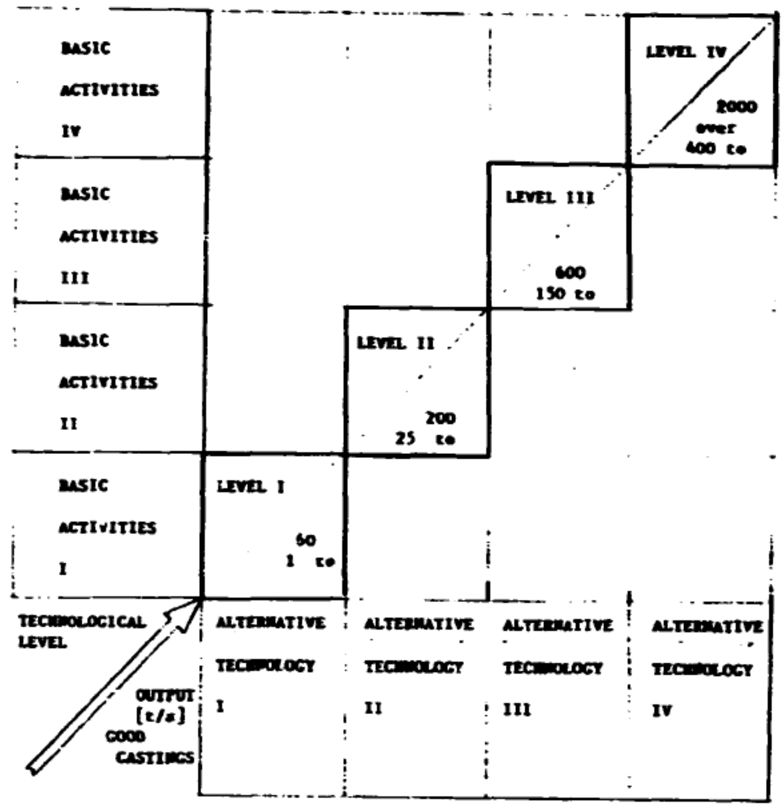
a) melting unit: In the case of melting iron a cold blast cupola furnace type is to be employed, unless local stringent pollution requirements or available energy sources demand other technoque. Cupola is the traditional furnace design, simple, straightforward and easy to operate and control (basically it is a verical cylinder lined with refractories). A cupola is relatively inexpensive to construct. However the performance of a cupola depends upon its design and expert advice should be sought if a "home-made" cupola is being planned. For small scale production of non-ferrous metal castings the use of crucible furnaces is the most common melting method;

b) moulding: sand moulding by hand (mold is to be made directly on the floor);

c) castings: simple castings with no special and/or high pattern-making requirements (elementar pattern-making with simple design).

d) other design requirements: a foundry (either mini or small or medium or large scale) must have sufficient room for the process to be used. In case of floor moulding space requirements might be about 10 to 15 m^2 of mould pouring area per tonne production per week. Space is also needed for melting, moulding and other foundry related operations corresponding to the level of technology of the respective foundry (Tables 3.5 & 3.6). In addition there

Table: 3.5 : Casting Technology Level for Foundries in Developing countries.



LEVEL I: very simple to simple
LEVEL II: simple to medium
LEVEL III: medium to high
LEVEL IV: very high

Table 3.6 : Casting Technology Level (example based on the classification presented in Table 3.5)
Case country: INDONESIA

BASIC ACTIVITIES IV	Fully automatic plant with machine preparation, smelting in checked charge electric automatic cupola, automatic casting, etc. Special casting.	ALTERNATIVE TECHNOLOGY IV	Special alloys. Rather unusual cases. Very large parts. Very strict quality control. Automatic installation.
BASIC ACTIVITIES III	Sand preparation with mixing and proportising machine. Machine moulding with pattern. Automatic furnace smelting. Semi automatic casting and shake out equipment. Shot blasting and cast cleaning machine. Tunnel sand blasting.	ALTERNATIVE TECHNOLOGY III	Malleable and Nodular cast iron alloyed with Mn, Cu, Ni and other elements. Complex parts. Semi mechanized casting. Control of earth and sands. Very thin walls microporosity, etc.
BASIC ACTIVITIES II	Sand preparation with mixing machine. Manual moulding with wooden pattern. Cupola smelting. Simple crane transport. Hand shake out and knock out. Hand controlled.	ALTERNATIVE TECHNOLOGY II	To standards. Ordinary grey iron and white iron. Limited weight. Mechanical moulding for smaller parts. Electric furnaces occasionally used.
BASIC ACTIVITIES I	Manual sand preparations. Manual moulding with tools. Simple furnace (cold blast cupola)* smelting. Hand Transport. Hand shake out and knock out.	ALTERNATIVE TECHNOLOGY I	Conventional process. No standards.

* Some small scale industries use tilting furnace with open stack thus a lot of heat is lost.

should be room available for storage of raw materials and sand. As indicated above a new foundry may start small and simple but future needs for expansion on the same site should also be considered. It is not feasible to transport molten metal for long distances. Some foundry processes can produce smoke, smells, or fumes. It is therefore sensible to keep foundries away from and if possible down-wind of housing, schools, hospitals, etc. Wooden buildings should not be used because of the danger of fire. Foundry roofs should always be water-proof. Surface drainage should be good with no fear of flooding since the dangers of mixing water and molten metal can lead to explosions. As much head room as possible should be provided for ventilation with good natural or artificial draught, especially in hot climates. A reliable power supply is necessary for many processes, and water supply is important. Good road access for transport of castings and raw materials should be assured.

In foundry work handling and transport of metal, sand and moulding boxes, tools etc. occupies more effort and time than the actual production processes. In small foundries it is likely that much of the transport will be by hand and wheelbarrow, with cranes or hoists for heavy weights. The lay-out should be such as to minimise distances *) for the transport of molten metal, since every few minutes ofdelay can lose a few degrees of temperature and mean higher fuel and melting costs. This applies whether metal is carried by hand in small ladles or by crane in larger ladles. Pouring areas should be near the melting furnaces. Raw material stocks should also be kept near the furnace area. Patterns and inflammable chemicals should be stored away from molten metal.

As an approximate guide a cupola should have an internal diameter

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*) Larger foundries may need the use of forklift trucks for internal transport. In mechanical green sand foundries the sand transport system from storage hopper to mixer to moulding machines, and from shake-out through storage and back again, represents a major part of the investment. Conveyor belts occupy a large part of the foundry space. Additional design criteria with respect to pattern shop are given in chapter 6.1.

and be equipped with an air blower as specified below:

Melting rate [t/h]	Approximate internal diameter [cm]	Approximate volume of air [m^3/min] at .1 [kg/cm^2] pressure
1	45	23
2	60	40
4	75	60
6	90	90

Source: Reference Nr. 71

Hard charcoal has also been used as a cupola fuel, alone or with coke, although the results are not very satisfactory even on small cupolas. It is uneconomical to fire up a cupola for short runs. Also moulds in a small foundry may have to be accumulated for several days. Unlike cupolas which produce molten metal mainly continuously, rotary furnaces are gas or oil batch furnaces.

The above outlined classification and accordingly conception is to be considered as a first step in establising a foundry with low demands as far as the complexity of products, shape and grades concerns. It involves the concept of mini-foundry in a linearized relation with low facility and size demands.

Many foundries in developing countries are considered as small (or medium) scale in accordance with the number of persons employed, (Table 3.7). They require special attention as they lack capital, know-how, technical, marketing and management ability. They have to compete with the large scale industries, with the laters being capable to manufacture the same product in an automated way at a cheaper cost. Moreover, due to the absence of adequate quality control and quality inspection at small (and medium) scale foundries their castings are usually of poorer quality. In that case they need to upgrade their castings quality through technology improvement, quality control and maintenance. These measurs result in a removal towards higher

Distribution of foundries in accordance with the number of persons employed in selected developing countries of the ESCAP region. [1]

	Year	Per cent distribution of foundries by the number of employees										Total number of foundries
		Below 10	Over 10	Over 20	Over 30	Over 50	Over 100	Over 200	Over 300	Over 500	Over 1,000	
Singapore	1979	40	←38→		←14→		8	-	-	-	-	64 *
Republic of Korea	1978	0.001	13.8	17.5	20.1	22.2	12.4	8.4	2.2	1.8	0.01	275 *
India	1978	←83→				←17→						6,000
Nepal	1980	-	←100→		-	-	-	-	-	-	-	4
Thailand	1980	27.3	29	11	8	7	6	←3→				88 *
Indonesia	1980	←96→				←4→						157 **
The Philippines [2]	1976	←25→		←39→		18	13	←5→				147

* Foundries covered by surveys

** Ferrous foundries

Table 3.7

technology level(s), see Tables 3.5 & 3.6), associated with higher investment costs. (An alternative way to avoid high investment costs could be the employment of second hand equipment).

The way towards higher technology levels can follow various paths as illustrated in Table 3.8.

3.6 A concept for planning foundries in developing countries

Countries in the process of industrial development usually are forced to purchase the necessary know-how along with the plant and equipment. Clear oulining of the duties of the consulting engineer is an essential basis for both parts of the scheme. The functions may also extend to establishing an optimum and economical range of production on the basis of a market study and/or analysis, or sometimes of the desired manufacturing capacity. Among these functions is the need to strike balance between genuine demand incorporating future perspectives on the one hand and what is actually realizable with the given financial, technical and manpower facilities on the other. Determining the future range of manufacture then leads to calculation of the basic data for planning. In foundry operations especially, with their large requirement of raw materials, calculation of these requirements is extremely important for clarifying procurement opportunities, inventory schemes, stock planning and preliminary decisions on the technologies to be employed. Actual planning gets underway with preliminary designs once these calculations and clarifications have been made. At this stage the purpose is to illustrate alternatives for different approaches with regard to basic technology, technical operation and size of the shop. Final decision on siting can then be reached after agreement is achieved in these matters. The purpose of the consultant is to furnish the principals with individual and objective advice in exploring the project alternatives up for consideration, which in turn means that he must be in possession of the corresponing planning and engineering experience. Conclusions arrived at from discussion of the preliminary design enable work to proceed on the master plan and on specification of all necessary machinery, plant and buildings.

Table 3.8

BASIC ACTIVITIES LEVEL (from lower to higher)				
IV	I, IV	II, IV	III, IV	IV, IV
III	I, III	II, III	III, III	IV, III
II	I, II	II, II	III, II	IV, II
I	I, I	II, I	III, I	IV, I
	I	II	III	IV

ALTERNATIVE TECHNOLOGY LEVEL

(from lower to higher level)

Examples of possible technology paths:

a) I,I-II,II-III,III-IV,IV (illustrated in Tables 3.5 & 3.6)

b) I,I-I,II-II,III-III,IV-IV,IV

etc

Note: The tehnology paths (combinations) are to be considered as theoretical possibilities of sequential development. One should never ignore the factor of optimization (when deriving such a path). Example a) illustrates a realistic variant and and can serve as a guide-approach.

Table 3.9

Typical Training Times for Foundry Personnel

Position	Approximate Training Times	Remarks
Foundry Technicians	6-24 months	Requires prior technical education
Pattern Making (Machine Molding)	12-36 months	
Pattern Design	6-12 months	Requires prior knowledge of technical drawing
Pattern Making (Simple Wood)	3- 6 months	Prior knowledge of woodwork & tools
Molding (Hand, Simple Patterns)	2- 6 months	
Molding (Hand, Complex Patterns)	6-24 months	
Molding (Machine)	1- 6 weeks	
Shell Molding	1- 5 days	
Coremaking (Hand)	1- 3 months	Specialized foundry courses & on-the-job training
Furnace Operation:		
Crucible	1- 2 months	
Cupola	2- 9 months	
Electric Arc	2-12 months	
Metal Pouring	1- 6 weeks	

No later than then is when it should be decided how the equipment and other facilities are to be purchased. Possibilities open in this direction are separate ordering from the respective manufacturers, overall supply through trading companies or a general contractor, or inviting tenders for a turn-key project. In either case the engineer in charge of planning has the important task of precisely formulating the layout and specifications so that such items as the methods of melting metals, compacting sand in moulds, production of cores, dressing castings, inspecting and controlling production, etc. are clearly laid down in advance. Furthermore the specifications must state all the necessary technical data for the separate equipment-capacities, volumes, dimensions, temperatures, and so on -in order for bidders to be able to respond in a qualified manner while still leaving them sufficient scope to work out proposals from the range of equipment they have available.

It must be clear to the principals that the purchase of machinery and plant for a definite technology does not simultaneously buy the know-how to apply that technology. For example, ordering machines to produce hot-box cores still leaves the purchaser in need of knowing the right sand mixture for using them. Foundry engineering textbooks will not prepare the owner sufficiently for working with technologies of this kind either. Even independent planning by expert engineers does not automatically solve the problem of transmitting technology and know-how. As soon as as the project reaches the purchasing stage, it is high time for counselling to be started by qualified specialists. Know-how contracts will be essential for intricate operations or when patented processes are to be employed. It may also be necessary to arrange for broad staff training at all levels of management and production. This will depend on the prior qualifications of the personnel available to fill the corresponding posts. Individual training will be required in any case and should for the greater part take place in the country where the new plant is being installed. Supplementary training of a smaller key group in plants located in the country supplying the equipment or in other countries having the necessary foundry know-how is always advisable.

Further steps in planning can cover evaluation of tenders, comparisons and recommendations, followed by the placement of orders by the project owner. Subsequent phases of examining layout drawings and foundation plans, coordination of work on buildings and plant and finnaly erection and installation of the equipment are undertaken according to an accurately planned timetable and supervised by the consulting engineer. All this takes place within the overall scheme of planning and executing the infrastructure of the new plant, which involves supply of energy, provision of transportation connections, buildings to house offices and staff amenities, stores for finished products, etc., factory inspections, and a detailed plan of action for commissioning individual items of equipment and the plant as a whole, again under supervision by the project consultant. Then comes the final handing-over of the new foundry and inspection of production.

Detailed activities description, production alternatives and equipment are given systematically in the chapters 4. and ownwards as well as in the annexes.

3.7 Manpower and Production, Technical Assistance, Training

The problem in this area centers around shortages of skilled manpower, high costs due to low productivity and inadequate management competence. Despite abundance of labor, many foundries in countries such as Singapore, taiwan, India, and Pakistan would find it difficult to improve their labor force, due to a combination of lack of proper work environment, management effectiviness and low compensation. Some countries like Hong kong, Thailand, Philippines and Mexico have shortage of skilled labor and need technicians and engineers. Here again the causes are the poor working conditions and inadequacy of training schemes.

The lower cost of labor in developing countries is frequently quoted as a major advantage when compared with developed countries, but can be significantly eroded if the productivity levels fall too low below the other countries. When discussing productivity it is desireable to distinguish between an individual's productivity and the plant productivity. In many foundries in developing countries individual productivity and physical effort seem to match or even exceed those customarily expected in foundries in the industrialized countries. However, the main cause of low level overall productivity is to a large extent due to the poor plant performance. Irrespective of the differing detailed problems, the main issues in plant productivity seems to be poor management and lack of skills in the areas of maintenance leading to high downtime, inventory control affecting timely availability of materials, production planning and control (which needs to be particularly good in view of the relatively small batches and a wide range of products dictated by local demand). Further,poor quality of materials, lack of in process quality control, and often inadequate quality consciousness leading to considerable rejection and rework increase costs. In this context, it would be desirable to note that the productivity improvements achieved over the last 30 years by Japanese foundries (output increase from 30 tons/man-year to 70 tons per man-year) were largely due to the introduction of modern plants and production systems (mainly molding) and to increased quality awareness developed through better employee communication and involvement. It is appropriate to state that this is a major area where thorough technical assistance and systematic training the competitiveness of the developing countries could be enhanced.

Most foundry companies need a great deal of technical assistance. The technical assistance ranges from provision of technical information on machines, processes, comparisons of performance of different producers, practical information on standards and measurements such as are commonly found in trade and similar publication, adaptive research and development and testing to determine the aspects of design and operation that could be incorporated in various enterprises, testing the performance of specific materials in particular with respect to performance characteristics and other topical technical areas. This is a type of assistance that would be related uniquely to the problem of foundries.

foremost in the industrialization process is the development of human resources in a country closely followed by the Scientific and Technological Development. Both require a long lead time amid structural and institutional constraints. Therefore,countries embarking upon industrialization would have to plan early to provide suitable training to engineers, technicians and skilled workers in foundry processes and technologies. Typical training times for technologists and engineers are 3 to 5 years given the availability of suitable learning and training establishments. Typical training times for foundry technicians and skilled personnel are given in Table 3.9 . The period of training would vary depending upon the type of foundry and the caliber of trainee and trainer.

One can say that, one of the reasons for avoiding a highly sophisticated greenfield plant for developing countries is the lack of well-trained foundry technicians which could be an over-simplification for the choice of technology and which would normally be on the basis of the market demand/product mix consideration. The ease with which a sophisticated plant can be maintained deserves study and can be achieved by proper selection and training of people. The real problem in the maintenance of the plant may be due to the difficulty in getting required spares and timely service. The varied nature of the product line tends to favor semi-mechanized rather than an automated approach to foundry design. Less sophisticated equipment would cater to simplified and efficient maintenance procedures and unit breakdowns are less critical than in a fully automated plant.

3.8 Safety

Every foundry whether large or small should take safety precautions into consideration. The most obvious source of danger is from molten metal. The following precautions are necessary:

(i) Ladles and furnaces must be properly constructed and maintained and the lining should be inspected and renewed whenever necessary.

(ii) All furnaces, ladles, moulds and floors must be dry. Molten metal, especially castiron, can explode if it comes into contact with water.

(iii) Moulds should be properly clamped and weighted together.

(iv) Molten metal and furnaces should always be attended by experienced and qualified people with proper supervision and equipment.

(v) People working anywhere near molten metal should wear protective clothing e.g. goggles, gloves, solid boots, and other clothing as appropriate (aprons, jackets, hats, etc.) depending upon the actual job being done.

Many foundry accidents result from other causes, especially cuts and injuries from poor handling of equipment or castings.

Lifting equipment should be properly designed, be strong enough for the work and not damaged by wear or heat. Operators should be trained to use it safely.

Heavy duty leathergloves should be worn if castings or scrap with sharp corners are to be handled. Sand should be sieved to remove sharp pieces of metal, and anyone who is grinding or chipping castings should wear goggles.

Longer term health problems can be caused by breathing foundry dust especially dust from sand moulds. Operators who are knocking out, grinding, handling or cleaning sandy castings should wear a mask type respirator to keep the dust from the mouth and nose.

Every foundry should have a supply of elementary first aid materials and one or more employees should have basic first aid training.

The most important safety precaution is to ensure that employees receive proper training in the processes and use of equipment before starting to work with anything unfamiliar. External assistance is as important from this aspect as from the technical point of view.

4. Foundry Processes and Castability of metals

Foundry operation consists mainly of the following elements:

- Patternmaking
- Mouldmaking
- Coremaking
- Melting
- Sand preparation and conditioning
- Pouring
- Cooling
- Surface cleaning and finishing
- Heat treatment if necessary
- Inspection and quality control

Above mentioned steps and/or operations are independant of each other, but they must be closely co-ordinated. Each operational step in the process must be performed within prescribed limits and according to well defined procedures. Failure to adhere to the specific process or the use of materials not meeting standards can result in a product of inferior quality. Figure 4.1 shows the main operational steps of the foundry process.

A typical example of the way in which the flow of material takes place in a foundry is presented in Figure 4.2a and Figure 4.2b.

All metals and alloys can be liquified by the application of heat and are thus able to flow and fill a mould cavity. However, there are certain properties of metals and alloys that affect castability and the ease by which satisfactory castings can be produced.

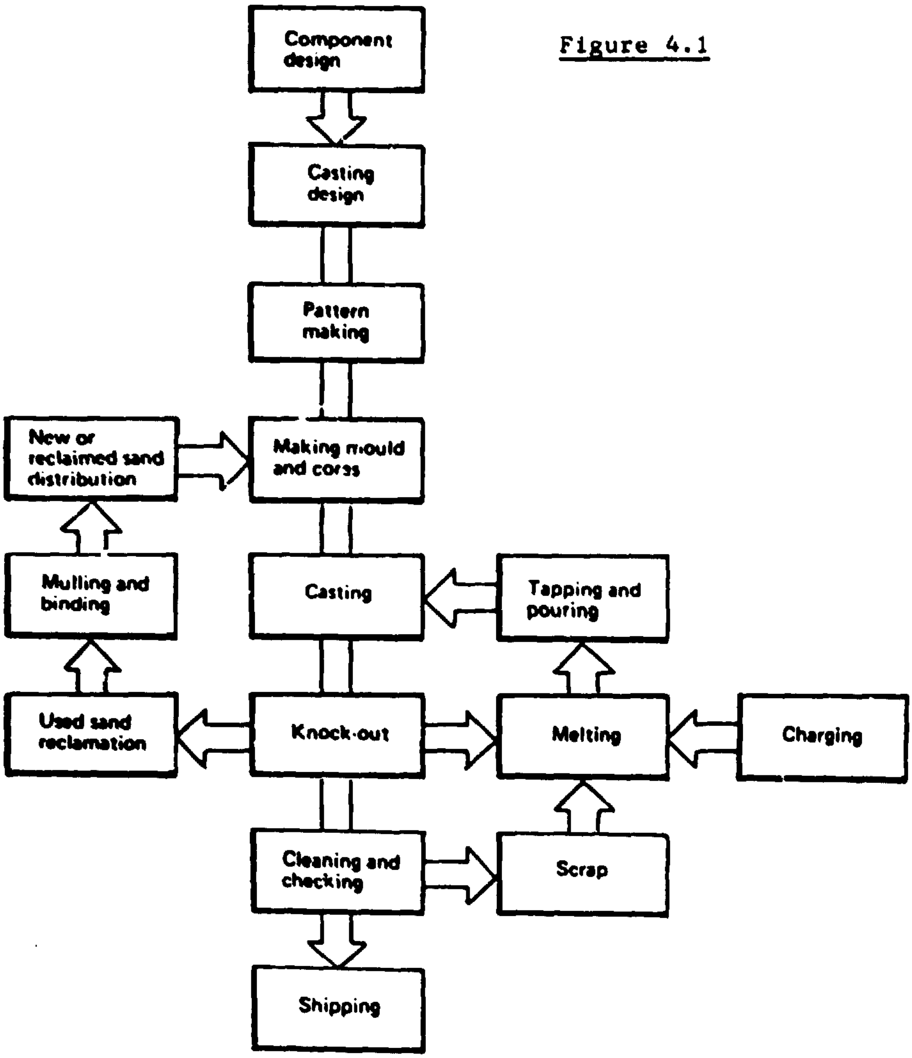
- Fluidity: Is the ability of molten metal to completely fill a mould cavity and reproduce its details. Fluidity is influenced by certain physical and chemical properties of the molten metal and the composition and characteristics of the mould.
- Volume contraction: Meatls and alloys undergo three distinct

volume changes. These are: liquid contraction, solidification contraction and solid contraction. Table 4.1a gives some idea of the liquid contraction.

- Low strength during solidification: Many alloys possess practically no strength or ductility during their last stages of solidification.

Table 4.1b provides a general guide to the four important characteristics, as fluidity, solidification shrinkage, slag/dross formation, pouring temperature, which significantly affect the castability.

Figure 4.1



Process sequence of the main steps of the foundry processes

Table 4.1a	Liquid shrinkage vol %
Soft grey iron (3.5% to 4.0% total carbon)	0.6
Aluminium alloy (11% to 13% silicon)	3.5
Copper (deoxidised)	3.8
Aluminium bronze (90% copper, 10% aluminium)	4.1
Grey iron (3.0% to 3.25% total carbon)	4.2
Manganese bronze (40% zinc, 1.25% iron, 1% aluminium, 0.5% manganese, 0.5% tin)	4.6
Grey iron, high duty (2.5% to 2.75% total carbon)	5.0
Nickel silver (20% nickel, 15% zinc, 65% copper)	5.5
Ni-resist austenitic cast iron	5.6
White iron, chill cast	5.75
Nickel (98% nickel, 1.5% silicon, 0.1% carbon)	6.1
Monel (1.0% silicon)	6.3
Yellow Brass (27% zinc, 2% lead, 1% tin)	6.4
Nickel silver (20% nickel, 15% zinc, 4% tin, 5% lead)	6.5
Aluminium rich alloys not containing silicon	6.5 to 8.0
Steel	7.22
White iron, malleable	7.25
Bearing bronze (10% tin, 10% lead)	7.3

Table 4.1b *A General Guide to Shrinkage, Fluidity, Slag/Dross Formation and Pouring Temperature for Several Common Casting Alloys*

Alloy group	Solidification shrinkage: Type	Solidification shrinkage: Amount	Fluidity	Slag/dross	Pouring temperature
Ferrous:					
Grey iron	medium	very little	excellent	little	warm
Ductile iron	med-narrow	little	excellent	little-moderate	warm
Carbon & low alloy steel	narrow	large	poor	moderate	hot
High alloy steel	med-narrow	moderate	fair	moderate	hot
Nonferrous:					
Zinc	medium – wide	little – moderate-large	excellent – good	little	cold
Aluminum alloys	med-narrow – wide	little – moderate-large	excellent – fair	moderate – large	cool
Magnesium alloys	narrow – medium	little – moderate	excellent	little – moderate	cool
Red & yellow brasses & bronzes	wide	moderate – large	very good – fair	little – moderate	warmer
Aluminum bronzes	medium – wide	moderate – large	good – fair	moderate – large	warm

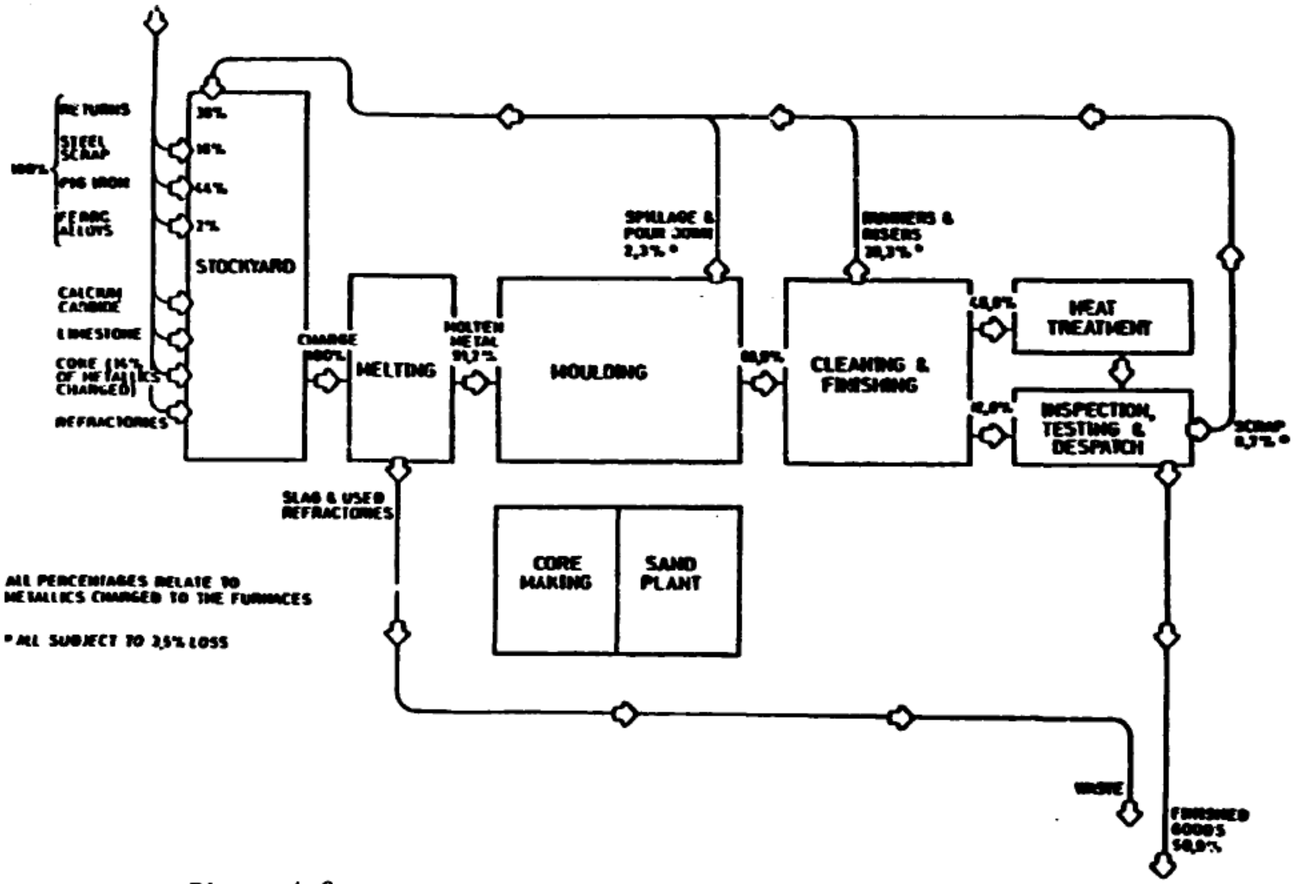


Figure 4.2a

MATERIAL FLOW FOR A TYPICAL MODERN IRON FOUNDRY : DIRECT METALLICS

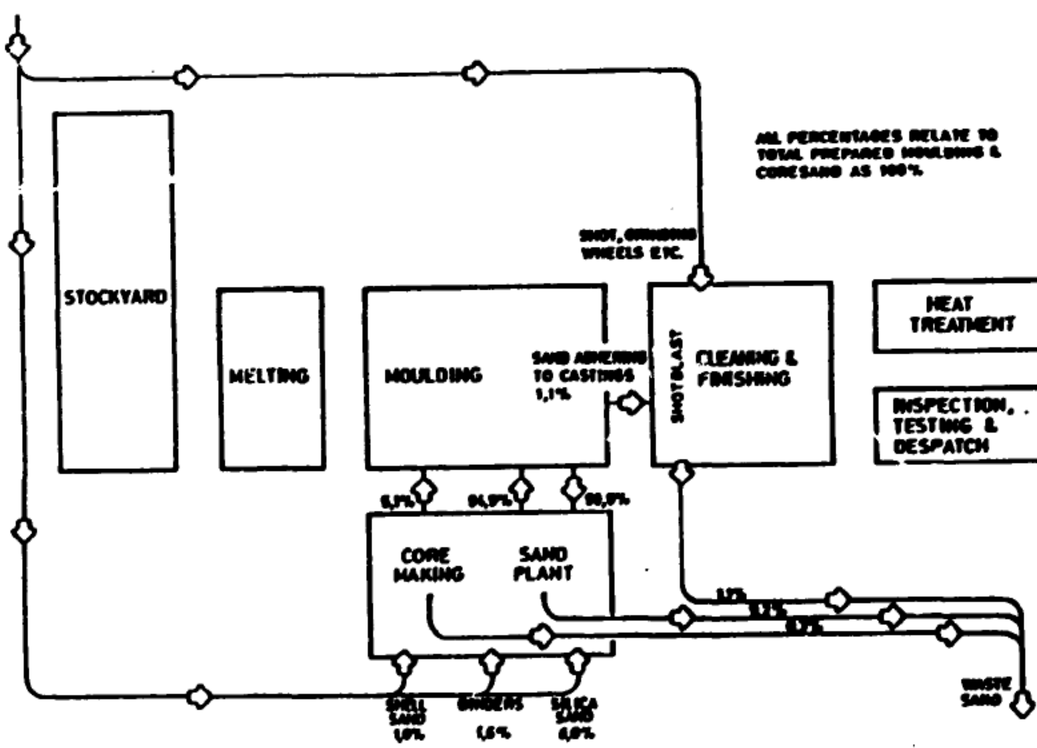


Figure 4.2b

MATERIAL FLOW FOR A TYPICAL MODERN IRON FOUNDRY: MOULD & CORE SANDS

5. Melting and melting equipment

The choice of melting process and of the equipment depends on the availability and characteristics of local raw materials, refractories, fuels and electric power, and any environmental requirements. The rate of demand for molten metal, the storage area for unpoured moulds and the variety of metal compositions to be produced must also be considered when selecting equipment.

For melting non-ferrous metals and cast iron, both fuel-fired and electric furnaces can be used (see Table 5.1a & 5.1b).

But the overriding issues in metal melting are materials and energy costs. They will dictate whether electric or cupola melting should be installed, independent of any consideration of labour cost cr utilization. Cupolas are somewhat more labour intensive and require lower operator and maintenance skills. While some foundries in developing countries have used novel sources of energy (an Aluminium Foundry in Paraguay uses alcohol supplied from an organic fermentation plant), the high temperatures required for iron and for steel melting restrict the opportunities for this type of innovation (see Table 5.2a).

5.1 Melting of cast irons

The influence in casting quality of the alternative furnace designs is minimal and the cupola, inuction and electric arc furnaces can be considered production alternatives. Nevertheless the coke-fired cupola furnace remains the principal melting employed by iron foundries despite the increasing adoption of electric melting. Conventional cupola: The conventional cold blast acid lined cupola is supplied with air from a fan or roots blower. Ccke provides the energy for melting and is also an important source of carbon to the melt. Figure 5.1a illustrates a conventional cold-air cupola. Table 5.2b illustrates cupola operation data. Considerations of

Table 5.1a

SUMMARY OF CHARACTERISTICS OF MAIN TYPES OF MELTING PROCESS

	For Cast Iron	For Steel	For non-ferrous	Furnace Costs	Lining Costs	Skill needed	For very low output	For high output
Cupola	Yes	No	No	Mod.	Mod.	High	No	Yes
Rotary	Yes	No	Yes	Mod.	Mod.	Mod.	Yes	Yes
Crucible, natural draught	No	No	Yes	Low	*	Mod.	Yes	No
Crucible, forced draught	Yes	No†	Yes	Low	*	Low	Yes	No
Electric Induction	Yes	Yes	Yes	High	High	High	Yes†	Yes
Electric Arc	Yes	Yes	No	High	Mod.	High	No	Yes
Electric Resistance	Yes	No	Yes	Mod.	Mod.	Low	Yes	No†

* No lining costs as such, but replacement crucibles required.

† Possible, but not generally used

Table 5.1b

FOUNDRY MELTING FURNACES

Energy	*Basic type (see Figure 8.35)*	Sub-type	*Furnace*	*Means of heating*	*Main fields of application*
I. Fuel fired	Shaft		Cupola	Coke. Charge in direct contact with fuel. Continuous melting	Cast iron; steel (duplex with converter)
	Hearth		Reverbatory (air)	Gas; oil; solid fuel	Non-ferrous alloys; cast iron, malleable
			Open hearth	Gas: oil	Steel (heavy)
			Rotary (rotating or rocking)	Gas, oil; pulverised solid fuel	Non-ferrous alloys; cast iron, esp. malleable and special. Duplex holding
	Crucible		Crucible		
			Lift out or pit type	Gas; oil; solid fuel	} Most alloys, except steel
			Tilting	Gas; oil; solid fuel	
			Bale out	Gas; oil	Light castings, especially die castings
II. Electric	Hearth	Arc	Direct arc	Arc to charge	Steel; cast iron
		Arc	Indirect arc (rocking)	Radiant arc	Non-ferrous alloys; high alloy steel and special irons
	Crucible	Resistance	Resistor (static or rocking)	Radiant resistor rod	Steel; cast iron; copper alloys
		Resistance	Resistance	Elements (shroud or immersion)	Non-ferrous alloys, especially holding for die casting
		Induction	Coreless induction	High frequency induction	Steel, esp. alloy and small tonnage; Ni base
	Melting channel	Induction	Cored induction	Low frequency induction	Cast irons
				Low frequency induction	Non-ferrous alloys; holding for die and light castings

Figure 5.1a A conventional cold-air cupola

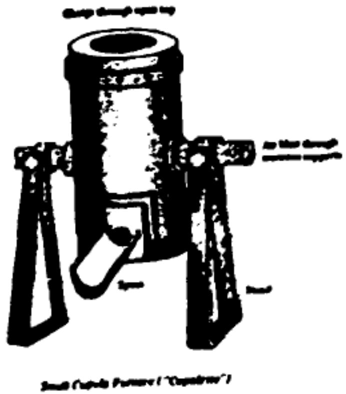
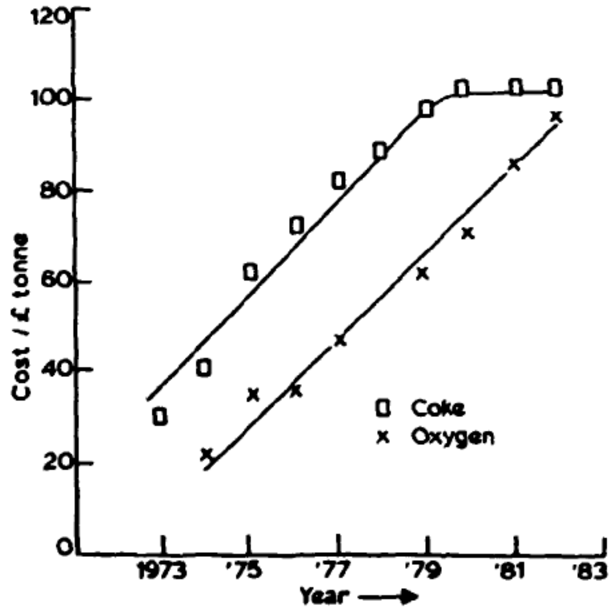


Figure 5.1b



Comparison between coke and oxygen over the last decade.

Figure 5.2

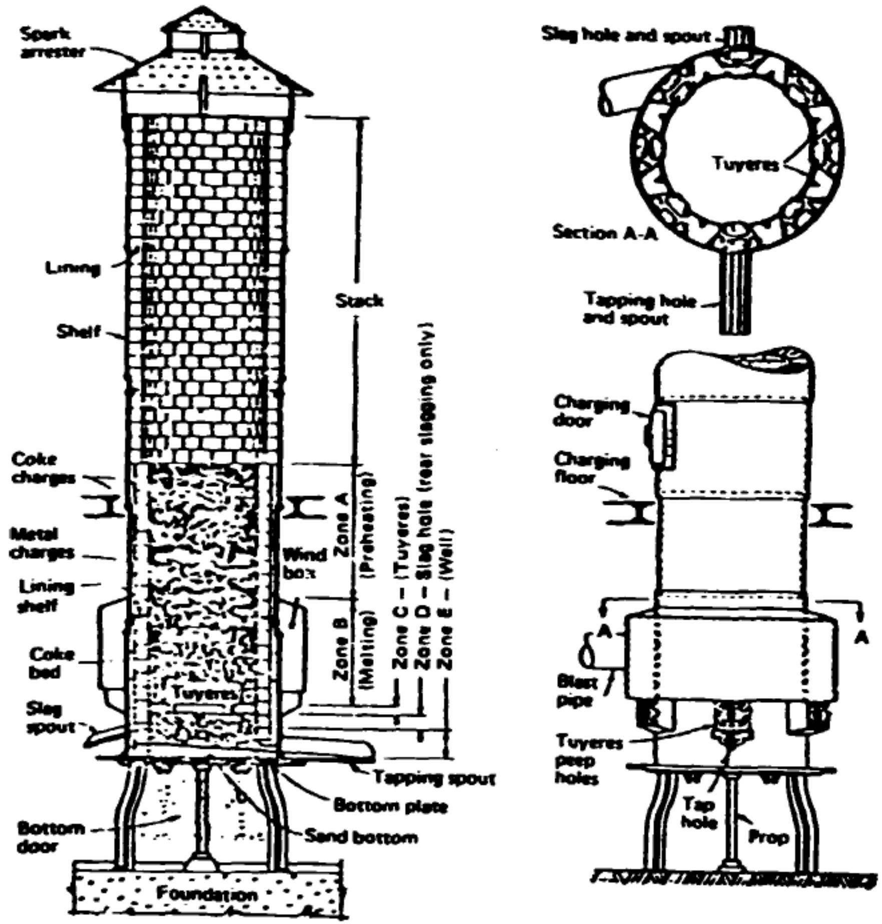

Spark arrester
Lining
Shelf
Stack
Coke charges
Metal charges
Lining shelf
Coke bed
Slag spout
Wind box
Tuyeres
Zone A (Preheating)
Zone B (Melting)
Zone C – (Tuyeres)
Zone D – Slag hole (rear slagging only)
Zone E – (Well)
Tapping spout
Bottom plate
Sand bottom
Bottom door
Foundation
Slag hole and spout
Tuyeres
Section A-A
Tapping hole and spout
Charging door
Charging floor
A
A
Blast pipe
Tuyeres peep holes
Tap hole
Prop

Table 5.2a

PROPERTIES AND HEAT REQUIREMENTS FOR METAL MELTING*

Metal	*Melting point* t_m	*Mean specific heat 20°–t_m °C* s	*Latent heat of fusion* L	*Total heat requirements for melting,* $L + s(t_m - 20)$			
				For 1 kg	*For 1 litre*	*For 1 lb*	*For 1 in³*
	°C	cal/g deg C	cal/g	kcal	kcal	BThU	BThU
Iron	1537	0.141	65.0	279	2204	502	141
Nickel	1453	0.131	72.1	259	2305	466	149
Copper	1083	0.105	48.9	161	1449	290	93
Aluminium	660	0.237	92.7	244	659	439	43
Magnesium	650	0.289	85.6	268	456	482	29
Zinc	420	0.101	26.3	68	482	122	32
Lead	327	0.034	5.7	16	187	29	12
Tin	232	0.058	14.2	27	197	49	13

1 kcal = 4.1868 kJ

Table 5.2b

CUPOLA OPERATION DATA (METRIC)

Inside diameter at melting zone (cm)	Area at melting zone (cm²)	Total tuyere area (cm²)	Melting rate per hour tonnes	Coke charge (kg)	Iron charge (kg)	Limestone charge (kg)	Blast volume (m³ per min)	Blast pressure (cm W.G.)	Bed height above tuyeres (cm)	Fan force de cheval	Height from tuyeres to charge door sill (metres)
46	1640	320	1.0	11	100	3.6	17.5	30	100	2.0	2.5
61	2900	645	2.0	20	200	6.3	31	30	100	5.0	3.0
76	4500	1130	3.0	32	320	10.4	48	35	105	7.0	3.0
91	6550	1290	4.5	45	450	15	69	38	105	12.0	3.5
107	8900	1800	6.0	60	600	20	93	40	110	17.0	3.5
122	11700	1930	8.0	82	820	27	123	43	110	23.0	4.0
137	14700	2450	10.0	101	1010	32	156	45	110	30.0	4.0
152	18300	2570	12.5	125	1250	41	191	48	110	40.0	4.5
168	22000	3150	15.0	158	1580	50	232	51	110	50.0	5.0
183	24200	3225	18.0	180	1800	60	278	51	110	60.0	5.0
198	31000	3850	21.0	210	2100	68	326	51	110	70.0	5.5
213	35800	4450	25.0	250	2500	82	382	53	115	85.0	6.0
229	41000	5100	28.5	280	2800	90	439	56	115	110.0	6.0

The above figures represent good average practice. They are by no means critical values and can vary considerably according to individual conditio and circumstances. Their main purpose here is to act as a guide in cases where such help is required.

Table 5.3a

Dimensions of the continuously tapped cupolas

	Single blast	Divided blast
Internal diameter (cm)	122	122
No. of Tuyeres	6	12
Diameter of Tuyeres (cm)	15.5	12.8
Well depth (cm)	91.5	91.5

Table 5.3b

The effect of the additional monthly service charge on the cost of oxygen when reduced tonnages are melted

Tonnage/ month	Service charge/ tonne iron melted	Oxygen cost/ tonne iron melted	Total cost/ tonne
200	£2.70	£3.90	£6.60
300	£1.80	£3.90	£5.70
400	£1.35	£3.90	£5.25
600	£0.90	£3.90	£4.80
1000	£0.55	£3.90	£4.45

suitability, cost, training needs etc. lead to the selection of a cold-air cupola plant with an unheated furnace for the establishment of a small scale foundry in a developing country. Very small cupolas (cupolettes) are often made to tilt on trunnions to help in tapping and slagging, Fig. 5.1b. Larger furnaces do not tilt. They require experienced operators to conduct the melt so as to control the air, metal and slag flow.

Some cupola developments: Made to improve the efficiency and operational characteristics of the cupola and permit a reduction in the proportions of the more costly basic raw materials in charges such as coke and pig iron. Hot blast cupolas operate with a preheated air supply usually obtained from a fully-recuperative system. The efficiency and output of the furnaces is higher than conventional units of the same size, the energy (coke) requirements are lower, high carbon pick-up is maintained, metal temperatures are higher as are the steel scrap levels in the charge. The hot blast cupola is a costly installation and can only be justified for larger foundries where it can be operated for extended daily period. The past ten years have seen the introduction of water cooled liningless cupolas into a number of large foundries of high output, capable of operating continuously for an average of three weeks, providing very large savings in labour and refractory costs and accepting scrap of lower quality and cost than any other furnace. Recently, the performance of conventional acid lined cupolas has been markedly improved by injecting oxygen. The use of supplementary oxygen reduces coke consumption, and increases melting rates. Installation of "divided blast" where the blast is divided approximately evenly between two rows of correctly spaced tuyeres provides savings in coke consumption, higher temperatures and melting rates, compared to cupolas using single rows of tuyeres. Investigations having been carried out in United Kingdom to examine the practical and economical aspects of operating single and divided cold blast cupolas with and without supplementary oxygen enrichment to the blast main have shown that the most economical method of producing a required as-tapped metal temperature, and hence metal analysis was to operate with a divided blast cupola using no supplementary oxygen enrichment. Figure 2 and the Tables 5.3a, 5.3b, 5.3c and 5.3d briefly illustrate above made conclusions.

A few foundries are using "cokeless" cupolas which involve oil or gas firing to produce irons of low sulphur and medium to high carbon content after carbon injection into the wall. It is claimed that the irons produced are very consistant in composition and properties and serve as an ideal base for the production of SG iron. The influence of the elimination of the need to desulphurise, the lack of pollution and possibility of changing the charge makeup all have bearings on the overall economics of cokeless cupola melting which does offer in many cases a potential saving but its application may not be suitable for every situation. Three comparisons of actual foundries have been included in order to give to the reader some more idea of the economic picture, see Tables 5.4a, 5.4b and 5.4c.

Rotary furnace: These furnaces are a reverberatory type of unit in which the horizontal refractory-lined shell rotates after initial melting is completed to bring the metal continually into contact with the walls of the furnace. Many rotary furnaces have a limited size of charging aperture so that large pieces of scrap cannot be used. Rotary furnaces are equipped with heat exchangers to pre-heat the combustion air with the escaping flue gas, thus saving fuel, Fig. 5.3. These furnaces can be made with capacities from 500 kg (sometime even 250 kg) up to 25 tonnes or more. Some manufacturers of rotary furnaces produce burners which can be used to adapt the furnaces to run on powered coal instead of oil or gas. Gas or oil fired crucible furnaces as used for non-ferrous metal melting can also be used for melting cast iron in batches of up to .5 to .75 of a ton. Fuel consumption would be approximately .3 to .6 litres of oil per kg of iron. Table 5.5 illustrates characteriscics of fuel-fired melting furnaces.

Electric melting: Electric furnaces may be used for melting cast iron, scrap or pig iron, (also for the melting of non-ferrous metals and steel scrap). These are expensive in themselves and also require capital expenditure for electrical supply, transformers, capacitors, and contacttors. Nevertheless their flexibility and adaptability

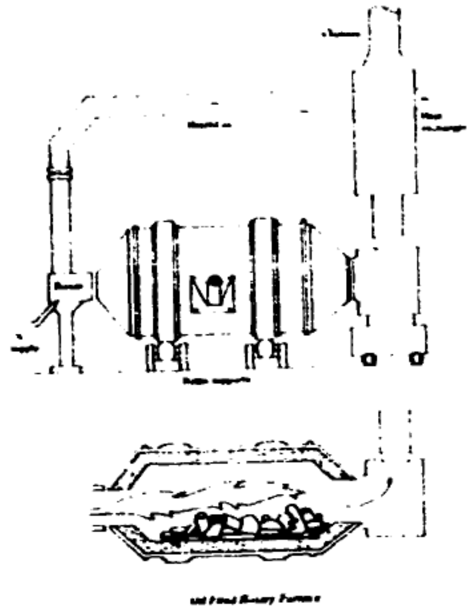
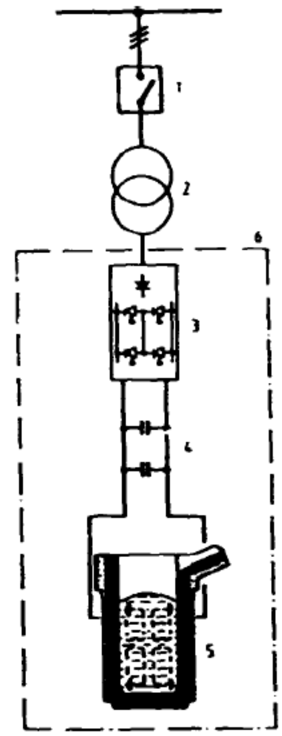
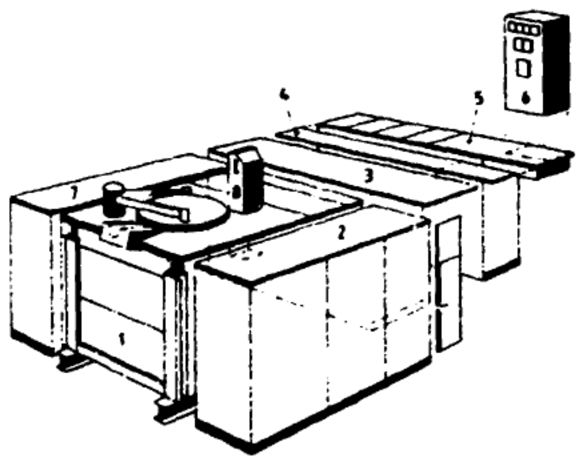


Figure 5.3



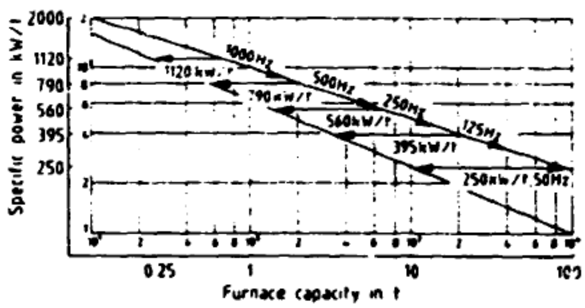
Schematic diagram of the design of a medium-frequency crucible-type induction furnace

Figure 5.4



Compact melting plant in modular design (type Meltpac/BBC)

Figure 5.5



Frequence	1000Hz	500Hz	250Hz	125Hz	50Hz
Furnace capacity (grey iron and steel)	0 25 1 5t	0 6 6t	1 5 12 5t	3 2 22t (40t)	10 60t (100t)

Relationships between maximum specific furnace power on the one hand, and frequency and furnace capacity on the other (for cast iron and St) with practically constant bath movement

Figure 5.6

Table 5.3c

Metallic charge make-up

	%C	%Si	%S	%Mn	%P	%	%C	%Si	%S	%Mn	%P
Pig iron	3.7	4.0	0.02	0.7	0.06	13	0.48	0.52	0.01	0.1	0.01
Steel	0.2	0.2	0.03	0.4	0.03	28	0.06	0.05	0.01	0.5	0.01
Cylinder scrap	3.3	2.2	0.08	0.6	0.08	27	0.89	0.60	0.02	0.15	0.03
Foundry returns	3.3	2.0	0.12	0.6	0.08	32	1.06	0.66	0.04	0.20	0.03
Additions								0.60		0.4	
Average charge comp.							2.49	2.43	0.08	0.9	0.08

Table 5.3d

The variation in melting cost/tonne iron melted with different melting practices

Furnace type	Oxygen enrichment	Oxygen cost/ tonne iron melted	Bed coke height (cm)	Bed coke cost/ tonne iron melted	% Fusion coke	Fusion coke cost/tonne iron melted	Total cost
Single blast	—	—	180	£4.80	15	£16.50	£21.30
Single blast	2%	£5.05	180	£4.80	13.5	£14.85	£24.70
Divided blast	—	—	260	£6.80	12.0	£13.20	£19.95
Divided blast	2%	£5.05	260	£6.80	10.0	£11.00	£22.80

The following assumptions being applicable:
(a) The daily tonnage melted being 25.
(b) The cost of coke is £110/tonne.
(c) The total cost of oxygen is £5.05/tonne iron melted.
(d) The weight of 100cm of bed coke is equivalent to 0.60 tonnes.

Table 5.4a

Economic comparison for U.K. foundry melting all cast iron scrap

		COKE OPERATION		COKELESS OPERATION	
Material	Cost £/Unit	Consumption	Cost £	Consumption	Cost £
Coke	135/tonne	14.7%	19.85	—	—
Ca C2	280/tonne	2.0%	5.60	—	—
O 2	8.48/hcm	2.0%	0.98	—	—
Fe. Mn.	170/tonne	0.4%	0.68	—	—
Tank Rental	2596/qtr	—	0.65	—	—
Pollution (Coke)	30000/annum	—	1.88	estimate (cokeless)	0.50
Gas	0.33/therm	—	—	25 therms	8.25
Spheres	500/tonne	—	—	1.0%	5.00
Recarburiser	165/tonne	—	—	0.4%	0.66
Electricity	0.045/kW	—	—	55kW	2.45

	29.64	16.86
Total melting cost/tonne	£29.64	£16.86
Saving/tonne of metal melted	= £29.64 – £16.86	
	= £12.78	

With 16000 tonnes of metal melted per annum
Annual saving = 12.78 × 16,000
= £204,480

Table 5.4b

Economic comparison for Japanese foundry producing ductile iron

Exchange rate £1.00 = 262 Yen

Material	Cost Yen/Unit	COKE OPERATION Consumption	COKE OPERATION Cost	COKELESS OPERATION Consumption	COKELESS OPERATION Cost
Coke	63500/tonne	16.7%	10605	—	—
Oxygen		2.0%	524	—	—
Oil for hotblast	70/litre	5 litre	350	—	—
Pollution		estimate	655	estimate	200
Ca C2	150/kgm	2.0%	3000	—	—
Oil for melting	70/litre	—	—	70 litre	4900
Spheres	215/kgm	—	—	1.25%	2688
Graphite	118/kgm	—	—	1.4%	1652
Electricity	22.5/kW	—	—	75kW	1688
			15134		11128

Total melting cost in Yen/tonne = 15134 Yen 11128 Yen

Saving/tonne of metal melted = 15134 Y-11128 Y = 4006 Yen

With 6000 tonnes/annum of metal melted
Annual savings = 4006 x 6000 = 24,036,000 Yen

Table 5.4c

Economic comparison of Mexican foundry producing grey iron

Exchange rate £1.00 = 650 pesos

Material	Cost Peso/Unit	COKE OPERATION Consumption	COKE OPERATION Cost	COKELESS OPERATION Consumption	COKELESS OPERATION Cost
Coke	70/kgm	25%	17,500	—	—
Oil	66/litre	—	—	80 litres	5280
Spheres	300/kgm	—	—	3%	9000
Recarburiser	122/kgm	—	—	1%	1220
			17500		15500

Total melting cost in pesos/tonne = 17500 15500

Saving/tonne of metal melted = 17500-15500 = 2000 pesos

With 4400 tonnes/annum of metal melted
Annual saving = 2000 x 5500 = 11,000,000 pesos

Table 5.5 see next page

Table 5.6

Characteristic	Cupola Conventional	Cupola Water-cooled, hot-blast	Coreless induction furnace	Arc furnace
Type of operation	Continuous	Continuous	Cont. or batch	Batch
Shape	Cylinder	Cylinder	Cup	Saucer
Source of energy	Coke	Coke and gas	Electricity	Electricity
Meltdown efficiency	60 to 70%	50 to 60%	70%	80%
Superheat efficiency	5 %	5 %	70 %	20 to 30 %
Refractories	Acid	Carbon or base	Acid	Acid or base
Slag chemistry	Acid	Acid or ase	Acid	Acid or base
Control of composition	Fair	Fair	Excellent	Excellent
Control of temperature	Fair	Good	Excellent	Excellent
Capital cost, installed, $/ton/hr	$10-20,000	$[illegible]	$60,000	$60,000

Comparison of Melting Equipment [illegible] Grey Iron Foundry

Table 5.5

CHARACTERISTICS OF FUEL-FIRED MELTING FURNACES

Furnace type	*Heat source*	*Charge*	*Capacity*	*Lining and life*	*Remarks*
Cupola					
Cold air	Coke	Pig-iron, foundry residues, scrap steel, coke, ferro-alloys	1 to 15 t/h (continuous)	Usually acid, lining needs daily relining	A receiver is required for over-heating and as a holding furnace
Coke with blower	Coke enriched with O_2				
Charcoal	Charcoal (experimental)	Charcoal	0.6 to 0.8 t/h (continuous)	Acid or sand lining	A forehearth furance is essential
Hot air with air cooling	Coke		4 to 100 t/h (continuous)	Acid or carbon rammed lining is the most widespread use. Lining life can exceed one week. Basic lining gives good results and long operation	A receiver is required, it may be an electrical channel or core-less furnace or a static or reverberatory furnace (recuperator and lining are optional)
Hot air with water cooling					
With O_2	Coke with O_2	Coke may be used to provide carbon			
With additional burners	Coke with natural gas or coke with fuel oil, or coke with calcium carbide				
With double rows of nozzles	Coke				
Gas					
Natural gas	Natural gas	Coke acts as com-bustion material	4 to 5 t/h		
Propane or oil	Propane or fuel oil				
Crucible	Coke, gas or fuel oil	Scrap, cast iron pigs and ferro-alloys	Up to 1 t (batch process)	Crucible may be made of graphite or have lined and rammed metal frame	For small quantities of cast iron, including alloys, air may be pre-heated. Crucible may be fixed or tilting
Static reverberatory furnace (hearth type)	Cannel, gas or oil	Scrap, cast iron pigs and liquid ferro-alloys	Up to 50 t (batch process)	Acid (siliceous or silico-aluminous)	Air pre-heating (if used) will increase production and allow larger sizes
Reverberatory rotating furnace	Fluid coal, gas, fuel oil, gas-fuel oil mixture	High carbon content cast iron	Up to 10 t (Batch process with solid charge) Continuous process uses liquid charge	Usually acid. Lining life is 250 to 400 charges	Good deoxidizing and de-gassing. Good for malleable cast iron (recuperator and tilting optional)

make them the selected unit for many foundries, even when electrical supplies are not available and it is necessary to install generators. The economics of using an electric furnace depend upon the cost of energy, which can sometimes be offset by the use of cheaper or more readily available raw materials such as steel scrap. Also the elimination of environmental*) and fuel handling costs and the improved quality control of the melt have strengthened the popularity increase of electric melting. A comparisson of the characteristics of electric melting and cupola is given in Table 5.6.

Electric furnace maintenance requires skilled electricians and engineers and expensive spare parts. The selection of the type of electric furnace will depend on several factors relating to the special sircumstances of the country and the type and volume of castings to be produced. A classification of the electric melting according to the type of furnace used is given in Table 5.7.

As an approximate guide to power consumption, a continuously utilized efficient electric furnace will consume between 500 and 600 kWh/ton of iron melted. However with intermittent operation power consumption over twice this level is not uncommon. For a small speciality foundry producing mainly grey cast iron, a combination of a small cupola and either indirect-arc or coreless induction furnace would provide a good arrangement for meeting demand for its products at low investment cost.

The most widely employed coreless induction furnace for prime-melting duties in iron foundries has been the line frequency (50Hz) type ranging in capacity from about 1-5 to 60 tonnes. Medium frequency furnaces (200-1000Hz) in the past have been powered by rotary generators and their use has been confined to production of special irons in relatively small furnaces (500 kg to 2 tonnes). Thanks to new techniques and constant further development, medium-frequency crucible-type induction furnaces with static frequency converters have now become efficient, environmentally safe and very reliable melting units for a wide range of applications. Figure 5.4 illustrates the general design of a medium-frequency melting furnace.

In addition to the conventional design, i.e. installation of the

*) The major problem with cupola melting is the large amount of particulate and chemical pollutants released to the atmosphere. To help control these, air pollution equipment is required, usually more expensive than the cupola itself.

Table 5.7

CHARACTERISTICS OF ELECTRIC MELTING FURNACES

Furnace type	Heat source	Electrical characteristics	Capacity	pH	Lining	Energy consumption (kWh/t)	Other characteristics
Rotating furnace							
Indirect arc	An arc between two horizontal electrodes	Network troubles	Up to 1.5 t	Neutral. Generally slag is not required considering the CO saturation of the furnace atmosphere	Alumina with corundum cover	From 550-700	Quality grey iron may be melted for small and medium-size foundries. Single-phase current may cause network troubles. Electrodes consume 3 to 5 m³/h cooling water
Graphite resistor	Energy is dissipated in a graphite bar	Charge is constant: 50-700 kVA, 20-80 V					
Induction channel furnace	Heat is generated in a secondary channel by induction and then transferred to the charge by conduction and convection	For melting from 30 kW to 2 000 kW, for holding from 100 kW to 2 000 kW or more at lower frequencies. One or two inductors	For melting up to 10 t, for holding more than 100 t	Acid, basic or neutral depending on lining nature	Crucible normally lined with corundum bricks and insulating bricks. Corundum, zircon, and magnesite linings are used for channel and inductor	For melting 500-620, for holding 20-40, for overheating 35-70	Generally used as holding furnace, infrequently as a melting furnace. If coupled with a cupola its capacity is twice the hourly production. Vertical channel, tilting horizontal channel and opened channel types. Inductor replacement causes furnace stops and could occur every 2-3 months. Relining occurs after longer periods
Induction coreless furnace							
Low frequency	An alternating current passes through a cooled coil which surrounds the crucible. An induced current generates heat	50-60 Hz, 300-25 000 kW	Up to 60 t	Generally acid or neutral	Sand in very pure SiO_2 bonded with furnace-sintered and rammed boric acid linings of magnesium alumina or aluminium bricks are also used	Low frequency melting 520-650. Medium frequency melting 650-700	May be used as melting furnace or holding furnace with batch or continuous operation. Charge may be cold, pre-heated or liquid. It is the most flexible and efficient furnace for alloyed iron (or steel). Coil cooling and good maintenance are very important
Thyristor or rotating converter		500-4 000 Hz	Up to 3 000 kg				
Intermediate frequency (or three frequency)		150-300 Hz	Up to 300 kg				
Direct arc three phase furnace	An arc between the electrodes and the charge	Maximum voltage 300 V. The ratio of power to capacity (kVA) is important. Generally 400 kVa per t	5 to more than 50	Acid or basic	The roof is of alumina bricks. The sides are rammed dolomite, magnesite or silica. The hearth is generally basic lined	Approximately 600	It is the most suitable furnace for transforming charges in good quality liquid metal. Large amounts of electricity are required for melting. Graphite electrodes used up at a rate of approximately 5 kg/t of production may break and cause stoppage

Table 5.8b

Principal technical data of comparable mains and medium frequency coreless furnaces and channel furnaces

Characteristic	Mains frequency coreless furnace	Medium frequency coreless furnace (250 Hz)	Channel furnace
Total holding capacity in kg	4500	2000	4500
Efficient capacity in kg	4500	2000	2500
Electric power in kW	1000	1000	850
Connected load in kVA	1250	1250	1050
Melting rate up to 700 °C in kg/h	1900	1900	1900
Current consumption up to 700 °C in kW·h/t	520	520	430
Superheating rate (full furnace) in K/min	10	22	10
Superheating rate (level of fill: 25% of efficient capacity) in K/min	20	80	17

Table 5.8a

Typical data of various plants

Crucible capacity kg	Frequency kHz	MF power kW	Specific power kW/kg	Melting time min
120-200	1.0	100-200	2.0-1.0	15-30
250-550	1-0.75	200-500	1.0-0.9	20-45
550-1100	0.75-0.5	320-810	0.9-0.7	22-35
1100-2200	0.5	500-1000	0.7-0.5	22-65

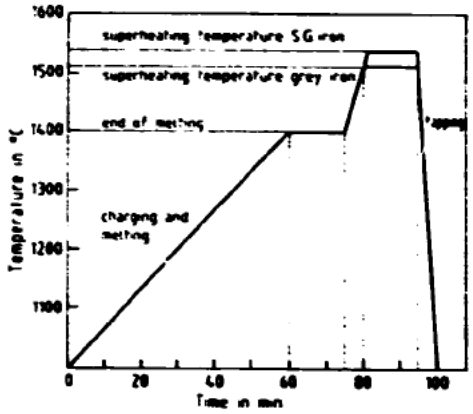
individual plant elements such as the furnace, capacitor bank and frequency converter in brick-lined boxes, compact melting plants mounted in a foundation plate have been operated successfully for many years in a large number of countries, particularly where the costs of foundation construction, installation and start-up are of major importanc· These types of compact plants are produced in two different designs:

(i) modular design (Fig. 5.5) for furnace ratings from 1250 to 4250 kW with 12-pulse converters for the frequency range from 250 to 500 Hz;

(ii) one-piece design whereby furnace, hydraulic unit and capacitor bank form a constructional unit for ratings from 250 to 1250 kW with 6-pulse converters for the frequency range from 500 to 1000 Hz.

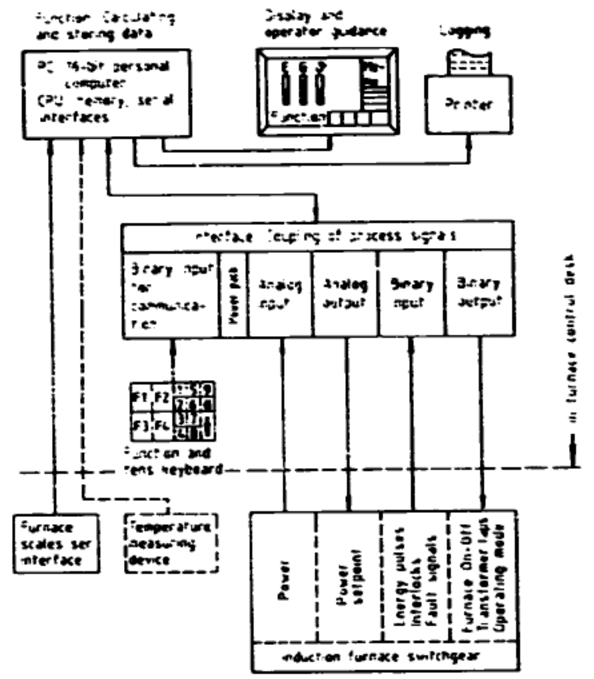
The parameters relationships derived from above illustrated designs are depicted in Figure 5.6. These types of furnaces are used for: melting of cast iron (Figs 5.7a & 5.7b); melting of steel and cast iron; melting of non ferrous metals (Table 5.8a). The investment cost for an induction or indirect-arc furnace is lower than a three-phase direct-arc furnace of equivalent volume with needed pollution control facilities. Arc-furnaces are particularly useful for large scale steel melting (see UNIDO publication IPCT/R.3, Technological Profile on Mini-Steel Plants). Table 5.7 illustrates characteristis of electric melting furnaces.

Treatment of molten iron: Treatment of molten metal after leaving the melting furnace is a common feature of the production of many types of cast iron. Related terms are duplexing(=holding of molten metal), desulphurisation, magnesiumtreatment, inoculation(=final ladle treatment), inmold process, etc.



Sequence of a melting cycle in a 6 t MF furnace.

Figure 5.7a



Schematic overview of the hardware of the melt processor

Figure 5.7b

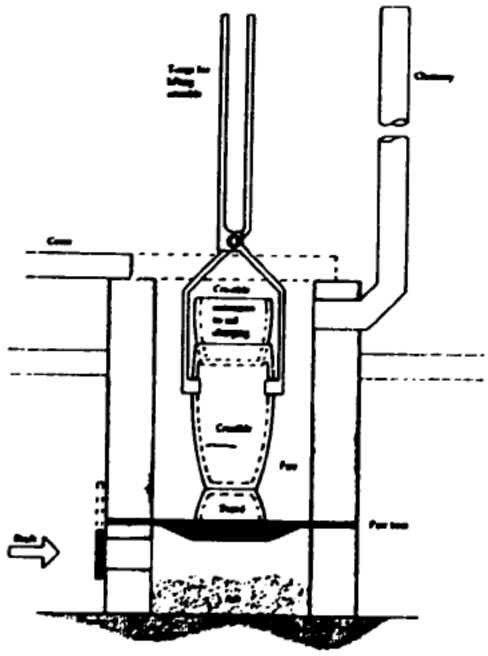


Figure 5.8b

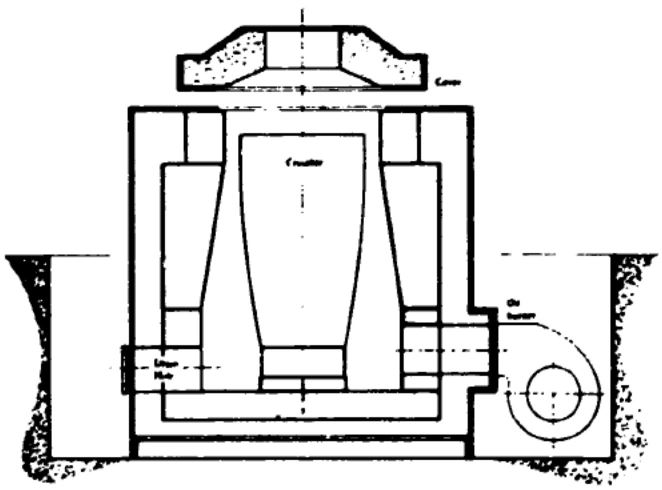


Figure 5.8a: Oil-Fired Crucible Furnace

5.2 Melting of non-ferrous metals

Non-ferrous metals may be melted in oil-fired furnaces, gas-fired furnaces, electric furnaces or crucible furnaces. The crucible furnaces constitute one of the widest ranges of melting units available to the non-ferrous founder. They may be fired by solid fuel, oil or gas, or heated electrically. Crucible furnaces may be of the lift-out, tilting or ball-out type. With a lift-out stationary furnace the metal is melted in a crucible and at the end of the melting cycle the crucible is liftid out of the furnace and used as the pouring ladle (see Figures 5.8a and 5.8b). "Lift-out" or "push-up" crucibles are not normally larger than 150 kg capacity because of the difficulty of handling larger crucibles full of metal. Crucible type furnaces are generally used where small amounts of metal are required at frequent intervals. Tilting crucible furnaces are available in capacities of up to 750 kg charge weight. Separate crucibles should always be used for each type of alloy being melted, to avoid contamination.

Reverberatory furnaces are flame fuel-fired furnaces in which the charge is melted by radiation from hot refractory walls and roof and by convection from the movement of hot gases. Furnace capacities ranges from 50 kg to 50 tonnes and the furnaces may tilt for tapping or be of the non-tilt type.

Pot furnaces mainly used for low melting point metals are commonly employed in conjunction with the diecasting process using metal moulds.

Electric induction is also very suitable for non-ferrous metals. Induction melting units are available in which the metal is placed in crucibles which are themselves placed within an electric induction coil. This type of furnace, although relatively expensive is an extremely satisfactory way of melting small to medium quantities of a variety of non-ferrous metals (see Table 5.8b).

Melting copper alloys: The melting of copper alloys is essentially a remelting process based on charges composed of virgin materials, pre-alloyed ingots, selected scrap and foundry returns. Alloying elements are added to the melting unit in the correct order to ensure their maximum recovery to the melt. When melting bronze, if dirty scrap is used, it may be necessary to flux bronzes, although normally it is sufficient to add a few pieces of charcoal to the melt. Bronze and other copper alloys should not be left in the molten state for long periods. Induction push-up furnaces operate at medium frequency and melting times are as short as 15-20 minutes for 100 kg of copper based alloys. When melting copper-based alloys, reverberatory furnaces are generally used as batch melters. Core (channel) type induction furnaces efficiently melt copper and copper alloys are well suited to melting and holding brass and bronze when pressure diecasting, in almost continuous operation.

Aluminium alloys: Many types of furnaces are used for melting aluminium. For small quantities of metal, crucible furnaces of low capacities are commonly used, but where considerable quantities of metal are required bulk melters are employed, the molten metal being distributed to smaller holding furnaces of the bull-out type. Improved channel furnace with melting capacities of up to 45 tonnes are now being used in a number of aluminium foundries (in industrialized countries) without any problems arising from oxide build-up, however, channel type furnaces are most economic if operated 24 hours per day. Molten aluminium alloys are very reactive and combine readily with other metals and sometimes refractories. Thus aluminium can pick-up iron from unprotected surfaces and where iron is present, sludge is a danger. In such a case it is necessary to coat the side of the pot with clay to avoid metal contamination. However aluminium is melted it is subject to the risk of scum and dross formation, and to the pick-up of gas, both of which cause casting defects. It is possible to add special fluxes just before pouring to reduce this risk. These fluxes, such as aluminium chloride, or proprietary mixtures, help the dross to coagulate into a slag which can be skimmed off, and also liberate a gas which bubbles through the metal and cleans it from the types of gas which cause the defects.

Magnesium alloys: Due to the violent reactions that occur between molten magnesium and some refractories, it is customary to melt magnesium alloys in cast or fabricated steel crucibles. Pouring ladles should also be constructed of steel similar to that for melting crucibles. The charging and pouring operations require particular techniques and additives to clean the melt and remove non-metallic impurities.

6. Patterns, moulding and coremaking, gating and pouring

6.1 Patterns and patternmaking

Almost all casting production starts with the manufacture of a pattern. A pattern is a form made of suitable material which gives its shape to the refractory mould cavity where the metal solidifies to the desired contour and dimensions. Patterns may be costly to produce but on the other hand, castings cannot be made more accurate than the pattern equipment from which the mould and cores are made. The decision as to the type of pattern equipment to make, depends on several factors such as:

(i) Number of castings to be produced.

(ii) Moulding and core making process to be employed.

(iii) Dimensional tolerances required.

(iv) Size and shape of casting.

Patterns are classified in a number of ways and according to

(a) the material of construction, e.g. wood, resins, metal;

(b) the method of mounting such as 'loose' pattern or one mounted in a permanent manner;

(c) form such as a full or jointed pattern, skeleton or a sweep pattern, special patterns such as expanded polystyrene patterns, wax patterns, etc.

It is not necessary that patterns or core boxes be constructed entirely of any one material. For example, wood patterns may have plastic or metal inserts on wear surfaces.

Wood patterns: Wood is probably the most widely used pattern making material as it is inexpensive and easy to shape. Wood patterns damage and wear more easily than resin or metal patterns and thus have a shorter working life. British Standards 467:1957 contains specifications for Wood Pattern Equipment for Foundries including basic classification, construction, colouring and marking to be used for six classes of patterns. The specified standard colours and marking which apply to all wood patterns irrespective of the metal to be cast, are given in Table 6.1. The paint or varnish applied to wood pattern equipment must resist attack by the binder system in the sand. Alkali or acid resistant coatings must be applied on pattern equipment intended for use with sodium silicate or acid catalysed resin bonded sands. Generally, resin and metal patterns are left unpained.

Table 6.1:

Part of Patterns		Colour
As-cast surfaces which are to be left unmachined		Red or orange
Surfaces which are to be machined		Yellow
Core prints for unmachined openings and end prints	Periphery	Black
	Ends	Black
Core prints for machined openings	'A' Periphery	Yellow stripes on black
	'B' Ends	Black
Pattern joint (split patterns)	'A' cored section	Black
	'B' metal section	Clear varnish
Touch core	Cored shape	Black
	Legend	'Touch'
Seats of an for loose pieces and loose core prints		Green
Stops offs		Diagonal black stripe with clear varnish
Chilled surfaces	Outlined in	Black
	Legend	'Chill'

Table 6.2:

WEIGHT OF CASTING FROM WEIGHT OF PATTERN
Allowance must be made for the weight of any metal in the pattern.
The patterns are without cores.

A pattern weighing 1 lb when made of	Will weight when cast in							
	Cast iron	Cast steel	Yellow brass	Gunmetal or bronze	Bell bronze	Zinc	Copper	Aluminium
Alder	12.8	14.6	14.3	14.8	15.5	12.2	15.6	4.6
Baywood	8.8	9.8	9.9	10.3	14.0	8.5	10.5	3.2
Beechwood	8.5	9.5	9.5	10.0	12.0	8.2	10.1	3.1
Birch	10.6	11.2	11.9	12.3	12.9	10.2	12.0	3.9
Cedar	12.5	14.5	14.2	14.7	15.3	12.0	15.7	4.5
Cherry	10.7	12.0	12.0	12.6	13.5	10.4	12.8	3.9
Lime	13.4	14.2	15.1	15.6	16.3	12.9	15.3	4.9
Linden	12.0	13.3	13.5	14.1	15.0	11.6	14.3	4.3
Mahogany	8.5	9.5	9.5	10.0	10.5	8.2	10.1	3.1
Maple	9.2	10.3	10.3	10.6	10.9	8.9	11.0	3.2
Oak	9.4	10.4	10.5	10.8	11.0	9.1	11.2	3.4
Pear	10.9	12.1	12.2	12.8	14.0	10.6	13.0	3.9
Pine	14.7	16.3	16.5	16.6	17.3	14.3	17.5	5.3
Whitewood	16.4	18.1	18.4	19.3	20.0	15.9	19.5	5.9
Brass	0.84	0.98	0.95	0.99	1.0	0.81	1.04	0.31
Iron	0.97	1.09	1.09	1.13	1.18	0.93	1.17	0.35
Lead	0.64	0.75	0.72	0.74	0.78	0.61	0.8	0.23
Tin (¼–⅓ lead)	0.89	1.1	1.00	1.00	1.12	0.85	1.18	0.32
Zinc	1.00	1.16	1.13	1.17	1.22	0.96	1.18	0.36

Table 6.3:

Alloy		Patternmakers' Contraction Allowance
Aluminium alloys		
Commercially pure		
Al-Cu-Si alloys	e.g. LM4	
Al-Si alloys	e.g. LM6, LM28, LM29, LM30	
Al-Cu alloys	e.g. LM12	1.3% or 1/75
Al-Mg 5-10%	e.g. LM5, LM10	
Low expansion Al-Si-Ni	e.g. LM13	
Aluminium bronze		2.0-2.3%
Beryllium-Copper		1.6%
Bismuth		1.3%
Brass, yellow (thick)		1.3%
Brass, yellow (thin)		1.6%
*Cast iron, grey		0.9-1.3%
Cast iron, white		2.0%
Copper		1.6%
Delta Bronze		1.6%
Gunmetal		1.0-1.6%
Lead		2.6%
Magnesium		2.0%
Magnesium alloys (5%, or over of alloys, excluding cadmium, which has no effect on the shrinkage of magnesium)		1.6%
Magnanese bronze		2.0%
Monel		2.0%
Nickel		2.0%
Nickel silver		1.0-1.6%
Phosphor-bronze		1.0-1.6%
Silicon bronze		1.3-1.6%
Steel, carbon		1.6-2.0%
Steel, chromium		2.0%
Steel, manganese		2.6%
Stone's gear wheel bronze		1.0%
Tin		2.0%
White metal		0.6%
Zinc and zinc-base alloys		2.6%

*The amount of contraction in cast iron depends chiefly upon the speed with which the casting cools, greater contraction resulting from more rapid cooling, and vice versa. Large hollow castings contract less in a vertical than in a horizontal direction.

Resin patterns: Patterns made from epoxy or polyurethane resin based materials have excellent mechanical properties and dimensional stability. They provide high resistance to the abrasive action of the granular moulding material, are not subject to shrinkage or swelling. Resin patterns have an excellent surface finish together with very positive loose piece and corelocation arrangements. Whilst being more costly than those made of wood, resin patterns have a much longer working life and are therefore, more suitable for long production units.

Metal patterns: Are normally made from an aluminium alloy or grey or SG (nodular) iron. They may be cast to shape and finished by machining or completely shaped by machining. Modern pattern shops are therefore, equipped with the facilities of conventional tool or diemaking shop using such techniques as spark erosion, electro forming, etc and employing nummerically controlled and electronic copying machine tools. Where sustained production is required with corresponding consistency of dimensional accuracy, meatl pattern equipment is essential. Metal pattern equipment is also essential where the equipment is heated to cause hardening (curing) of the sand mould or core as in shell moulding and coremaking and hot box core production.

Table 6.2 illustrates pattern weight to weight of castings. An important factor to be taken into account when designing and constructing pattern equipment is the solid contraction which takes place as the casting cools in the mould from the metal freezing temperature to room temperature. Different casting alloys have different contraction rates. Although average values for unrestricted cooling conditions are available as set out in the Table 6.3 it must be borne in mind that these can vary considerably according to the resistance offered by moulds and cores.

Machine Finish Allowance: Many castings are machined on some of their many faces. Extra meatl is therefore, required on these faces and provision must be made for this on the the pattern or in the core box.

Pattern making equipment: In order to make accurate patterns capable of producing high quality castings, it is necessary that adequate facilities are available. Equipment for making simple engineering drawings and the skills to prepare, read and interpret drawings are required. Pattern-making tocls include all conventional wood-working and metal working hand tools. Accurate measuring equipment is essential (rules, verniers, scales, etc.) and a flat reference surface is necessary.

If power tools are available a disc sander, a planing machine, and and a band saw will increase the range of patterns which can be made, reduce the labour content, and improve the accuracy of the work. A lathe is needed for many types of pattern. For metall pattern-making a multi-speed drilling machine, an accurate lathe, and for some types of pattern a turret type milling machine are likely to be most useful. The pattern shop must be well lit, and provided with adequate benches, vices, and tool and material storage space. Parts of patterns must be located together accurately. It is also necessary to provide accurate location for coreboxes and for moulding boxes. For these purposes accurate bushes (sockets) and pins or dowels are needed. For the most accurate work these should be purchased from specialist manufacturers and made in hardened steel. However, for less critical castings, simple metal location pegs and bushes may be made in pattern shops. The use of wooden location pegs is not recommended. A good supply of screws and bolts of different sizes is also necessary as is a good quality adhesive and a hard setting "filler" material.

Pattern storage: If repeat casting orders are likely, patterns should be stored with care-especially since the pattern is often (depending upon the commercial arrangements) the property of the foundry's customer. Wooden and metal patterns should be kept on racks away from the foundry and the risks of accidental bruising or damage, fire hazrds or damp. In designing a foundry , adequate space should be provided for pattern storage. Table 6.4 illustrates the characteristics of various pattern-making techniques. A view of pattern-making equipment with respect to advanced technologies is given in the Appendix of this technology profile.

Table 6.4: CHARACTERISTICS OF VARIOUS PATTERN-MAKING TECHNIQUES

Pattern-making technique	*Materials used for pattern*	*Number of mouldings produced*	*Moulding method*	*Level of technical skill required*	*Relative cost*	*Relative casting size*	*Auxiliary tools used*	*Comments*	*Appropriateness for developing countries*
Full pattern									
Loose									
Single	Wood or plastic	Up to 40 (wood) Up to 100 (plastic)	By hand	Medium	Very low		Hand tools (pneumatic rammers)		Appropriate for a few simple parts
Split	Wood or plastic	Up to 40 (wood) Up to 100 (plastic)	By hand	Low to medium	Very low to low		Hand tools (pneumatic rammers)	Generally for first parts of a series	
On pattern board									
Matchplate	Wood, plastic or metal	Up to 300 (wood) 500-1 000 (plastic) 1 000-5 000 (metal)	By machine	Low	Low to medium	Medium	Precision flasks, moulding machines	Use of metal for pattern is infrequent	
Cope and drag	Wood, plastic or metal	150-300 (wood) 500-1 000 (plastic) 1 000-5 000 (metal)	By machine or hand	Low	Medium to high	Medium		Use of metal for pattern is infrequent	
Flaskless	Wood, plastic or metal	50-100 (wood) 500-1 000 (plastic) More than 5 000 (metal)	By hand, machine or mixer	Medium to high	Medium to very high	Medium	Mixer or blowing machine	Good surface precision	Appropriate if mixers or blowing machines are available
Special equipment pattern									
Skeleton pattern	Wood	Few	By hand	Medium to high	Minimal	Large	Hand tools and slinger machines for fillings		
Sweep pattern	Wood	Few	By hand	Medium to high	Minimal	Large			
Template pattern	Wood	Few	By hand	Medium to high	Minimal	Large			
Expendable pattern									
Full mould process	Polystyrene foam	One (not reusable)	By hand or mixer	Low to medium	Minimal	Medium and large	Self-hardening material needed		

6.2 Moulding and coremaking

The method of moulding to be used must be related to the type of castings to be produced and to the skills and equipment available in the foundry. Small castings are usually produced in sand moulds, by hand if the quantities are not large, or on moulding machines for repitition work. Larger castings may also be made with moulding machines. It will be necessary to handle large moulds with a crane, whether these are made by machine or by hand. Table 6.5a presents traditional mould materials and their temperature limits.

Mould preparation

The basic functions of a mould are:

(i) to provide a cavity which is a faithful reproduction of the shape of the casting which has to be produced;

(ii) to withstand the action of the poured metal and to extract heat from the molten metal in such a way as to produce optimum properties in the casting

(iii) to be constructed and used in the most economical manner possible.

Moulds can be permanent metal moulds as used in die or centrifugal casting or expendable ones made in refractory aggregates. Sand moulding, accounts for the largest tonnage of shaped castings (around 90% of the total tonnage). The basic techniques employed in making a simple sand mould are shown in Table 6.5b and Figure 6.1.In this case, the casting is a small valve body and as only few components are to be made, a loose wood pattern is employed, constructed in two halves. The techniques used to produce moulds and cores is largely dependent upon type of bonding material in the sand. Also the type of sand used may have a profound effect on casting quality particularly the quality surface of the castings.

Sand moulding processes

Whilst the basic principles of sand moulding remains virtually unchanged, developments in technique have been made particularly over the last few decades, and and these continue at the present time. The oldest and still most widely used moulding process is the compaction of clay-bonded quartz sands. Figure 6.2 illustrates the

Table 6.5a:

Traditional Mold Materials and Their Temperature Limits

Mold Material	Refractory Limit ° F
Plaster of Paris	approx. 1600
Metal	approx. 2000
Sand, ceramic	3000–3300
Graphite*	approx. 5000

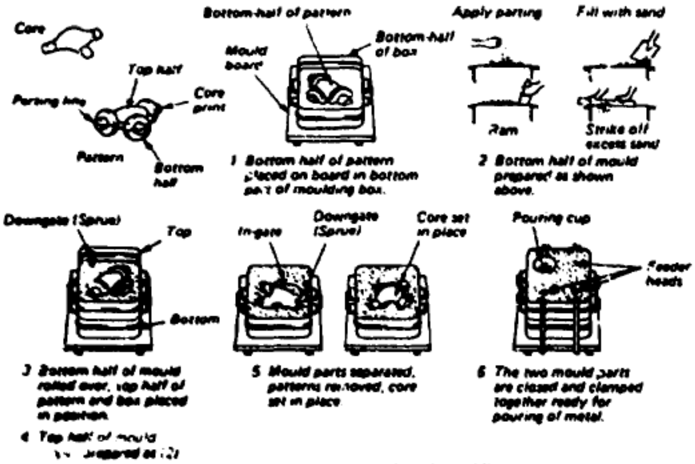
* Begins oxidizing at 750F

	HAND	MECHANIZED	AUTOMATED
Sand Cycle Time	once/day	once/day	30 minutes
Tramp Metal Separation	1/4" mesh screen and shovel	magnetic	magnetic
Mulling and Aeration	watered, mixed and riddled on floor	batch muller	continuous or batch muller
Distribution of Green Sand	shovel and wheelbarrow	front loader transports to molding station c/b overhead	overhead sand conveyor and chutes

Table 6.5b: Typical Hand, Mechanized, and Automated Sand Handling Alternatives

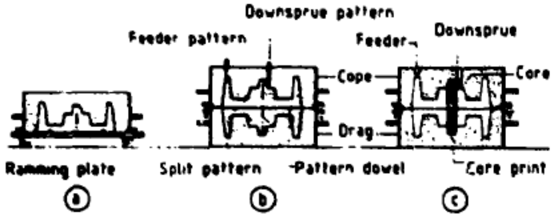
Table 6.5c: Survey of compacting processes for clay-bonded sands

Moulding sand filled into the flask and pre-compacted by	Moulding sand compacted by
Slinger-moulding (final compaction achieved)	-
Gravitational force (minimal compaction)	Jolting Squeezing Jolting and squeezing Jolting and jolt-squeezing 'Air flow' and squeezing Impulse moulding - air impulse - gas impact
Shooting/blowing	Squeezing
Vacuum	Squeezing



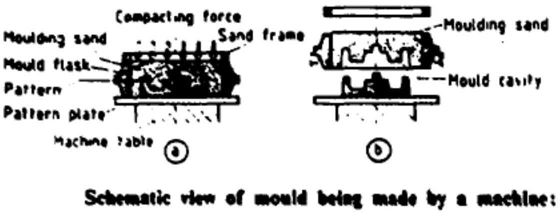
Basic techniques of sand moulding

Figure 6.1



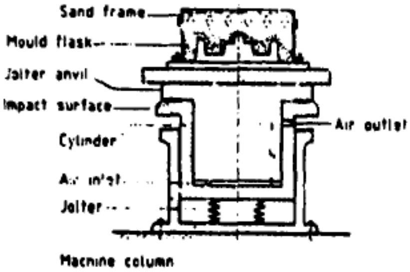
Schematic view of a mould being made by hand: a) drag being moulded, b) cope being moulded, c) mould being assembled

Figure 6.2



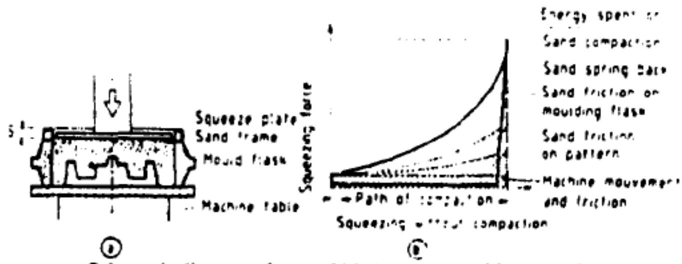
Schematic view of mould being made by a machine: a) moulding sand being filled into flask and being compacted, b) stripping of mould half

Figure 6.3



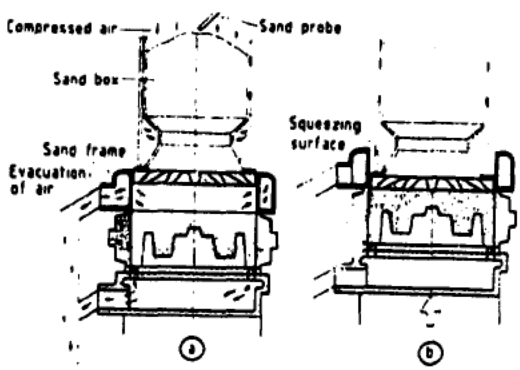
Schematic diagram of a mould be- nacted by jolting

Figure 6.4



Schema'c diagram of a mould being compacted by squeezing: a) schematic diagram, b) ino:cator diagram of the energy spent during squeeze moulding

Figure 6.5



Schematic diagram of mould compaction by means of shooting and squeezing: a) filling and pre-compaction, b) squeezing

Figure 6.6

principle of sand moulding that has been used for centuries. Not every sand is suitable for the production of castings. In order to produce a mould, the sand grains must be stuck or bonded together. The bond is usually provided by clay. Many sand deposits contain sufficient natural clay for this bond. Such"natural" sands with about 12% to 15% of clay are found in many parts of the world. It is possible by laboratory testing to determine whether a sand will be suitable for a foundry process, although it is usually better to carry out trials in a foundry. Many foundries use sand which contains no natural clay, and add clay separately (usually between 5 and 10% by weight). This type of sand must be clean, and in particular free from mica, volcanic ash, crushed sea shell or coal. The grain size should be uniform, the fineness determining the smoothness of the castins. The grain shape should be round, or sub-angular; wind blown sands or sands which have been washed as by-product of mineral extraction are often suitable. Lake sands and river sands are frequently used but sea beach sand is sometimes contaminated with shell or salt. Sand from some deposits may require washing and cleaning before use, or at very least sieving to remove lumps or foreign matter. Washed sand is likely to contain too much water for foundry use and may require drying- a simple sand dryer is not difficult to construct.

Where separate clay additions are made, the best type of clay to use is bentonite. This material is available commercially for foundry, and also for oil-well use. Fireclay and other types of clay are also used in certain cases. Sand bonded with clay must have the right amount of moisture in order to make good moulds. The water content depends upon the amount and type of clay present, varying from about 3 to about 7% by weight. The water content can be measured by accurately weighing a sample of sand before and after drying in an oven-other chemical and electrical methods can also be used in laboratories.

Green sand moulding: This is the most widely used moulding method for small to medium castings in all types of metals. The moulding sand is clay bonded and the moulds remain moist ("green") Throughout all their stages of production and at the pouring operation. Green sand moulding has the following advantages:

- ready availability of the raw materials quartz sands and clay;

- possibility of using recycled moulding sand--as the minor quality deteriorlation after casting can easily be compensated for
- production of quality castings due to the high degree of mould strength and gas permeability of the mould.

One disadvantage of green sand moulding, as compared with other moulding processes, is the relatively great effort required to compact the mould. This is a problem to be considered in relation to the shape and size of pattern used. Figure 6.3 shows a mould being produced in a moulding machine, with the pattern firmly placed on a pattern plate fixed to the machine table. The choice of green sand moulding usually implies that the user considers the production of the mould halves by sand compaction to be the most important stage in the metal casting process-from the initial design to the finished casting- as it is during this stage that the quality of the finished product and the efficiency and economy of the production process are largely determined. The choice of the most appropriate compacting process is of utmost importance. Table 6.5c lists the compaction processes that have been developed until now, and the Figures 6.4 to 6.10 illustrate these processes. Figure 6.11 depicts a selection of typical castings produced with a shoot-squeeze moulding machine. Figure 6.12 shows that all modern moulding processes are capable of producing a good distribution of mould strength. A favourable distribution would be one with a higher degree of strength at the patternplate gradually decreasing towards the back of the mould. Jolt moulding, because of the adverse environmental problems it causes is being used less and less. The Table 6.6 summarizes the typical features of proven mould compaction processes.

Dry sand moulding: This is an extension of the green sand technique. Slow rate of production and high skilled labour requirement. Largely replaced by cold set-moulding techniques.

Loam moulding: Slow and laborious process requiring much skill, all of the work being done by hand. Has been largely replaced by modern moulding techniques.

Cement moulding: Is the forecomer of the cold-setting processes. Cement bonded sand mixes are inexpensive and the sand may be reclaimed. Casting quality is good but mould hardening and rate of production slower than when using the newer cold-setting systems. Cement sand mouldin is used for heavy casting in steel or cast iron and for the moulding of heavy marine propellers.

Characteristics of different compacting processes exemplified by a mould measuring 1000 × 800 × 300/300 mm — Table 6.6

Compacting process	Compacting energy in kJ	Relative cost of compacting energy*)	Machine cycle period in seconds	Remarks
Hand moulding with compressed air rammer 9.2 m³ compressed air, according to [9])	2100	39	1200	Considerable strain on operating personnel due to noise and vibrations
Slinger moulding 1.7 kW·h for drive, according to [9])	6100	27	600	Strain on operating personnel due to noise and vibrations; requires subsequent ramming on the back of the mould
Jolt moulding 2 m³ compressed air**)	450	8	30	Strain on operating personnel due to noise and fast wear of machine components; expedient in conjunction with squeezing for high and medium-height moulds
High pressure squeezing 0.06 kW·h for hydraulics**)	210	1	26	Expedient for flat moulds; highest density on back of the mould
Shooting without squeezing 6 m³ compressed air	1400	25	26	for medium-height moulds; in conjunction with high pressure moulding - universal application
Vacuum without squeezing 0.9 kW·h**)	3200	14	26	for medium-height moulds; in conjunction with high pressure squeezing - universal application
Air flow without squeezing 12 m³ compressed air**)	2700	50	30	for medium-height and high moulds; in conjunction with high-pressure squeezing - universal application
Impulse moulding (compressed air) 2.5 m³**)	560	10	30	for medium-height and high moulds - universal application
Impulse moulding (gas impact) 0.15 m³ natural gas, according to [10])	4400	10	30	for medium-height and high moulds - universal application

*) high pressure squeezing ≙ 1
**) Manufacturers' indication

1 m³ compressed air (operating conditions) = 225 kJ
1 m³ natural gas (standard conditions) = 29 310 kJ
1 kW·h = 3600 kJ

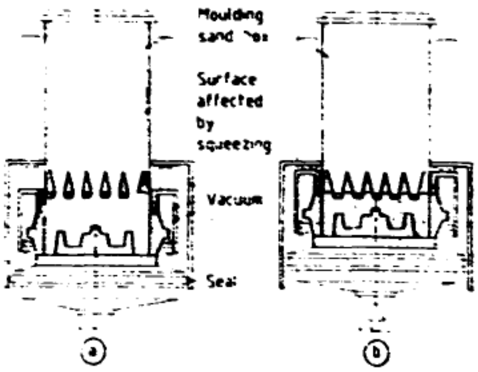
Comparative mix sand cost for cold box process — Table 6.7a

Process	Alkaline phenolic	Polyurethane	SO_2/furan
Binder level	1.5% BSR1	1.25% (Total Parts 1 & 2)	1.0% Furan 0.4% Peroxide
Binder cost/tonne	£760	£1150/1200	£1400/1900
Gas level	0.3% BSH 10	0.1% DMEA or TEA	0.1% SO_2
Gas cost/tonne	£1280	£1750	£500
Total binder cost/ tonne mixed sand	£15.25	£16.39	£22.10

Advantages:
Reduced operating costs
Reduced capital equipment costs
Improved quality and productivity
Cleaner, quieter working conditions
Inexpensive patterns
No pattern storage
Less risering
Less cleaning time
Less molding space required
Less skilled labor required
Defects such as scabs and buckles cannot occur
Elimination of nonmetallic inclusions and hot tears in steel
No cores
Castings can be made to closer tolerances and walls as thin as 0.120 in. have been cast
No binders or other additives are required
Sand is reusable
Casting cleaning is minimized since there are no parting lines or core fins
Improved dimensional control
Simplified sand handling
No parting lines or parting line flash
Shakeout is simplified
Longer tooling life
Flexibility
Easily automated
Low energy and material costs
Lower scrap and reclaim

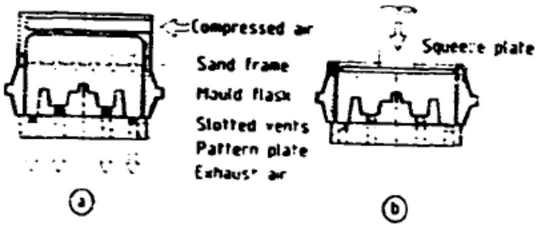
Disadvantages:
Alcohol wash and speedy drying yield vapors
Distortion
Surface finish may not be as good
Pouring operation more dangerous (flame from gases)
Little more penetration (temp hotter)
Possibility of runouts
Material shrinkage
Castings take longer to cool

Table 6.7b



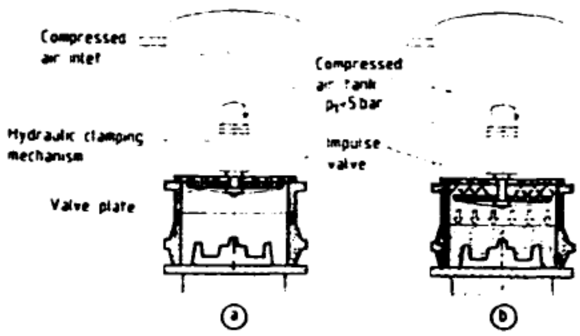
Schematic diagram of moulding sand by vacuum and squeezing: a) filling and pre-compaction, b) squeezing

Figure 6.7



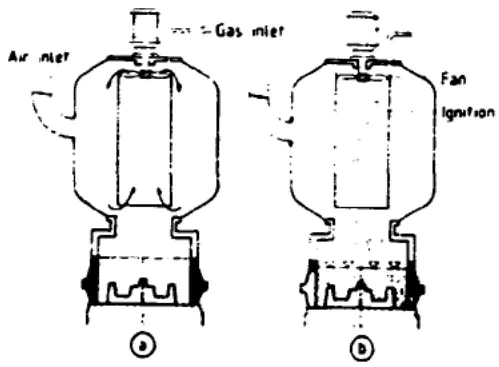
Schematic diagram of mould compaction by 'air flow' and squeezing: a) pre-compaction, b) squeezing

Figure 6.8



Schematic diagram of mould compaction by air impulse, i.e. the expansion of compression air above the mould via a special-design impulse valve: a) prior to compaction, b) after compaction

Figure 6.9



Schematic diagram of mould compaction by the combustion of natural gas: a) natural gas and air being mixed, b) impact being produced by the combustion of the gas and air mixture

Figure 6.10

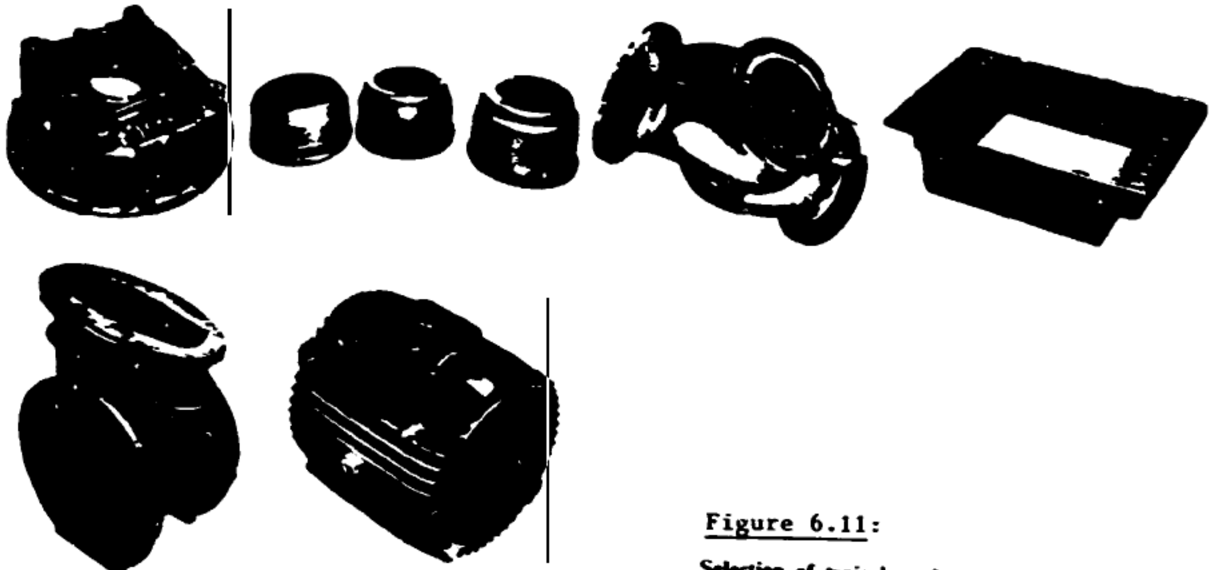
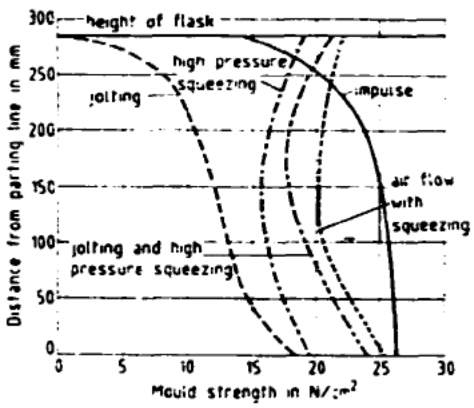


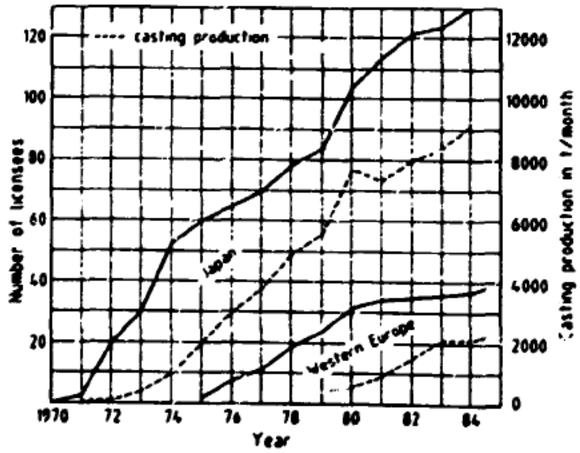
Figure 6.11:

Selection of typical castings produced with a shoot-squeeze moulding machine



Schematic diagram of the distribution of mould strength within the mould half (without pattern) achieved with compacting processes presently used

Figure 6.12



Development of the vacuum moulding process in Japan and Western Europe: a) number of licensees; b) casting production

Figure 6.13

CO$_2$ Process: The carbon dioxide/sodium silicate process for the bonding of moulds is simple. A binder based on a solution of sodium silicate is mixed with silica sand and the flowable mix is easily compacted to form the mould. The CO_2 gassing process has a profound effect on the strength of moulds. Various mould gassing arrangements are used. Highly efficient gassing is obtained where moulds are placed in a chamber from which air is evacuated prior to introducing CO_2. Castings made by this process are dimensionally accurate, have a good surface finish and are less likely to suffer from porosity and blowhole defects. CO_2 process mould may be made on jolt-squeeze moulding machines.

Cold-set sand moulding: Such sands harden in a predictable manner at room temperature. Binder systems are based on furan, phenol formaldehyde or phenolic urethane resins or sodium silicates and a suitable hardening agent or catalyst- is added during the mixing of the sand. The speed of cold setting is controlled by the amount or strength of hardener that is added to the sand/binder mix. Cold-setting may be extremely rapid as is required for high rates of small mould production, or slow when making large moulds. The moulding layout may be very simple and consist of a stationary mixer with moulding boxes and moulds circulating on a roller track around the mixer. Wood patterns are perfectly satisfactory they are of high quality and properly coated. Reproducible accurate casting dimensions are obtained and casting surface quality is generally excellent. The cold-set moulding process is very flexible and is used for producing castings in all metals and alloys weighing from a few kilogrammes up to 200 tonnes. Table 6.7a gives comparative mix sand cost for cold box process.

Shell moulding process: This requires the use of metal patterns. These are heated to about 250°C and then covered (either by damping or blowing using a special machine) with sand which has been previously mixed with 3 to 5 % of a heat-curing phenolic resin. After a few minutes a hardened layer of 1 or 2 cm builds up on the pattern; the loose sand behind is tipped away for re-use and the hardened shell is removed when cured by further heating. Two shells are clamped or glued together for pouring. The powdered resin may be simply mixed with the sand but it is more effective to use sand whose grains have been coated with resin. It is possible to purchase coated sand: although the coating process is not very complicated, it requires careful technical control and is not usually worthwhile for small quantities. Shell moulding requires relatively little skill from the operators although it demands high skills from the pattern makers. The process can produce accurate, smooth, high quality castings in most types of metal. Shell moulds can be stored for long periods without damage and the process can be modified in many ways for high production. Shell moulding is not a cheap method, especially if resin coated sand has to be purchased from a distance. It is suitable only when relatively highly priced castings are to be made which justify the cost of the resins and the expensive metal patterns.

Other gas hardening moulding processes: In recent years, systems using gaseous amines to harden phenolic urethane bonded sands and and sulphur dioxide to harden furan and phenol formaldehyde resin bonded sands have been introduced. Outputs of mould can be high and accurate castings with a good surface finish are produced from wood and plastic patterns. The technoques are used only for making small castings in mass or small quality production. Machines are available, that produce gas hardened contoured moulds as possible alternatives to normal shell moulds, and whilst the shells are thicker, binder and energy usage is less and high quality castings are made using much lower cost patterns.

Special sand moulding processes: These constitute the V-process and the EPC process.

a) The V-process moulding (Vacuum Sealed Moulding Process) was originated in Japan and the technique of this process involves the use of a vented pattern on a hollow carrier plate or suction box. A thin plastic film with specific physical properties is softened by radiant heat and draped over the pattern. The carrier plate is then evacuated, causing the film to conform to the contours of the pattern. A moulding box is placed over the film coated pattern and filled with dry unbonded sand which is consolidated by vibration. The top of the box is similarly covered with a plastic film, air is evacuated through vents in hollow walls or pipes in the box and the sand mould becomes rigid. The pattern is withdrawn after releasing the vacuum applied to the hollow carrier plate. The second half of the mould is made in a similar manner. The moulds are kept under vacuum during subsequent handling and pouring and until the metal has completely solidified.

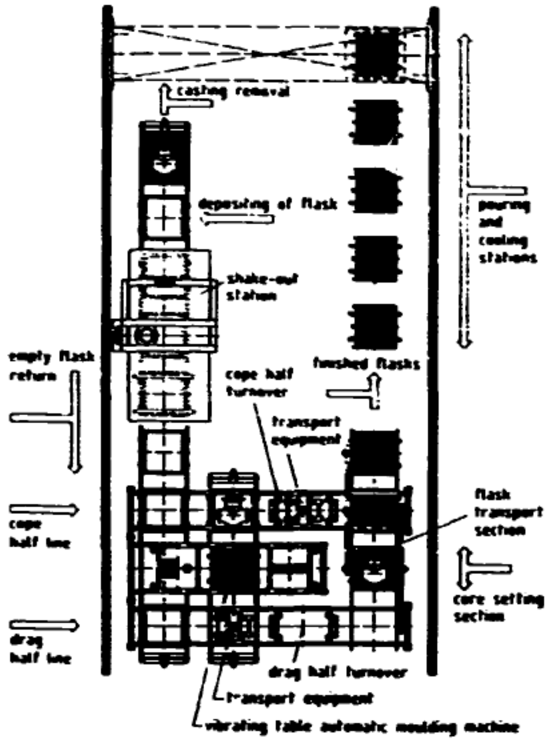
The technique is used for producing many shapes and sizes of castings in most casting alloys. Its best application is for small quantity production of larger castings-one to several tonnes-of simple configuration. The castings have good dimensional accuracy and surface finish and the process has the capability of producing thin metal sections. Figure 6.13 illustrates the development of the V-moulding process in Japan and W.Europe. Figure 6.14 shows a fully automatic moulding plant. Shuttle and rotary type plants are illustrated in the Figures 6.15 and 6.16 respectively. Figure 6.17 shows a vacuum moulding plant suitable for the production of baths with 2000 x 1000 x 750/200 mm flasks. This plant achieves a capacity of 50 - 60 moulds/h and is the largest installed in Europe.

b) EPC (Evaporative Pattern Casting): In this process an expendable pattern of vaporisable material such as polystyrene foam is embedded in the moulding material in a moulding box, generally a one part box, the mould then being immediately ready for pouring without the need to remove the pattern. Molten metal is poured into the 'Full Mould', vaporising the pattern as filling proceeds and perfectly reproducing the pattern. Figures 6.18a and 6.18b show this process schematically. Casting quality can be satisfactory and for single or very small batches of castings, pattern and moulding costs are lower than when using corresponding wooden patterns. Figure 6.18c illustrates an EPC pilot plant and Table 6.7b summarizes advantages and disadvantages of the process. A comparisson of the main sand moulding methods is given in Table 6.8.

A view with moulding making equipment is contained in the Appendix.

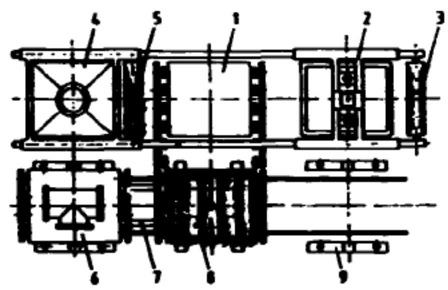
Sand cores and coremaking

Certain types of casting can be produced without the need for cores. However many designs contain internal cavities or undercuts which cannot be made by normal moulding methods. Very few foundries can operate without some core producing facilities. The bonding of sand to form cores is similar to that which is required in order to form moulds; many of the same processes are used. There are, however, some differences. A core has to be harder and stronger than the mould since it must be handled and perhaps stored, handled again and laid into the mould by hand. Cores are often almost completely surrounded by molten metal and as the metal solidifies and contracts the core must break down in order not to set up stresses or crack the metal.



Vacuum moulding plant with mould transfer station

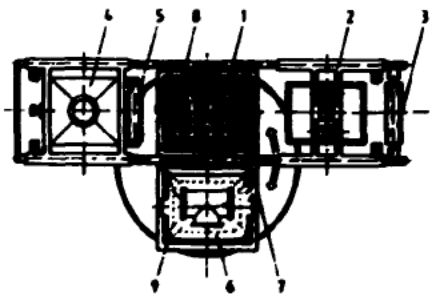
Figure 6.14



1 Vibrating table
2 Foil laying equipment
3 Pattern foil roll
4 Sand dosing equipment
5 Mould covering foil roll
6 Pattern plate and carrier
7 Shuttle
8 Flask
9 Pin lifting

Shuttle type vacuum moulding plant.

Figure 6.15



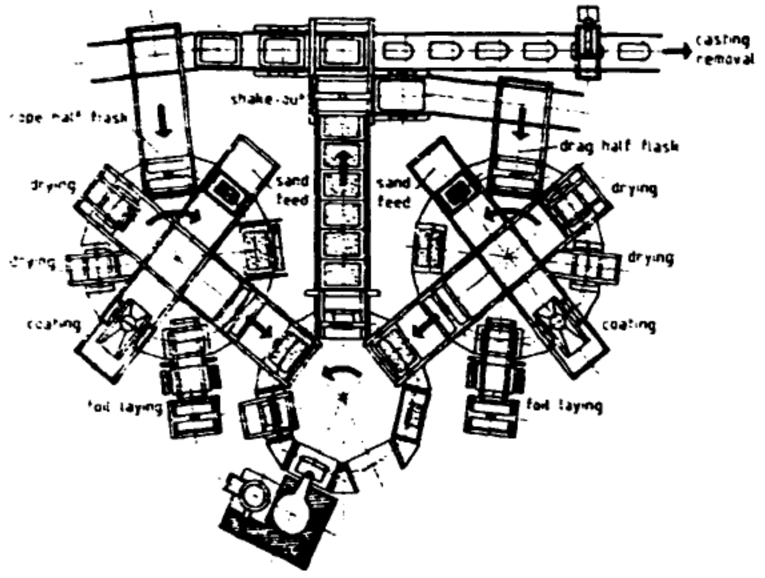
1 Vibrating table
2 Foil laying equipment
3 Pattern foil roll
4 Sand dosing equipment
5 Mould covering foil roll
6 Pattern plate and carrier
7 2-station rotary table
8 Flask
9 Pin lifting

Rotary table vacuum moulding plant

Figure 6.16

Vacuum moulding plant for baths

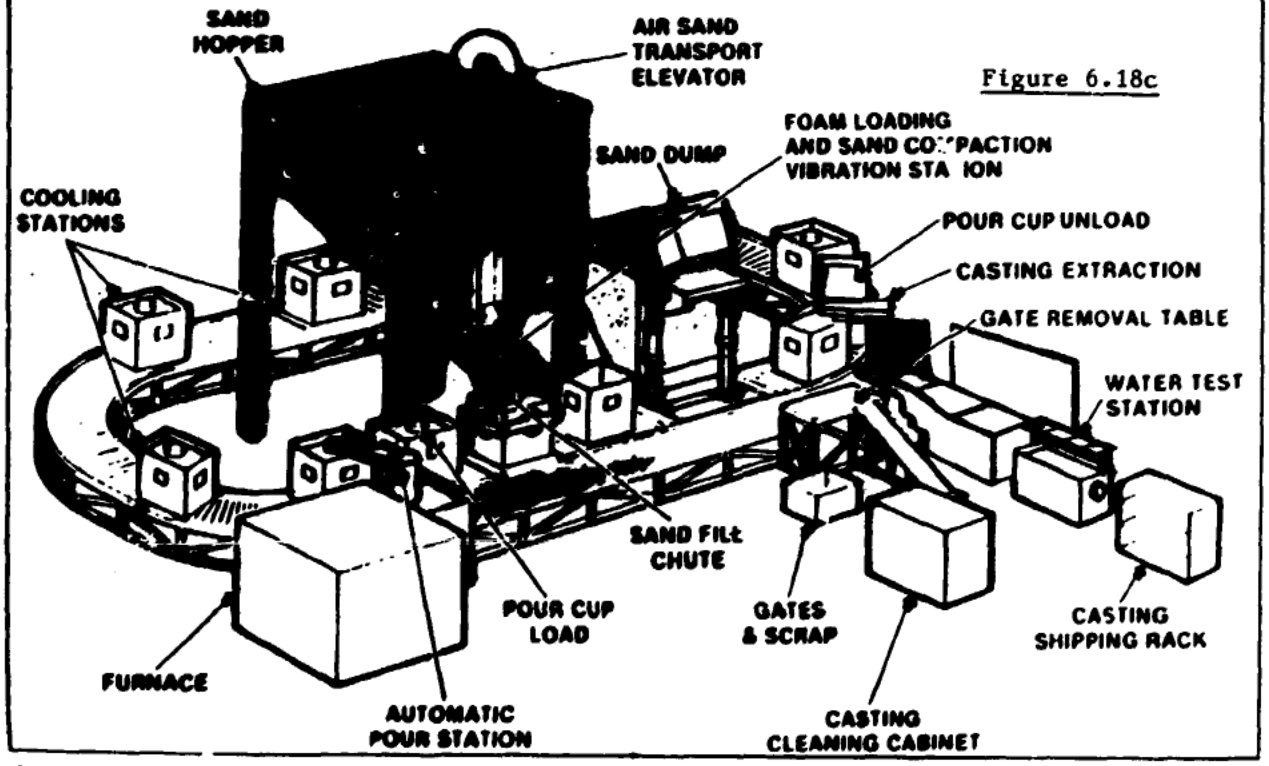
Figure 6.17



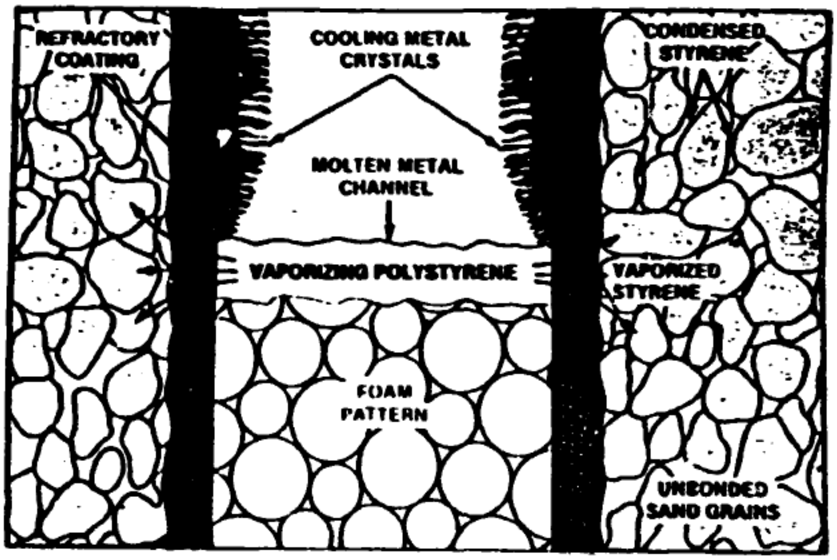
Figures 6.18a and 6.18b see next page.

ECP PILOT OPERATION

Figure 6.18c

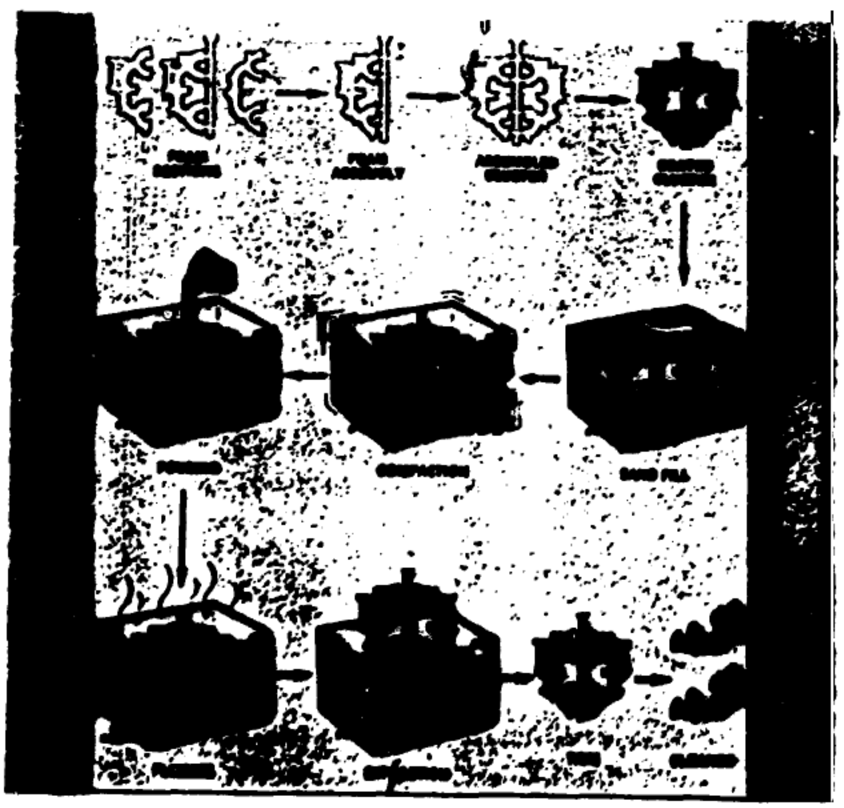


Ford Motor's research into the EPC process included installation of a pilot line at the Essex Aluminum Casting Plant in Essex, Ontario. The line was specifically installed to verify costs as well as solve some of the technical issues in the production of intake manifolds, oil pans and heads.



Shown schematically, as molten metal advances during casting of the ECP part, a zone of liquid and gases is created. The gases pass through the refractory coating and into the sand where some of it condenses. The pattern coating must be permeable enough to allow the gases to escape, but not so great that internal pressure is released causing mold collapse.

Figure 6.18a



This illustration gives a step-by-step view of the evaporative casting process as it is utilized by the Ford Motor Co.

Figure 6.18b

A COMPARISON OF THE MAIN SAND MOULDING PROCESSES (approximate and depending upon the alloy to be cast)

Moulding Process	Casting weight	Number of Castings min.	Number of Castings max.	Type of pattern	Relative cost in small numbers	Relative cost in quantity	Dimensional accuracy (casting)	Surface finish (casting)	Relative ease of changing design in production
Green sand	0.025 kg to 1 tonne	1	Limited to pattern life	Wood Resin Metal	Low	Lowest	Poor to very good	Poor to very good	Poor to good
Dry sand	1 tonne to 100 tonne	1	Limited to pattern life	Wood	High	Highest	Poor to moderate	Good	Very good
Cement sand	1 tonne to 50 tonne	1	Limited to pattern life	Wood	High	High	Moderate	Good	Very Good
CO_2 Process	0.025 kg to 20 tonne	1	Limited to pattern life	Wood Resin	High	Low	Good	Very good	Very good
Cold-set sands	0.025 kg to 200 tonne	1	Limited to pattern life	Wood Resin	High	Low	Good to very good	Very good	Very good
Shell moulding	0.025 kg to 100 kg	500	Limited to pattern life	Metal	Highest	Low	Excellent	Excellent	Very poor
V-Process	200 kg to 10 tonne	1	Limited to pattern life	Wood	Low	High	Very good	Very good	Very good
Expendable pattern (a) Bonded sand	20 kg to 20 tonne	1	5	Polystyrene	Lowest	Very high	Poor to good	Poor to good	Excellent
(b) Unbonded sand (vacuum)	1 kg to 250 kg	500	20,000+	Polystyrene	Very high	Low	Very good	Very good	Very poor

Table 6.8

A COMPARISON OF THE MAIN SAND CORE MAKING PROCESSES (approximate and depending upon the alloy to be cast)

Core making process	Core size limitations	Type of core box	Hardening System	Core box tie-up period	Cores ready for pouring	Rate of core production	Dimensional accuracy (cores)	Surface finish (casting)	Ease of core knockout
Oil sand	Very small to medium	Not critical. Wood: Resin: Metal	Heat	Few seconds to blow core	Few hours	Slow to very rapid	Poor to good	Good	Good to very good
Air-setting oil sand	Medium to large	Wood	Oxidising agent and heat	30 min to 4 hrs	Several hours	Very slow	Moderate	Good	Good
Shell cores	Very small to small	Metal	Heat	2 to 4 mins	Immediately	Very rapid	Excellent	Excellent	Excellent
Hot box cores	Very small to small	Metal	Heat	5–60 secs	Immediately	Extremely rapid	Excellent	Very good	Very good
Cold-setting sands	Small to very large	Wood: Resin.	Acid catalyst or tertiary amine	5 min to 4 hours	Few hours to 16 hours	Slow to rapid	Very good	Good	Good to very good
CO_2 process	Small to very large	Wood: Resin	CO_2 gas	10 sec to 4 min	Immediately to several hours	Very rapid	Very good	Good	Poor to moderate
Gas hardening Cold processes	Small to medium	Wood: Resin: Metal	Tertiary amine vapour or SO_2 gas	20 sec to 1 min	Immediately	Extremely rapid	Excellent	Very good	Very good

Table 6.9a

Cores must not be bonded with chemicals which produce large quantities of gas when subjected to heat since gas bubbles can pass into the liquid metal and form blow holes on solidification.

Cores binders: Cores may be made from clay-bonded sand. However clay-bonded cores are very fragile and require considerable skill in manufacture and support in handling. The use of green sand and dried sand cores has decreased considerably in recent years. The CO_2 process using water-glass and carbon dioxide gas is an extremely useful coremaking process. This technique is described before. CO_2 process cores can be made with special sand additives to reduce the casting cracking problem which sometimes occurs. A number of other chemical systems have been developed for producing cores which harden rapidly in their core boxes without heat. A number of chemical resin systems based on phenol formaldehyde, urethane, furfuryl alcohol or other resins harden on the passage of amine gas or of sulphur dioxide. Other resins hrden by the action of catalysts mixed with the sand just before coremaking, as with the air-set moulding process. Many of these chemicals are expensive and some present health hazards so that they can only be used with special equipment. Smaller foundries should usually consider only the CO_2 process or the air-set mixer-filler process for cold setting core making. The hot box process needs a heated metal core box: the sand is mixed with resins which cure on the application of heat. This process produces solid cores but in other respects it is similar to the shell moulding process which may also be used for making cores. After 1cm to 1½cm of sand has cured shell cores may be emptied out so that hollow cores are produced. Both hot box and shell cores have to be made on special coremaking machines with heaters for metal core boxes. These processes are convenient and require little operator skill, but the equipment and core-box making and tooling costs are high, so that the processes are usually restricted to foundries requiring high production rates. Many cores can be made with 'natural' binders. Certain vegetables oils, such as linseed oil, cottonwood oil and others, when subjected to heat (temperatures of the order of $250^{\circ}C$), become hard and strong. Cores are made in simple wooden or metal core boxes but complicated shapes may require support on sand or metal formers until they are baked. Other natural organic materials are used alone or in conjunction with hardening oils and include starch, flour, mo' es, or sugar derivatives. many types of flour when mixed with wa... provide a suitable medium for bonding sand to produce cores. A disadvantage is that starch-bonded cores tend to produce large quantities of gas on pouring. Frequently a mixture of starch and oil is used to give a combination between a workable sand before curing and a hard and strong core after heating. It is possible to purchase specially prepared core binders and oils. Some of these oils are based on mineral oils and on fish oils as well as on natural vegetable oils. It is worth carrying out experiments with locally available oils as these may provide more economical corebinders than purchased, specially produced, proprietory materials. A typical mixture might contain 2% oil, 1½% starch, and 2 to 3% of water. Such cores should be cured by baking at 250°C for approximately 45 minutes in an oven. These oil-bonded sand mixtures may also be used for moulding when particularly strong moulds are needed. The mixing and preparation of coremaking sand must be carefully carried out. It is usually unsatisfactory to attempt to mix sand by hand, and a small sand mixer of the type used for moulding sand, or even a concrete mixer type, should be used. The composition of core sand mixes must be carefully controlled eiter by weighing or by measuring the ingredients. Cores which are cured by heat or by the passage of CO_2 gas must be made under controlled conditions. CO_2 process sand hardens slowly in the air, so that to avoid waste it should be mixed in small batches as it is required. Mixers must be cleaned after use to avoid contaminating other batches.

Coremaking: Cores may be made in metal, wooden or plastic core boxes. these core boxes are part of the pattern equipment for the castings. The simplest method of making cores is to ram the sand into the core box with a wooden rammer. Many cores may need reinforcement with wire or nails in order to provide internal support. Coremaking for complicated shapes is a skilled process requiring several months of training, although simple cors can be made after a few days or weeks of practice. An alternative method of producing cores is to blow the sand into the core boxes. Core blowing machines can be bought which are suitable for both hot and cold core making processes. A range of machines is available from simple manually-operated blowers up to fully automatic equipment for the production of intricate cores on a large scale. Such coremaking machines require compressed air, power or gas services and maintenance, and can usually only be justified for repetition castings in conjunction with mechanised mould production. Cores that have been bonded with oil, starch or some resins must be cured before use. Core stoves may be fired by oil, by gas, by coke, wood or other suitable fuels. It is important that air should be allowed to circulate within the stove since the curing process is by oxidation as well as by the application of heat. It is necessary for the core stove to have reasonably accurate temperature control.

Core Assembly Moulding: Coremaking methods are sometimes used to produce complete moulds. The mixer filler or air-set moulding process are such examples, but most coremaking processes can be used for moulding with the advantages of flexibility, rigid moulds, easy stripping, and absence of the need for moulding boxes. Moulds made from assemblies of cores have to be securely clamped and sealed together before pouring the metal. Coremaking sands are usually more expensive than moulding sands, so coremoulding is only used when there are definite technical advantages. Table 6.9a illustrates a comparisson of the main sand coremaking processes. Characteristics of core sand moulding methods are given in Table 6.9b. Features of main sand binder systems are tabulated in Table 6.9c. An illustration of coremaking equipment is given in the Appendix.

Mould and Core coatings: It is common practice to coat moulds and cores with a suitable "paint" or dressing which serves as an imprevious stable refractory barrier between the molten metal and the sand. By its use, surface finish of the final coating may be greatly enhanced, metal penetration into the intertices of the sand grains avoided, the sand surface protected from erosion and a number of other casting ills prevented. Every conceivable method of presenting mould and core dressings to the user has at some time been utilised. These range from dry powders for soft camel hair brush application, through powders and pastes for dispersion in both water and various flammable solvents, ready-to-use suspensions in the same solvents, air-drying versions and electrostatically deposited powders, to inclusion of the powder dressing in the sand mix itself. Similarly, all possible methods of placing the dressing on the mould or core surface have been explored-swabbing, brushing, spraying, dipping and flow-coating of liquid with electrostatic spray, shaker-bag and soft brush for powders.

Table 6.9b: CHARACTERISTICS OF CORE SAND MOULDING METHODS

Method	*Main variants of the method*	*Moulding material*	*Comments*	*Equipment*	*Relative productivity index (number)*	*Other required operations and equipment*	*Advisability for developing countries*
By hand							
Using moulding profiles	Sweep, template (single or multiple)	Natural or synthetic, oil-sand or highly refractory special sand	Large size and minimum series cores	Wood	1	Baking arbors	Processes require skilled labour
By lathe	Vertical or horizontal axis	Natural or synthetic sand	Small series, large circular segment cores	Wood	1	Baking, centrally supported spindle	
Skeleton		Synthetic and oil-sand or highly refractory mixture	Minimum series, large cores	Wood	1	Baking, many reinforcing rods	
In core box	The core box structure may have movable parts	Cement, CO_2-silicate, oil-sand. No-bake	Several dimensions, small series	Wood	3	Baking, oil moulding requires reinforcing rods	For small series with large dimensions
Jolt machine	Core box rollover and hauling is mechanized	Synthetic or natural sand	Cheap, small series production	Wood, plastic (some metal)	10	Baking, special reinforcing stalks	Not advisable
Air compression							
Single post machine		Oil-sand, CO_2-silicate. Hot box, or cold box. No-bake	Medium series production. All operations in sequence	Metals (some wood)	20	Baking according to mixture	
Double post		Generally hot or cold hardening mixtures	Medium to large series. Alternative operations	Metal, complicated core boxes	35	Baking on machine, if required	Not advisable
Multiple posts			Large to very large series. Distributed operations	Sophisticated cast-iron or steel core boxes	More than 50	Baking on machine, if required	Not advisable
Swing slinger	Ancillary equipment includes a rotatory table, and a rollover for continuous cycle	Synthetic sand and oil-sand	Flexible for medium series with core box rotation	Wood, plastic, metal (aluminium), boxes. Average co-	10 to 15	Baking, reinforcing rods	Versatile but subject to tool wear and need for rotating impellers
Continuous mixer	Uses simultaneous binder addition or pre-mixing	No-bake mixtures (plastics, catalysts)	Surface precision, flexibility for small medium series cores	Wood, plastic (some metal). Good equipment life	10 to 15		Many advantages

SUMMARY OF FEATURES OF MAIN SAND BINDER SYSTEMS

	Clay-bonded sands: Green sand	Clay-bonded sands: Dry sand	CO_2 Process	Air-set Process	Oil & Starch Binders	Shell Process	Hot box Process
Material costs	Low	Low	Moderate	High	Moderate	High	High
Pattern or corebox costs	Low	Low	Low	Low	Low	High	High
Costs of machines	Low Hand High Machine	Low Hand	Low	Moderate	Low Hand	High	High
Level of skills	High Hand Low Machine	High	Low	Low	Moderate	Low	Low
For small moulds	Yes	Yes	Yes	Yes	Yes*	Yes	No
For large moulds	No	Yes	Yes	Yes	No	No	No
For small cores	No	Yes*	Yes	Yes*	Yes	Yes	Yes
For large cores	No	No	Yes	Yes	Yes	No	No
Re-use of sand	Yes	Yes	Some	Some	Some	No	No
Need for heat to cure	No	Yes	No	No	Yes	Yes	Yes
Accuracy and finish quality	Fair	Fair	Fair	Fair	Low	Good	Good
For high production	Yes	No	Yes	Fair	Fair	Yes	Yes

* Possible, but not generally used

↑ Table 6.9c

↓ Table 6.11

INFLUENCES OF CASTING VARIABLES UPON STRUCTURE

Variable	Effect	Structural tendency
Increasing pouring temperature	Decreases freezing rate and inhibits nucleation	Columnar; coarse
	Increases temperature gradient to optimum	Columnar
	Decreases temperature gradient beyond optimum	Equiaxed
Decreasing mould temperature	Increases freezing rate and promotes nucleation	Equiaxed; fine
	Increases temperature gradient	Columnar
Decreasing pouring rate	Increases temperature gradient	Columnar
	Increases mechanical disturbance: promotes crystal fragmentation, disturbs undercooled layer	Equiaxed, fine Columnar
Increasing rotational speed	Increases mechanical disturbance: promotes crystal fragmentation, disturbs undercooled layer	Equiaxed; fine Columnar

Table 6.10: Machine model and products

Name	model	products
No. 1	Horizontal	Sleeve type rolls Hearth rolls
No. 2	Inclined	Work rolls for hot strip mill
No. 3	Horizontal	Work rolls for hot strip mill
No. 4	Horizontal	Work rolls for plate mill
No. 5	Inclined	Tools for seamless pipe
No. 6	Horizontal	Composite liners Composite pipes
No. 7	Horizontal	Column joints

Table 6,12 *Metal Alloys and Their Approximate Pouring Temperatures*

Alloy	°F
Solder	approx. 450
Tin	approx. 600
Lead	approx. 650
Zinc alloys	650–850
Aluminum alloys	1150–1350
Magnesium alloys	1150–1350
Copper-base alloys	1650–2150
Cast irons, gray, ductile, malleable	2450–2700
High manganese steel	2550–2650
Monel (70% Ni, 30% Cu)	2500–2800
Nickel-base superalloys	2600–2800
High alloy steels	2700–2900
High alloy irons	2800–3000
Carbon & low alloy steels	2850–3100
Titanium alloys	3100–3300
Zirconium alloys	3350–3450

Some special moulding and casting processes

Investment casting or lost wax process: This is based on an ancient method of making castings; a one part mould is produced by coating (investing) a wax replica of the final casting with a refractory slurry that sets at room temperature. The wax is then melted or burned out leaving a cavity in the mould of exactly the same shape as the original wax pattern. This casting technique has been established as an accurate one for the manufacture of extremely critical castings and reliable engineering components. The two main techniques in general use for the production of moulds in the investment casting process are

(a) the preparation of a "block" or solid mould

(b) the manufacture of a ceramic shell.

The investment casting process is used for a wide range of alloys including nickel-rich materials, the socalled super alloys, stainless steels, irons, copper based alloys and light metals. Machining requirements of the castings are minimal. Mechanisation of the process is gaining momentum and robot mechanical aids can be used for readily programmed sequences such as shell build-up investment.

Ceramic moulding: Casting quality lies between that obtained by investment casting and sand casting. Ceramic moulded castings have excellent surface finish. There are virtually no alloy limitations. Automatic machines are available for producing ceramic shell moulds at an output of 240 shells an hour and the ceramic moulding process has produced castings from a few grammes up to three tonnes in weight. The process is used for manufacturing golf heads, food machinery, aluminium parts for electronics, pattern equipment, dies for casting, forging etc.

Plaster moulding process: Probably the best known form of plaster moulding is the Antioch process developed in the 1930's. The process is mainly used for light alloy casting production, although most copper-base alloys can be cast in "Antioch Process" mould. The castings have an excellent surface finish and close dimensional tolerances within a single mould half. It is a well established process for tyre moulds, impellers, rotors etc.

Die Castings: This technique yields medium to long runs of precise, intricate, smooth surface castings in a wide range of alloys; the die or mould is invariably of cast iron or steel, although refractory metal dies based on such materials as tungsten and molybdenum are employed when casting high melting point alloys, such as stainless steels. The trend is towards increasingly thinner and more accurate castings with complete automation of the casting process. Robots have now been successfully integrated into br ss diecasting production lines, there are three methods of diecsting: gravity, low pressure, high pressure.

(i) Gravity diecasting: The process is often used where capital outlay is limited and where the overall volume of castings does not justify the high initial die cost of the pressure diecasting process, and it may be used for smaller scale production. The moulds are arranged to open and close and be clamped together manually or mechanically, as they are likely to be too hot and heavy for hand operation. Metal is poured manually and after solidification the casting is removed. The maximum weight of gravity die castings is around 15 kg, ie in copper and aluminium based alloys and grey and SG irons, although very large (350kg) relatively simple aluminium alloy castings are claimed to have been made satisfactorily by the technique in the USA. Slush casting is a seldum used technique similar to gravity casting. It produces a hollow casting without the use of cores.

(ii) Low pressure diecasting: This can be regarded as an extension of the gravity process but pouring of the metal is more closely controlled and production rates are higher. Low pressure die-casting may compare favourably with high pressure diecasting as regards process capability but has a slower cycle and is therefore better suited to lower quantity requirements. This casting process can be completely automated with precise machine control and weights of castings can range from less than one kg up to 150 kg. The metals employed are usually aluminium alloys (British Standard 1490 of the "LM" series) but is not necessarily limited to aluminium castings.

(iii) High pressure diecasting: This casting process is widely used for large volumes -5000 minimum of zinc and aluminium castings of intricate shape. Automatic casting machines are capable of producing castings at the rate of one every few seconds and components as minute as zip fasteners, to large castings such as light alloy automobile engine blocks. In recent years pressure diecasting has been extended to steels and other high melting point alloys. Pressure diecasting tooling and pressure diecasting machines are specialised and very expensive. Some information regarding developments in the diecasting machines and the diemaking equipment is contained in the appendix.

The Accurad process developed by the General motors may be regarded as a midway between the low-pressure technique and high pressure technique. The process is claimed to produce denser castings, minimum flashing between dies and more accurate aluminium alloy components.

The following points are of importance for the production of sound pressure die-castings in whatever metal or alloy.

1. Use as low an injection temperature as will ensure complete filling of the die cavity.
2. Maintain a suitable average die temperature free from sharp local temperatures gradients.
3. Position the gate so that the injected metal does not impinge directly upon die or core surfsces.
4. Employ an injection pressure high enough for a strong pressure pulse to be transmitted through the solidifying casting at the end of the injection stroke. Where these conditions are observed the incidence of porosity, shrinkage voids and surface imperfections is reduced to negligible proportions.

The Centrifugal Casting: The essence of centrifugal casting can be given by the following outline. "Centrifugal casting force due to the revolution of mould, whose axis is either horizontal, inclined or vertical, presses the fluid metal against the interior surface of the mould, and a better casting is thereby produced." The characteristics of centrifugal casting are as follows:

(i) The control of wall thickness is easy.
(ii) As the centrifugal casting force helps to feed the solid-liquid interface, the microstructure across the wall is fine and dense.
(iii) Impurities are confined near the inside surface by centrifugal casting force.
(iv) This method is useful in producing dual metal castings, which consist of two concentric layers bonded together metallurgically.
(v) This method is ideal for efficiently manufacturing the same shape and size of products.

On a large scale, this process is used for cast iron and SG (spheroidal graphite) iron water-pipes; smaller centrifugally cast bronze tubes are used for making bearings, and cast iron cylinder liners for engines are also produced by this process. Centrifugal casting is also used for the manufacturing of mill rolls (adamite rolls, high chromium composite rolls). The speed of rotation has to be related to the castings being made. For general casstings, such as bronze bushes, about 200 rpm is normal, whilst for the highest quality cast iron cylinder liners speeds up to 900 rpm are used. Figure 6.19a shows the mould and casting design of centrifugally cast rolls. The bottom and top parts are the dry mould and the metal mold is coated with refractory to prevent burning. Table 6.10 shows the machine model for manufacturing rolls for hot strip mills, sleeves and cylinder liners. The complexity of structure control in centrifugal castings is indicated in Table 6.11. Figure 6.19b illustrates the product size of above machines. Other forms of centrifugal casting include "semi-centrifugal" techniques where a sand or metal core is provided to form the cental cavity, or that of pressure casting whereby centrifugal rotation is used to feed a mould with metal via a central runner. This method is used for small castings.

Continuous casting: The high control requirements of the process and the large amounts of material produced mean that it is a process unlikely to be of interest to small scale foundries. Continuous casting as being of importance for steelmaking constitutes a very considerable stage of the mini-steel plant concept. For more extensive information regarding this subject the author wishes to refer to the following UNIDO publication:

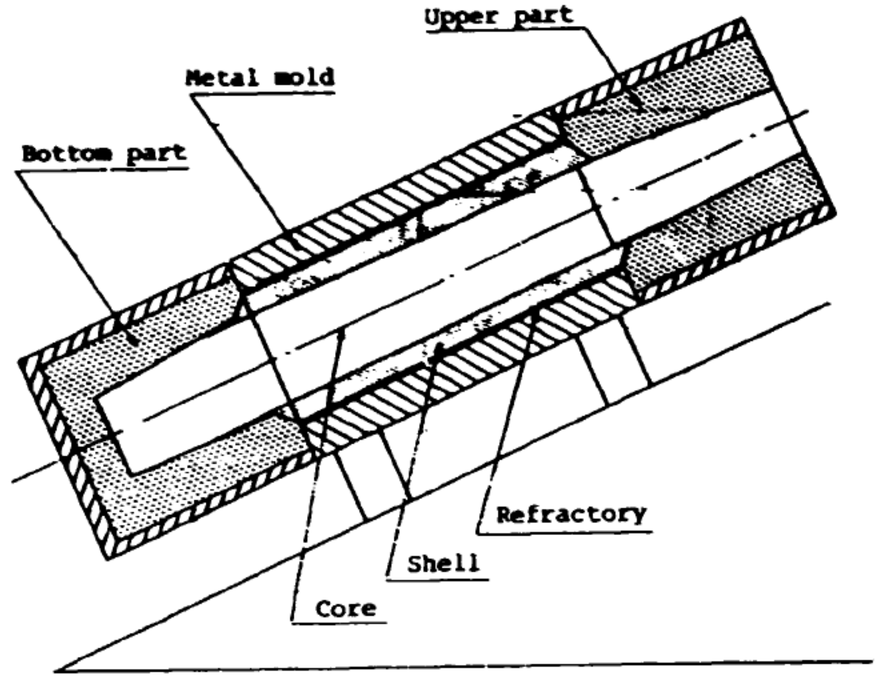
Technology profile on mini steel plants.
UNIDO/IPCT/R.3
December 1986.

Some additional data with respect to the impact of continuously cast iron (in particular horizontal continuous casting) on the foundry industry are briefly illustrated in the Appendix.

6.3 Gating, feeding and pouring equipment

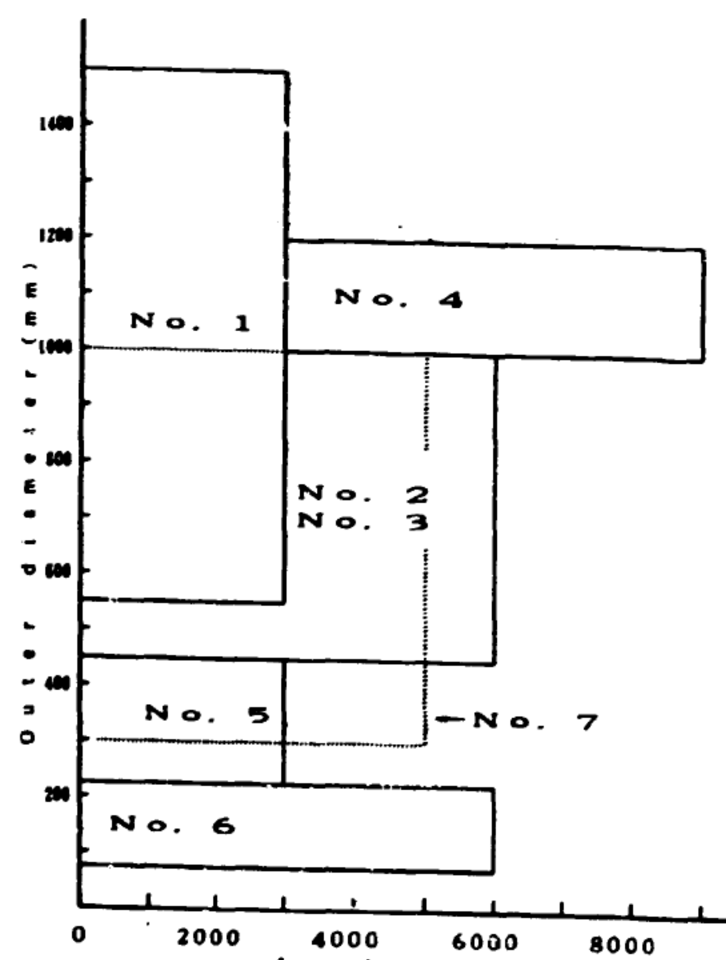
Gating and feeding

This important part of foundry work ensures that the metal enters a casting in as clean and state as possible and as liquid and liquid



Mold and casting design of centrifugal casting

Figure 6.19a



Product size of each machine

Figure 6.19b

contraction takes place the voids in the solidifying casting are replenished with molten metal from the feader heads. The desired features required of a running system are

(i) the metal should flow quietly without undue turbulence to completely fill the mould cavity;

(ii) the metal should be distributed in such a manner as to produce sound castings;

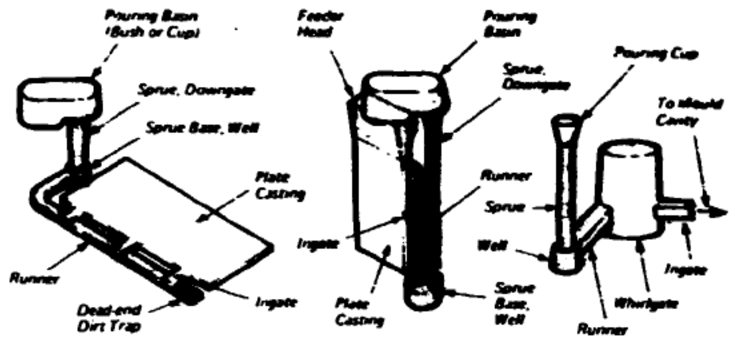
(iii) metal quality must be maintained during flow, avoiding oxidation of the metal stream and entrairment of gases, slag or mould material;

(iv) high velocity metal streams should not impinge directly onto the mould or core to cause sand erosion or wear of dies, etc.

Running systems used in sand moulds are generally more complex and varied than in other casting process because of their important part in controlling the quality of the castings produced. The terms of running systems used are depicted in the Figures 6.20a, 6.20b and 6.20c. Runners with ingates are generally positioned to prevent metal falling large distances in the mould cavity with consequent risk of splashing and mould and core erosion. Multiple ingates are advantageous with "rangy" castings to achieve equal and rapid disribution of the poured metal. Running system design is based on the practical application of hydraulic studies plus experience in foundries when pouring particular alloys.

Feeding of castings is an essential part of the art and science of producing sound castings. These function of a feeder head is to remain molten longer than the casting and provide a sufficient volume of liquid feed metal to compensate for the volume contraction of the particular alloy while the casting is solidifying. Feeder heads (Fig. 6.21) are therefore, generally large in size to safeguard the availability of the relatively small amount of metal needed to feed the casting. To facilitate the removal of the feeder heads techniques are employed that greatly reduced the contact area between the head and the casting without reducing feeding efficiency.

An example of pressurised gating system for red brass alloys is illustrated in the Appendix.



(a) Horizontal Poured Casting (b) Vertical Poured Casting (Side Step Gate) (c) Whirlgate Dirt Trap

Terminology of running systems

Figure 6.20a

GATING TERMS AND METHODS

Parting Gates

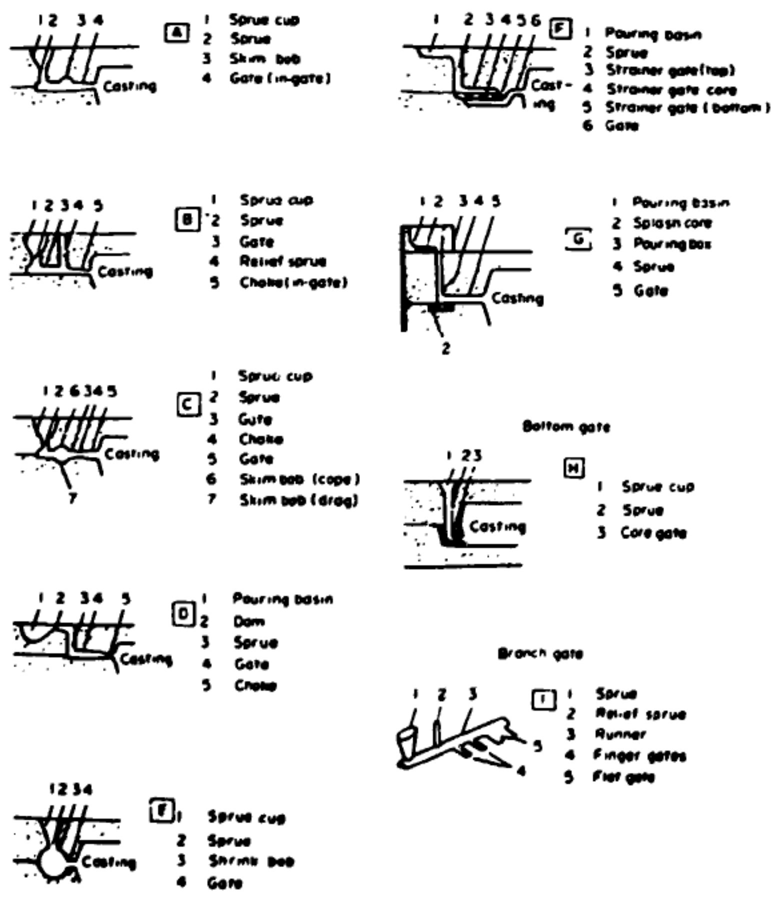
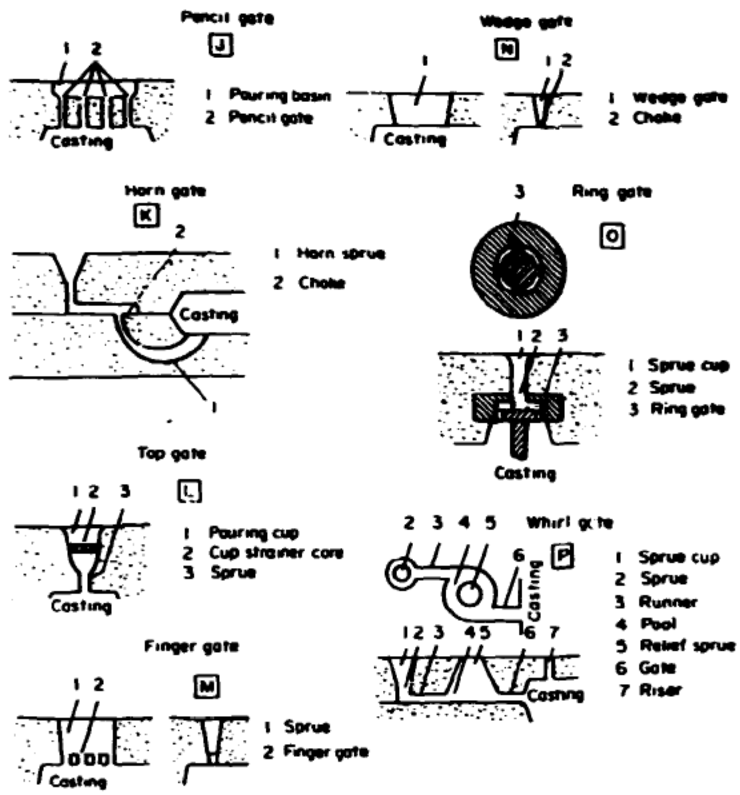
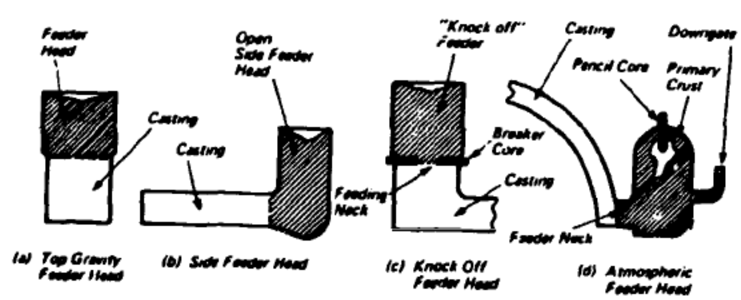


Figure 6.20b



This figure shows the nomenclature recommended by a sub-committee of the American Foundryman's Society (AFS) for the various types of gating arrangements. It is recognised that very many local terms, colloquialisms, and variants are used, but the names given are largely self-explanatory and should be identifiable everywhere.

Figure 6.20c



Feeder heads

Figure 6.21

Pouring and pouring equipment

As mentioned before one of the keys to quality lies in metal-pouring practices. Pouring of metal (clean and free of slag, in a clean pre-heated ladle, at the right temperature) should be steady and fast enough to fill the moulds without entraining of air or scum from the metal surface. Lack of proper equipment should not be permitted to detract from good procedures. Ladle equipment must allow for proper pouring rates at the desired temperature (see Table 6.12). The ladle and the metal should not tax the worker's strength. Overhead monorails with manual hoists should be used whereever possible. Ladles must be large enough to pour several moulds so that traffic to and from the source of liquid iron is held to minimum. Up to 10kg of metal can be handled in one-man shank ladles, while up to 50-60 kg can be carried in two-man shank ladles. Above this limit, overhead lifting facilities are essential. Small- to medium sized moulds are poured most effectively with one-man ladles suspended and transported on a monorail. Large castings are poured from geared ladles carried by an overhead bridge crane. Automatic pouring systems are designed to operate alongside or over a line of moulds issuing from a high pressure moulding unit; they are generally based on induction heated pressurized holding furnaces and the molten metal is dispensed directly into the mould via a teapot arrangement or through an automatically actuated stopper oerated pouring orifice, sited in an intermediate tundish. Such systems are becoming established in the aluminium industry and are also applicable to irons. The widespread use of immersion pyrometers for measuring and controlling metal pouring temperatures assist considerable in preventing problems. Ladle drying and heating equipment, preferably gas-fired, is needed to prevent the loss of metal temperature that occurs in tapping into unheated ladles. Thorough drying will minimize the possibility that moisture will remain in the refractory ladle lining and that the metal will absorb gas.

7. Castings

Castings, the products of the metal founding industry, are manufactured in a simple step from liquid metal. Casting is amongst the oldest and most versatile of the metal-shaping processes. There are virtually no restrictions to the type of metal or alloy that can be cast, although it is usually beneficial to use alloys designed for castings. Castings are available commercially in a wide range of alloy systems based on at least the following: aluminium, cobalt, copper, gold, "iron and steel", lead, magnesium, nickel, platinum, silicon, silver, tin, titanium, uranium,zinc and zirconium. Special cast alloys have been developed for the provision of a wide range of requirements including, high strength, toughness and fatigue properties; performance at cryogenic temperatures; oxidation, corrosion and wear resistance, special electrical and magnetic properties, etc.

7.1 Iron castings

Iron castings are important engineering materials and they afford the designer and user the widest selection of properties at the lowest cost of any available materials.
During the past two decades, iron casting has undergone rapid developments. Modern iron foundries are now routinely producing castings to tolerances and metallurgical specifications meeting high level quality and applicability demands. Iron castings will continue to be redesigned into thinner, lighter, more functional shapes to take advantage of better metallurgy and improved process control. The basic kinds of cast iron are:

(i) white iron (includes also chilled and mottled iron);
(ii) malleable iron (generally as ferritic or standard malleable iron, bainitic malleable iron, pearlitic malleable iron);
(iii) grey iron (most widely used for general engineering purposes);
(iv) ductile iron (also known as nodular iron or spheroidal graphite (SG) iron, and shows ferritic, pearlitic and heat treated types);
(v) compacted graphite iron (CG).

Each of the above kinds may be moderately alloyed or treated (heat) without changing its basic classification.

The chemical composition of unalloyed iron suitable for different

Table 7.1a:

CHEMICAL COMPOSITION OF UNALLOYED IRONS SUITABLE FOR DIFFERENT CLASSES OF CASTINGS

Where it is intended to make alloy additions to obtain improved properties, the analysis given may be taken as that of the base iron. To obtain the maximum benefit from the alloys it is intended to add, it will be necessary to adjust the base composition, before making the additions, so as to balance it with respect to the influence of the elements to be added.

Class of Casting	Size	Total Carbon	Silicon	Manganese	Sulphur	Phosphorus
Acid Resisting	Thin	3.25	2.0	0.75	0.05	0.4
	Medium	3.00	1.5	1.0	0.05	0.3
	Thick	3.00	1.0	1.25	0.05	0.2
Agricultural	Thin	3.75	3.0	0.60	0.06	1.3
	Medium	3.50	2.5	0.70	0.08	1.0
	Thick	3.25	2.0	0.80	0.10	0.75
Air Cylinders	Thin	3.40	1.8	0.75	0.08	0.6
	Medium	3.20	1.50	1.0	0.1	0.4
	Thick	3.0	1.0	1.0	0.1	0.3
Annealing Boxes	1" sect.	2.9	0.75	0.5	0.08	0.2
Balls for Mills	Medium	3.0	0.90	1.0	0.15	0.6
Bed Plates	Thin	3.5	2.0	0.70	0.08	1.0
	Medium	3.3	1.75	0.75	0.10	0.75
	Thick	3.2	1.5	0.8	0.10	0.50
Brake Shoes	Medium	3.25	1.5	1.50	0.10	0.60
Car Wheels	Thick	3.0	1.0	1.0	0.12	0.3
Do.—Chilled	Thick	3.3	0.7	0.8	0.13	0.3
Caustic Pots	Medium	3.25	1.25	0.75	0.08	0.3
Chills	Medium	3.5	2.5	0.75	0.05	0.2
Chilled Rolls	Small	3.3	0.8	0.3	0.05	0.5
	Medium	3.2	0.7	0.3	0.06	0.4
	Large	3.0	0.6	0.3	0.07	0.3
Couplings	Medium	3.3	1.75	0.7	0.08	0.5
Crusher Jaws	Medium	3.4	1.0	1.0	0.15	0.5
	Large	3.2	0.8	1.2	0.1[illegible]	0.4
Cylinders—Ammonia	Medium	3.0	1.5	1.0	0.1	0.8
Do.—Automobile	Small	3.25	1.9	0.8	0.1	0.4
	Medium	3.0	1.75	1.0	0.1	0.3
Do.—Gas Engine and Diesel	Small	3.5	2.0	0.6	0.08	0.5
	Medium	3.25	1.50	0.8	0.09	0.4
	Large	3.0	1.25	1.0	0.10	0.3
Cylinders—Hydraulic	Medium	3.25	1.5	0.8	0.1	0.40
	Thick	3.0	1.0	1.0	0.12	0.30
Do.—Locomotive	Medium	3.5	1.75	0.8	0.09	0.75
Do.—Steam	Thick	3.25	1.5	1.0	0.1	0.50
Do.—Motor Cycle	Thin	3.3	1.8	1.0	0.1	0.80
Dynamo Frames	Small	3.25	3.0	0.5	0.05	0.60
	Large	3.00	2.5	0.5	0.06	0.50
Electric Work	Thin	3.40	3.25	0.5	0.06	1.25
	Medium	3.25	2.50	0.6	0.08	1.00
Engine Frames	Medium	3.50	2.0	1.0	0.08	1.00
	Large	3.25	1.5	1.0	0.1	0.75
Fan Cases	Medium	3.3	2.25	1.0	0.08	1.0
Fly Wheels	Thin	3.[illegible]	2.0	0.6	0.07	0.7
	Medium	3.2	1.75	0.8	0.08	0.5
	Thick	3.0	1.25	1.0	0.10	0.3

Table 7.1b:

CHEMICAL COMPOSITION OF UNALLOYED IRONS SUITABLE FOR DIFFERENT CLASSES OF CASTINGS

Class of Casting	Size	Total Carbon	Silicon	Manganese	Sulphur	Phosphorus
Friction Clutches	Thin	3.6	2.75	0.6	0.06	0.7
	Medium	3.5	2.50	0.7	0.08	0.5
Gears	Small	3.5	2.25	1.0	0.08	1.0
	Medium	3.25	1.75	1.0	0.09	0.7
	Large	3.00	1.50	1.0	0.10	0.5
Glass Moulds	Small	3.50	2.50	0.5	0.07	0.5
	Medium	3.30	2.0	0.75	0.08	0.3
	Large	3.20	1.75	1.0	0.10	0.2
Grate Bars	1" Thick	3.20	1.25	1.0	0.12	0.3
Grinding Balls	Small	3.25	1.5	0.3	0.10	0.3
Grinding Plates	Medium	3.5	0.6	0.6	0.12	0.3
Hardening Pots	Thin	3.2	1.0	0.6	0.06	0.2
Hardware	Thin	3.5	2.75	0.6	0.08	1.5
Heat Resisting	Medium	3.3	1.6	1.0	0.08	0.25
	Thick	3.0	1.2	1.0	0.10	0.10
Hollow Ware	Thin	3.5	2.7	1.0	0.07	1.5
Ingot Moulds	Medium	3.6	1.5	1.0	0.06	0.1
	Large	3.3	1.2	1.0	0.05	0.1
Machine Tools	Thin	3.50	2.3	0.75	0.08	1.0
	Medium	3.25	2.0	1.0	0.1	0.75
	Thick	3.00	1.2	1.0	0.1	0.50
Mine Car Wheels	Medium	3.1	1.0	0.75	0.1	0.40
Mowers	Thin	3.5	2.5	0.50	0.1	1.0
Ornamental Work	Thin	3.6	3.0	0.50	0.05	1.25
	Medium	3.5	2.75	0.60	0.05	1.00
	Thick	3.25	2.50	0.70	0.06	0.75
Permanent Moulds	Medium	3.5	2.3	0.90	0.07	0.4
Do.—M. Castings	Medium	3.2	3.0	1.0	0.06	0.8
Piano Frames	Medium	3.4	2.5	0.8	0.08	0.6
Pipes (Water)	Thin	3.5	2.5	0.6	0.1	1.0
	Medium	3.3	2.25	0.8	0.1	1.0
Do.—(Steam)	Medium	3.25	1.50	0.9	0.07	0.3
Pistons (Automobile)	Thin	3.3	1.8	0.7	0.1	0.7
Do.—Rings	Thin	3.5	2.0	0.7	0.1	0.7
	Medium	3.25	1.75	0.8	0.1	0.5
Plough Points	Thin	3.25	1.0	0.9	0.08	0.3
Pulleys	Thin	3.6	2.75	1.0	0.07	1.0
	Medium	3.3	2.25	1.0	0.08	0.75
	Thick	3.0	1.75	1.0	0.10	0.6
Radiators	Thin	3.5	2.5	0.7	0.06	0.8
Rolls	Medium	3.2	0.7	0.3	0.1	0.4
	Large	3.0	0.6	0.5	0.1	0.2
Soft Castings	Thin	3.7	2.75	0.5	0.05	0.6
	Medium	3.5	2.50	0.6	0.06	0.5
Slag Pots	Medium	3.3	1.70	0.8	0.07	0.2
Stove Plates	Thin	3.5	2.7	0.5	0.06	1.0
	Medium	3.25	2.25	0.6	0.08	1.0
Typewriter Frames	Thin	3.5	2.30	0.5	0.07	1.0
Valves	Thin	3.3	2.2	0.6	0.07	0.6
	Medium	3.0	1.8	0.8	0.08	0.5
	Thick	2.8	1.2	1.0	0.1	0.3
White Iron Castings	Medium	3.0	0.8	0.4	0.15	0.5

Table 7.2:

A summary of the main foundry characteristics of various kinds of cast iron

Foundry properties	Grey irons	CG irons	Ductile irons
Fluidity	Good	No difference at same C.E.V./ temperature	
Dross	None	Dross forming	Bad dross forming
Chill formation	Moderate	Moderate-heavy	Heavy
Typical inoculation	0.1-0.3%	0.2-0.5%	0.5-1.0%
Feeding	Often unnecessary	Some feeding required	Heavy feeding required
Typical yield	80-90%	75-80%,	60-65%
Fading	None	Pour quickly	Pour immediately
Heat treatment	None [illegible]	May be necessary to break down carbides or for ferritisation	Probably necessary to break down carbides and for ferritisation

Table 7.3a:

Typical fatigue properties for various cast iron.

Type of cast iron		Tensile strength MPa	Unnotched fatigue		V-notched fatigue	
			Fatigue limit MPa	Endurance	Fatigue limit MPa	Reduction factor
Grey iron	20	138	63	0.46	63	1.0
	25	172	82	0.48	79	1.03
	30	206	103	0.50	94	1.1
		232	152	0.65	108	1.4
		294	161	0.54	131	1.26
Malleable iron	ferritic	329	193	0.58	147	1.32
	Pearlitic	570	263	0.46	154	1.7
Ductile iron	60-45-12	490	210	0.43	145	1.4
	80-55-06	621	276	0.44	166	1.7
	120-90-02	931	330	0.36	207	1.6
CG iron	ferritic	388	178	0.46	100	1.77
	Pearlitic	414	185	0.45	108	1.72

Table 7.3b:

summary of tensile and hardness properties for various cast iron.

grades of cast iron		yield strength 0.15% offset PSi	N/mm²	Tensile strength PSi	N/mm²	Elongation	Brineel hardness	modulus of elasticity psi x 10⁶	GPa	Remark
grey iron ASTM A48-47	class 25	15000	103	25000	175	Nil	187	16.6	114	
	class 30	20000	137	30000	206	Nil	207	17.0	117	
	class 40	25000	175	45000	310	Nil	235	18.2	126	
Malleable iron	ferritic	32000	220	50000	345	10	174	22.8 to 24.6	157 to 169	
	pearlitic	40-90000	275-620	60000 105000	414 724	1-10	241-301	22.4 to 25.8	154 to 177	
Compacted graphite iron	Type 1	65000	448	65000	448	1% min	217-270	20 to 23	137 to 158	% Pearlite 90% min
	2	50000	345	50000	345	1% min	163-241			10-90%
	3	40000	276	40000	270	3-5% min	130-179			10% max.
Ductile iron ASTM A-536-77	60-40-18	60000	414	40000	276	18	149-187	25 to 27	172 to 186	ferrite
	65-45-12	65000	448	45000	310	12	170-207			ferrite & pearlite
	80-55-06	80000	552	55000	379	6	187-255			pearlite & ferrite
	100-70-03	100000	690	70000	483	3	217-269			pearlite
	120-90-02	120000	828	90000	621	2	240-300			tempered martensite

Table 7.3c:

INFLUENCE OF THE ELEMENTS NORMALLY PRESENT IN CAST IRON ON THE PHYSICAL PROPERTIES

Element	Fluidity	Softness	Shrinkage	Strength	Density	Chill	Sulphur	Combined Carbon	Graphite
Combined Carbon	Decreases	Decreases	Increases	Increases	Increases	Increases	Neutral	—	Decreases
Graphite	Increases	Increases	Decreases	Decreases	Decreases	Decreases	Neutral	Decreases	-
Silicon	Increases	Increases	Decreases	Decreases	Decreases	Decreases	Decreases	Decreases	Increases
Manganese	Increases	up to 1% Increases	Little effect	Increases	Increases	above 1% Increases	Decreases	Increases	Decreases
Sulphur	Decreases	Decreases	Increases	Decreases	Increases	Promotes	—	Increases	Decreases
Phosphorus	Increases	Decreases	Aggravates	Decreases	Neutral	Little effect	Neutral	Tends to Increase	Neutral

Table 7.4:

INFLUENCE OF SOME ALLOYING ELEMENTS USED IN THE PRODUCTION OF CAST IRON UPON ITS STRUCTURE

Element	Percentage most frequently used	Effect on chill	Effect on structure	Comments
Aluminium	Up to 2.0	Reduces. 1.0% is approximately equivalent to 0.5% Silicon.	Stabilises Ferrite. Increases and coarsens the Graphite. Decreases the hardness.	Generally used in small percentages as a deoxidant and scavenger only.
Chromium	0.15 to 1.00	Increases. 1.0% approximately neutralises the graphitising effect of 1.0% Silicon.	Stabilises Cementite. Reduces and refines the Graphite. Increases the hardness.	Used for hardness, chilling power and wear resistance.
Copper	0.5 to 2.0	Decreases. 1.0% is approximately equivalent to 0.35% Silicon. Assists in control of chill depth.	Tends to increase and refine the Graphite.	Toughens the matrix and increases the fluidity.
Manganese	0.3 to 1.25	By first combining with Sulphur it tends to reduce the chill. In excess of this amount it increases the chill. 1.0% of Manganese neutralises about 0.25% Silicon.	Stabilises Austenite. Refines the Graphite and Pearlite.	Also acts as a deoxidiser. Gives grain refinement, density and increased fluidity.
Molybdenum	0.30 to 1.00	Increases. 1.0% is as effective as about 0.33% Chromium and neutralises the effect of 0.35% Silicon.	Refines the Graphite and Pearlite.	Used chiefly in combination with Nickel, Copper and Chromium in the production of high strength irons.
Nickel	0.10 to 3.00	Decreases. 1.0% is about equal to 0.33% Silicon and offsets the chilling effect of about 0.33% Chromium.	Stabilises Austenite. Refines the Pearlite and Graphite.	Improves the density and toughness. Evens out the hardness between light and heavy sections.
Silicon	0.5 to 3.50	Reduces.	Stabilises Ferrite. Increases the quantity and coarseness of the Graphite.	Softens, weakens and imparts an open grained structure.
Titanium	0.05 to 0.10	Decreases powerfully.	Increases but refines the Graphite.	Used chiefly as a deoxidiser and degasser. Improves fluidity.
Vanadium	0.15 to 0.50	Increases strongly. 1.0% Vanadium offsets the chill reducing influence of about 1.75% Silicon.	Stabilises Cementite and improves the structure of the chill.	Increases hardness and resistance to wear and heat.
Zirconium	0.10 to 0.30	Mildly reduces.	Assists formation of Graphite	Reduces hardness. Deoxidises and improves the fluidity and density.

Table 7.5:

Commonly Desired Component Characteristics and Metal Properites Related to Them

Desired Component Characteristic	Related Material Property
Static strength	Yield strength
Dynamic strength	Endurance (fatigue) limit
Shock overload	Crack propagation energy at service temperature
Machinability	Microstructure and hardness
Wear resistance	Hardness and microstructure
Weight	Density
Vibration absorption	Specific damping capacity
Corrosion resistance	Alloy content or coating
Strength at temperature	Stress rupture strength
Accuracy as finished under load at temperature	Stress relieved Modulus of elasticity Coefficient of thermal expansion vs. that of other components
under load at temperature	Creep rate
Oxidization resistance	Alloy content
Heat shock resistance	Thermal fatigue-Related to thermal conductivity divided by modulus of elasticity

Table 7.6:

Advantages of using magnesium-ferrosilicon

1	LOW COST	By using silicon instead of more expensive carriers, magnesium-ferrosilicon is an economical form of adding magnesium to iron. The low levels of magnesium in Elkem magnesium-ferrosilicon give high recoveries, allowing smaller additions.
2	INCREASED CONSISTENCY	The lower magnesium content in Elkem magnesium-ferrosilicon reduces reactivity and gives more consistent results. Use of the cerium-bearing grades neutralises contaminants in iron that hinder the formation of the nodular-graphite structure.
3	BETTER ENVIRONMENT	The less reactive alloys offered by Elkem substantially reduce smoke and flare. Special grades and sizes for the mould nodularising and tundish practices allow environmentally sound production without expensive fume-collection equipment.
4	HIGHER DEGREE OF NUCLEATION	The controlled calcium and cerium levels in magnesium-ferrosilicon give higher nodule counts with improved physical properties. These ingredients also reduce the amount of post inoculant needed to get as cast, carbide-free structures.

Typical nodulariser analyses

% Range	Mg	Ce	Ca	Al	Si
Reg alloy	5–6	0.4–0.6	0.6–1.0	0.5–1.0	46–50
High Ce	5–6	0.8–1.2	0.8–1.2	0.5–1.0	46–50
Remag	2.5–3.5	1.75–2.5	0.4–0.8	0.5–1.0	46–50
High Mg	8–10	0.4–0.6	0.6–1.0	0.5–1.0	46–50

Increasing the cerium added by magnesium-ferrosilicon yields higher nodule counts, especially in thin sections. It also eliminates hard iron carbides that reduce machinability.

EFFECT OF CERIUM ON NODULE COUNT OF CASTINGS HAVING DIFFERENT SECTION THICKNESSES

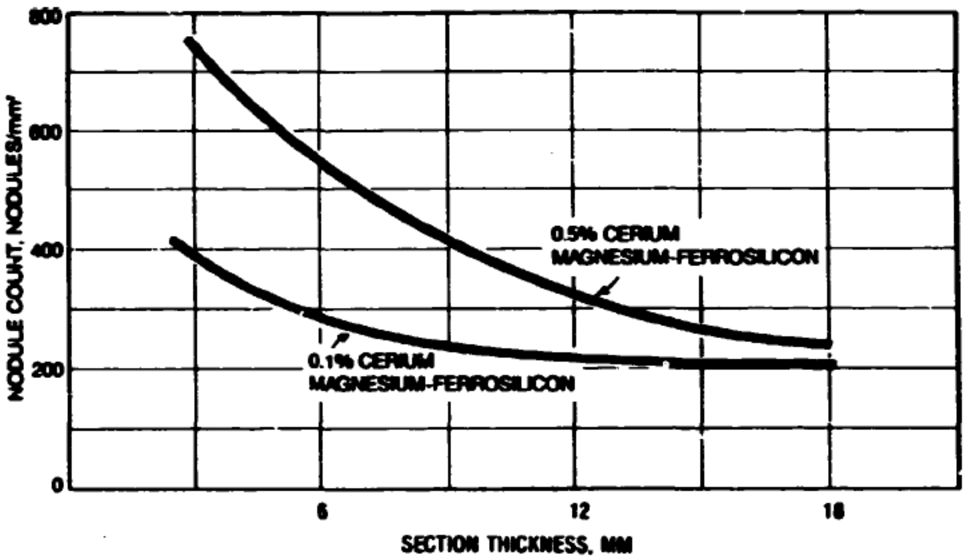


Figure 7.1

classes of casrings are given in the Tables 7.1a and 7.1b, and Table 7.2 illustrates the main foundry characteristics of various kinds of cast iron. A summarized illustration of typical properties for various kinds of cast iron is given in the Tables 7.3a and 7.3b. The influence of the elements normally present in cast iron on its physical properties can be obtained from table 7.3c. The high alloy irons, generally containing over 3% of added alloy, can also be classified as white, grey or ductile iron, but the high alloy irons are classified commercially as a separate group. In these irons, the alloy content (up to 50%) is sufficiently high to change rather than just modify the properties of the base iron (see again the Tables 7.1a and 7.1b). To obtain the maximum benefit from the alloys it is intended to add, it will be necessary to adjust the base composition, before making the additions, so as to balance it with respect to the influence of the elements to be added. The information necessary for this purpose is given in the Table 7.4. The functional requirement of a product or component may be simple or quite complex. For some applications, concern may only be necessary for the manufacturing proprties such as machinability. for other uses, there may be several critical requirements. Some of the common component requirements and the metal properties related to each requirement are listed in Table 7.5. Some special requirements (e.g. very low thermal expansion, non-magnetic characteristics etc.) are usually specialised by their chemical compositions, e.g. high silicon iron, high chromium iron etc. An illustrative example to this regard is afforded by means of Table 7.6 and Figure 7.1.

7.2 Steel castings

The production of steel castings is more difficult than the production of iron castings, due principally to the fact that the melting point of steel is higher than that of cast iron so that higher melting and pouring temperatures are necessary. It is not possible to melt steel in cupolas nor in rotary furnaces. Steel may be melted in some types of crucible furnace; however most steel foundries use electric furnaces. Medium frequency iduction furnaces, although expensive, are the most suitable for steel castings. Arc furnaces may be used for producing heats of 150 kg and greater. Maintenance problems are less critical compared to induction furnaces.

If special types of alloy steel are being made - for example for wear or corrosion resistance-it may be necessary to use special basic

(Chromite or Magnesite) furnace linings. Many steels can be made from scrap, although it is likely to be necessary to check the composition in a laboratory and to add ferro alloys or alloying metals if close specifications have to be met. Control of the melting operation and metal composition is even more important for steel than for cast iron. Steel castings have different shrinkage behaviour from that of iron castings. Pattern design, runner systems and other techniques are different. In particular steel castings require larger feeders to ensure the absence of shrinkage cavities. The yield of good castings to metal melted is therefore usually lower for steel than for cast iron. One advantage of steel castings over cast iron castings is their weldability, so that they may be repaired if necessary and joined to other components by welding. Steel castings may be made in green sand moulds (without coal dust), shell moulds, dry sand, CO_2 sand and other types of moulds. Some types of chemical binders may have to be specially selected for steel castings to avoid the risk of surface defects. Most steel castings have to be heat treated (normalised or annealed) after casting or after weld repair. Heat treatment furnaces fired by oil, gas, electricity or solid fuel, should be well insulated to avoid heat wastage. A typical heat treatment is to heat the castings to 850°C and hold them at that temperature for 2 hours. The castings are then cooled slowly in the furnace to anneal them, or withdrawn from the furnace to cool in the air if they are to be normalised. Furnaces capable of providing controlled heat treatment at this temperature have to be carefully designed and constructed. In general the production of steel castings requires more specialised equipment and more complicated technical processes than does the production of grey iron, aluminium, or bronze castings. An experienced small-scale foundry should not attempt to produce steel castings without comprehensive external advice and assistance.
Table 7.7 briefly gives the American Specifications for steel castings. For more information regarding steelcasting the reader be referred to the UNIDO publication IPCT/ᴾ.3, December 1986.

7.3 Non-ferrous metal castings

Aluminium: Aluminium castings should ideally be made from different alloys from those which are generally used for rolled aluminium

AMERICAN SPECIFICATIONS FOR STEEL CASTINGS

Carbon and Low Alloy Cast Steels

ASTM	A 27-62 Mild to Medium-Strength Carbon-Steel Castings for General Application.
ASTM	A 148-60 High-Strength Steel Castings for Structural Purposes.
ASTM	A 216-63T Carbon Steel Castings Suitable for Fusion Welding for High Temperature Service.
ASTM	A 217-60T Alloy Steel Castings for Pressure Containing Parts Suitable for High Temperature Service.
ASTM	A 352-60T Ferritic Steel Castings for Pressure Containing Parts Suitable for Low Temperature Service.
ASTM	A 356-60T Heavy-Walled Carbon and Low Alloy Steel Castings for Steam Turbines.
ASTM	389-60T Alloy Steel Castings Specially Heat Treated for Pressure Containing Parts Suitable for High Temperature Service.
ASTM	A 486-63T Steel Castings for Highway Bridges.
ASTM	A 487-63T Low Alloy Steel Castings Suitable for Pressure Service.
SAE	1962 Automotive Steel Castings.
AAR	M 201-62 Steel Castings.
ABS	Am. Bur. Shipping Steel Castings—1964 Rules Edition—Machinery and Hull Castings.

Lloyds' Register of Shipping 1963—Steel Castings.

High Alloy Cast Steels

ASTM A128-60	Austenitic Manganese Steel Castings.
ASTM A296-63T	Corrosion-Resistant Iron-Chromium and Iron-Chromium-Nickel Alloy Castings for General Application.
ASTM A297-63	Heat Resistant Iron-Chromium and Iron-Chromium-Nickel Alloy Castings for General Application.
ASTM A351-63T	Ferritic and Austenitic Steel Castings for High Temp. Service.
ASTM A447-50	Chromium-Nickel-Iron Alloy Castings (25-12 Class) for High Temp. Service.
ASTM 448-50	Nickel-Chromium-Iron Alloy Castings (35-15 Class) for High Temp. Service.
MILITARY	MIL-S-16993A December 1954 Steel Castings (12 per cent Chromium).
	MIL-S-867A December 1951 Steel Castings Corrosion Resisting Austenitic.

Table 7.7

products. Most aluminium castings are made from alloys with about 5%, 7% or 13% silicon.Tables 7.8a, 7.8b and 7.8c illustrate aluminium casting alloys, their characteristics and their chemical composition according to the British Standards 1490, respectively.

Copper: The most commonly produced copper casting alloys are brass and bronze. The original bronze alloys were of copper with tin as the main alloying element. Such a wide variety of bronze and gunmetal alloys now exist, however that it has become necessary to classify them according to their basic chemical composition. Table 7.9a gives some examples. Table 7.9b shows the order in which various elements are added in the alloying of copper and nickel alloys. The base metal with which the melt commences is usually marked as "1", whilst the various elements added afterwards are marked under their respective heading with the number giving their stage of addition.
Example: GUNMETAL. 88% Copper, 10% Tin, 2% Zinc. Charge crucible with "1" copper, then add "2" tin, afterwards "3" zinc.

Table 7.10 summarizes outstanding characteristics of casting alloy groups, as influences in characteristics.

ALUMINIUM CASTING ALLOYS—LM SERIES

USES AND GENERAL REMARKS

Table 7.8a

LM0	Mainly used for sand castings for electrical, chemical, and food applications.
LM2	One of the two most widely used alloys for all types of die castings.
LM4	The most versatile of the alloys; has very good casting characteristics and is used for a very wide range of applications. Strength and hardness can be greatly increased by heat treatment.
LM5	Suitable for sand and chill castings requiring *maximum resistance* to corrosion, e.g. marine applications.
LM6	Suitable for large, intricate, and thin-walled castings in all types of moulds; also used where corrosion resistance or ductility is required.
LM9	Used for applications especially low-pressure die castings requiring the characteristics of LM6 but higher tensile properties following heat-treatment.
LM10	Mainly used for sand and chill castings requiring high strength and shock resistance. Requires special foundry technique; heat-treated.
LM12	Mainly used where a very good machined surface finish and hardness is required.
LM13	Mainly used for pistons.
LM16	Suitable where high mechanical properties are desired in fairly intricate sand or chill castings. Requires heat-treatment.
LM18	Combines good foundry characteristics with high resistance to corrosion.
LM20	Mainly used for die castings. Similar to LM6 but a little better machinability and hardness.
LM21	Generally similar to LM4-M in characteristics and applications but better machinability and higher proof strength.
LM22	Used for chill castings requiring good foundry characteristics with good ductility. Requires heat treatment.
LM24	One of the two most widely used alloys for all types of die castings.
LM25	Suitable where good resistance to corrosion combined with high strength is required.
LM26	Mainly used for pistons as alternative to LM13.
LM27	A versatile sand and chill casting alloy introduced as an alternative to LM4 and LM21.
LM28	Piston alloy with lower coefficient of expansion than LM13. Requires special foundry technique.
LM29	As LM28 but lower coefficient of expansion.
LM30	For unlined die-cast cylinder blocks with low expansion and excellent wear resistance.

The Tables appearing on pages 127–138 inclusive are based on data given in The Properties and Characteristics of Aluminium Casting Alloys, published by the Association of Light Alloy Refiners and Smelters (Alar), London.

Table 7.8b:

CASTING CHARACTERISTICS

BS 1490	Sand casting	Chill casting	Die casting	Fluidity	Resistance to hot-tearing	Pressure tightness
LM0	F	F	F	F	P	F
LM2	G*	G*	E	G	E	G
LM4	G	G	G	G	G	G
LM5	F	F	F*	F	F	P
LM6	E	E	G	E	E	E
LM9	G	E	G*	G	E	G
LM10	F	F	F*	F	G	P
LM12	F	G	U*	F	G	G
LM13	G	G	F*	G	E	F
LM16	G	G	G*	G	G	G
LM18	G	[illegible]	G*	G	E	[illegible]
LM20	E*	E	G	E	E	E
LM21	G	G	G*	G	G	G
LM22	G*	G	G*	G	G	G
LM24	F*	F*	E	G	G	G
LM25	G	E	G*	G	G	G
LM26	G	G	F*	G	G	F
LM27	G	E	G*	G	G	G
LM28	P	F	—	F	G	F
LM29	P	F	—	F	G	F
LM30	*	F	G	G	G	F

*Not normally used in this form.
E—Excellent G—Good F—Fair P—Poor U—Unsuitable

Table 7.8c:

CHEMICAL COMPOSITION (%)*

BS 1490	Cu	Mg	Si	Fe	Mn	Ni
LM0	0.03	0.03	0.30	0.40	0.03	0.03
LM2	0.7-2.5	0.30	9.0-11.5	1.0	0.5	0.5
LM4	2.0-4.0	0.15	4.0-6.0	0.8	0.2-0.6	0.3
LM5	0.1	3.0-6.0	0.3	0.6	0.3-0.7	0.1
LM6	0.1	0.10	10.0-13.0	0.6	0.5	0.1
LM9	0.1	0.2-0.6	10.0-13.0	0.6	0.3-0.7	0.1
LM10	0.1	9.5-11.0	0.25	0.35	0.10	0.10
LM12	9.0-11.0	0.2-0.4	2.5	1.0	0.6	0.5
LM13	0.7-1.5	0.8-1.5	10.0-12.0	1.0	0.5	1.5
LM16	1.0-1.5	0.4-0.6	4.5-5.5	0.6	0.5	0.25
LM18	0.1	0.10	4.5-6.0	0.6	0.5	0.1
LM20	0.4	0.2	10.0-13.0	1.0	0.5	0.1
LM21	3.0-5.0	0.1-0.3	5.0-7.0	1.0	0.2-0.6	0.3
LM22	2.8-3.8	0.05	4.0-6.0	0.6	0.2-0.6	0.15
LM24	3.0-4.0	0.1	7.5-9.5	1.3	0.5	0.5
LM25	0.1	0.20-0.45	6.5-7.5	0.5	0.3	0.1
LM26	2.0-4.0	0.5-1.5	8.5-10.5	1.2	0.5	1.0
LM27	1.5-2.5	0.3	6.0-8.0	0.8	0.2-0.6	0.3
LM28	1.3-1.8	0.8-1.5	17-20	0.7	0.6	0.8-1.5
LM29	0.8-1.3	0.8-1.3	22-25	0.7	0.6	0.8-1.3
LM30	4.0-5.0	0.4-0.7	16-18	1.1	0.3	0.1

*—single figures in this table are maxima b—0.2% in castings

Zn	Pb	Sn	Ti	Others
0.07	0.03	0.03	-	Al 99.50 min
2.0	0.3	0.2	0.2	—
0.5	0.1	0.1	0.2	—
0.1	0.05	0.05	0.2	—
0.1	0.1	0.05	0.2	—
0.1	0.1	0.05	0.2	—
0.10	0.05	0.05	0.2[a]	—
0.8	0.1	0.1	0.2	—
0.5	0.1	0.1	0.2	—
0.1	0.1	0.05	0.2[b]	—
0.1	0.1	0.05	0.2	—
0.2	0.1	0.1	0.2	—
2.0	0.2	0.1	0.2	—
0.15	0.1	0.05	0.2	—
3.0	0.3	0.2	0.2	—
0.1	0.1	0.05	0.2[c]	—
1.0	0.2	0.1	0.2	—
1.0	0.2	0.1	0.2	—
0.2	0.1	0.1	0.2	Cr 0.6; Co 0.5
0.2	0.1	0.1	0.2	Cr 0.6; Co 0.5
0.2	0.1	0.1	0.2	—

Table 7.9a:

COPPER ALLOYS—BRONZES AND GUNMETALS

TIN BRONZES:—Copper-based alloys having tin as the main alloying element. Alloys having between 3% and 7% tin are not normally produced as castings but in billet form for subsequent drawing or rolling operations. Alloys containing between 15% and 20% tin are widely used for the casting of bells. As the tin content reaches this magnitude, the alloy becomes increasingly harder and difficult to machine.

PHOSPHOR BRONZES:—Copper based, having from 5% up to 10% tin as the main alloying constituent together with an intentional phosphorus addition which may vary from 0.5 to 1.0%. These alloys are used to make what are widely known as phosphor-bronze bearings. Tin provides the necessary toughness for the alloy whilst phosphorus additions give castings the necessary hardness and therefore, wear resistance.

GUNMETAL:—Copper based, with tin and zinc as the alloying constituents. Tin usually predominates and an example of this type of alloy is Admiralty gunmetal, 88% copper, 10% tin, 2% zinc. This alloy is used for a variety of purposes, ranging from casting of gears and bearings to hydraulic castings and castings subjected to moderate stresses.

LEADED GUNMETAL:—Copper based with tin, zinc, and lead present in varying proportions. Numerous alloys of this type exist, a widely known example being 85/5/5/5 alloy, in which tin, zinc and led are present in equal proportions. These alloys are extremely popular thoughout the world and are used for a number of purposes, mainly in the casting of hydraulic components, plumbers' fittings, etc. They are also used as bearing alloys operating under moderate loads.

LEADED BRONZE:—Copper-tin, or copper-tin-phosphorus alloys containing from 5-15% lead. These alloys are used almost exclusively for casting heavy duty bearings, in which wear resistance combined with the ability to undergo plastic deformation is required.

Table 7.9b:

	Copper	Tin	Zinc	Lead	Nickel	Phos-phorus	Remarks
Brass	1	—	2	—	—	—	Stir very well after zinc has been added
Naval brass	1	*2	3	—	—	—	Stir very well after zinc has been added
Gunmetal copper, tin, zinc, such as 88/10/2	1	*2	3	—	—	—	Stir well before pouring
Gunmetal with lead such as 85/5/5/5.	1	*2	4	3	—	—	Stir very well before pouring
Bronzes such as 90% copper, 10% tin	1	*2	—	—	—	—	Stir well before pouring
Phosphor bronze	1	3	—	—	—	**2 **4	Stir well
Nickel silver or white metal	***2	3 if any	5	5	***1	—	Stir very well
Cupro nickel or *nickel bronzes*	***2	—	—	—	***1	—	Stir well

*Deoxidise well with deoxidising tubes DS before "2" is added.

**Phosphorus is best added as phosphor copper. Half the total amount before "3" is added, the other half afterwards.

***Charge the total amount of nickel, then add as much of the copper as crucible will hold. Then commence melting and continue to add copper as melt proceeds in the usual fashion.

Table 7.10:

OUTSTANDING CHARACTERISTICS OF CASTING ALLOY GROUPS, AS INFLUENCES IN SELECTION

Alloy type	*Main positive characteristics*	*Examples of applications emphasising main characteristics**
Cast iron (grey)	Low cost combined with appreciable hardness, tensile strength and rigidity; high compressive strength; high damping capacity and thermal shock resistance; excellent founding qualities for complex designs	Manhole cover; tunnel segment; lathe bed; i.c. cylinder block; brake drum; ingot mould; gear blank; piston ring
(ductile, malleable and special)	Higher tensile strength with ductility; wear resistance; corrosion resistance, low or moderate cost	Crankshaft; agricultural implements; ball mill liner; pump and valve components for acid plant
Steel (carbon and low alloy)	High yield and tensile strength, stiffness and strength–weight ratio, combined with toughness and fatigue resistance, at moderate cost	Track link; aircraft undercarriage member; mill housing; die block; heavy duty gear blank
(high alloy)	Corrosion resistance under a wide range of conditions; resistance to high temperature creep and oxidation; abrasion resistance	Water turbine runner; pump and valve components; gas turbine casing; radiant tube; tube support; carburising box; excavator bucket lip; rock crusher jaw
Copper alloy	Corrosion resistance, especially to seawater, combined with high strength if required; bearing properties; electrical properties	Marine propeller; hydraulic and steam pump and valve components; rolling mill bearing; switchgear contacts; gear blanks
Aluminium alloy	High strength-weight ratio; useful corrosion resistance, especially to atmospheric corrosion; high thermal diffusivity; comprehensive range of cast products and alloys available at moderate cost	Clutch housing; automotive piston; i.c. cylinder head; exhaust manifold; marine fittings; beer cask
Magnesium alloy	High strength–weight ratio; low density; intricate sand and die castings available	Crankcase; transmission casing; binocular body
Nickel alloy	High corrosion resistance; strong resistance to high temperature creep and oxidation	Pump and valve components for chemical plant; gas turbine blade.
Zinc alloy	Pressure die cast forms give intricate components of reasonable strength and toughness by mass production at low cost	Radiator grill; door handle; carburettor body

* The selected examples, although typical, are neither fully nor exclusively representative of the alloy groups. Many properties and applications are common to several groups of alloys, the more specialised applications cannot be included in a brief review

8. Finishing of castings, quality control and reclamation

8.1 Finishing of castings

After cooling and solidifying in the mould -for from 20 minutes to 24 hours depending on size- castings are separated and removed from their sand moulds and boxes by hand or by means of equipment such as shaking beams, vibrating knock-out grids, punch and devices, rotating drums, or by shot blasting units. The operation is dusty and noisy and suitable environmental control measures must be observed. Castings are then ready for their finishing processes and the type, number and sequence of these depend upon the composition and quality requirements of the casting and the process by which the casting was made. Finishing costs can constitute up to 30% of the total process costs for ferrous castings.

Finishing involves:

(i) cleaning, the removal of moulding material and scale,

(ii) removal of excess metal such as feeder heads, runner systems, and any metal that is superflous to the casting,

(iii) removal of blemishes and defects; rectification is usually affected by welding,

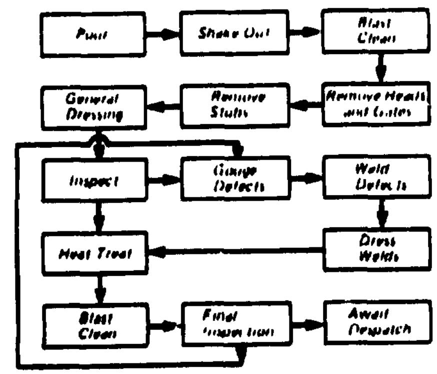
(iv) smoothing over of weldments, areas from which metal has been cut, or any rough areas on the casting surface, generally by grinding.

These operations may be referred to as fettling or dressing. Finishing in a wider sense includes also heat treatment, checking, gauging, straightening, testing and inspection and in some cases, surface treatments such as polishing, plating annodizing, painting, etc. Tables 8.1a and 8.1b illustrate characteristics of some finishing operations. Figure 8.1 shows as an example the sequence of operations for finishing plain carbon steel castings.

Methods of cleaning castings: The methods available for cleaning castings are many and varied selection depending on cost and application. In some non-ferrous applications shot blasting is too severe and alternative methods are required. Principal cleaning methods are: wire brush, water blast (hydroblast), chemical methods (pickling, leaching), tumbler barrel, vibratory cleaning, ultrasonic cleaning, powder brushes, air blast cleaning, shot blasting. The most common method employed for cleaning castings, is shot blasting.

Table 8.1a: CHARACTERISTICS OF CLEANING OPERATIONS

Operation	*Techniques used*	*Remarks with respect to adaptation by developing countries*
Knock-down	By hand with shocks and hammers	Correct notching on gates and risers allows easy breaking both during and after knocking out
	By power with disc saws, abrasive discs, presses, and other equipment	Except for special cases, the use of abrasive discs and of portable tools may be best
Sandblasting (particular care must be paid to dust removal from abrasive steel shot)	In compressed air cabin	Advisable for large to medium (greater than 50 kg) size castings. This is a cheap method.
	Rotatory table or rotatory belt technique with abrasive throwing impellers	The type fitted with small chamber seems to be the most suitable
	Suspended table or monorail belt technique with abrasive throwing impellers	A good but expensive means for continuous production
	In tumbling barrel with castings and abrasives	Suitable for rough castings. Cheap, noisy and not very productive
Finishing		
Chipping	Hand operated pneumatic tool on bench or conveyors	Pneumatic tools are used on fixed bench for small castings or on the floor for large to medium castings
Press operation	Machines are arranged to trim casting residues or to coin in the final stage. Technique generally used for long run castings	Only for nodular cast iron castings



—Sequence of operations for finishing plain carbon steel castings

Figure 8.1

Table 8.1b:

Operation	*Techniques used*	*Remarks with respect to adaptation by developing countries*
Grinding	Portable air grinder Swing or supported fixed grinders and special and multiple grinders	Portable grinders may be used for medium and large castings. Swing or pedestal supported grinders are recommended for small castings
Heat treatment	Single or double hearth furnaces Continuous furnaces Standard or neutral atmosphere	A double hearth furnace could be used for special and spheroidal graphite cast-iron treatment: tightness could be assured by means of sand and lute
Checking		
Casting composition analysis	Chemistry, spectographs, and other means	
Visual	Lights and magnifying lenses	Defined standards must be set
Dimensional	Gauges, inspection fixtures, marking-off instruments	To be manufactured in-house
Surface integrity	Penetrating fluids—different techniques create and detect magnetic field	The used penetrating fluids should be sufficient for most cases. A careful inspection may require the use of a magnetoscope
Metallurgic structure	Reflection microscope	A 1 000 to 2 000 magnification optical microscope
Internal integrity	Penetrating radiation including X-rays and ultrasonic vibration	An X-ray apparatus (300 kW) may be bought for large-scale productions
Moulding sand	Instruments for checking hardness, humidity, strength, permeability and grade fineness	

Blasting can be defined as: the cleaning, smoothing, roughening or removing of part of the surface of any article by the use of an abrasive, of a jet of sand, metal shot or grit, or other material, propelled by a blast of air or steam or by a wheel.

Types of shot blasting equipment: Shot blast rooms and cabinets have the advantage of flexibility and effective cleaning through the close control of the hand-held hose. The final choice of equipment is to be governed by the type, size and output of castings. Tables 8.2, 8.3 & 8.4 illustrate the variety of machines available and can be used as a general guide for machine selection.

Types, grades and size of abrasives: The correct choice of abrasive type will have considerable influence on whether the objectives of the process are met at the optimum cost. Metallic abrasives appear in two major forms, shot and grit. Non-metallic abrasives, eg aluminium oxide, glass beads, etc are used where iron contamination is not acceptable - as on stainless steels and non-ferrous metals. Table 8.5 lists principal types of metallic abrasives. To obtain optimum cleaning conditions, a "balanced" mixture of particle sizes is required in the machine. Table 8.6 is intended as a guide to the grades of chilled iron and steel abrasives in general use.

Shot blast process and its operation: Having selected the best abrasive type and size for a given application it is essential that users carry out the correct operating procedure being dependent upon the following criteria:

(i) process requirements

(ii) process control

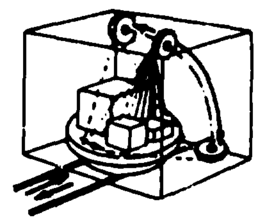
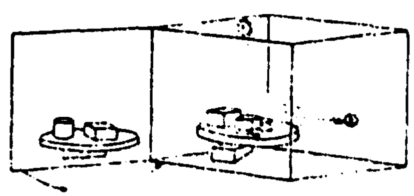
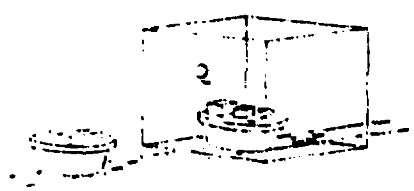
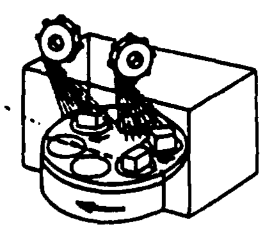
(iii) operators training

(iv) process problems and their proper solution

(v) disposal of waste material (if recycling or further use not possible)

Table 8.7 afford possible solutions to common problems encountered in sand blasting. Maintenance: Shot blast machines are maintenance intensive since they are subject to a high rate of wear relative to operational time when compared to most other items of foundry plant. Table 8.8 can be used as a guide for the design of a preventive maintenance programme. Costs of shot blasting: The cost of work processed can differ widely because of a plethora of reasons, e.g. machine characteristics, work handling, abrasive type, rework, maintenance etc, but most important of all is the human element. No matter how carefully the parameters of the process are monitored

Table 8.2: Table machines

Type of machine	Sketch	Size and type of casting	Features	Notes
Plain table		Mixed loads, usually medium to large castings	1 to 3 impellors (15-40 hp)	Table rotates. Suitable for fragile castings
Swing door table		Mixed loads, usually medium to large castings	1 to 2 impellors (20-40 hp)	Can be of single or double door type
Twin-table shuttle type		Medium to small parts	1 impellor (15 hp)	
Multi-satellite table		Flat castings	1 to 2 impellors (20 hp)	

N.B. A feature of all table machines is that castings must be physically turned over to expose the surfaces to be shot blasted.

Table 8.3: **Tumble machines**

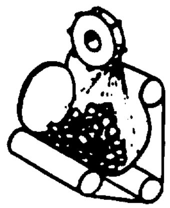
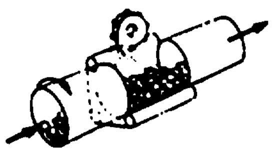
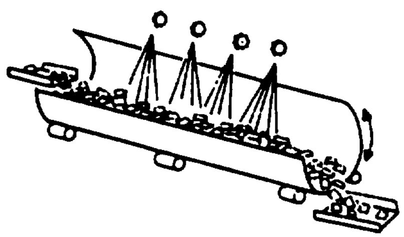
Type of machine	Sketch	Size and type of casting	Features	Notes
Batch barrel		Very wide range of casting weights, but castings must be robust.	1 to 2 impellors (5-75 hp)	Thorough cleaning of all faces
Continuous barrels		As for batch.	1 to 2 impellors (25 hp)	
Continuous oscillating barrel		Mixed loads, small to medium castings	Up to 8 impellors (30 hp)	Very high output.

Table 8.4: **Continuous machines**

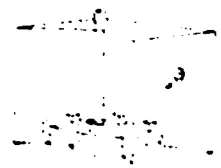
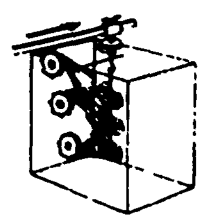
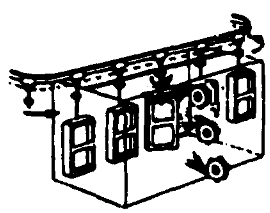
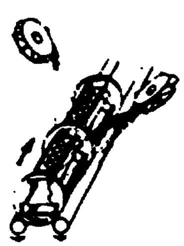
Type of machine	Sketch	Size and type of casting	Features	Notes
Continuous table		Small to medium	1 to 3 impellors	Operator loads, turns and unloads castings on the exposed segment of the table
Continuous belt		Small to medium	1 to 3 impellors	Rubber belt with downthrowing wheels
Hook		Very useful for medium to large complex castings	Multi-wheels 1 to 4 impellors (15-30 hp)	Casting powered into and out of cabinet on hook
Monorail		Medium to large	Multi-wheels (20-40 hp)	High production rates. Can be used as knockout machine
Ram cage/tunnel		Medium — cage is designed to suit the casting	Multi-wheel	Special purpose machine very high output. Castings or cages rammed against one in front as they pass through shotblast tunnel.

Table 8.5:

Characteristics of principal types of abrasive

Abrasive type	Typical hardness	Guide specification	Microstructure
Chilled iron	56-64 RC	2.80/3.20 %C; 1.00/2.00 %Si; 0.50/1.50 %S; 0.20/1.00 %P; 0.50/1.00 %Mn	Network of carbides in a matrix of martensite
Malleable iron	30-40 RC	As for chilled iron	Nodules of temper carbon in a matrix of pearlite
Cut wire pellets		Cut from wire with a tensile strength of 161-180 Kg/mm^2	
Steel	40-50 RC	0.85/1.20 %C; 0.40 min. %Si; 0.05 max. %S; 0.05 max. %P; 0.60/1.20 %Mn	Uniformly tempered martensite with fine, well distributed carbides

Table 8.6:

Typical grades of steel and chilled iron abrasives used for cleaning various castings

	Shot (round)		Grit (angular)	
Castings	BSI/SAE	BSI	SAE	Nominal size (mm)
Grey iron				
Large	S550-S460	G55-G47	G14-G16	1.40/1.20
Medium	S460-S390-S330	G47-G39-G34	G16-G18-G25	1.20/1.00/0.85
Small	S330-S230	G24	G25	0.85/0.60
Malleable				
Large	S550-S460	G55-G47	G14-G16	1.40/1.20
Medium	S390-S330	G39-G34	G18-G25	1.00/0.85
Small	S330-S230	G34(G24)-G17	G25-G40	0.85/0.60/0.42
Steel				
Large	S780-S660	G66-G55	G12-G14	2.00/1.70/1.40
Medium	S550-S460-S390	G47-G39	G16-G18	1.40/1.20/1.00
Small	S330-S280	G39-G34	G18-G25	1.00/0.85
Non-ferrous				
Large	S230-S170	G17-G11	G40-G50	0.60/0.42/0.30
Medium	S110	G11-G07	G50-G80	0.13/0.18
Small	S70	G07	G80	0.18

Table 8.7: **Common problems encountered in shot blasting**

Complaint	Check	Action	Effect
1. Excessive or increased abrasive usage	(a) The plant structure for severe leakage also seals and wheel hoods	(a) Repair as quickly as possible all sources of major leakage	(a) Poorly balanced operating mixes
	(b) The coarse and fine dust (dust collector) discard for serviceable abrasive contamination	(b) Adjust separator controls and main duct blast gates	(b) Underloaded impellor wheels
	(c) The plant pit for excessive spillage	(c) Return to the plant as quickly as possible and determine source of spillage. Used abrasive should be reclaimed with equal amounts of 'new' abrasive.	(c) High operating costs
	(d) Incorrectly adjusted 'blast pattern/s' which allows abrasive to miss the workload and hit hard metal wear plates	(d) Locate control cages in correct positions	(d) Abrasive starvation
	(e) Excessive 'carry out' with the workload due to casting design e.g. cylinder blocks	(e) Establish a system to 'empty' the castings and return spillage to plant	(e) Poor cleaning
	(f) When last addition to the abrasive charge was made	(f) Additions of new abrasive should be small and regular	(f) Inefficient separation systems
	(g) Work hanging/placing techniques have been changed	(g) Investigate blast area	
	(h) Abrasive quality	(h) Following laboratory checks contact abrasive supplier	
2. Poor cleaning	(a) Ammeter reading as indication of: i Abrasive starvation ii Underloaded 'impellor wheels'	a (i) and d Replenish but not a large addition of new material (mix with spillage or with new middle/fine grades whichever required)	(a) High cost and bottlenecks in the plant
	(b) Incorrectly adjusted control cage settings, blast patterns missing or not correctly positioned on workload	(ii) Check worn blades, replace if required or reset abrasive control valve	
	(c) Workload incorrectly positioned causing masking	(c) Carry out blast pattern checks and adjust accordingly if required	
	(d) Poorly 'balanced' operating mix		
3. Inefficient separation	(a) Abrasive levels in the storage hopper/s	(a) Make additions of new abrasive but not in large amounts	(a) Poorly balanced operating mix
	(b) Protecting screening systems (rotary sieves, scalping trays) are not partially blocked with contaminants	(b) Free blockages	(b) A dust laden atmosphere around the machine area
	(c) Spreader plates worn or incorrectly positioned	(c) Worn plates replaced and correctly located	(c) Poor cleaning
	(d) Adjustable baffle/swinging baffle are correctly positioned	(d) & (e) Correct adjustment of baffles	(d) Becomes difficult to achieve consistent surface finish
	(e) Adjustable 'skimmer' plate is correctly located	(e) Free the pipes and hoppers	(e) A 'build up' of fines affects directional control of the blast patterns
	(f) The coarse dust pipe or hopper/s are not blocked		(f) Excessive 'fines' increase plant wear and particularly impellor blades
	(g) The blast gate/s in the separator/cabinet exhaust lines are correctly adjusted to allow the required air velocity through the unit or orifice		(g) A greater load is put on the dust collector than it was probably designed for
	(h) Dust collection/filtration equipment is working efficiently i.e. airflow is adequate	(h) Check with manometer	
4. Inefficient use of impellor wheels	(a) Tensioning of 'V' drive belts		(a) Lengthy cleaning cycles
	(b) Ammeters functioning correctly		(b) Unsatisfactory finish
	(c) Abrasive hopper levels		
	(d) The abrasive feed to the impellor wheel/s for restrictions, (hopper, feed trough, feed pipe, wheel assembly)		
	(e) The abrasive valves for correct adjustment		

Table 8.7 (continued):

Complaint	Check	Action	Effect
5. Excessive machine wear Poor cleaning	Over/underloading the equipment	Correct situation as quickly as possible	(a) Underloading causes increased plant wear and abrasive usage (b) Overloading reduces cleaning efficiency and results in a reblast condition (c) Indiscriminate loading can result in masking of certain areas of the work causing reblasting
6. Abrasive starvation	(a) The abrasive curtain across the separator weir plate, i.e. it is of uniform distribution (b) The angle or repose of the abrasive in the storage hopper in relation to the position of the feed pipes feeding the impellor wheels (c) There is no preferential charging of abrasive to one area of the machine, e.g. monorail plants (d) Unavoidable excessive spillage is being returned to the plant on a regular basis	(a) Adjust spreader plate/swinging baffle to produce even curtain (b) Add new abrasive but not in large amounts (d) Replenish with abrasive of equal amounts to both ends of the machine	
7. Tumbler apron jamming	(a) Condition of cabinet interior (b) Slack chain (c) Machine loading (d) Suitability of casting for machine	(a) Repair or adjust for wear (b) Repair or adjust for wear (c) Check for over/under loading (d) Use alternative type of machine if appropriate	(a) An incomplete abrasive curtain causes uneven abrasive distribution across the hopper

Maintenance check programme (daily/weekly basis)

Cabinet check . . .
1. Loading doors, seals, entrance/exit vestibules for abrasive losses.
2. Interior for wear which may indicate incorrect blast patterns, inefficient work loading/hanging techniques.
3. Wheel hoods and lining plates.
4. Abrasive spillage and return any to the machine.

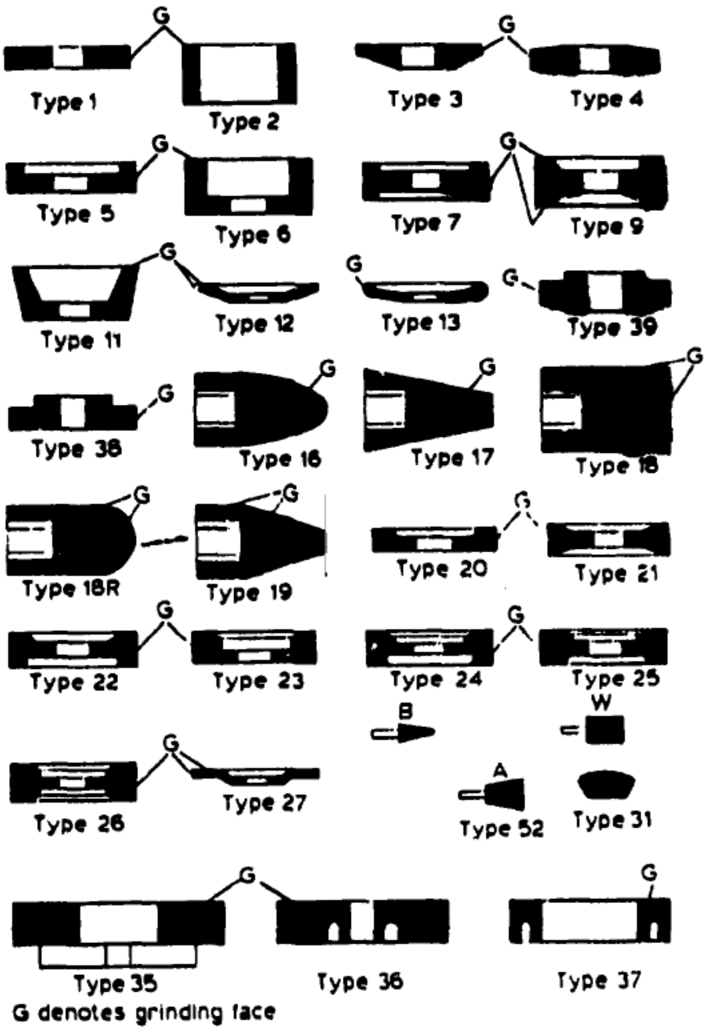
Separator system check . . .
1. Shedder plates, baffle plates, hopper structure for wear.
2. Abrasive curtain flows uniformly and covers the air orifice.
3. Discharge from both separator and dust collector.
4. Hopper for abrasive level.

Dust collector and ventilating system check . . .
1. Atmosphere around blast cleaning equipment, to ensure that it is free from dust.
2. Blast gate settings are unaltered.
3. Duct work for leaks.
4. Manometer reading.
5. Dust hoppers are empty.
6. Shaker mechanism is functioning correctly.
7. Dust bags or filters.

Abrasive feed system check . . .
1. Abrasive valves for free operation and correct opening.
2. Feed pipes, feed spouts, screws.
3. Elevator belt for tension, worn or missing buckets.
4. Scalping screens/mesh protection for holes or blockage.

Wheel units and instruments check . . .
1. Wheel for vibration.
2. Impellor blades/control cages for wear.
3. Wheel belts.
4. Blast pattern for correct location.
5. Ammeter for accuracy.

Table 8.8



Standard types and shapes of grinding wheels.

Table 8.9

and controlled, unless the operator is given the correct training and supervision, shot blasting can cost considerably more than necessary. Since different types of machines exhibit different performance levels and hence operational costs, it is important in machine selection and/or operational control to have knowledge of the relative running costs of individual machines. A shot blast analysis schedule is presented in the Appendix of this profile and indicates the information required to assess the relative operating costs of differing machines. In general considerable savings can be made by paying careful attention to ways of reducing the amount of shot blasting carried out: (i) only shot blasting when necessary,

(ii) pay attention to storage conditions of castings,

(iii) ensure the shot blasting machine is running at its optimum efficiency,

(iv) minimise the incidence of flash, burn-on and other surface defects.

Dressing of castings: On release from the mould a casting is rarely in a satisfactory condition for immediate despatch to the customer. After cleaning it will require some dressing before it is acceptable to the customer. It has been stated that dressing accounts for between 10 and 60% of the cost of producing a casting. The variation within this range may be accounted for by numerous factors among which are:

(i) complexity of the casting
(ii) customers' requirements
(iii) foundry production methods
(iv) condition of pattern corebox equipment
(v) condition of foundry production equipment etc.

Not all of these are fully within the control of the producing foundry although to a greater or lesser extent it will have opportunities to influence some or all of the factors.

Meeting customers' specifications is the deciding factor in dressing but the production facilities available to the foundry will dictate the amount necessary in order to produce in the most economic manner. The as-cast casting, having been cleaned by shot blasting, or a similar method, reaches the dressing shop and:

(i) may have varying degrees of flash around the joint line or core prints which require trimming;

(ii) if ductile as-cast, feeders normally remain which require cutting off;

(iii) excess material such as feeder pads, gates, risers, ties and cracking strips will have to be removed;

(iv) certain cosmetic operations may be required to correct the following faults: a) rough surface finish
b) ram off
c) finning
d) swelling
e) metal penetration
f) sand inclusions

(v) where a heat treatment has been carried out, a straightening operation may be necessary.

Thus the amount of dressing required will depend on the production facilities available, the care taken and control exerted during production and the decisions taken at the planning stage.

Methods of dressing castings: The various processes and procedures associated with the dressing operations may be summarised as:

(i) grinding
- a) pedestal or stand grinders
- b) swing frame grinders
- c) rotary hand tools
- d) automatic grinders
- e) abrasive belt machines

(ii) flash removal
- a) hand held hammer and chisel
- b) percussion tools
- c) barrelling

(iii) special operations
- a) machine dressing
- b) press broaching
- c) feeder head removal

(iv) ancillaries
- a) manipulators
- b) robots

The dressing shop may also be required to cater for some reclamation by welding and while it is not required as a dressing operation, many customers require castings to be painted before despatch to obviate rusting.

Abrassives used: The properties required of any substance to be used as an abrasive are: (i) the appropriate hardness;
(ii) available as particles in the mesh size;

required;

(iii) chemically and physically it must not present a health hazard when in use;

(iv) ability of the particles to be bonded in a desired shape or to a rigid or flexible substrate:

(v) the substance must be available:

a) in controlled quality

b) in quantity

c) at a price commensurate with its acceptability for the above purpose.

To apply abrasives effectively for the purpose of dressing castings, the grit particles must be coated with a suitable bond, moulded to shape at an appropriate density or coated on a substrate, hardened, finally shaped and tested to ensure suitability for purpose and safety in use. Grinding wheels are available in various specifications, according to the type of metal to be ground and the speed of the grinding machine. The Grinding Wheel Institute of America and the American Standards Society established a list of grinding wheel shapes which assigns type numbers to recognised shapes of wheels in general demand and these type numbers are internationally accepted as the primary description of a wheel shape. Table 8.9 illustrates a list of these types: numbers 1,4,6,11,16,17,18,18R,19,27 and 52 being applicable to fettling. It is dangerous practice to exert side pressure on thin grinding wheels and only type 27 (depressed centre wheels) are specifically designed for this use.

Maintenance requirements of dressing equipment: Maintenance of dressing equipment is essential to ensure the continuity of production of castings of consistent quality and known cost. Poorly maintained tools and machinery will cost more in interrupted or lost production than an efficient, in-house "service exchange" system for hand tools, or cost effective planned maintenance applied to machinery.

a.1) Hand tools: electrically, pneumatically, hydraulically operated grinders; chipping hammers; deburring tools.

a.2) Maintenance requirements: airline filter lubricator; tool service exchange maintenance; dressing both dust extractor filter.

b.1) Grinding: stand grinders; swing frame grinders; flashline trimmers.

b.2) Maintenance requirements: time based visual inspection of wearing parts; lubrication; condition monitoring of impeller bearings and

and vibration analysis; condition monitoring of associated dust extraction equipment.

c.1) Shot blasting: manually operated; mechanical airless.

c.2) Maintenance requirements: time based visual inspection of wearing parts; lubrication; condition monitoring of impeller bearings and vibration analysis; condition monitoring of associated dust extraction equipment.

8.2 Metal cutting

Feeder heads and runner systems are separated from the casting by oxygen/fuel gas cutting, sawing, shearing or with brittle alloys simply by manual knock-off.

Oxygen/fuel cutting or flame cutting is commonly used to sever feeder heads and ingots from steel castings and the fuel gas may be acetylene, propane or natural gas. When used in conjunction with iron powder (powder cutting) it is effective for cutting oxidation resistant alloys. Band sawing is commonly used with non-ferrous castings, particularly those in aluminium alloys and permits the operator to follow the contour to the casting more closely than other cutting methods. It is also used with other alloys. Abrasive cutting, can be used virtually on any alloy and is the only method of severing excess metal in some ultra hard alloy castings. Gold shearing is employed as a fast and economical method of removing small feeder heads and stubs of ingate systems providing the cast alloy is relatively soft, e.g. malleable iron, low carbon steel, copper, aluminium, magnesium and zinc based alloys.

One of the most widely used methods for removing excess metall from steel castings as well as employed for cutting ingates and feeder heads from stainless, SG, iron and non-ferrous castings in the air-carbon arc process. It is much more economical than methods using pneumatic chisels, portable grinding machines etc.

Maintenance requirements for arc/air cutting equipment: time based visual inspection of wearing parts.

Other finishing operations include: visual inspection of castings through their finishing operations; rectification of defects by welding; straightening of castings, where required by hydraulic press or die operation and where the alloy permits this. heat treatment etc.

Automation of many operations in high-capacity foundries has been the key in attaining very large volume output with important reductions in labour and over-all costs. Its consideration in a small foundry is justifiable only where improved uniformity in quality can be attained, since the productive output possible cannot be absorbed.

8.3 Casting quality and control and casting reclamation

To attain the primary goal of a high standard of quality in the foundry product, techniques of control must be employed. The goal of a properly organised quality control programme is to ensure uniformity in operating conditions and the resulting product.
The raw materials used in both product and process must be standardized and determined. The quality control department should be given the authority to reject incoming material not conforming to specification, although it may not be feasible to sample all purchased materials such as refractories or slag materials. The most important function of a quality-control department is to establish standards of performance for the foundry process and to undertake the routine testing required to ensure adherence to those standards. This includes routine sampling of liquid metal at the furnace, a regular check on tapping and pouring temperatures, testing of backing and facing sand and checking heat-treating schedules and temperature. Regular tests are made on the physical properties of the metal from test bars and of hardness of the castings. Whether castings are acceptable for shipment or further machining depends on their dimensional accuracy, the surface quality and the casting soundness.

Laboratory facilities: The willingness and frequently necessity of small scale foundries to be technically upgraded lead to the inclusion of a testing laboratory as a part of their operational concept.
If such facility is not located nearby (university or other institution) the establishment of a properly equipped laboratory as physical component of the foundry in question is essential.

Inspection and testing of castings: Inspection and testing of the finished casting are necessary steps to ensure that the product shall meet the buyer's specification. The extent of testing and inspection depends on the use to which castings are to be put. Many defects are visible on the outside of the castings. Such defects include cracks, blow holes etc. Other defects may have to be checked in other ways (eg. by measuring of dimensions of castings or by weighing castings). Some castings are subject to internal porosity, which is difficult to detect without expensive special purpose ultrasonic or X-ray equipment.

A list of equipment recommended for inclusion in each laboratory is given in the Appendix. A summary of non-destructive techniques used by foundries is also presented there.

Casting reclamation

Castings which fail to meet inspection requirements can sometimes be reclaimed or repaired. In steel foundries rectification by welding is an important and accepted part of the production cycle, rectification and repair by fusion welding. Manual metal arc with coated electrodes is universally used; developments of this are low hydrogen electrodes, shielding gases such as CO_2 and argon, submerged arc and electro-slag.

Cast iron is usually regarded as a difficult material to weld but reclamation repairs are by no means uncommon. Only the softer irons are welded although malleable and SG irons may be repaired if subsequently heat treated. Welding methods include: oxy-acetylene gas welding, metal arc welding using nickel-base rods and copper brazing; repairs are usually confined to non-critical areas.

All copper-base alloys except the high lead type can be welded but repairs are best confined to the one-off type rather than small, long production castings. Normal method is metal arc or inert gas arc using high heat input and the deposition of large amounts of weld. Inert gas is generally superior.

Welding is used to repair aluminium alloy castings and best welding methods are inert gas shielded metal arc (MIG) or argon or helium tungsten arc (TIG). Some aluminium alloys are 'hot short' and should not be welded, where welding is practicable it should be done before heat treatment.

Impregnation (Sealing): Sealing may be used where castings are rejected due to lack of pressure tightness from dispersed porosity. The technique is mainly used with aluminium and copper based alloys and occasionally with irons. The technique is not intended for salvaging castings with severe shrinkage.

9. Raw materials: specification and consumption

Effective control of the quality of the product and of its cost requires that all raw materiala be purchased to a specification and then, upon receipt, be checked for conformity to the specification. In establishing limits for a purchased material, the capability of the vendor to meet the specification must be taken into account. The most important goal of any specification for a purchased material is to ensure uniformity. The exact value is not as critical as having the material conform to the limits consistently. (The material flow for a typical modern iron foundry has been already illustrated in the Figures 4.2a and 4.2b).

Metallic charge

The furnace charge may consist of pre-alloyed pig or "ingot", virgin metals and "hardener" alloys, scrap from outside sources or from internal fettling and machine shops, or any mixture of these materials. The task of melting depends on the state of division as wellas the composition of the charge. Large pieces, for example pigs and heavy scrap, have a small surface area and are therefore least susceptible to melting losses and contamination. Finely divided bulky materials such as swarf or turnings are much less satisfactory: they are most readily absorbed by feeding directly into a liquid bath this introduces dangers of gas contamination. It is nevertheless economically desirable that these materials be returned to the production cycle at the earliest stage if necessary by premelting and casting in denser form: this also assists in maintaining accurate control of composition, although double melting losses are then incurred. The question of materials utilization in furnace charges is one in which the computer is finding increasing application, both for calculation of minimum cost charges and for subsequent adjustment of bath composition to secure precise control.

Pig iron: Uniformity of carbon-silicon levels from lot to lot is essential, while low values for phosphorus and sulphur are desirable. Certfication by the supplier of the chemical analysis of each lot should be required. For use in the manufacture of ductile iron, the content of manganese, sulphur, phosphorus and trace of subversive elements must be as low as possible.

Cast-iron, purchased scrap: Uniformity is the principal characteristic required. Scrap should be segregated by type of casting, such as auto blocks, ingot moulds, machine tool frames.

Steel scrap: The composition of process scrap from a forge or stamping shop is more constant than the miscellaneous material obtained from scrapping automobils, machinery, ships etc. Alloy steels must be segregated from carbon steel scrap. Many foundrymen are often in doubt when faced with a scrap casting, and very often the cure is obtained by rule-of-thumb methods, no direct approach to the trouble being made. It is hoped that the Tables 9.1a and 9.1b will help in a quicker diagnosis of scrap and its cure.

Ferro-alloys and inoculants: All materials should be purchased with a certified statement of the chemical analysis. It is more important to know the actual chemical composition than to purchase materials to restrictive specifications on composition. Alloys required are ferro-silicon (45% and 75%), high- and medium-high carbon ferro-manganese and ferro-chromium, ferro-molybdenum and nickel. For ladle additions of molybdenum and chromium, special compounds are available that combine readily at the lower melting point of iron.

Fluxes

Specifications on limestone and fluorspar depend on the availability of the materials locally. Size and minimum moisture content are important elements to control.

Fuels

If fuel oils are used for melting furnaces, the sulphur content should be restricted to below 1%. Light oil is preferable to heavy, paraffin-base oils, since the latter must be preheated to ensure adequate and uniform viscosity. The quality of coke employed as a fuel in cupola furnaces directly affects the metallurgical performance of the furnace and its efficiency. Most specifications set limits for ash content, volatile matter, combustibility and reactivity in addition to particle size and impact strength. Where a good grade of foundry coke is scarce or even unavailable, it may be necessary to use a lower grade of coke, such as gas-retort coke or hard wood charcoal. In this case, the cupola melting practice must be adapted to the grade of fuel used. Low sulphur content in the material is desirable if obtainable.

Scrap Diagnosis—Its Cause and Cure with Particular Application to Iron Castings

Many foundrymen are often in doubt when faced with a scrap casting, and very often the cure is obtained by rule-of-thumb methods, no direct approach to the trouble being made. It is hoped that the following list will help in a quicker diagnosis of scrap and its cure.

Defects	Appearance	Cause	Remedies
MISRUN	May appear as: 1. Holes in the thin sections of a casting. Edges are smooth and well rounded; surface of metal round holes smooth and often shiny. 2. As a line, when two streams of metal have met but not fused together. Fracture may occur along this line. Casting surface may be smooth and shiny.	1. Low pouring temperature. 2. Low fluidity. 3. Hard mould (mainly on very thin casting). 4. Core shift, causing uneven thicknesses. 5. Vent low on sand. 6. Very high moisture content. 7. Pouring practice.	1. Provide hotter metal at cupola spout; reduce heat losses in ladle by using flux coverings. 2. Increase Carbon and Phosphorus 3. Avoid excessive ramming 4. Take extra care in positioning. 5. Increase vent by means of vent wire or by adding Silica sand in mixing. 6. Reduce moisture compatible with moulding. 7. Keep runner bush full of metal during pouring.
SHRINKAGE and DRAWS	Rough cavities entering casting on heavy sections, or at the joint of change of sections. Saucer-shaped depressions on heavy sections, usually with rough edges.	1. Incorrect gating and feeding.	1. Use risers to feed heavy sections and ensure that they are filled with hot metal. If using open risers, use feeding flux, if using blind risers use feeding cores. Embody chills where a heavy section of boss cannot be fed directly with a riser.
SLAG	Similar to above. See Shrinkage and Draws (previous page). Cavities are generally more saucer-shaped and smoother. Slag may be seen before cleaning the castings.	1. Dirty metal. 2. Incorrect gating.	1. Remove all slag from metal before pouring. Thicken slag with sand before skimming. 2. Incorporate skim gates or strainer cores in runner systems. Keep runner bush full whilst pouring.
POROSITY	Castings "weep" under pressure test. Machined surfaces show cavities in thick sections or a series of pin-holes on machined skin.	1. Wrong type of metal. 2. Running and feeding system. 3. Gassy metal.	1. Reduce Silicon or Phosphorus content. 2. See shrinkage. 3. Degas and scavenge well.
HARD METAL	Bright areas on machined faces, often at corners or edges of thinnest sections. May occur as scattered hard spots. Shows, when broken, a white fracture.	1. Wrong type of metal. 2. High moisture content. 3. Pouring practice.	1. Increase Silicon content by: (*a*) altering metal mixture; (*b*) introducing Silicon into ladle. 2. Reduce moisture. 3. Avoid splashing metal down runners and risers—"plug" sprues very helpful.
SCABS	Rough "warty" excretions on surface of casting, mainly on heavy sections.	1. Uneven ramming. 2. Incorrect gating. 3. Improperly dried moulds. 4. High clay content in moulding sand.	1. Ram more evenly 2. Gate so that an even flow of metal is obtained over surface 3. Avoid too rapid drying and allow time for heat to penetrate through the mould. 4. Change moulding sand.

Table 9.1a

SCRAP DIAGNOSIS —ITS CAUSE AND CURE
WITH PARTICULAR APPLICATIONS TO IRON CASTINGS—*(continued)*

Defects	Appearance	Cause	Remedies
DISTORTION	Casting shows swelling on surface.	1. Uneven mould hardness due to insufficient ramming to withstand metal pressure. 2. Poor weighting practice.	1. Ram evenly and firmly. 2. Increase weight on moulds and ensure it is distributed evenly.
ROUGH SURFACE	Casting surface rough	1. Metal penetration. 2. Low coal dust content. 3. Hard sand surface with low permeability. 4. Moulding sand too "open."	1. Use finer sand or use mould dressing. 2. Make additions of coal dust. 3. Open up the sand. 4. Close-up sand somewhat.
CRACKS	Hair line cracks showing on casting. When broken, discoloration shows that crack was produced while casting was hot. No discoloration shows cold crack.	1. High dry strength of sand. 2. Cores too hard. 3. Casting strains. 4. Mechanical reasons.	1. Ram softer to allow casting to contract. 2. Reduce oil in cores. 3. Gate evenly to avoid these. Break mould to allow of free contraction. 4. Pack casting with wood or old tyres in tumbler. Take care in breaking off risers. See that risers are provided with correctly designed necks.
BLOW-HOLES	Rough shaped holes occurring on the outside of the casting or in the thicker sections. May be found just below surface on machining. In severe cases, section of casting may be hollow. Cavities may be dull or bright depending on conditions under which they have formed	1. Low vent or moulding or core sand. 2. Hard ramming. 3. High moisture content. 4. Rusty or damp chills and chaplets. 5. Very hard cores. 6. Insufficient venting in cores. 7. Incomplete baking. 8. Damp pouring ladles. 9. Too low a pouring temperature.	1. Increase vent by use of vent wire or open sand with additions of Silica or by the use of a coarser Silica sand. 2. Avoid excess ramming. 3. Reduce moisture to minimum, consistent with workability. 4. Ensure chaplets are dry, and coat chills with oil or proprietary dressing before use. 5. Reduce oil in sand 6. Ensure vents are clear. 7. Bake until centre is dry and hard. 8. Thoroughly dry all pouring ladles. 9. Increase pouring temperature.
DIRT	Rough cavities and pits in casting surface If examined before cleaning the sand may often be seen.	1. Strength of sand low. 2. Loose ramming. 3. Direct wash of metal on sand surface, e.g., cods, corners, etc. 4. Poor finish of gating system. 5. Displacement of sand by cores. 6. Disturbed moulds. 7. Insufficient taper on patterns.	1. Increase green bond 2. Ram evenly. 3. Avoid direct wash with well designed runners. 4. Finish of running system should be as good as mould. Make bushes and runners with good facing sand. 5. Blow out after placing cores. 6. Place weights carefully; avoid knocking moulds 7. Increase taper to allow clean lift.

Table 9.1b

Refractories

Definition - classification: The term'refractory'is applied to various heat resisting materials, the accepted definition being a non-metallic material or product (not excluding those containing a proportion of metal) having a pyrometric cone equivalent corresponding to not less than 1500^{o}C or Cone 18 (British Standards 3446 1962 "Glosary of Terms Relating to the Manufacture and Use of Refractory Materials).

Refractory materials are supplied as fired or unfired bricks or shapes, jointing cements, and as monolithic materials, known as mouldables, castables or gunning mixtures. A modern classification based on chemical composition is as follows:

(i) Basic refractory materials: Materials with a high content of alkaline earth oxides, usually those of magnesium and/or calcium.

(ii) Alumino silicates: These are materials in which the main oxides are alumina (Al_2O_3) and silica (SiO_2). They fall into a number of important groups based on the relative proportions of these two oxides present in the material in the fired state.

(iii) Special refractories: These include products based on carbon, graphite, zircon, silicon carbide, other carbides and nitrides, pure oxides, and spinels other than chromite.

Selection and financial considerations: The bricks or blocks used for lining furnaces should be selected according to the conditions to which they will be subjected. Ideally refractory materials should resist pressures from weight of the furnace parts or contents, thermal shock from rapid heating and cooling rates, mechanical wear and chemical attack from heated solids, liquids, gases and fumes when in use at high temperature. The final decision has to be made after all the technical, physical and quality trade-offs have been weighed. At the outset, decisions based solely on price can lead to selections that yield less than optimum results. With sophisticated melting equipment, such as coreless and channel furnaces, the cost of material is secondary to the total cost of downtime if the operation is running close to capacity. The most logical common denominator to use as a starting point in the refractory selection process is chemical capability between the molten metals, oxides and the refractory material. Selecting a refractory based on chemical compatibility is facilitated by a two-phase process. First, the data collection phase including:

- general description of application (ore reduction, primary melting, secondary melting, holding, reaction vessel, reheat application, etc);
- type of furnace or vessel for which refractory application is being considered (channel induction, coreless induction, etc);
- metals or alloys produced - general category (ferrous, supersl1oy, nonferrous, special alloy or pure metal, mixed campaign);
- alloy changes (deliberate changes to melt chemistry from that of incoming primary alloy or scrap, including master alloys, pure elemental additions, deoxidizers or refining agents);
- thermo mechanical considerations of furnace operation (sintering as a function of temperature, differntial expansion/thermal shock, mechanical abuse, such as charge impact abrasion, etc);
- current refractory and its performance to date (generic type, chemical composition, mode of installation/firing - including forms used, dry out and heat up schedule, final fire, initial charging and cure method on initial melt).

The second half of the process,the judgement phase of refractory selection, can begin only when allof the parameters are known. After reviewing all pertinent factors in the profile, select the four best generic choices based on chemical compatibility between molten metal and refracctory material, without considering positive or negative effects of thermal, mechanical and business/financial considerations. Screen the four choises selected above against the thermal, electrical and mechanical conditions and/or constraints in the data profile to determine if the ranking must be amended or even changed. The selection process must now focus on the feasibility of the four generic choices, recognizing existing commitments whithin the operation that cannot be changed. It is now possible to compile a viable list of specific commercial brands for generic choices derived from the sequential steps in this judgement phase of refractory selection. Vendors should be ranked and qualified according to quality of product, proximity of warehouses delivery, product shelf life, pertinent product experience, reputation, product support and application engineering capability. Tha final step in the judgement phase is the integration of the technical and business considerations, weighed against the cost of the products identified under vendor qualification and the relative risks of each choice. Risk analysis must consider the vendor's abilty to ensure repeatability of product and provide customer service with a strong problem-solving component weighed against the realism of potential cost savings. Risk analysis must include a critical review of costs of downtime, lost production, equipment repair and employee risk. Decisions should be based on the cost of the refractoru per ton of product produced and not on the unit cost alone. Obviously, greater risk can be taken if furnace utilization is low, while little risk can be assumed in a 24-hour-a-day continuous operation with low work - in - process inventory.

Types of furnaces and refractories: The type of cupola linings depends on whether acid or basic practice is employed. Because of the lower temperatures involved and reduced exposure to heating and cooling, less costly refractories may be used.
Silica-alumina fire bricks are normally used for cupolas and for rotary furnaces. In addition to fire bricks it is necessary to have heat resistant fire clay available for the preheating and repairing of furnaces. Clay by itself tends to crack and to crumble when dried, and for this reason it is usually mixed with sand or with crushed fire bricks in order to make refractory patching materials. Fire clay mixtures of this type are often used for ladle linings as well as for furnace repairs. Ladle linings must be most carefully dried and pre-heated in order to ensure that no moisture remains in the lining. If molteniron is poured onto any damp material there is a danger of boiling, splashing or explosion. Another method of lining ladles is to use sand. Some naturally bonded moulding sands are suitable for lining small ladles. Silica sand bonded with water-glass, either dried or gassed with CO_2 can also give satisfactory results. For larger ladles holding more than 200 to 300 kg of iron it is adviseable to use stronger ladle lining materials such as fire brick or fire clay mixtures.
Electric-arc, induction and reverberatory furnaces are lined generally with high-grade silica-alumina refractories containing at least 65% alumina. The tables 9.2 and 9.3 illustarte the refractory selection procedure for channel and coreless induction furnace respectively.

Table 9.2

REFRACTORY SELECTION FOR CORELESS INDUCTION FURNACES

PREDOMINANT METAL	LINING	TOPPING	SPOUT	PATCH	PRIMER	LADLE
Cast Iron						
Gray, Malleable, Alloyed	Mullite bonded alumina	Dry alumina designed to harden at low temperatures, or wet clay bonded air setting cement	Phosphate bonded alumina ramming cement (low temperature heat set)	Fine grain alumina, phosphate or silicate bonded, wet air setting patch	Fine alumina to provide base for patching	Bauxite based clay bonded general purpose ramming cement, or hydraulic setting tabular alumina castable
Ductile	Magnesia bonded alumina	Dry magnesia bonded alumina designed to harden at low temperatures	↓	Fine grain magnesia alumina air setting patch	Fine magnesia to provide base for patching	↓
Steels						
Carbon	Magnesia bonded alumina	Dry magnesia bonded alumina designed to harden at low temperatures	Phosphate bonded alumina ramming cement for low temperature heat set	Magnesia-alumina spinel forming air setting patching cement	Fine alumina for patching, primer and sealer	Hydraulic setting tabular alumina castable, or magnesia bonded dry vibration cement
	High magnesia for extremely high temperature applications	Dry vibration or wet heat setting magnesia alumina spinel forming for air melt		↓	Fine magnesia for spray or paint on sealer and undercoat for patching	↓
Stainless, Superalloy Air Melt	Alumina chrome dry vibration cement or wet heat setting ramming cement	Alumina chrome low temperature dry or wet heat setting ramming cement	Alumina chrome air setting wet ramming cement	Alumina chrome fine grained air setting patch	Fine alumina for patching, primer, and sealer	Mullite or magnesia bonded dry vibration cement, or hydraulic setting tabular alumina castable
	Magnesia bonded alumina for extremely high temperature applications	Dry magnesia bonded alumina designed to harden at low temperatures	Magnesia alumina air setting wet ramming cement	Magnesia-alumina spinel forming air setting patch	Fine magnesia for paint sealer and/or undercoat for patching	↓
High Carbon, High Manganese	High magnesia	Dry heat setting cement that is magnesia/alumina spinel forming for coreless vacuum or air melt	Phosphate bonded alumina ramming cement	Magnesia based spinel forming air setting wet ramming cement	Fine magnesia for spray or paint sealer and undercoat for patching	Hydraulic setting tabular alumina castable, or magnesia based spinel forming air setting wet ramming cement
Superalloys-Vacuum	Crystalline spinel refractory for very critical superalloys	Wet air setting fused spinel ramming cement	Wet air setting spinel or alumina ramming cement	Fine grain fused spinel patching cement	Fused spinel patch sealer/primer	(Normally none used)
	Magnesia-alumina spinel forming dry vibration cement	Magnesia-alumina spinel forming dry heat setting or wet air setting cement	Magnesia-alumina wet air setting ramming cement	Magnesia-alumina spinel forming patching cement	Fine magnesia for spray or paint sealer and undercoat for patching	Tabular alumina hydraulic setting castable
Copper Alloys						
Brass, Bronze	Mullite bonded alumina or mullite dry vibration cement with silicon carbide	Clay bonded air setting or dry heat setting cement				Mullite bonded alumina dry vibration cement, or bauxite based hydraulic setting general purpose castable, or bauxite based clay bonded general purpose ramming cement
Copper, Copper-Nickel Alloys	Magnesia bonded alumina dry vibration cement	Magnesia bonded alumina dry vibration or wet air setting cement	Phosphate or silicate bonded air setting alumina ramming cement	Phosphate or silicate bonded air setting alumina ramming cement	Fine magnesia or alumina for patch, undercoat or sealer	
	Mullite bonded alumina dry vibration cement	Mullite bonded dry vibration cement or clay bonded air setting cement				↓
Aluminum						
Alloys, Hardeners (Severe Service)	Fused alumina low temperature bonded dry vibration cement	Clay bonded air setting cement or low temperature dry vibration cement	Phosphate or silicate bonded air setting alumina ramming cement	Phosphate or silicate bonded air setting alumina ramming cement	Fine alumina for patch, undercoat or sealer, or fine magnesia as release agent for dross removal	Mullite bonded, mullite based hydraulic setting castable, or mullite dry vibration cement, or bauxite based hydraulic setting general purpose castable
Aluminum (Mild Service)	Mullite based low temperature bonded dry vibration cement	Clay bonded air setting mullite or low temperature dry vibration cement	Phosphate or silicate bonded mullite ramming cement	Phosphate or silicate bonded ramming cement	↓	

Table 9.3

REFRACTORY SELECTION FOR CHANNEL INDUCTION FURNACES

PREDOMINANT METAL	INDUCTOR	UPPER CASE	SPOUT, TOPPING, ETC.	PATCH	PATCH PRIMER OR LADLE WASHCOAT	LADLE
Cast Irons						
Ductile or Malleable (High Temperature/Power)	Magnesia alumina spinel dry vibration cement	Magnesia bonded alumina dry vibration cement	Phosphate bonded alumina ramming cement, hydraulic setting castable or clay bonded air setting cement	Clay bonded high alumina gunning cement for hot patching, or hydraulic setting alumina gunning cement for hot or cold patching, or phosphate bonded alumina ramming cement for cold patching	Fine magnesia for spray or paint sealer and undercoat for patching, or fine alumina for spray or paint sealer and undercoat for patching (Use like materials, i.e. magnesia with magnesia based; aluminum with predominantly aluminum)	Bauxite based hydraulic setting castable, or bauxite based clay bonded general purpose ramming cement
Ductile or Alloyed (Moderate Temperature; Heavy Slag in Upper Case)	Magnesia bonded alumina dry vibration cement	Alumina chrome	↓			↓
Gray or Low Temperature Malleable	Mullite bonded alumina dry vibration cement	High alumina mullite bonded dry mix fused for removable forms, or high alumina castable hydraulic setting, or clay bonded alumina		↓	↓	Mullite bonded alumina based dry vibration cement, or mullite bonded mullite hydraulic setting cement
Cuprous Alloys						
Brass and Bronzes	Mullite bonded alumina or mullite based dry vibration cement with silicon carbide	Mullite bonded alumina based dry vibration cement with silicon carbide	Phosphate or clay bonded alumina ramming cement, hydraulic setting castable	Phosphate or clay bonded alumina, mullite or bauxite based ramming cement	Fine magnesia or alumina for spray or paint sealer and undercoat for patching	Mullite bonded alumina based dry vibration cement, or mullite bonded mullite based hydraulic setting castable, or bauxite based hydraulic setting castable, or bauxite based clay bonded ramming cement
	Mullite bonded alumina wet ram with silicon carbide	Mullite bonded alumina wet ram with silicon carbide	↓	↓		
		Hydraulic setting high alumina, or bauxite based hydraulic setting general purpose castable				↓
	Bauxite based clay bonded general purpose ramming cement	Bauxite based clay bonded general purpose ramming cement				
Coppers	Mullite bonded alumina dry vibration cement with silicon carbide	Mullite bonded alumina dry vibration cement with silicon carbide	Phosphate bonded alumina ramming cement			Mullite bonded alumina with silicon carbide
Copper-Nickel Alloys	Magnesia bonded alumina dry ram for a range of nickel-bearing applications	Magnesia or clay bonded dry alumina	Phosphate bonded alumina air setting cement	Phosphate bonded alumina ramming cement, or clay bonded high alumina gunning cement for hot patching	Fine magnesia or alumina for spray or paint on sealer and undercoat for patching	Magnesia bonded dry vibration cement, or clay bonded ramming cement, or hydraulic setting castable for all copper-nickels
	Hydraulic setting high alumina castable	Hydraulic setting high alumina castable	Hydraulic setting high alumina castable			
	Spinel forming magnesia based ramming cement for high nickel copper alloys	Magnesia bonded alumina dry vibration cement		↓	↓	↓
Aluminum						
Alloys and Hardeners	Fused alumina low temperature heat setting dry vibration cement	Fused alumina low temperature heat setting dry vibration cement	Phosphate bonded alumina ramming cement	Phosphate bonded alumina ramming cement	Fine alumina for spray or paint on sealer and undercoat for patching, or fine magnesia as release agent for dross control	Mullite bonded dry vibration cement, or bauxite based hydraulic setting general purpose castable, or mullite based hydraulic setting castable
	Phosphate bonded alumina ramming cement	Mullite based hydraulic setting castable	↓	↓		
	Mullite based hydraulic setting castable	↓			↓	↓

Operation and maintenance practice: As the use of induction furnaces for melting non-ferrous metals becomes more widespread the operation and maintenance practices with respect to the refractories used in these furnaces is illustrated below.

The type of charge material should be clean and generally small in size. The best size melting stock is that which would fill the furnace to about 50-60% of capacity when starting from cold. Long and irregularly shaped pieces may be used, but care should be taken to be certain that bridging does not occur. If charging is not done properly, voids between the charge material and crucibel wall may cause localized hot or cold spots which can result in cracking and blistering of the refractory and ultimate failure. Crucibles are somewhat more sensitive than rammed linings in this respect.

During a melting cycle, if the metal or the charge has a tendency to freeze over and form a bridge, then it should be carefully broken using a steel bar. If this does not work, then the furnace should be rocked gently to allow the molten metal underneath to melt through the bridge. Under no circumstances should a furnace be operated at high power while a bridge exists. The operator should be continuously aware of the amount of kw input over a period of time for the weight of metal in the furnace.

When monolithic linings, full power should not be applied on a cold furnace at the beginning of a production day. Monolithic linings have definite cracking patterns when cooled down that reheal when the lining is heated up again. However, if molten metal begins to form in the furnace before the cracks have healed, finning will occur and lead to early failure. When starting up a cold furnace, the charge should be heated to a temperature just below the melting point of the metal and held at that level for at least a full hour before allowing any molten metal to begin to form. On furnaces larger than 2000 lb capacity, this time must be extended to 1½-2 hr, depending on size.

The major zone on the furnace lining requiring repair is the top cap and spout area. Plastic-type refractories are best suited for this, but certain damp ramming patch materials may also be used. After completion of the top cap repair, it may be desirable to use a wash-type refractory to coat the hot face of the crucible or lining. This helps to seal fine cracks and facilitates easy removal of slag or dross buildup. Even if there is not any significant wear or abuse of the top cap material, it is advisable to remove it after every ten heats or so to check to see that the backup material has not settled down unevenly behind the crucible leaving a void.

Additional tips for good crucible performance are:

- Crucibles should be unpacked when received and stored in a warm, dry place. This helps prevent the pickup of moisture.
- After installation, it is preferred to preheat the crucible to 200 F for three to four hours minimum, to aid in drying out residual moisture as well as moisture from the top cap.
- Slag and/or dross buildup should be scraped from the crucible while it is still hot. At the completion of the production day, the crucible should be completely emptied and scraped as clean as possible.
- A metal heel should not be allowed to freeze in the crucible of rammed linings. Expansion when the heel is subsequently reheated would cause cracking.
- Crucibles and linings can be cracked by careless charging such as throwing in large ingot or scrap pieces. Also, if large amounts of cold metal are added to a small amount of molten metal then the molten metal bath can freeze and cause substantial cracking due to expansion when again heated.
- Again, the possibility of cracking or blistering caused by localized overheating must be mentioned. This can only be avoided by uniform placing of the charge in contact with the crucible walls.
- Patching cements and wash materials used for maintenance on the crucible should be of similar composition to the crucible itself.
- After the last heat of the day it is adviseable to cover the furnace to allow the crucible to cool slowly. This helps to minimize cracking due to thermal shock.

The recommendation on cooling is completely the opposite for rammed linings. Since rammed linings are monolithic from hot face to coil and it is impossible to prevent cracking no matter how slowly they are cooled, it si desirable to develop a cracking pattern that is more favorable. This is obtained by fast-cooling the lining which causes more cracking, but the cracks that form are much smaller in nature. With rammed linings it is adviseable to leave the top of the furnace open and if possible, use a fan blowing air to aid in fast cooling the lining.

Patching of rammed linings is recommended only in the melt line, top cap and spout areas. Excessive wear in the melt zone is indicative of a need to reline or of a need to reline or of a problem needing attention.

Least-cost charging

Least cost-charging is the process of choosing the unique mix of available charge materials that will produce metal not only to the chemistry specification, but also for the least amount of money. There may be several charges mixes that will satisfy the chemistry, but only one will produce the least-cost charge for any specific foundry operation. There are now least-cost charge programmes available that run on a variety of inexpensive microcomputers, and the cost of such programmes is quite reasonable. Some of the benefits and savings of least-cost charging are as follows:

- fast calculations
- optimized calculations
- purchase evaluations
- inventory reduction
- indicator of furnace operation
- improved consistency.

Table 9.4 illustrates typical components of a Least-Cost Charge Calculation.

Moulding and core-making materials

Sand: Sand represents the most significant materials flow in a foundry. The types and grain sizes of the molding sands dirctly influence the quality and surface finish of the cast product. The techniques by which the sand is handled in a foundry directly influence the molding, and mold handling systems and the general plant layout. The types of sand and additives used represent process alternatives. The types of processing and transport equipment selected represent production alternatives.

Sand qualities of interest in casting are:

(i) Flowability during moulding.

(ii) Green strength (as molded).

(iii) Dry strength (when the molten metal is flowing).

(iv) Hot strength (as the liquid cools).

(v) Permeability (ability to release gases).

(vi) Thermal stability (dimensional stability when heated).

(vii) Refractories (ressistance to melting, sticking, or softening during pouring).

Table 9.4:

Typical Components of a Least-Cost Charge Calculation

Alloy: Demo CI

Material	Pounds	% of Charge
FeMn	3.56	0.16
SiC	95.49	4.38
Steel 1	400.00	18.36
Steel 2	667.17	30.62
Return 1	800.00	36.72
Pig Iron	200.00	9.18
Graphite	12.69	0.58
Total weight	2178.91	

Charge Materials Considered

FeSi50	FeSi75	S1000
Steel 1	Steel 2	
Graphite		
FeMn	SiC	TiBriqet
Return 1	Pig Iron	Return 2

Desired Chemistry

Si	<2.200
C	<3.300
S	<0.120
P	<0.050
Mn	=0.700
Si	>2.000
C	>3.200
S	>0.040

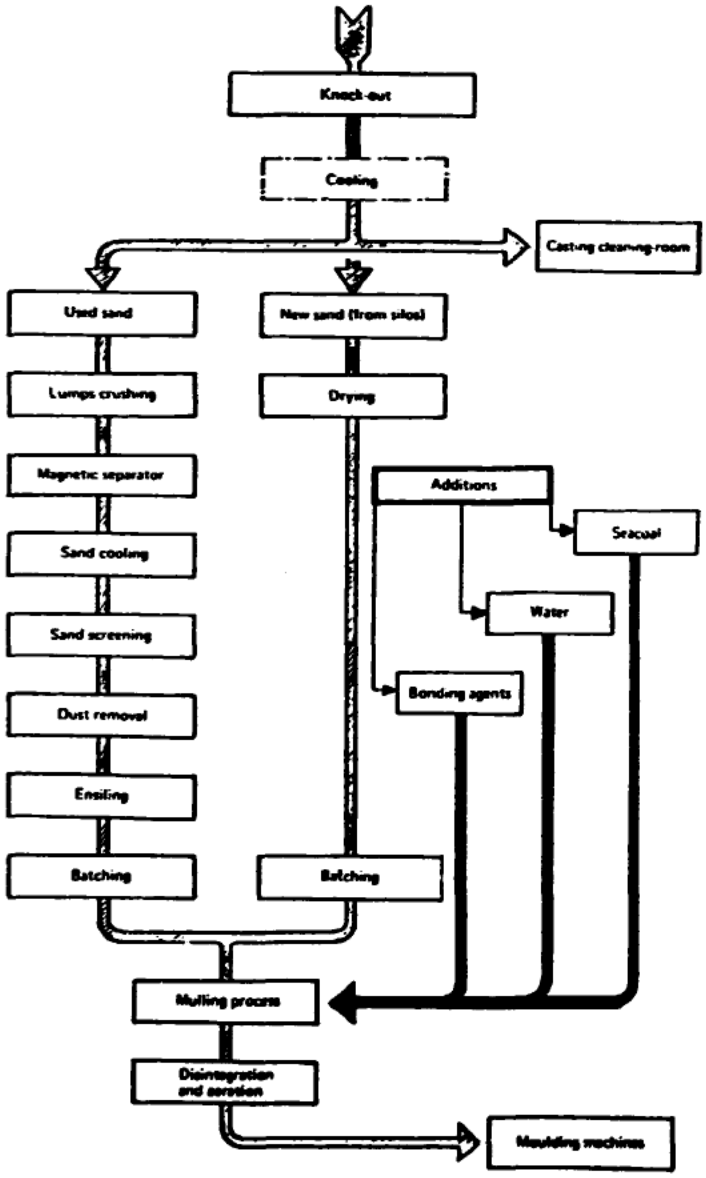
Tap Chemistry

Si	=2.000
C	=3.200
S	=0.090
P	=0.041
Mn	=0.700
Si	=2.000
C	=3.200
S	=0.090

Element Recovery

87.50%
105.00%
100.00%
100.00%
90.00%
87.50%
105.00%
100.00%

Cost for charge	=61.82
Charge weight	=2178.913
Cost/lb charged	=0.02837
Metal weight	=2000.000
Cost/lb metal	=0.03091
Yield(%)	=91.79



Steps in the reclamation of moulding sand

Figure 9.1

(viii) Grain shape: round, angular, subangular (will affect all properties above).

Silica sand, ideally having over 98% SiO_2, is the basic component of moulding and core sands. Although olivine, zircon and chromite sands are used in special situations, silica is the most widely used sand. It is the most plentiful mineral in the world, but too frequently the natural sand contains a high percentage of clay and silt or other minerals, such as mica, feldspar or iron oxide, that have a lower refractory index than silica. A local supply is essential in view of shipping costs, but it may be necessary for the sand to be washed, classified or graded and dried, either at the sand pit or when received at the foundry, to make the material acceptable.

In addition to high purity, a foundry sand should preferably have individual grains with a rounded or subangular shape (as mentioned before under viii). Sharp sand grains obtained through crushing sandstone are usable but not so durable and require greater amounts of binder to produce the same strength. A specification for sand should use both the AFS[*)] grain fineness number (GFN)[*)], which gives a measure of the coarseness (low number) or fineness (high number) of the sand, and the distribution as measured by a sieve analysis. An ideal distribution has no more than 40% of a sample on any one screen and a total of 80% on three adjacent screens.

A typical distribution would be:

	Coarse								Fine
Successive screens in the standard series	1	2	3	4	5	6	7	8	9
Percentage of sand retained on each screen in the mesh	1	2	6	22	36	21	8	3	1

In practice, a sand with the distribution shown above having a GFN between 60 and 65 should produce iron castings with a good finish and minimum of sand defects if correctly bonded. A finer sand with a GFN of 80-85 will be useful in the core department.

Binders: Local bentonite clays may be of acceptable quality, but careful investigation is essential to prove their suitability. The normal standard of quality for steel castings is the sodium bentonite found in a small area in the west of the United States

*) AFS = American Foundrymen's Society
GFN = Grain Fineness Number

of Ameriaca. Less durable but completely useful for moulding cast iron is the "southern", or calcium, bentonite. Bentonites are found in other locations in the world and have properties similar to both of the above-mentioned types. Other bentonites should be tested by producing castings and evaluating their quality. Green compresion strength and active clay tests are useful in measuring the durability of sand in reuse.
Organic binders, such as cornflour or dextrin, and finely ground coal and special oil or resin core binders that may be available locally can be purchased only after thorough testing in making castings.

The composition of moulding and core sand mixes varies depending on the characteristics of the raw materials available.
Minimum properties considered acceptable for small iron castings are:

Green compression strength	.5-.7 kg/m^2
Dry compression strength	5.6-6.4 kg/m^2
Permeability-green	60 - 80

Typical sand mixes for the production of small iron castings in green sand are as follows (% of dry weight):

	Green sand	Facing sand	Backing sand
New sand - GFN 60-65	-	50	-
Return sand	95.5	42	98.5
Bentonite-western, sodium	.5	1	-
Bentonite-southern, calcium	1.5	2.5	1.5
Cereal, organic	.5	.5	-
Sea coal	2.0	4.0	-
(Water added)	3-3.5	3.5-4	3.0

For small castings, a green-sand mix composed of all old or return sand is economical and yields excellent surfaces. For havier castings, facing sand having part new and part old sand may be required. In this case, the mould is filled with backing sand after facing sand has been packed around the pattern.
Core mixes require a washed and dried sand free of clay. A basic mix for small castings is composed of (% of dry weight):

Sand-GFN 80-85	97.5
Bentonite *)	.5
Ceral	1.0
Oil or resin binder	1.0
(Water added)	4-5

*) Bentonite is added only for green strength to assist in producing the core.

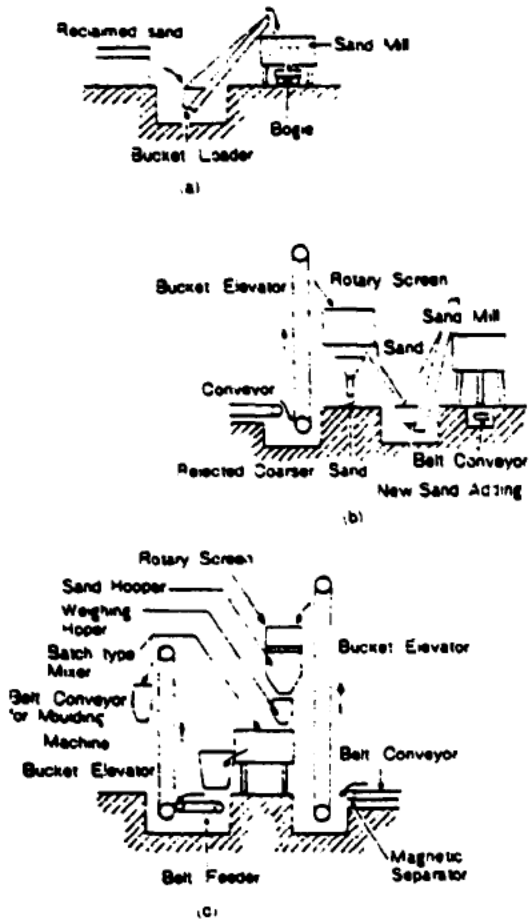
Furnace charges may vary widely and still produce metal of acceptable quality. The amounts of charge elements will vary for different types of furnaces. A typical charge for producing grey iron in the induction furnace based upon the normal yield of good castings, is as follows(%):

Recycled cast-iron scrap	38
Produced cast-iron scrap	20
Steel scrap	28
Pig iron	10
Ferro-silicon	2
Ferro-manganese	.5
Carbon, graphite, charcoal	1.5
	100.0

During start-up, purchased cast-iron scrap may amount to 58% of the charge until enough gates and risers are recycled.
For cupola operation, the raw materials differ somewhat from those mentioned above. The charge requires more pig iron and less steel scrap, as shown below:

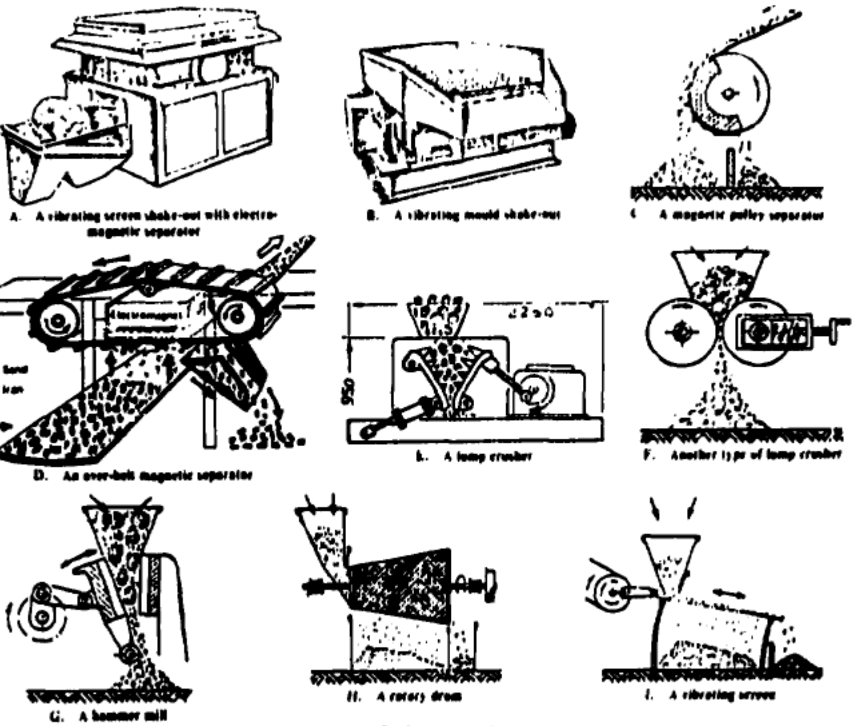
Recycled cast-iron	35
Pig iron	25
Purchased cast-iron scrap	16.5
Steel scrap	20
Ferro silicon	3
Ferro-manganese	.5
	100.0 %

A substantial volume of the materials used in the foundry process is basically continuously recycled. The sand handling cycle begins when the casting is removed from the cooled mould. Before the sand can be used to make another mould, any iron scrap must be removed, and lumps of moulding or core sand must also be removed. The green strength must be restored by mixing water (and additives as needed) with the sand. The prepared sand must then be distributed to the moulding stations. Figure 9.1 shows the steps in the reclamation of moulding sand and Figure 9.2 illustrates three levels of mechanization in sand processing equipment, and suggests the range of "production" alternatives available. Figure 9.3 shows sand recovery equipment and table 9.5 illustrates characteristics of machinery for recovery operations. All the sand handling operations may be performed by hand, batch or continuously operating equipment. The iron scrap is removed by screening or magnetic separating conveyors. Rotary screens can be used to remove any lumps, though often these are not necessary. The key to the sand processing is the mixing or "mulling" of the sand, water, and any additives to restore the green strength to the sand. Figures 9.4a and 9.4b illustrate alternative methods of mulling.



Three Types of Sand Conditioning Plants(1)

Figure 9.2

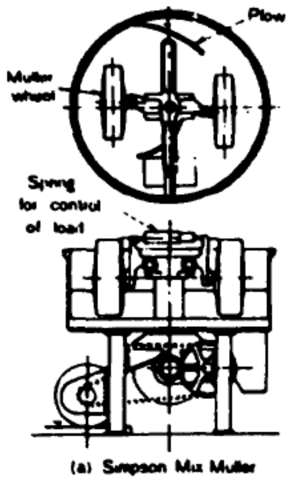


Sand recovery equipment

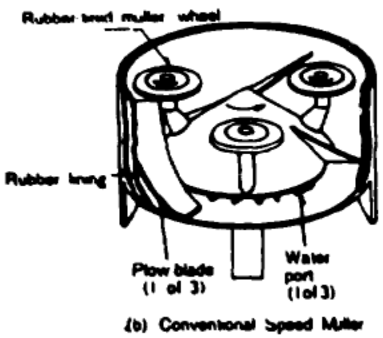
Figure 9.3

Table 9.5: MACHINERY FOR AND CHARACTERISTICS OF SAND RECOVERY OPERATIONS

Operation	*Machinery or technique used*	*Characteristics of concern for developing countries*
Knocking-out	By hand on fixed grate Vibrating grate or shake-out grate	Small and medium size castings done on a free shake-out grate. Large-size castings done on a fixed grate. Hand knock-out is advisable to avoid high costs
Lump breaking	Elastic compression crushing rolls Hammer crusher Disintegrating crusher	No-bake sand crushing requires the use of disintegrator
Magnetic separation	Magnetic pulley Magnetic over-belt separator	
Cooling	Rotatory cooling drums (castings and sand together) Cooling elevator Water coils cooler	Homogeneous castings and installation under working floor are required
Screening	Rotatory screens Vibrating screens Meshes for grading	The rotatory screen is generally used in medium-large plants. Jolting screens are suitable for smaller plants
Dust collection	Suction, from screens or other processes	Dust must be separated from the flow of sand in small plants. This requires a good suction device
Transport and storage	Belt conveyors, elevators, skips. Conveyors are widely used for the flat transfer of green sand. Pneumatic systems are often used for chemically bonded sands. Storage is done in differently shaped silos	Elevators save space. A skip tends to pack the sand. The pneumatic conveyor is suggested only for the hauling of new sand from the storage bins to continuous mixer hopper
Addition of agents	There are a wide range of mixing devices	A semi-manual method offers the most reliable operation. Skilled personnel are needed
Mulling	Fixed bowl continuous cycle Rotatory bowl continuous cycle Fixed bowl discontinuous cycle Rotatory bowl discontinuous cycle Intensive muller	Many of these types are suitable. A fixed bowl discontinuous cycle muller for which the operation sequences time may be pre-selected is advisable. Cycle time is very important in manual proportioning
Disintegration and aeration	Several means can be used for sand aeration during transport	Advisable for small plants



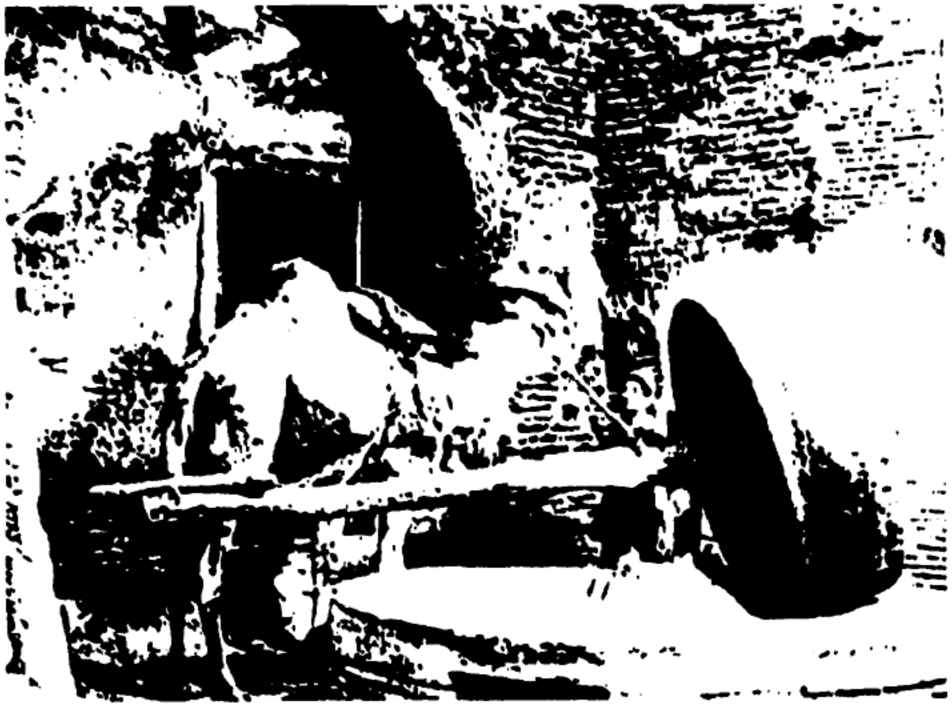
(a) Simpson Mix-Muller



(b) Conventional Speed Muller

Modern Mulling Machines

Figure 9.4a



A Traditional Method of Sand Mulling

Figure 9.4b

10. Economics of the Foundry Industry

In any foundry, the product mix, predetermined by the market research of an existing production programme, leads to the choice of appropriate melting, moulding, core shop and finishing processes. The specification of capacities and dimensions of the equipment and facilities to a large extent depends on this product mix. The enquiries received by the foundry at a later date could also relate to a wide range of castings which will match the production facilities with varying degrees of efficiency. Due to this reason it would be difficult to define a standard cost for a particular casting which will apply throughout industry. Table 10.1 gives some of the main cost items. Within one country the unit cost of materials, labor and energy may be common to a number of foundries, but the utilization of these elements of costs for particular castings could vary according to plant installed in each of the foundries compared.
Nevertheless it is possible to analyze the cost structure and make comparisons among various countries to assess the competitive advantage of the foundry industry.

Capital costs: The attempt made in the following lines has to indicate the effect of foundry facilities on cost of castings production. The setting down rules for calculation of investment cost to suit the wide range of foundry facilities, from the low capital cost, labor intensive, jobbing operation to capital intensive, automated mass production plant is to be considered as very difficult or even impossible. The vast majority of foundry projects being considered in developing countries involve a compromise which is based on the difficulty in justifying sophisticated, automated plants for a product more comprising of a wide range of differing components required in relatively low volumes. The published data available on investment figures vary widely and must be treated with caution. Table 10.2 presents presents an indication of minimum cost levels for four different types of foundry based on the assumption that the product mix would be of one type of mould production in each case. Decisions on the establishments of foundry facilities in a developing country are more likely to depend on the ability of the proposed casting selling price structure (very often set by international price levels of industrialized countries) to support the investment necessary to establish a foundry, rather than on the margin between local wage rates and those of the foundry workers in

Table 10.1: SOME FACTORS INFLUENCING CASTING COSTS

Circumstance		*Major effects on product costs* — *Tooling costs*	*Foundry operational costs*	*Material and melting costs*
A DESIGN CHARACTERISTIC	1. Alloy type and composition			Metal (intrinsic cost, losses and metallic yield) Melting (thermal properties and energy consumption)
	2. Basic dimensions	Pattern (size)	Moulding (mould volume) Finishing (casting surface area)	Metal (weight) Melting (weight)
	3. Shape	Pattern (complexity)	Moulding (complexity) Finishing (casting surface area and complexity)	Melting (casting yield)
	4. Quality standards	Pattern (type, material and construction)	Moulding (method and materials) Finishing (fettling and inspection standards) Rejection rate	Metal (raw materials) Melting (compositional tolerances)
B. QUANTITY REQUIREMENT		Pattern (number, type, material and construction)	Moulding (production method)	

Table 10.2:

TYPICAL CAPITAL INVESTMENT FOR IRON FOUNDRY UNITS BASED ON A SINGLE MOULD PRODUCTION CENTRE (US DOLLARS)

	Annual Production (Tonnes): 0 – 5 000	5 000 – 10 000	10 000 – 20 000	20 000 – 40 000
JOBBING (HAND) MOULDING	9 000 000	12 000 000	15 000 000	
JOBBING PATTERN FLOW MOULDING	10 000 000	12 500 000		
SEMI-MECHANISED REPETITION GREENSAND MOULDING	11 000 000	14 500 000	16 500 000	
MECHANISED REPETITION GREENSAND MOULDING	14 500 000	18 000 000	20 000 000	30 000 000

Exclusions :
- Land.
- Freight, handling, etc. on plant.
- All taxation and duties.
- Pre-operating expenses.
- Patterns and toolings.

N.B. All the examples are based on foundries with a single mould production centre and therefore on a product mix which is restricted in terms of metal specification and uniform in terms of casting type.

industrialized countries. Table 10.3 gives a rough estimate of capital cost for a 10,000 tons per year foundry in three countries:

DC1 $\hat{=}$ Developing Country 1 (from the region Middle East);

DC2 $\hat{=}$ Developing Country 2 (from the region Asia and the Pacific);

IC $\hat{=}$ Industrialized Country;

DC1 is a small country, DC2 is a large country.

It could be inferred that:

(a) land cost is very low in DC2 (probably due to the current stipulation or dispersal of industries to mofussil areas;

(b) land cost is higher in DC1 (probably due to the level of development of the country and availability of land);

(c) for building and services high labor cost and non-availability of materials locally results in high cost whereas in the DC2 local availability of material and cheap labor is offset by transportation cost and availability of skills in proposed areas. In the IC country high labor costs increase the cost of services;

(d) for plant and equipment and tooling cost is higher in DC1 because it has to be totally imported with high spare part content due to absence of suitable infrastructure. In DC2 some equipment could be locally available but high duties on capital goods and need to keep imported spares increase costs. In the IC competition and availability provide cost containment. But the IC would have to provide additional facilities to meet the environmental regulations;

(e) for project engineering DC1 has highest cost (probably due to: technological transfer fees and/or requirement of having high expatriate staff required for implementation and simultaneously improve the capability of local staff by training whereas this situation could be less severe in DC2 and is minimal in the IC);

(f) for preproduction expenses in DC1 and DC2 it would be necessary to overstock materials due to availability and locational constraints and also extra manning for training whereas this situation does not exist in the IC.

All these possible factors outlined above lead to increased capital cost in developing countries which to some extent could be reduced by proper planning and training of perso[illegible] nd appropriate policies. However the establishing of small scale fo[illegible] in developing countries with a low level of technology and not too sophisticated

Estimated Capital Cost for a 10,000 Ton per Year Foundry
(in US$ million)

	DC1	DC2	An IC Country
Land	0.33	0.10	0.5
Buildings, Services & Civil Engineering	8.10	7.00	10.0
Plant & Equipment	21.10	20.00	16.0
Tooling	1.63	1.00	0.5
Project Engineering	3.97	2.00	1.0
Preproduction Expenses	2.92	2.00	1.0
Total	38.02	32.10	28.0

Table 10.3

Percentage (%) of Total Costs

	Material	Labor	Energy	Overheads
(Average for Comparison) Industrialized countries	20-25	45	10-15	20
Developing countries:				
Mexico	66	14	4	16a/
Turkey	25-55	20-34	9-15	4-26
India	55	14	15	16
Jordan c/	32	22	19	27
Taiwan	60-65	20-25	b/	10-20
Kuwait	22	27	b/	50
Tunisia c/	31	39	12	18
Ivory Coast	25	50	b/	25

a/ Includes 3% rejects.
b/ Presumed energy costs are included in overhead.
c/ Feasibility study.

Table 10.4

Cost of Production of Castings in an IE
US$ per ton of castings

	Automatic Greensand Production				Jobbing Chemical Bond Production	
	Malleable Iron		Ductile Iron		Ductile Iron	
	$	%	$	%	$	%
Materials	271	31.4	327	41.2	358	41.0
Labor	278	32.2	199	25.1	248	28.4
Power & Fuel	145	16.8	98	12.4	98	11.2
Overheads	169	19.6	169	21.3	169	19.4
Total	869	100.0	793	100.0	873	100.0

Table 10.5

facilities result in lower capital costs.

Individual requirements need to be thoroughly investigated and appropriate choices made to achieve the optimum capital cost.

Production costs for castings in developing countries: It would appear that the operating costs incured by different foundries within any given country could be subject to considerable variation. This is due in part to the varying rature of the product mix which the foundries were originally designed to produce, developing into a "fixed" plant configuration and the labor practoces within each individual unit. There would also be considerable variation in the extent to which materials and services are negotiated and procured. Table 10.4 provides in %-age terms the total cost in industrialized countries and some developing countries. Table 10.5 lists the elements of costs in the production of two types of iron castings, for a foundry in an industrialized country, for two alternative methods of production.

It would be difficult,however, to draw conclusions and comparisons between these figures and similar figures for selected developing countries without some knowledge of the cost in currency terms since variations in cost distribution are so great that intra-country comparisons may provide only indicative trends. It is accepted that the unit cost of labour in developing countries will, in generall, be much lower than that in industrialized countries.

As already indicated in the preceeding paregraphs the cost materials and investment in foundry facilities would differ widely between countries. It is necessary to review each case of foundry development on the basis of the elements of cost applying at each site. The continuation of circumstances justifying implementation of a foundry project in one developing country cannot be reproduced exactly in any other country, or even in a different region of the same country.

In the case of raw materials very few developing countries have advantage over industrialized countries. The dominant material for castings production is steel scrap, which is half of the price of pig iron in industrialized countries although requiring a more sophisticated melting technology. It may be anticipated that steel scrap prices in developing countries will be in line with world prices except where demand exceeds supply, as it happened in India & Pakistan in 1979-80. This led to the establishment of one of the largest ship breaking yards in Pakistan.

Nevertheless the various constraints are usually more than offset by the ability of foundries in the developing countries to supply castings locally to various industries and assisting industrial growth.

It would be desirable to have a cost/price relationship developed for the foundry products, but the nature of the products and trade patterns prevent such an attempt. In the case of the developing countries, prices to a large extent depend on various incentives and subsidies and restricted availability of costs in absolute value terms. The selling of foundry products by many foundries on marginal cost complicates the comparison further.

11. Financial assessment of foundry projects

Methods and brief description

The evaluation of capital investment projects is one of the most important tasks of manafement. The correct investment decisions can improve efficiency, increase profitability and ensure the survival of the foundry in one of the most highly competitive industries. It is vital that the evaluation process is carried out in such a manner, as to yield the maximum amount of relevant information, for the most objective appraisal of an investment project. The methods of appraisal which give management the greatest amount of relevant information are those which incorporate discounted cash flow techniques. Therefore, it is evident that future cash flows generated by an investment project should be discounted to a present day value. There are two main techniques, Net Present Value (N.P.V.) and Internal Rate of Return (I.R.R.), which are based on the above principle. N.P.V. expresses the result in terms of a cash value, whereas I.R.R. presents the result in terms of a percentage. I.R.R. is conceptually easier and the format is more familiar, in that the result is presented in the same dimensions as the risks involved.

The process of investment appraisal

Risk and uncertainty and their possible scurces: The process of investment appraisal is one of estimating. Little, if any, of the financial information used in the appraisal is fact, the majority of the information must of necessity be estimated on the basis of past data. Thus, by its very nature, it is highly probable that these estimates will be to a greater or lesser degree incorrect. Given, therefore, that uncertainty is an ever present element of the investment appraisal process, the question is raised as to how to handle the problem. The ideal would be to eliminate the uncertainty from the process but this is obviously impossible as many of the uncertain factors are exogeneous. The alternative is to attempt to evaluate the risks involved and to quantify their possible effects. The major form of risk is that the forecast levels of expenditure and receipts will be inaccurate. This will be the case on all projects as the forecasting of the future is by definition an inexact art. There are factors which will icrease or decrease the extent of this inaccuracy. If the proposed project is one which opens new fields, then the inherent risk will be greater. Thus, the launching of a new product presents the business with the problems of forecasting the unknown.

Market research and the launching of the product will require the investment of substantial funds. Sales volume, selling prices, cost of marketing and production, as well as other uncertainties, will also be present, hence the discounted cash flow,D.C.F.,return will vary with the accuracy of the forecasting of these factors. If the proposed project involves the replacement of plant and machinery, the risks are less great-firm quotation for the items to be purchased may have already been received and the potential savings in labour and other costs will be capable of fairly close estimation. The only real uncertainties may lie in the life and residual value of the plant, in taxation and other changes resulting from changes in government policy. It is possible to limit the inaccuracies of forecasting by basing the forecasts on detailed studies into areas which are uncertain. Thus, the launching of a new product will necessitate an exhaustive market study to establish the needs of the market and the size of the market it is intended to enter. The result of a D.C.F. appraisal will be, at best, no better than the data that has been provided by the budgeting techniques used. If the business is to achieve a higher than average degree of success in choosing profitable projects for investment, its whole forecasting system must be of the highest standards.

Methods of catering for uncertainty: Risk as a function of time.
There is a school of opinion which correlates the time that a project will exist, to the risks that will be encountered. While this method has the advantages of simplicity, it assumes that all variables are equally uncertain and does not make explicit the extent of the uncertainty inherent in the figures which together, constitute a factor affecting the degree of risk involved.
Sensitivity analysis. Sensitivity analysis involves assessing the effect on the return of small percentage changes in each one of the factors affecting the cash flow. By this means, it is possible to identify those factors, whose changes have the greates effect on the D.C.F. criteria. The sensitivity analysis information also shows how 'robust' the anticipated outcome is. This kind of analysis is an extremely useful tool in the analysis of a project's profitability but it gives no indication of the likelihood of variations from

the original forecast level.

Risk analysis. The essence of risk analysis is the isolating of each of the forecast elements of cash flow and assessing the probability ot each forecast actually being fulfilled. This approach enables management to have a definite idea as to the likelihood of the project's outcome and gives a much more complete view of the project. This analysis involves a great amount of work and the accurate assessment of probabilities - both are considered to be too great a task to be ordinary justified.

A practical evaluation of investment projects: It is necessary to combine the techniques which have been above described into a practical method of evaluating a project to allow management to take decision based on the most complete information available. It is recommended that for significant projects, the internal rate of return be calculated and compared with the cost of finance to give the initial criteria by which the viability of the project may be judged. Although, according to the preceeded analysis, the ideal solution is a full probability analysis of all the factors, this is impractical both in the assessment of probabilities and in the volume of work involved. Therefore, to place the project in perspective a best plus worst case should be calculated which will show the limits which are likely to be achieved. The above described pocess is illustrated by reference to a worked example in the Appendix.

Productivity and break-even point

When a new foundry is built, it is sometimes inaccurately assumed that it will be able to make all castings more economocally than other existing foundries. Pricing by the unit of weifht, for example, can still get many foundries in trouble. What needs to be known is the optimum mix for any given foundry. The typical foundry will most likely cast a variety of different parts. Even the highly automated and captive foundries seldom have the luxury of making one or two parts. It is not unuual for a single foundry to cast hundreds of different parts. Regardless of the variety of the product mix, however, the basic foundry process is the same. Typically there are four steps in the basic foundry process (see also previous chapters):

- coremaking
- melting
- molding
- finishing.

These steps are independent of each other, but they must be closely co-ordinated. The molding unit in a foundry is considered to have a fixed cycle time. All other foundry activities are support and are staffed to satisfy the requirements of the molding unit.

The relationships occuring among the four main steps above mentioned are based on logical operational links that foundrymen work with every day. Their sound and strategic synchronization improves productivity and determines product mix optimization.

The particular concepts to be applied in this regard are illustrated below:

- Break-even and capacity must be expressed in terms of the foundry's limiting factor: The concepts of break-even and capacity are inseparable. In fact the break-even level of any foundry is almost always expressed as a percent of that foundry's capacity. Then, it is important that the capacity of any foundry be expressed relative to that foundry's limiting factor.
- Measuring financial benefits by removing production bottlenecks (increasing capacity of limiting factors).
- Pricing by the unit of weight may be very misleading.

Concluding we can say that eventhough individual parts look desirable to run, they need to be evaluated in the context of all the parts presently run in the foundry. What may happen is that eventhough an individual part has a high cotribution per unit of weight or maybe even perhaps a high contribution per mould, it may tie up support-department resources that could be used by even more desirable parts. The entire product mix needs to be examined simultaneously. Foundries can evaluate or even reevaluate their entire strategies relative to capacity analysis. Linear programming provides an excellent tool to do just that.

An illustrative example is presented in the Appendix.

Cost estimate: its content

The objectives in attempting to estimate the cost of a casting with a reasonable degree of accuracy are two fold: firstly, for purposes of determining the price to charge the customer and secondly of controlling costs. A major function of the cost estimate is to supply the appropriate information to those who have functional objectives to fulfill i.e. to determine prices, to control costs, to make business plans. basically, a foundry wants to know the value of materials, labour, energy and "overhead" services that will be embodied in a particular casting.
The calculation of the direct cost of specific inputs is reasonably straightforward; complications can arise when handling the indirect or non-specific factors and it is there that foundries may decide that different levels of complexity are appropriate. The greatest problem when it comes to using the cost estimate for price determination purposes is that the cost of a particular casting, so far as indirect, common or non-specific elements are concerned, will depend on what other activities the foundry is carrying out at the same time. For example, a casting will "cost" more the lower the overall degree of capacity utilisation, a casting may "cost" less if it can be worked in with another job and so on.
One thing the selling function may want to know is the price that marks the limit of "usefulness" of the job to the foundry as a contributor towards the foundry's overall objective. This suggests that the cost estimate must give a clear indication to the user of the magnitude of cost that must be recovered if the operation is to be worthwhile in the terms of the foundry's and/or company's general objective.
The cost estimate should also have some multivalued dimension which would inform the user as to critical elements such as cost at differing levels of capacity utilisation, or cost under differing conditions of product mix.
The cost estimate here plays a some what ambivalent role in as much that it may both be based, in part, upon standards and be a determinant of standards. Foundries vary considerably in size complexity and sophistication and the degree to which standard elements of cost will be used will differ from one to another. In many foundries it will be common practice to estimate the time taken to carry out the main operations in making a casting-

coremaking, moulding and fettling - and to multiply those number of minutes (or hours) by the expected (probably current) labour rate. Overhead burdens in such cases may be calculated on a historical basis, as may such shared costs as melting; allowances for rejects too may be made by reference to a similar principle. Details regarding the overhead costs and direct costs are illustrated in the Appendix.

Reverting to the preparation of a cost estimate for purposes of determining the price of a casting not produced hitherto, the foundry is likely to be provided witn a drawing and with a specification as to the material and properties required. There will also be information as to the quantity required and the rate at which they should be delivered.

12. Computer Applications in the Foundry Industry

The computer represents the most significant and universally applicable development in business and commercial activities. All industries can benefit from the introduction of computers and this includes the foundry industry. The initial impact of computers has now passed and many foundries have installed them and accepted their implications. The applications for computers within the foundry industry may be classified under the headings of commercial or technical, although it is inevitable that there will be some overlap between the activities.

The process of running a foundry involves the interaction of numerous management functions and a multitude of interconnecting information. As greater pressure is currently being put upon foundries to improve the overall performance, it is necessary for them to consider ways in which they can respond more quickly to the ever-changing needs of their customers, to be able to evaluate qiuckly and accurately their overall financial situation and to be able to allocate their limited resources in the most effective way.

To be able to achieve these objectives, the management of a company will have to create an effective integrated management information system (IMIS) which will provide the required and relevant iformato enable them to take the necessary decisions in a timely and effective manner. A management information system can therefor be defined as a collection of data which is being constancly updated. A large integrated collection of data available to a variety of users constitutes a data base. Data bases provide the basis of most commercial management information systems. A comprehensive integrated management informationsystem will, therefore, cover the areas of: financial accounting, management accounting, estimating, sales order processing, process control, production control, quality control, maintenance, despatch and invoicing, payroll, stock control, purchasing, credit control and incorporate a sophisticated report generator of produce reports as required. According to a U.K. census of production most of the manufacturing activities in the U.K are now carried out in relatively small units. The modern micro-computer with its specially designed software is capable of handling significant quantities of information which already exist in many smaller companies. It has become apparent in recent years that the market for small compact computerised information systems is growing at a more rapid rate for the small company than the larger systems designed for the large scale company.

The first step in creating an effective management information system is to define clearly what is required from the proposed system. In some instances it may be prefearable to employ consultants who c... advice on suitable systems or a computer company to write a specific programme. Whichever method is selected, a certain amount of flexibility must be built into the system as it will need to be extended to meet future foundry requirements.

Capabilities of computers

The capabilities of computers can be compared using many different criteria such as memory size, word size, CPU cycle time, disk size etc, but ultimately the most important aspect of the computer is the software.

The major classification of the computers used to be micro-, mini-, mainframe computer, the differences being basically 8 bit, 16 bit and 32 bit wordlength respectively. Recently, strict classification has been somewhat blurred as new machines have now crossed the former barriers. Additionally a new category of supermicro has been introduced bringing the powe of the mini into the price range of the micro. Further it is also possible to link together or "network" normal microcomputers. The categorisation of computers is complicated by the fact that the top end of one range compares very closely with the bottom of the next range making the cut-off point between the ranges unclear. The relative capabilities can best be expressed by reference to the type of software available and for the type of use the different machines can be put to within the foundry industry. The Table 12.1 illustrates a comparisson of the physical characteristics of the various types of computers. More information and in particular with emphasis on process control, production control, CAD/CAM application, maintenance control etc, is given in the Appendix.

Table 12.1

Discription	Traditional ranges	Current ranges	Word size [bit]	Costs £
MICRO	X	X	8/16	100-5000
SUPER-MICRO		X	16	5000-25000
Networked MICRO		X	16	5000-25000
MINI	X	X	16/32	25000-100000
MAIN FRAME	X	X	32/64	higher than 100000

Table A.0/1

ECONOMIC INDICATORS OF HIGH AND LOW CASTINGS INTENSITY: SELECTED INDUSTRIALISED COUNTRIES

	GNP/HEAD $'000	2.0 - 2.5		4.0 - 4.5		8.5 - 9.0		9.5 - 10.5		11.5 - 12.0	
	COUNTRIES	Yugoslavia	Portugal	Spain	Ireland	Japan	Austria	France	Netherlands	Germany	Sweden
	CASTING INTENSITY	High	Low	High	Low	High	Low	High	Low	High	Low
Manufacturing industry's share in the GDP		31	37	-	-	30	29	25	29	38	23
Proportion of total V.A. derived from machinery and transport equipment		21	20	20	11	33	22	32	26	37	33
Exports of fuel and minerals as % of merchandise exports		9	4	5	3	2	5	6	19	6	6
Exports of machinery and transport equipment as % of merchandise exports		32	14	25	14	57	28	36	18	47	43
Proportion of machinery and transport equipment in merchandise imports		37	28	19	30	7	31	23	24	21	30
Index of growth of urbanisation between 1960 and 1980		150	135	130	126	126	108	126	95	110	119
Production of raw steel - Kgs per head of population		160	66	331	21	966	656	437	415	752	570
Production of passenger cars - units per 1000 heads of population		9	-	27	-	53	0.4	70	6	64	41

Table A.0/2

ECONOMIC INDICATORS OF HIGH AND LOW CASTINGS INTENSITY: SELECTED DEVELOPING COUNTRIES

GNP/HEAD $'000	1.3 - 1.5		1.0 - 1.2		0.5 - 0.8		0.25 - 0.3		0.15 - 0.25	
COUNTRIES	Korea	Turkey	Chile	Tunisia	Peru	Thai-land	China	Pakis-stan	India	Sri Lanka
CASTING INTENSITY	High	Low	High	Low	High	Low	High	Low	High	Low
Manufacturing industry's share in the GDP	27	21	24	12	26	19	.	16	18	21
Proportion of total V.A. derived from machinery and transport equipment	19	.	13	7	11	.	.	.	18	.
Exports of fuel and minerals as % of merchandise exports	1	6	74	44	46	11	13	4	10	11
Exports of machinery and transport equipment as % of merchandise exports	21	1	*	3	1	3	3	2	6	*
Proportion of machinery and transport equipment in merchandise imports	33	31	22	31	33	31	18	25	19	24
Index of growth in urbanisation between 1960 and 1980	196	157	118	144	146	108	.	127	122	150
Production of raw steel kgs per head of population	201	54	61	24	26	10	36	.	15	.
Production of passenger cars - units per 1000 heads of population	3	-	-	-	-	-	.004	-	.04	-

* Less than 1 percent

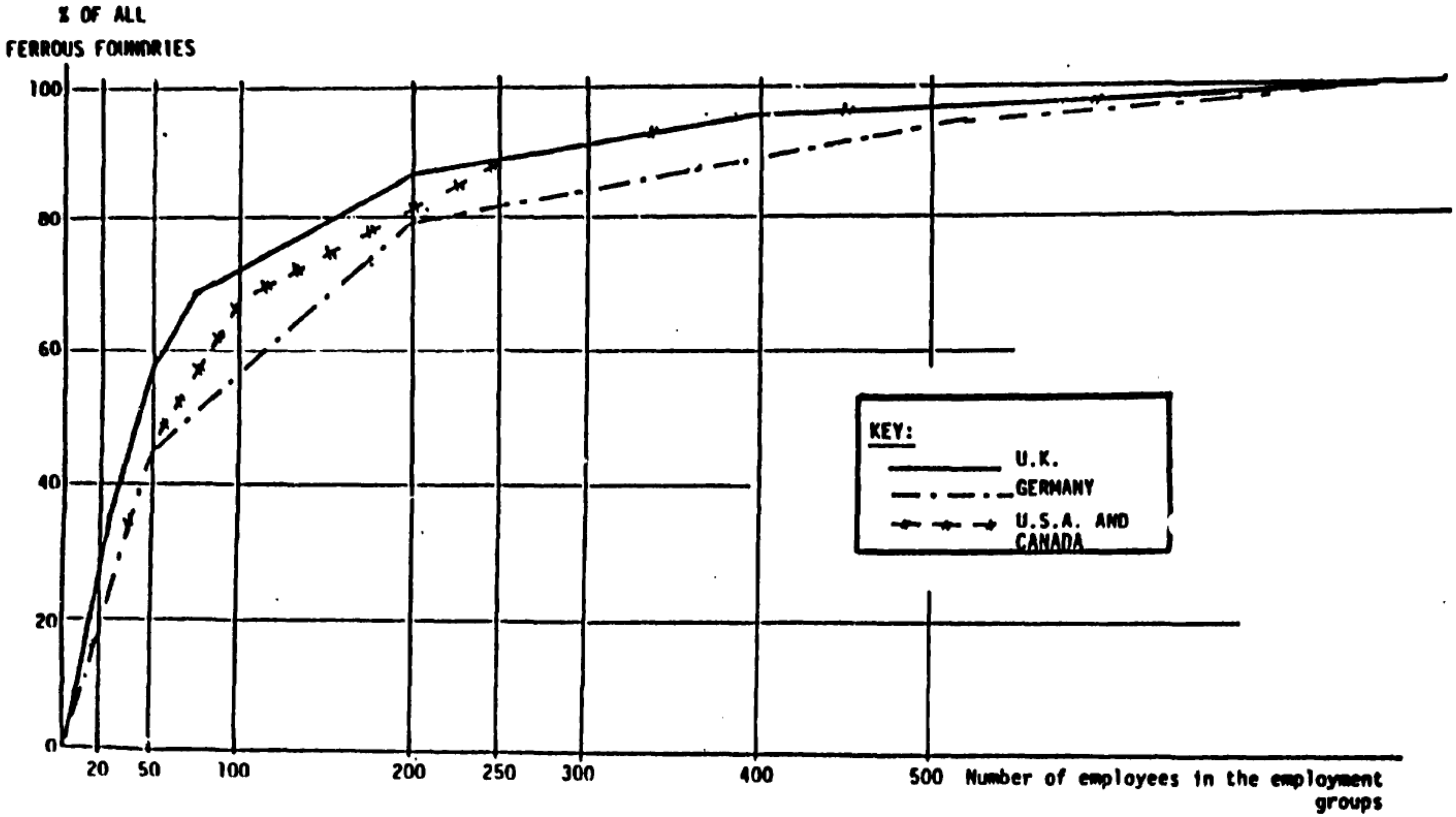


Figure A.0/1

TYPICAL EMPLOYMENT PROFILE CURVES

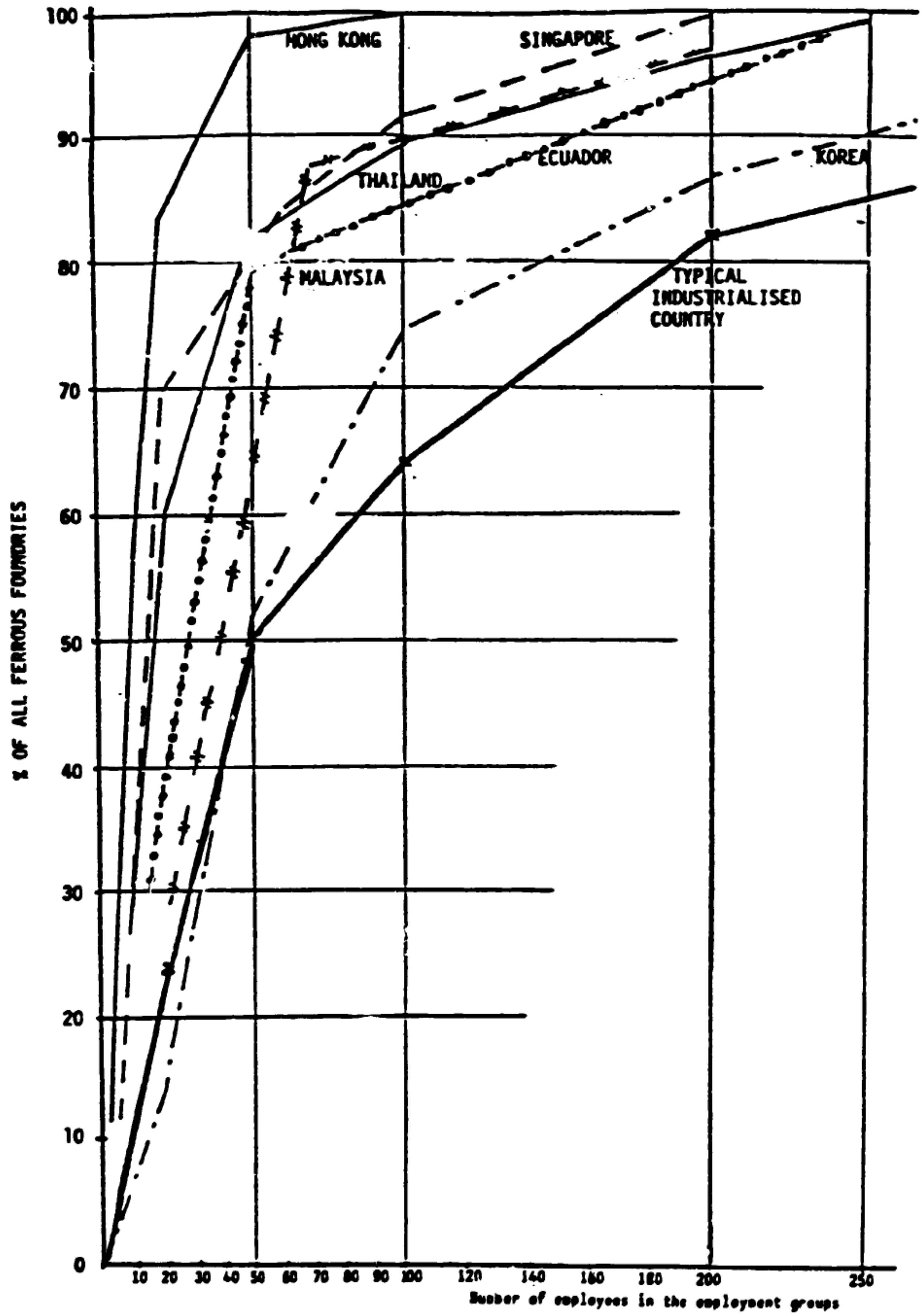


Figure A.0/2: **COMPARISON OF THE EMPLOYMENT PROFILE CURVES IN INDUSTRIALISED AND DEVELOPING COUNTRIES**

Appendix A.I

Equipment of a mini foundry for gray iron production with a capacity of 200 tpy (calculated with 8 working hours per day and 300 working days per year). Produced are canalisation accessories and railway material.

Charging material: As charging material for the cupola hematite pig is needed (because of the small furnace diameter very fine crushing is necessary); further charging materials are, return material from own yield (finely crushed), bought scrap (very finely crushed), steel scrap (small size), ferro-silicon and ferro – manganes briquettes for cupola charging.

Setting up of operating equipment

a. Melting Furnace

200 tpy ≙ 660 kg/day.

Smallest practicably cupola furnace with 400 mm diameter; for an easier repair work a divided furnace shaft can be considered.

Melting capacity per hour appr. 1000 kg

Throughput per working day:	660 kg	output
	240 kg	returns (appr. 40%)
	900 kg	
	+ 50 kg	rejects (appr. 6%)

results in 950 kg. This would demand a daily melting time of about 1 hour. Thereby it is to take into considerationthat the greatest dimension of the metal charge must not exceed above 160 mm (other wise danger for sticking of melting column).

For economical reasons it is recommended to pour only each second day. After each melting day it is left enough time for a careful reconditioning of the cupola and besides this a longer melting time increases the economy of the melting operation.

Weight of iron charge appr. 80 to 100kg

consisting of appr.	25 %	hematite
	40 %	returns
	35 %	scrap iron

coke charge 12-10 % = 10 kg

blower capacity appr. 20 Nm^3/min.

b. Surface Requirements

Assuming a medium piece weight of 5kg, the production per working day would be 660:5 = 132 moulds at appr. 10 kg - 66 flasks.

Assumed medium flask size 600 x 450 mm = .27 m^2.

Theoretical installation area for daily production .27 x 132 =	36 m^2
Handling place fourfold	= 144 m^2
Installation area for 2 productions per day	= 288 m^2
Cupola house with blower room	= 12 m^2
Core shop	= 15 m^2
Sand preparing	= 20 m^2
Other and traffic routes	= 80 m^2
at least	415 m^2

c. Moulding Material

When pouring only every second day, the danger of mould drying exists. Therefore, moulds have to be closed immediately and then to be kept in this condition. For the reasons mentioned above a clay-free, lime lime-free naturally bonded sand is most suitable because of its slowest drying tendency.
At the volume of a pair of flasks of 600 x 450 x 500 mm the following results can be obtained: sand volume / mould = .135 m^3, at 132 moulds per working day = 18 m^3 consisting of approx. 5 m^3 new sand and 13 m^3 used sand. To the new sand there are to add approx. 5% coal dust and 5 - 6% water.

During one working day a quantity of approx. 5m^3 used sand must be carried off and, therefore a suitable situated place for deposing it should be provided for.

As core material, washed and dryed lime-free quartz sand is used with the grain size distribution .1 to .3 mm.

As core sand binder are in question waterglass - CO_2- hardened and/or cold box sand binder.

d. Foundry Equipment

1 Cupola 400 mm diameter
1 Cupola blower, capacity 20 Nm^3/min
1 Charging top for 150 to 200 kg carrying capacity
(electrical crane to convey the charge)
1 Sand and squeezing mixer for appr. 2.5 m^3/h (capacity)
(possible as complete aggregate or separate)
1 Sand centrifugal machine for milled sand
1 Vibrating or rotary screen for used sand
1 Core sand mixer

1 Pin lift jolt squeeze moulding machine for drag boxes

1 Turnover-jolt squeeze moulding machinefor cope boxes of table size according to the largest (canal lattice) to be made on the machines.

1 Light, hand operated travelling crane for setting up and pouring the moulds.

1 Core shooter

2 Floor grinder of high speed

1 Airless steel shot blasting machine

1 Compressor, supplier for: 2 moulding machines
1 core shooter
(1 light travelling crane)
4 compressed-air rammers
3 cleaning hammers
3 portable grinders

1 Blade stacker truck

1 Weighing equipment for cupola charge

Various hand trucks.

The small size of the plant - mini foundry - does not justify the procurement of test of test and control equipment as well as instruments. The sand quality is very sufficiently controlled by hand.

The cast iron quality is very sufficiently controlled by the cast wedge sample, which will be broken after quenching in water and where the chilling tendency is observed at the top. When the chilling tendency reaches too much into the wedge, the casting quality can still be influenced before pouring small additions additions of ferro-silicon into the ladle. For the requested kind the chilling tendency must be kept very low (1 - 2 mm). The fractured surface should be uniformly fine gray grain.

Appendix A.II

Illustration of a multipurpose mini-foundry
(to serve as an example and variant of approach to the mini concept)

Product mix: a) Ferrous

Grey iron and high duty graded iron castings such as brake drums, clutch housings, gearbox castings and other automobile cast component for Threshere and Rice haulers, special cast pipes and fittings such as bands, tees gate and globe valves, pump impellers, diesel engine cylinderliners ironing press, metric weight, etc. 480-600 tpy

b) Non-ferrous castings

b.1) Aluminium and aluminium based alloys such as components for automobile and diesel engines, power fillers and tractors.

b.2) copper and copper base alloys such as gunmetal bushes, shafts, propellers, pump impellers, etc. 50-60 tpy

Production sections

Melting section: (a) 8 to 10 heats producing per day (24 hours) about 1600 to 2000 kg of liquid iron or steel for conversion into shaped castings or on the basis of 300 working days in a year a total of about 480 to 600 tonnes of liquid metal. (Melting unit: 200 kg mini, basic lined, Direct Arc Furnace). (b) A furnace having capacity of 100 kg by operating on a single shift of 8 hours per day will produce about 200 kg of liquid metal or 50 to 60 tonnes per year. (Melting unit: oil fired tilting crucible furnace).

Moulding and Coremaking Section: No-bake resin bonded sand practice is adopted for both ferrous and non-ferrous metal castings for which one Fordath mini mixer running about 3 tonnes of sand per hour is being installed. This mixer is able to prepare all the moulds and cores for both ferrous and non-ferrous castings. In this particular case the quantum of production by means of a low base price for silicon sand does not warrant reclaiming the used sand economically. Hence no sand reclamation is envisaged.

Fettling and heat treatment operators: After the hot metal has been poured in the sand moulds and solidified to normal temperature the shaped castings are separated from the moulds by breaking the sand moulds. These castings then undergo series of finishing operations such as cutting off or knocking off. Basically all castings ferrous or non-ferrous are shot-blasted in an airless shot blasting plant to secure better casting surfaces. after finishing operations the castings are heat treated by means of an electric heat treatment furnace. this will ensure physical properties. after heat treatment shotblasting in the wheelabrator plant follows. Pneumatic chisels are used for further finishing and removing extra metal flashes and fins.

Testing laboratory: For keeping strict watch on the quality of end products the following testing facilities have been provided with modern scientific apparatus: (i) chemical analysis section; (ii) sand testing section; (iii) mechanical testing section; (iv) metallography testing section.

Raw materials requirement and availability

A) Melting scrap

(i) Ferrous (availability of 2000 to 4000 tonnes of iron and steel scrap from various sources as, agricultural workshops, rejected vehicles, sunken boats, etc)

(ii) Non-ferrous metal: (Sufficient non-ferrous metallic scrap such as rejected gun metal bushings and propellers are available for remoulding. But certain amount of virgin copper or copper scrap, aluminium may have to be imported for adjusting quality and metal composition).

(iii) Fluxing and alloying elements, refractory materials: (limestone as the major fluxing material; alloying elements such as ferro-manganese, ferrosilicon, fluorspar etc; oxygen gas for oxidation; refractory materials such as magnesite and fire bricks; graphite electrodes). The additions are normally 10% of the total charge.

B) Moulding and core making materials

High purity silicon sand, bounding material such as bentonite or resin binders, mould and core paints.

Electric power characteristics

H.T.: 11 kv 3 Phase 50 Cycles

L.T.: 400/440

List of main equipment and brief specification

A) Melting Shop

1) Mini Direct Arc Furnace of 150/200 kg capacity, top charging type with tilting mechanism for slagging and tapping operations, manually operated electrode lowering and rising device furnace transformer connected to 400/440V 50 cycles, 3 phase ac line on the primary side and specially built to have three tappings om the secondary side at 135, 115 and 95 volts for operation with two graphite electrodes of 62.5mm dia and a control panel comprising of 3 ac voltmeter suitably scaled. 1 Ammeter suitably scaled, 1 set of indication lamps all mounted on the panel and tap changing switch built in the transformer, complete set of refractory material for the first lining and 62.5 mm dia graphite electrodes screwed and soketed type -complete unit- with all other essential accessories.
ONE UNIT

2) 100 kg capacity oil fired tilting furnace complete with oil burner of suitable capacity for melting copper, copperbase alloys, aluminium and aluminium alloys, airblower, electric motor starters and all essential accessories.
ONE

3) Ladles and hand shanks of following capacities
   a) 250 kg capacity - TWO UNITS
   b) 200 kg " - TWO
   c) 150 kg " - TWO
   d) 100 kg " - TWO
   e) 50 kg " - TWO

4) Ladle heater oil fired type with necessary burners and blowers- and electric motor starter mounted on a stand and with a top cover.
ONE

5) Portable platform weighing scales of 500 kg capacity-steelyard type.
ONE

6) Salters pan balance 50 kg capacity
ONE

7) Optical pyrometer range 1200 to 2000
ONE

B) Moulding shop

1) Sand Mixer of 100 kg batch capacity complete with electric motor and starter suitable for operation on 400/440 V, 3 Phase 50 cycles electric line.
ONE

2) Auto Riddle mounted on a tripped stand complete with electric motor and starter.
ONE

3) Fordath Mini Mixer for mixing furane or phenol formaldehyde type of no-bake cold setting resin-binder complete with liquid resin storage and pumps, sand storage hopper of 10 tons capacity mounted on the mixer and hoist of suitable capacity to raise sand from the ground bin to storage hopper. The mixer will be complete in all respects, for ramming molds and cores on roller conveyor , complete with all electrical motor starters and internal wiring suitable for 400/440 V, 50 cycles, 3 phase electric main.
ONE

4) 18" wide roller conveyor loop total length approx. 30 m with 4 quadding machines to make an endless loop.

5) Pneumatic rammer
TWO

6) Mould boxes of sizes:
750 x 750 x 150 mm : 4 pairs
600 x 600 x 150 mm : 6 pairs
500 x 500 x 125 mm : 6 pairs

C) Fettling shop

1) Wheel abrator type shot blast machine with cabinet complete with at least two high speed impellers suitably located for maximum efficiency of blasting operation complete with all electrical motor and starter of 400/440 V 3 phase 50 cycles electric line.
ONE

2) Double ended heavy duty type. Duplex pedestal grinder with 600 mm dia x 100 mm wide grinding wheels with electric motors starter and dust equipment.
ONE

3) Electric heat treatment furnace of 1250 mm x 1000 mm x 750 mm chamber size complete with operating door and all electricals for

temperature rise of 1100°C thermostatically controlled and with a built-in pyrometer indicator and thermocouples suitably positioned complete with refractory materials.

ONE

4) Transformer type electric welding set of 250 amps capacity

ONE

5) Pneumatic portable grinder suitable for 8" dia grinding wheel

ONE

6) Pneumatic portable grinder suitable for 6" dia grinding wheel

ONE

7) Pneumatic chipping hammer

THREE

8) Oxyacetylene gas cutting torches complete with one set of nozzles of different sizes, and rubber tubings etc

ONE

9) Marking table 4ft x 4ft size

ONE

D) Testing laboratory

I) Chemical section

1) Apparatus for determination of C & O complete unit with combustion furnace and combustion boats

ONE

2) Sensitive laboratory microbalance for weighing of samples

ONE

3) Laboratory muffle furnace of 150 mm x 100 mm x 75 mm chamber size suitable for temperature rise up to 1050°C with all essential accessories and pyrometer

ONE

4) Fume cupboard of approx. 3ft x 3ft x 3ft with sliding glass door exhaust fan and chimney

ONE

5) Electric hot plates: a) 1 kw -ONE

b) 2 kw -ONE

c) 3 kw -ONE

6) Destilling apparatus

ONE

7) Laboratory tables and complete set of neutral glass wares

8) Electrolysis apparatus for testing non-ferrous metals
ONE

9) Ralley's Pillar Drilling Machine for drilling about 1" dia hole in steel complete with all electric motor and starter.
ONE

II) Sand testing section

1) Rapid moistur teller
ONE

2) Standard permeability meter complete with ranning accessories specimen tube etc, cmplete unit.
ONE

3) Compression strength machine
ONE

4) Mould hardness tester
ONE

5) Core hardness tester
ONE

6) Complete set of sieves mounted on sieve shaker for granulometric analysis of base sand complete with electric motor and starter

III) Mechanical testing section

1) Universal testing machine table mounted model manually operated 20 tonnes maximum load working on hydraulic system suitable for tensile, transverse, bend testing and hardness testing attachement and with complete measuring instruments and gauges.
ONE

2) Test piece turning lathe 4 ft bed -6" height of centre complete with electric motor and starter
ONE

3) Double ended table mounted type duplex grinder with 6" dia grinding wheel complete with electric motor and starter.
ONE

IV) Metallography section

1) Metallurgical microscope with course and fire focusing attachment square stage 120 x 120 mm fitted with bright illuminator with field and apparature diaphragm 6-12 V step down transformer with extra straight monocular tube for fixing photographic camera.

   ONE

2) Valco polishing machine complete with all electricals

   ONE

3) Dark room accessories -for developing and printing

V) Miscellaneous

1) Hydraulic pressure testing apparatus with hand pump and pressure gauges and piping.

   ONE

2) Complete set of metric measuring scales, pattern maker's contraction rule, Vernier and micrometers, outside and inside callipers hammers, chisels etc, moulder tools such as cleaners, trowels, polishers etc.

Manpower requirements

Supervisory and technical staff

1. Manager (1)
2. Chief Metallurgist (1)
3. Foundry Methods Engineer (1)
4. Moulding Shop Foreman (1)
5. Fettling Shop Foreman (1)
6. Chief Inspection Foreman (1)
7. Metallurgical Chemist (2)
8. Metallurgical Tester (1)
9. Metallurgical Metallographer (1)
10. Sales Engineer (1)
11. Finance and Cost Controller (1)
12. Progress and Planning Clerk (1)
13. General Clerk (purchase and stores) (1)
14. Maintenance Engineer (1)

Operating technicians

Ferrous casting section

1. Furnace operators (4)
2. Ladle repairer/pourer (3)
3. Sand mill operator (3)
4. Moulders & core makers (4)
5. Helpers (3)
6. Grinding m/c operator (2)
7. Pneumatic chipping hammeroperator (1)
8. Welder/gas cutter (1)
9. Floor labourer (1)
10. Shot blast operator (1)
11. Heat tr. furnace operator (1)
12. Pattern makers (3)
13. Floor labourer (1)
14. Others (2)

Appendix A.III

Multi-product cast-iron foundry

This type of foundry will be capable of supplying small parts and components weighing up to 20 kg and made of grey cast-iron, grade 14 to 17. Its products will be needed by workshops and establishments at village level producing simple metalworking products. It is possible for such a foundry to expand the activities of related metalworking establishments in 10–25 villages. The viability of the foundry depends on local demand for trained manpower available at central village level.

Table A.III/1 EQUIPMENT REQUIREMENTS

Description of equipment	*Number required*	*Estimated price ($US)*
Cupola furnace for melting liquid cast-iron, capacity of 1/2 t/h, inside diameter of cupola, 30 cm, height of cupola, 3.0 m, with blower and motor, roof board and cupola lining	1 set	5 000
Charging hoist and structure, capacity of 0.5 t	1	300
Core oven and sand-conditioning equipment	1 set	2 000
Mould-making machine with maximum casting capacity of 30 cm^3 of steel	1	2 500
Core boxes for floor moulding (various sizes)	40	1 000
Platform scale for weights of 0–1.0 t	1	1 000
Ladles, capacity of 500 kg	1	300
Ladles, capacity of 100 kg	2	300
Hand shanks and ladles, capacities of 10–20 kg	6	200
Crane system with 1-t hoist	1 set	2 000
Shovel, riddles and screens		500
Double-ended grinding machine, wheel diameter of 30 cm	1	500
Tumbler, two air grinders, chipping hammers		800
Wheelbarrows	4	200
Exhaust fan and air compressor, about 50 l/s at a pressure of 8 bars	1 of each	2 500
Pattern-making shop		
Band-saw with a 12.5-mm blade	1	800
Wood-working tools		500
Belt sander	1	300
Hand-operated cross-cut	1	400
Drilling machine of 12.5 mm for mild steel	1	500
Wood-working lathe with a turning diameter of up to 15 cm	1	1 000
Total		22 600

Market aspects. The users would be small workshops manufacturing metalworking products in villages. The method of sales would be based on job orders ranging from single-unit castings to mixed-product batch castings. The potential market would be the local villages. A feasibility study would be necessary before investment.

Expert assistance would be required for training in foundry management and metallurgy, and pattern, core and mould making.

The foundry would be linked with various other industries, in particular the following: multi-product metalworking establishments at village level, woodworking establishments, repair shops for tractors and for automobile and agricultural implements.

The material specifications are as follows: *grey cast-iron, grade 14 to 17,* maximum casting weight of 20 kg.

With regard to production volume, a cupola furnace with a capacity of one half tonne (t) per hour will be charged two or three times a week depending upon the work-load. Output per week will be 10–12 t of liquid metal.

Machinery and equipment requirements are indicated in table A.III/1.

The following supplies are needed for operating the cupola: pig iron, scrap, coke for casting, wood for pattern making, moulding sand, fire bricks, fire clay, flux, core sand, core oils, wires, rods, chaplets.

The following floor area is required: covered 24 m × 30 m = 720 m²; open 30 m × 30 m = 900 m².

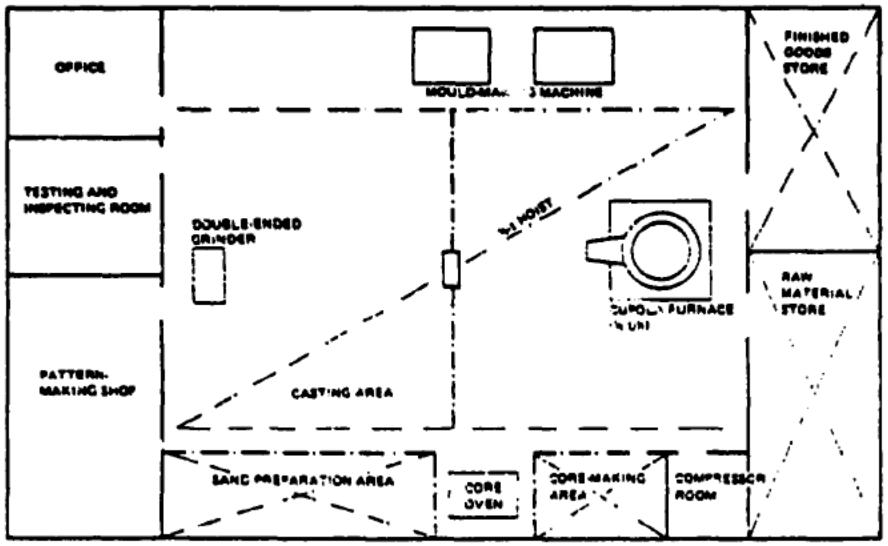
Manpower requirements are indicated below:

Direct labour	*Number required*
Skilled	6
Semi-skilled	5
Unskilled	12
Indirect labour	
Manager and foreman	2
Accounts clerk	1
Pattern-maker	2
Office and sales clerk	1
Watchman	1
Total	30

Special attention should be given to training the following personnel for foundry activities: mould-maker, cupola-charger and pattern-maker.

Figure A.III/1 shows the layout of a typical foundry of this type.

Figure A.III/1



Multi-product cast-iron foundry at central village level

Appendix A.IV

Description of a foundry unit for iron and non-ferrous

The foundry unit described below consists of an iron foundry, a small non-ferrous foundry, a machine tool and maintenance department and a pattern-making shop.

Casting technology: Production of sand castings involves the steps, production of the pattern, production of the mould, preparation of sand and bonding elements forming the mould, preparation of cores, preparation of molten metal, assembling the cores and clamping the moulds, pouring, knock-out, final conditioning, inspection (in line and on finished produvts).

Product types and costs: The plant consists of a casting unit producing mainly grey and nodular iron parts with a small shop for non-ferrous castings. The capacity of the plant is 2000 tpy of usable iron castings and 30 tpy of "good" non-ferrous castings. Figure A.IV/1 is a general floor plan of the foundry. Table A.IV/1 includes a detailed list of technological equipment and machinery, general installations, buildings and site development. The costs listed in Table A.IV/1 are brought together in Table A.IV/2 with the corresponding freight and installation costs. Details of production, personnel, wages and salaries will be found in the Tables A.IV/3 to A.IV/8. Operating costs, revenues and depreciation are detailed in the Tables A.IV/9 to A.IV/12. For rough castings 10% of the manufacturing cost has been considered a "contingency" to be added to obtain operating cost. Overheads for service sales and management are included in machine costs. Table A.IV/13 compares costs and income to yield predictions of profit and loss for the foundry during its first five years of operation. The break-even point will be reached in year 3.

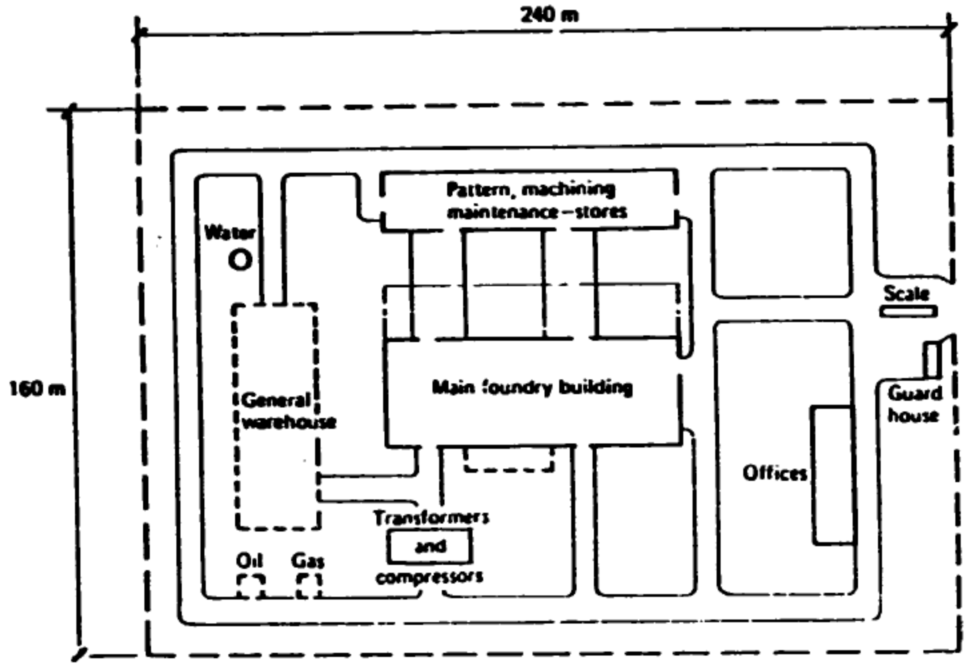


Figure A.IV/1: General floor plan of the foundry

Table A.IV/1:

ESTIMATED CAPITAL COSTS FOR THE FOUNDRY

The following list gives details about the costs of equipment, machinery, buildings and land for the main iron foundry:

Item	*Cost (Thousands of dollars)*
Melting and pouring cupola	86
Cold blast cupola (2 shells) 2 t/h weighing and charging devices, blowers, air control equipment, molten iron tapping and weighing apparatus, emission control, pouring monorail	
Induction furnace	140
Medium-frequency induction melting furnace (crucible capacity 1.5 t, hourly production 0.6 t, maximum electrical power demand 450 kW, coil water-cooling in closed circuit with heat exchanger), power transformers, safety devices, capacitors and control equipment in power cubicle. One crucible with hydraulic tilting devices	
Other melting and pouring equipment	9
Ladle heating station	
Scrap and alloy bins	
Pouring ladles and various equipment	
Total melting and pouring	235
New-sand equipment	33
Floor grit, bins, elevator for feeding store silo with new sand, silo (63 m^3), pneumatic conveyor	
Green-sand equipment	276
Vibrating shake-out unit	
Belts for conveying used sand	
Electromagnetic separators	
Elevators	
Rotating breaker screens	
Silos for used sand	
Sand cooling devices	
Reclaimed sand hoppers with volumetric dispensing	
Screw feeders for binders	
Sand muller (8 t/h)	
Special sand mixer	
Aerators	
Grits and belts for spill sand	
Carrying network structures	
No-bake sand equipment	18
Vibrating shake-out	
Belt for used sand	
Elevator and hopper for used sand removing	
Total sand	327
Green-sand moulding	150
Two jolt-squeezing machines (maximum static squeezing pressure 6 atm., maximum flask size 700 × 850 mm)	
Hoisting devices	

Table A.IV/1 (cont.)

Item	*Cost (Thousands of dollars)*
Rollers	
Roller transfer tables	
Moulding boxes	
No-bake moulding	60
New-sand silo	
Continuous mixer (3 to 4 t/h)	
New-sand storage bin	
Vibrating table	
Rollers	
Transfer tables	
Hoisting device for mould handling	
Pit moulding	5
Hand tools	
Pit with movable panels	
Pneumatic hammer	
Total moulding	215
Core room	35
Core sand mullers (2)	
Manually operated self-hardening sand-core machine (gas automatically controlled)	
Bench core blower (5 litre)	
Core blower (12 litre with mechanized core drawing devices)	
Core benches with sand hoppers (4)	
Core oven with heater unit (two compartments)	
Core racks for oven baking	
Manual low-bed lift truck for oven charging	
Fettling and cleaning room	90
Endless apron shotblast machine	
Air blast cabinet	
Pedestal grinders	
Abrasive cut-off machine (nodular iron)	
Benches for deburring	
Swing-frame grinder	
Snag grinders (portable)	
Arc welding (to be used only later)	
Other portable tools	
Overhead bridge cranes	90
Bridge crane (14.5 m span, controlled from the floor)	
Overhead bridge cranes (2) for the two bays (14.5 m span, controlled from the floor)	
Overhead bridge crane for furnace bay (4.5 m)	
Inspection and laboratory testing	100
Marking-off bench	
Magnetoscope	
Equipped marking-off bench	
Microscope and micrographic equipment	
Quantometer	
Laboratory equipment for analysis and sand control	
Inspection equipment	
Pattern making (wood or resin)	170
Milling machines (2)	
Copy milling machine	
Buzz planer	
Sandpapering surfacer	
Honing machine	
Belt saw	
Lathe	
Thicknessing machine	
Drilling machine	
Grinder	
Marking-off benches (2)	
Carpenter's benches (7)	
Machine shop equipment	323
Centre lathe	
Universal milling machine	
Front surface grinder	
Radial drill	
Column drills (2)	
Bench drill	
Back saw	
Double grinder	
Horizontal turret lathes (2)	
Press (15 t)	
Universal sharpening machine	
Arc welding machine 7 kW	
Portable oxyacetylene welding station	
Portable drill	
Reference table (1 500 × 1 500 mm)	
Benches with vices (8)	
Sets of wrenches, files, miscellaneous equipment (5 sets)	
Sets of tools and electrical instruments for maintenance (3 sets)	
Tools and fixtures	176
Gauges	35
Shelves, containers, supporting frames etc.	157
Total machine and maintenance shop	691
Material handling equipment	125
Fork-lift trucks (3)	
Battery charging stations (3)	
Trucks (2)	
Passenger cars (2)	
Power shovel	
Dumper	
Exhaust and dust-collection system	120
Wet-dust collector for sand plant (1 000 m^3/min)	
Wet-dust collector for shake-outs (sludge tank)	
Shot blast dry-bag system	
Grinders dry bag system	
Utilities	190
Air compressors 3 000 m^3/min with air dryer and refrigeration unit (2)	
Electric equipment: transformers 500 kVA (medium and low voltage boards). Stand-by generating set 100 kW and other electric facilities	
Service water systems (tank 1 000 m^3)	
Hydraulic-sanitary water system	
Gas, oil and other fuels and distribution system	
Main foundry buildings	400
Bay melting (16 m high)	
Foundry bays (12 m high)	
Cleaning room (9 m high)	
Silo shed (sand plant)	
Pattern making, machining maintenance and general store	140
Office buildings (at $300 per m^2)	300
Cabins for transformers and compressors	30
Total buildings	870
Roads and area arrangements (including scrap yards)	50
Fence	25
Sewers and drainage	15
Total site development	90

Table A.IV/1 (cont.)

The following equipment would be needed for the supplementary non-ferrous foundry: for melting, a fuel-oil crucible furnace (135 litre) with control equipment, three ladles and a heating station plus linings and refractory maintenance. For moulding, one moulding jolt machine for sand castings, hoppers, mixers, elevators, aerators for sand moulding, a bench for hand moulding, two gravity die-casting benches with manual operating sequences, and flasks and related equipment are needed. For core making, a cores room, mixers, a hopper, core benches for two work stations with a no-bake process, and auxiliary equipment is needed. For the cleaning and fettling shop, a belt saw, knock-out and fettling benches, two grinders, shop fixtures and equipment. For inspecting, sand and castings inspection laboratory equipment. Hoist devices include two service hoists for tapping and pouring. The total cost of equipment for the non-ferrous foundry is $106,000.

Table A.IV/2: TOTAL ESTIMATED CAPITAL COSTS FOR THE FOUNDRY

(Thousands of dollars)

Cost group	*Equipment*	*Freight and installation*	*Total*
Melting and pouring	235	127	362
Sand	327	130	457
Moulding	215	32	247
Core room	35	10	45
Fettling and cleaning room	90	34	124
Overhead bridge cranes	90	25	115
Inspection and laboratory testing	100	15	115
Pattern making	170	25	195
Machine and maintenance shop	691	59	780
Material handling equipment	125	10	135
Exhaust and dust collection	120	40	160
Utilities	190	40	230
Buildings	870	30	900
Site development	90	10	100
Non-ferrous foundry	106	32	138
Total	3 454	649	4 103

Table A.IV/3: **PRODUCTION AND PERSONNEL FOR THE FOUNDRY**

ROUGH CASTING PRODUCTION BY YEAR*

Item	Year 2		Year 3		Year 4		Year 5	
	Amount (t)	Fraction of total (%)	Amount (t)	Fraction of total (%)	Amount (t)	Fraction of total (%)	Amount (t)	Fraction of total (%)
Grey iron	500	90	1 000	89.5	1 250	88	1 360	83
Nodular iron	50	9	100	9	150	10	240	15
Non-ferrous	6	1	16	1.5	25	2	30	2
Total	556		1 116		1 425		1 630	

*Year 1 has no production.

Table A.IV/4: **NUMBER OF EMPLOYEES IN CASTING PRODUCTION BY YEAR**

Job category	Year 1	Year 2	Year 3	Year 4	Year 5
Skilled		20	20	24	30
Semi-skilled		37	37	45	48
Unskilled		45	45	52	52
Supervisors		10	10	12	12
Management staff and engineers		10	10	11	12
Total		122	122	144	154

Table A.IV/5: **NUMBER AND KINDS OF PERSONNEL IN THE FOUNDRY AT FULL PRODUCTION**

Department	Total	Job category: Skilled	Semi-skilled	Unskilled
Moulding	30	5	15	10
Melting	13	3	7	3
Pouring	8	—	4	4
Shake-out	6	—	1	5
Sand plant	7	2	3	2
Core making	8	3	3	2
Cleaning	26	2	6	18
Maintenance	8	8	—	—
Store	5	1	2	2
Shot blast	4	—	2	2
Laboratory inspection	8	3	4	1
General duties	7	3	1	3
Total production staff	130	30	48	52
Pattern shop	16	10	5	1
Machine shop	10	6	4	—
Total	156	46 (29%)	57 (37%)	53 (34%)

Table A.IV/6: WAGES AND SALARIES PER EMPLOYEE IN THE FOUNDRY BY YEAR

(Thousands of dollars)

Job category	Year 1	Year 2	Year 3	Year 4	Year 5
Skilled	1.5	2.0	2.5	2.8	3.0
Semi-skilled	1.0	1.2	1.5	1.8	2.0
Unskilled	1.0	1.1	1.4	1.6	1.8
Supervisor	3.0	3.5	4.0	4.5	5.0
Engineer	5.0	5.5	6.0	6.5	7.0
Management and staff	5.5	6.0	7.0	7.5	8.0
Total	17.0	19.3	22.4	24.7	26.8

Table A.IV/7: TOTAL WAGES AND SALARIES FOR ROUGH CASTING PRODUCTION BY YEAR

(Thousands of dollars)

Job category	Year 1	Year 2	Year 3	Year 4	Year 5
Skilled		40	50	67.2	90
Semi-skilled		44.4	55.5	81	96
Unskilled		49.5	63	83.2	93.6
Supervisor		35	40	54	60
Engineer		11	12	13	21
Management and staff		55	56	67.5	72
Total	165[a]	235	276	366	432

[a]Training cost only

Table A.IV/8: WAGES, SALARIES AND OVERHEADS FOR WORKSHOP AND ENGINEERING SERVICES IN THE FOUNDRY BY YEAR

Item	Year 1		Year 2		Year 3		Year 4		Year 5	
	Number of workers	Amount (thousands of dollars)	Number of workers	Amount (thousands of dollars)	Number of workers	Amount (thousands of dollars)	Number of workers	Amount (thousands of dollars)	Number of workers	Amount (thousands of dollars)
Pattern shop	4	6	8	16	8	20	10	28	10	30
Machine and maintenance shop	4	6	8	16	10	25	10	28	10	30
Engineers and technicians	2	11	8	48	10	70	12	90	12	96
Overheads[a]		40		80		90		100		100
Total	10	63	24	160	28	205	32	246	32	256

[a]Calculated as $5,000 per machine.

Table A.IV/9: COSTS AND REVENUE FOR THE FOUNDRY

MATERIAL COSTS

(Dollars per ton of rough castings)

Item	*Grey iron*	*Nodular iron*	*Non-ferrous*
Raw material			
Purchased scrap pig-iron, carburizing agents, ferrous and non-ferrous alloys	195	235	1 750
Auxiliary materials			
Sands, binders, fluxing materials, mould and core washes, abrasive and grinding wheels etc.	70	95	150
Energy for melting and molten metal refining, for core or hand mould drying including coke for cupola	110	165	120
Expendable materials			
Gas, fuel, energy, general installations, including cooling, dust collecting, lighting. Also water, oil, and other items	117	147	120
Maintenance materials			
Refractories, lining, pattern repair, spare parts	140	150	150
Total	632	792	2 290

Table A.IV/10: FOUNDRY PRODUCTION COSTS BY YEAR

(Thousands of dollars)

Item	*Year 1*	*Year 2*[a]	*Year 3*	*Year 4*	*Year 5*
Raw and auxiliary materials	—	160	247	329	396
Expendable and maintenance materials	—	90	134	185	245
Wages and salaries	165	235	276	366	432
Contingency (10% of manufacturing costs)	17	70	62	83	101
Total	182	555	719	963	1 174

[a]For the second year (when production begins) efficiency of production is considered to be 50% of optimum and a reject rate of 50% is assumed. Also contingency was increased to 15%. In subsequent years, increasing efficiency and a 10% reject rate are assumed.

Table A.IV/11: REVENUE FROM SALE OF WORKSHOP AND ENGINEERING SERVICES BY YEAR

(Thousands of dollars)

Type of service	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Workshop	9	35	86	151	182
Engineering	4	34	90	180	227
Total	13	69	176	331	409

Table A.IV/12: INVESTMENT AND DEPRECIATION BY YEAR

(Thousands of dollars)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Investment					
Buildings and site development	1 000	—	—	—	—
General installations	525	—	—	—	—
Technical equipment	1 500	420	350	305	—
Total	3 025	420	350	305	—
Depreciation					
Buildings and site development	40	40	40	40	40
General installations	26	26	26	26	26
Technical equipment	150	192	227	275	275
Total	216	258	293	341	341

Table A.IV/13: FOUNDRY PROFIT AND LOSS

(Thousands of dollars)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Income					
Sale of products	–	696	1 406	1 812	2 097
Sale of services	13	69	176	331	409
Training subsidy[a]	225	149	66	72	88
Total income	238	914	1 648	2 215	2 594
Costs					
Foundry production costs	182	555	719	963	1 114
Workshop and engineering services costs	63	160	205	236	256
Depreciation and loan interest	258	300	335	543	583
Total costs	503	1 015	1 259	1 782	1 953
Net profit (loss)	(265)	(101)	389	433	641

[a]For local training only

Aluminium re-melting plants

APPENDIX A.V

The very wide technical know-how of Dr. Schmitz + Apelt has already been transferred into technical equipment and installations of more than 30 aluminium re-melting plants. Some of these re-melting plants have been completely equipped by us, others have only been enlarged and modernized.

A very fundamental feature of the aluminium recycling is the fact that the scrap does not have to pass great parts of the smelting process again, but will only be re-melted and refined under considerable savings of energy.

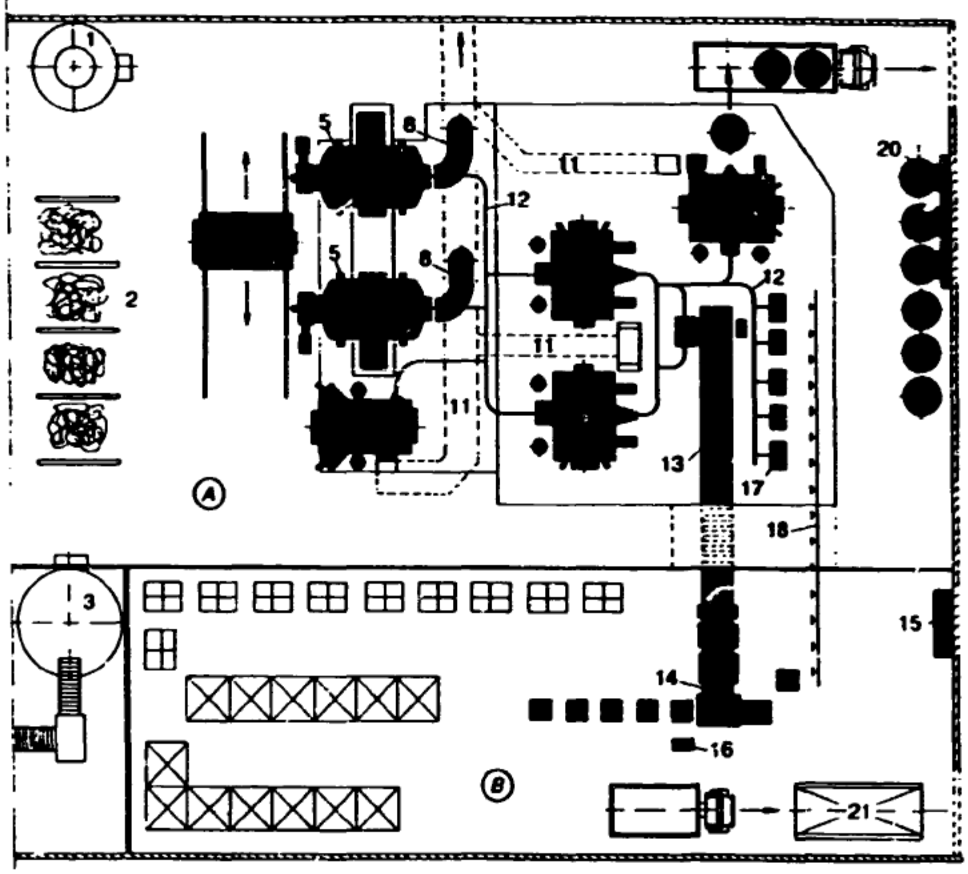
Energy consumption for the treatment of old aluminium as primary material, as compared with aluminium as secondary material:

Use of	Energy consumption for producing aluminium Kwh/t
primary material	16.000
secondary material	2.300

Flow scheme of a complete aluminium re-melting shop with ingot casting conveyor

A melting shop
B ingot storage

1 salt bunker
2 charge boxes
3 swarf bunker
4 charging device
5 rotary melting furnaces
6 slag bucket
7 melting furnace for bulky and iron-contai- materials
8 flue gas duct
9 tilting converter
10 holding furnace
11 flue gas channels
12 launders
13 ingot casting conveyor
14 stacking unit
15 control cabinet for stacking unit
16 switch-board for stacking unit
17 pouring site for palett ingots
18 conveyor for palett ingots
19 transport ladles for liquid metal
20 heating equipment for transport ladles
21 weighbrigde



First the melting furnaces (5) will be charged by means of the feeding unit (4) with salt from the salt bunker (1). When the salt is liquid, the furnaces (5) will be charged in intervals of abt. 20 minutes, with scrap from the charge bunkers (2), or with swarf from the swarf bunkers (3) by means of the charging units, during which the furnace doors with the burners are pivoted upwards. After finishing the melting process, the melt will be transferred via the launders (12) to one or the other or into both converters (9). In such converters the charge will be made ready for pouring, that is it will be chlorinated and alloyed. By tilting the converters will be emptied via a pouring trough into single moulds on the ingot casting conveyor (13). The ingots are cooling down in the casting conveyor by means of water cooling and air convection, and they are either dropped down on the stacking site, or they will be stacked by the automatic stacking unit(14). After cooling down, such stacked paletted ingots are strapped and are taken into the ingot storage. In case liquid transport is intended, the material will be taken from the converter (9) to the holding furnace (10) and from there on request to transport ladles (19), which have been pre-heated by the heating equipment (20) and will then be loaded on mobile trucks. After 2-3 furnaces charge the impurified and useless salt is tapped out of the melting furnaces into slag buckets (6). Either by crane or by hydraulic tables such buckets are taken to floor level and then removed.

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Appendix B

Horizontal continuous casting of ductile and grey cast iron

Cast iron has been produced by the horizontal continuous casting (HCC) method for over 25 years. Grey cast iron can be produced as wellas ductile iron and Niresist alloys. Continuously cast iron melt is cooled much more quickly in the water cooled moulds than the melt cast in sand moulds. Thanks to the economic and qualitative advantages, continuously cast iron has been able to take a firm place in the metal working industry (Fig.B/1). According to conservative estimates, the yearly production of continuously cast iron in Europe was 110000 t, in japan 50000t and in the USA 50000t and continues to increase.

An HCC plant for cast iron consists of a holding furnace, coolers, moulds, a withdrawal device with control unit, run-out tables, cutting unit and break-off unit.

Csat iron sections with lamellar and spheroidal graphite can be manufactured. The chemical composition depends on the cross section of the product, Table B/1. Round bars can have diameters of 18 up to 500 mm. Squares and rectangulars, special profiles and pipes can also be produced.

In Table B/2, Figures B /2 and B/3 the mechanical and physical properties are shown. A summary of the technological properties with more illustrative character is given in Table B/3. Guide figures for the tolerances and machining allowances can be taken from Table B/4.

Due to their extremely fine structure, HCC materials are ideal for hydraulic control devices. Sometimes it is even referred to as hydraulic material. The HCC process is a continuous process and is ideal for the rationalization and automation of foundry techniques. It is therefore usually cheaper to produce an HCC product than a similar product using another method.

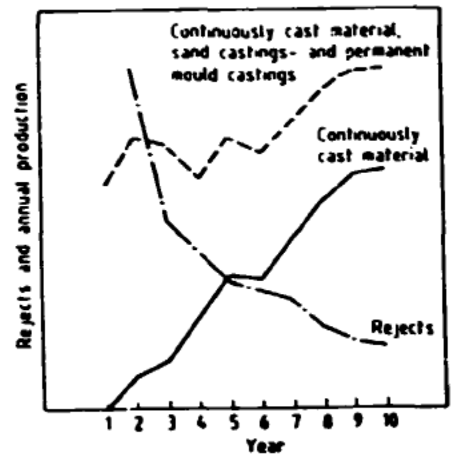
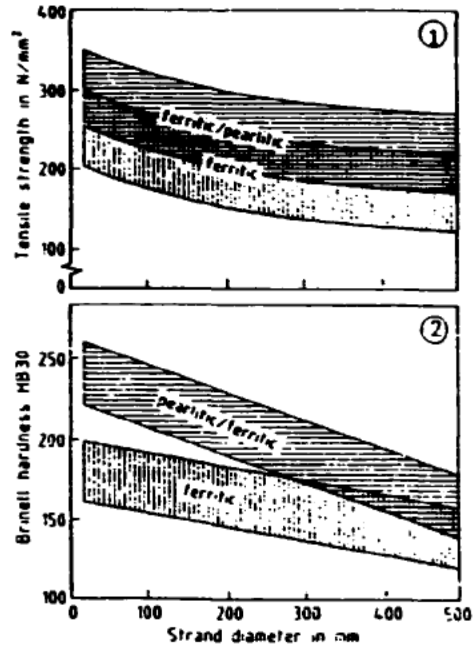


Fig. B/1 Tendency of the continuously cast iron production and the rejection rate in a foundry over a period of ten years



1) Tensile strength and 2) Brinell hardness of continuously cast bars of grey cast iron depended on microstructure and strand diameter

Figures B/1 & B/2

Table B/1 . Chemical composition of continuously cast iron with lamellar graphite (a) and nodular graphite (b)

	% C	% Si	% Mn	% P	% S
a	2.8-3.6	2.2-2.9	0.4-0.6	0.5 max.	0.1 max.
b	3.4-3.9	2.6-3.2	0.6 max.	0.15 max.	0.02 max.

Table B/2:

Mechanical and physical properties of continuously cast iron

Material grade	Grey iron		Ductile iron		
Structure	Pearlitic/ ferritic (normal quality) pearlitic (special quality)	Ferritic (annealed)	Mainly ferritic	Pearlitic/ ferritic	Ferritic (annealed)
Type of graphite	A + D lamellar	A + D lamellar	nodular	nodular	nodular
Mechanical properties: Tensile strength, N/mm²	See Figure 7a	See Figure 7a	600-750	500-650	400-550
Brinell hardness HB30	See Figure 7b	See Figure 7b	220-300	180-270	140-200
Elongation, %	-	-	3-8	5-10	12-17
Modulus of elasticity, 10^3 N/mm²	110.0-130.0	90.0-120.0	160.0-185.0	160.0-185.0	160.0-185.0
Bending strength, N/mm²	300-600	200-400	900-1200	800-1000	750-900
Physical properties: Density at 20°C, kg/dm³	7.3	7.2	7.3	7.2	7.1
Average thermal expansion (20-500°C), 10^{-6} m/(m·K)	9-12	10-13	10-13	10-13	10-13
Thermal conductivity (20-400°C) W/(m²·K)	$0.46\cdot10^{-4}$	$0.50\cdot10^{-4}$	$0.29\cdot10^{-4}$	$0.34\cdot10^{-4}$	$0.37\cdot10^{-4}$
Standard for sand casting DIN 1691/1693	GG-25 and GG-30	GG-20	GGG-60	GGG-50	GGG-40

Technological properties of HCC material from grey iron

	Structure	
	Pearlitic/ferritic	Ferritic
Machinability	good	very good
Polishability	very good	very good
Corrosion and acid resistance	very good	very good
Damping capacity	very good	very good
Wear resistance	good	limited
Galvanizing properties	good	good
Enamelling properties	good	good
Hardenability	good	-
Distortion	very slight	none

Table B/3

Tolerances and machining allowances for continuously cast iron (approximate values)

		Tolerances (mm)	Machining allowances (mm per side)
Round bars	up to 25 mm Ø	+1	1
	over 25-100 mm Ø	±1	2-3
	over 100-200 mm Ø	+2-1	4
	over 200 mm Ø	+3-1	5
Pipes	outer Ø	See round bars	
	inner Ø	+0-3	5
Square and rectangular bars, special profiles	length of side up to 100 mm	±1	3
	over 100 to 200 mm	+2-1	4
	over 200 mm	+3-1	5
	corner radius min. 3 mm		

Table B/4

Appendix C

Shot blast analysis schedule

As common factor for the cost estimate has been chosen the machine utilisation or wheel hour-run. In many cases the cost per wheel-hour run can be similar on differing machines. However, when comparing the costs per tonne processed, a differential of 200-300% can be found. It must therefore be emphasized that cost per tonne is not an ideal instrument for comparisson purposes due to the possibility of machines processing dissimilar castings.

Shot blast analysis schedule

Machine type	Machine no.	Cost centre	Time period From: To:	Date
Operational data	Work processed	Tonnes Time period	Hrs. Machine utilization =	
	Good	Wheel hours run	$\frac{\text{Wheel hours run}}{\text{Shift hours worked}} \times 100 =$	
	Rework	Shift hours worked	Tonnes per wheel hour	
	Total	M/c downtime	$= \frac{\text{Total processed tonnage}}{\text{Wheel hours run}} =$	
Section 1 Production consumables				
Cleaning media	Type	Cost/kg	Calculation	Cost/ WHR hour
		Unit	£	
Costs	Amount replenished (kg)	Replenishment cost	$\frac{\text{Replenishment cost}}{\text{Wheel hours run}}$	= £
			Section 1 sub-total	£
Section 2 Operational costs				
Manning	No. of operators (A)	Cost/operation hr. inc. O/H and supervision	$\frac{\text{(A)} \times \text{cost/hr.} \times \text{shift hrs.}}{\text{Wheel hours run}}$	£
Maintenance	Hours booked (B)	Cost/engineer hr. inc. O/H and supervision	$\frac{\text{(B)} \times \text{cost/engineer hour}}{\text{Wheel hours run}}$	£
Spares		Cost of spares	$\frac{\text{Cost of spares}}{\text{Wheel hours run}}$	= £
			Section 2 sub-total	£
Section 3 Service costs				
Electricity (inc. filter)	Units used (kW)	Unit cost/kW	$\frac{\text{Units used} \times \text{unit cost}}{\text{Wheel hours run}}$	= £
Others, air, etc.	Units used	Unit cost/kW	$\frac{\text{Units used} \times \text{unit cost}}{\text{Wheel hours run}}$	= £
Waste disposal (dust, sand)	Tonnes disposed	Cost/tonne	$\frac{\text{Tonnes disposed} \times \text{cost/t}}{\text{Wheel hours run}}$	= £
			Section 3 sub-total	£
Section 4 Recovery costs				
Departmental	Area (m^2)	Overheads/m^2/annum	$\frac{\text{Area} \times \text{overheads}}{\text{Shift hours/annum}}$	= £
Depreciation	(C) Replacement cost of M/C	Estimated C + D + E	Actual	
	(D) Write off period			
	(E) Est. hrs utilization P.A	$\frac{\text{Wheel hrs. run} \times \text{hrs P.A.}}{\text{Time period hrs}}$	= (F) C + D + F	£
		Section 4 sub-total estimated M/C costs £	Actual M/C costs	£

Summation of costs

Cost/wheel hour run	/WHR	Cost/tonne processed	/Tonne	Summation
Summate section 1	£	Cost/WHR ÷ tonnes/wheel hour 1	£	
Summate section 1 and 2	£	Cost/WHR ÷ tonnes/wheel hour 2	£	
Summate section 1, 2 and 3	£	Cost/WHR ÷ tonnes/wheel hour 3	£	
Summate section 1, 2, 3 and 4	£	Cost/WHR ÷ tonnes/wheel hour 4	£	

GIFA 84: Patternmaking and diemaking equipment

Rolf Roller, Herbrechtingen

CNC technology in the machining operations was indeed a major feature in pattern and diemaking at GIFA 84. Basically, the current state of technology in patternmaking is already so advanced that it is often the case that changes can only still be made in processes and specific properties of the materials.

CNC milling machines for patternmaking and diemaking

Since GIFA 84 and with a visit to the Bohner & Köhle stand it is now also clear to the pattern and diemaker that there is no way of overlooking the CNC technology. With the Euklid system the Fides company supplies one of the best known CAD/CAM software systems for the Bohner & Köhle milling machines, for example, the BOKO WF2-K with FIDIA control as shown in Figure 1. This machine enables mirror-image copying, enlargement and reduction copying and, via distortion and factors for the shrinkage allowance, the production of larger moulds from one pattern. In cases where the CAD/CAM process cannot be considered for master plates, marked-out milling programmes can be generated on-line directly from foil drawings by means of Nestler drafting machines and digitalisation equipment. The programme can also be provided by means of Stiefelmayer measuring machines with digitalisation equipment.

Figure 1. [illegible] milling machine with FIDIA control, suitable for the CAD/CAM system (Bohner & Köhle)

ing speed: R. Roller is lecturer at the Vocational School at Heidenheim.

The second Bohner & Köhle exhibit was the WF1/6-NC universal milling machine. In its standard form this machine is equipped with Heidenhain TNC 150 control which provides control in the three linear axes X, Y and Z. There is manual operation for the movement of the head through 90° to the right or left and a drilling and milling saddle that is installed in the milling head.

F. Zimmermann GmbH also offered the FZ 10/CNC pathcontrolled milling machine with the proven Heidenhain TNC 150 control. It is possible to add digitalization equipment, e.g. FIDIA. The most noteworthy feature of this exhibit is the long machine bed that supports the work table over its full traverse in the X axis. The milling head can be swung to both sides and, together with the infinitely variable drive, forms a closed unit.

Patternmaking machines

F. Zimmermann GmbH presented their full range of equipment on what was undoubtedly the largest stand for patternmaking machines. Mention will only here be made

Figure 2. VBZ 250 vertical belt slider (F. Zimmermann GmbH)

of the new features, such as the new VHZ 250 vertical belt sander (Figure 2). This machine provides for precision flat sanding over an unrestricted area of 400 mm high and 250 mm wide, with a uniform belt speed of 30 m/s. A particular feature here is the long life of the belt, because of its long length and uniform speed. Another new feature was the equipping of the milling, turning and sanding machines as well as the special patternmaker's band saws with digital position displays which can also be fitted to existing equipment.

H. Reinhard AG Maschinenfabrik exhibited disc sanders, pattern milling machines and lathes. The circular saw with a digital display was of particular interest (Figure 3). The segment cutting equipment is an interesting accessory that enables the fast and accurate sawing of ring segments

Figure 3. PKN 3000 precision circular saw with automatically positionable length stop and Type 2SA segment cutting equipment (H. Reinhard AG)

(see Figure 3). The three different types of machines can handle maximum diameters of 2300, 3100 and 6000 mm respectively.

The Roberto Landuzzo company, Italy, showed patternmaking machines at GIFA for the first time. The TMU 1200 lathe and the FMU 1500 milling machines featured digital design.

Measuring and marking out technology

The provision of a measuring and marking out machine is indeed the most urgent problem for many patternmaking shops. F. Zimmermann presented a complete measuring set-up at GIFA. The compact three coordinate measuring machine has digital display and is equipped with a Heidenhain encapsulated, dust sealed system. It can be subsequently fitted with a computer and printer and also supplemented with a dividing and marking out device.

The marking out and dividing equipment from the Reinhard company can be optionally fitted with a face plate with jaws or permanent magnet instead of the normal clamping plate with arms. A swivelling device enables the clamped workpiece to be additionally swung into a second plane and thereby offers all possibilities for marking out. It can be complemented by a parallel height measuring facility with one natural and five shrinkage scales.

Patterns and dies

By comparison with pattern equipment the display of metal dies was very much to the fore because metal patterns and dies are of greater importance to the exhibiting companies, as is the case with the Meissner[1]) and Siebenwurst[1]) exhibits. The Modellbau Saurer[1]) company was represented with a wide-ranging programme and a new feature in the metal spray technique. DISA (Dansk Industrie Syndikat A/S) showed a system for the production of optimum pattern plate equipment by a special resin-facing process (PUR process) for use on Disamatic plants[*]).

Mention should also be made of the following foreign exhibitors. The Spanish companies Uribesalgo S.A.[1]) as well as International Castings[1]) are two of the leading European manufacturers of tools for the foundry. G. Perry & Sons Ltd., England[1]), manufacture steel pattern equipment and core boxes (Figure 4).

Figure 4. Arrangement of core box for the production of shell cores for engine cylinder block crankcases (G. Perry & Sons Ltd.)

The Degussa Atlas M 130 cold reacting methacrylic castable resin was of particular interest. The resin can be highly filled and casts easily, with exceptional accuracy in the reproduction of shape.

Metal spray technology

In order to combine the advantages of a synthetic resin pattern, e.g. easy and economical production, with those of a metal pattern, e.g. higher resistance to scuffing, three companies offered the metal spray method. Ing.-Buro MST W. Hofmann') and HLK GmbH') sell the equipment and all accessories to the patternmaker, whilst the Saurer Modellbau company') sell finished patterns produced by the metal spray method. The basic principle of production is in each case the same: a skin layer is sprayed into the negative and this is then back-filled with synthetic resin.

Machining of foam materials

Every patternmaking shop that works with polystyrene foam knows the nasty problem of the dust and swarf that are electrostatically deposited at every point throughout the workshop. For this reason, the "suction milling" system from the A. Kessel company attracted great interest.

Figure 6. Milling machine with hollow spindle cutter head for the carving and machining of foamed polystyrene with the suction removal of waste (marketed by A. Kessel)

The company exhibited a hand machine and a table machine (**Figure 6**) for rotating rasping tools (more commonly known as milling cutters).

Pattern coatings

Eisbinger Farben- und Firnis-Fabrik Dr. Carl Kesau presented information on the new and/or further development of the second generation of Resolan pattern coatings. Among other things this development now offers pattern coatings paints with easier brushability, greater dry film thickness, an increase in the colourability with the individual tones and reduced fumes. For the foundry, among other things, it offers increased scuffing resistance and better chemical resistance to very aggressive moulding and core sand binders. In the further development particular attention has been given to the health of the worker and safety in the working area.

For further information circle

The Blomberger Holzindustrie B. Hausmann showed a new particularly moisture-resistant paint that is produced by Aschaffenburger Lackfabrik under the name of Alfa-Kontur and is a single component material in the family of highly cross-linked DD coatings.

Patternmaking accessories

The H. Willy Kraus company is an established manufacturer of all types of dowel pins and vents for patternmaking. They exhibited their new "Kronendüse" which has 20% more venting area. It is a self-cleaning brass vent with 0.3 mm wide slots.

The Hohnen company showed their full range of patternmaking tools and accessories. The introduction of a new plastic "pattern clock" for the fast and economical marking of the casting date on wood and synthetic resin patterns illustrates that thought has also been given to small things and details in the realm of miscellaneous materials.

Hofstetter Engineering introduced a new design of the established "Lift-Boy" stripping and ejection system for core boxes. Previously, the core was ejected by means of a hydraulically or pneumatically deformed rubber disc. The new system is equipped with variable stroke steel ejection cylinders for temperatures up to 180°C. The company also offered a special core box seal for the clean production of cores without flash.

CAD in diemaking

The Hasco company showed the possibility of using Computer Aided Design (CAD) in diemaking. The standard elements available, e.g. drilled and undrilled plates, ejector pins, bushes etc. (Figure 5), amount to more than 30000 individual components that are available on data storage media. The user's drawing programme specific to his computer refers to the index of standard elements and

Figure 5. Selection of stabilized elements for rational diemaking (Hasco)

presents the parts on the screen in either two or three dimensions. Hasco also showed a new precision machine for the cross-cutting and grinding to length of ejector pins etc. and also among other things, an electronic edge tracer.

Wood materials

Wood board materials have already gained in importance in the past because increasing labour costs for roughing down, hewing and other preparation work have made patternmaking from natural wood increasingly more uneconomical.

A new variant in the field of wood panels was presented by Blomberger Holzindustrie B. Hausmann. Delignit K 100 is a material that falls between the familiar Delignit Modellholz (DIN specification: plywood) and Delignit Pressholz (DIN specification: synthetic resin-compressed wood). The Delignit Modellholz Plus is also new. Both sides of this board have two parallel grain laminations that allow sanding a cone down to 4.8 mm without exposure of the underlying transverse grain lamination.

Röchling Haren KG also exhibited wood board materials. Their Lignostone-Formplatten products also include synthetic resin-compressed panels.

Synthetic resins

Synthetic resins for patternmaking were offered by Ashland's, Ciba-Geigy's, Degussa's, Deroplast-Chemie's, Ebalta's, Esslinger Farben- und Firnisfabrik Dr. Carl Resau's, Franz v. Furtenbach's, Hohnen's and Lechler's. Naturally, the widest coverage was given to epoxy resins, which each company incorporates in their range for the various processes and required properties. It is therefore not possible to itemize them all here.

Since GIFA 69, polyurethane resins have become more established and have won a considerable share of the market in synthetic resin patternmaking. In the meantime, the manufacturers have improved the properties of these materials and this can best be illustrated by their descriptions of some of the products:

- Ebalta Schnellgießmasse X 100: castable to very accurate and permanent dimensions in every thickness, hardens in 30 min.
- Lechler Uralite Gießmasse 3164: excellent flowability, high resistance to scuffing, minimum shrinkage, improved resistance to swelling.
- Resau Modellharz PU: mechanical resistance, low shrinkage.

Ciba drew attention to the good possibility of the chemical combination of their epoxy and polyurethane resins and quoted examples of application such as the use in a core box of a polyurethane resin that has impact toughness, combined with an epoxy resin back-filling. On the basis of this combination the Ebalta company have developed the special skin resin OH R/E for cold-box core boxes.

The highly reactive mechanically workable polyurethane system (HMP system) was exhibited on the Georg Fischer AG's stand, together with the PU-AC3 three component low pressure plant developed by Mawag Maschinenbau AG's for the process. The plant can handle foam or castable resin (from Ciba-Geigy). This process is a type of skin casting; the optimal skin thickness is between 1 and 3 mm. It is typical for small patterns to have a metal core, and in larger patterns a foam core is combined with light expanded clay balls. The latter also enables larger patterns to be produced in synthetic resin with low weight.

On account of the CAD/CAM system it is now more currently the practice to optimally cut a master plate from a suitable block material. The following companies offered synthetic resin block material at GIFA:

- Ciba-Geigy Ureol 450 which can be machined like wood,
- the Ebalta company offer "wood pattern boards" which are also produced on a polyurethane resin basis to a largest size of 1500 x 400 x 100 mm,
- the largest range of block material was offered by the Rasching's company.

GIFA 84: Green sand moulding techniques and sand preparation

Horst Tillmanns, Niddatal

The single stage compaction of materials by impact methods was the most important new feature in the field of moulding techniques. Furthermore, it was possible to recognize the consistent further development of technical changes that were first introduced several years ago: away from the noisy compaction with jolting and squeezing and towards pneumatic filling and compacting processes. In addition to the reduction of noise the developments have been primarily aimed at improved compaction of the sand, particularly in the immediate areas around the pattern, in order to obtain a better surface, dimensional accuracy and consistency of the weight of the casting and the reduction of its weight as a consequence of the lower tolerances. In many cases the pattern drafts can be less. However, the development of the processes has also been aimed at the reduction of the amount of spill sand and the achievement of longer intervals between maintenance.

Machines for the production of moulds in flasks

Georg Fischer Aktiengesellschaft, Switzerland, offered impulse compaction moulding machines. The "Gas-Impact" technique of generating the pressure by combustion of a gas mixture (Figure 1a) has already been proved in practice for a number of years. The "Air-Impact" process, where the compaction pressure is derived from pulses of compressed air, is a new feature in the +GF+ programme. A machine with 825 x 650 x 250/250 mm³ flasks was operated on the stand at GIFA. The pressure required for compaction is built up in a vessel fed from the compressed air mains. The rapid opening of the vessel produces an impact on the moulding material (Figure 1b). It is important to use a suitable valve that allows the sufficiently rapid outflow of the compressed air. In this case a poppet valve was used. The compaction unit can be used in various mechanical designs of machines and plants, e.g. in revolving machines which, with two individual moulding machines, it is possible to produce up to 240 moulds per hour (Figure 2).

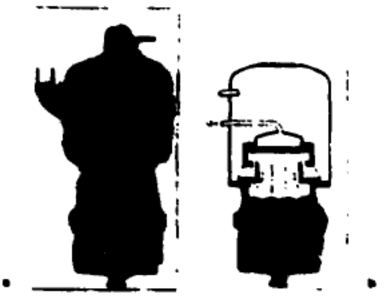


Figure 1. Impact compaction: a) with gas impact (ignition triggers the compacting operation); b) with compressed air (the impact on the sand is triggered by the opening of a valve)

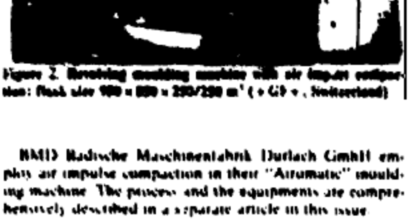


Figure 2. Revolving moulding machine with air impact compaction: flask size 900 x 800 x 250/250 m³ (+GF+, Switzerland)

BMD Badische Maschinenfabrik Durlach GmbH employs air impulse compaction in their "Airomatic" moulding machine. The process and the equipments are comprehensively described in a separate article in this issue.

BMM Weston, England, also displayed and demonstrated a machine working on the air impulse system. With 600 x 450 x 200/200 mm³ flasks, this machine should have a capacity of up to 100 complete moulds per hour. The pattern plates for cope and drag are used in the shuttle system.

Prof. Dr.-Ing. H. Tillmanns, Fachhochschule Giessen-Friedberg, West Germany

Kunkel-Wagner exhibited their "Vacupress" moulding machine at GIFA 79. In the meantime the concept has been proved in practice and it has been supplemented with two design variants. The sand is fed from the metering hopper into an evacuated space and in doing so it loses about 60% of its air content. This enables the achievement of a fine distribution at the pattern and a reduction in the springback. Final compaction is by squeezing. In the first design the metering hopper and a multi-piston squeeze head can be entered into the evacuated space. In one variant of this the metering hopper has a slotted base which corresponds with the shoot-squeeze plate, as is normal when operating with pneumatic pressure. After the filling operation the box is pressed upwards against this container base. The principle of the second variant is shown in Figure 3. After evacuation of the flask the sand enters through the filling gap around the edge of the squeeze head. The vacuum in the box draws the sand also to the middle of the flask. The flask is then moved against the squeeze plate that is fitted with a water-filled membrane and so achieves the final compaction. All three types of machine are continuously operating, with the drag and the cope being produced one after the other. The pattern plates are moved by means of a rotary table or on the shuttle system.

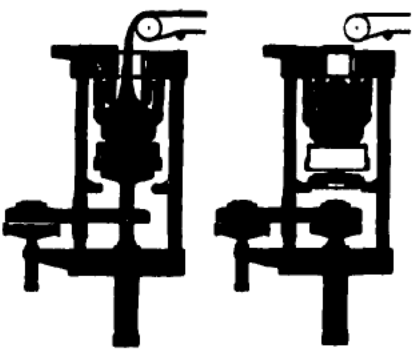


Figure 3. Schematic of the VACUPRESS moulding process - filling and flushed mould respectively (Kunkel-Wagner type)

Kunkel-Wagner also showed a conventional jolt-squeeze strip moulding machine and a rollover moulding machine.

The Heinrich Wagner Sinto company exhibited a new development. The machine operates on the "Air Flow Press Moulding" process (the Seiatsu process) and should produce around 100 moulds per hour with 750 x 650 x 250/250 mm³ flasks (Figure 4). The pattern plates for the drag and cope flasks are changed by means of a rotary table. After filling of the sand, the flask is closed with a hood, through which the material is subjected to a short duration flow of air. The air passes through the sand and exits via nozzles in the pattern plate. This produces increasing compaction of the sand towards the pattern plate. Final compaction is by means of a squeeze plate.

Figure 4. Moulding machine with "Air flow-Press" compaction to the Meleise process (Heinrich Wagner Sinto)

Another new feature from Wagner Sinto was the green sand core process. The difference from the usual production of green sand cores is that in this new process the sand is firstly shot into a core box and then a rod is pressed into the centre of the core. Instead of a rod the compaction can also be effected with a bag that is inflated inside the core.

Goetze AG made their first appearance as a manufacturer of moulding machines. An automatically operating machine developed specially for the production of piston rings was displayed in the working condition. The machine can produce moulds for small thin-walled batch-produced castings. It is particularly suitable for rectangular or round shapes with maximum cross-section of 415 x 365 mm² or 435 mm diameter and only 35 mm high. The output is up to 600 moulds per hour which are fitted together for stack moulding. Operation is with very fine natural sand with a consumption of up to 8000 kg per hour. Compaction is by means of vibrating and squeezing.

Huderus AG exhibited their "Bohrrobot", an interesting machine for the drilling of pouring bushes, feeders and vent holes. The equipment can cyclically perform up to 6 operations on 80 to 100 moulds per hour. Two drilling heads can be fitted with different drills. Together with freely programmable position control the three rotatory and one translatory axes of movement cover a variety of applications. When changing the pattern the drilling pattern can be reset by means of the programme register. Particular attention was given to mould compaction through "underpressing" (Figure 5). The pattern plate is pressed through the filling frame from below and against the opposing squeeze head. Because better compaction occurs on the minimum sand volume side it is particularly good in the areas around the pattern.

formed one after the other on the viewable pattern plate. The moulding material is filled by free-fall and compacted by vibration and squeezing.

GOSTOL, Jugoslavia, exhibited an automatic "boxless moulding machine". The method of operation incorporated a particular feature insofar as the cope and drag moulds are simultaneously shot and squeezed in a vertical position. They are then turned through 90°.

The following manufacturers of flaskless moulding machines presented information on their established and proven designs:
FDC Foundry Design Corp.[1]), Switzerland, on their "Bison" machine for approximately 1‿ moulds per hour;
the Webac company[1]) offered different models in the "Match-Biomatic" series;
Osborn[1]), France, also have a "boxless moulding machine" in their range;
A. Stotz AG[1]) promoted their automatic boxless moulding machine with horizontal and vertical parting;
Gisag[1]), GDR, showed a model of their "gisabloc 35" plant with which the cope and drag moulds are produced one after the other by the shoot-squeeze moulding process;
Machinoexport[1]), USSR, displayed the model of a machine that has been established for several years for flaskless moulding with vertical parting.

Plants for physical moulding processes and special processes

Plants for the vacuum moulding process (V-process) are practically always special designs which are layed out in accordance with the require‿ents of the customer. They are supplied by the Heinrich Wagner Sinto company. The moulding process with binder-free sand has captured a firm position in foundries. The production capacity is dependent upon the cooling time of the casting in the particularly well thermally insulated sand and allows for a maximum of ten moulds per hour.

The vacuum full mould process (vacuum evaporative pattern casting process), in which a foam pattern is gassed by the cast metal, was very impressively demonstrated by Vereinigung Vollformgießen[1]), Grünzweig & Hartmann AG[1]) and Full Mold International GmbH[1]). The foam pattern is introduced into a vented flask in which the binder-free sand is fluidized by means of compressed air. The surface of the sand is then covered with a plastic foil and the sand stabilized by vacuum. After casting, the vacuum is maintained until the metal has solidified. The advantage here is the absence of mould parting flash and that there are no cores.

A special moulding feature was pres‿ted by Kleine-Brockhoff GmbH in the form of the "Durpigen Vac" process, by which smaller castings, in particular aluminium castings, can be produced with extraordinary accuracy. The pattern is introduced into a mould frame which is prepared with porous hoses. After the application of a parting agent it is filled with a gypsum mass. This solidifies after approximately 25 minutes; the pattern is then removed. The mould pack is impacted with compressed air to drive out the excess water and is then dried at around 100°C. On casting, the hose system is set under vacuum so that the metal follows the finest contours.

Sand preparation machines

Development of sand preparation machines consists of efforts for the improvement of the high speed mixer, above all with turbo units. There is also now greater emphasis on the reduction of energy consumption and ease of maintenance.

Maschinenfabrik Gustav Eirich offered intensive mixers with capacities up to 400 t/hour. The characteristic feature is the rotating mixer pan that in new models is inclined at an angle. In some models the agitator can be removed. The mixers can be supplied either for batch working or for continuous operation.

Georg Fischer AG, Switzerland offered the Type STM turbine mixer. This machine combines the following movements: the mixer bottom rotates, the sand is slowed down on the stationary wall of the container and is then fed by the guide vanes to the front of the rapidly rotating mixing tools. The various types of movement provide an intensive preparation process. The complete sand preparation plant also incorporates a homogenizing drum, sand cooler and control system.

The A. Stotz AG[1]) "Tornado" turbo-mixer is available for capacities between 25 and 150 t/hour. Figure 6 shows

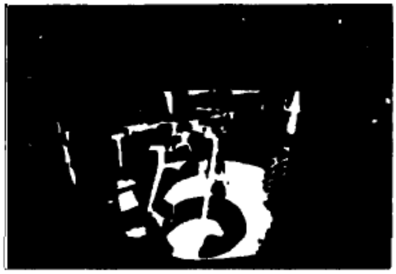
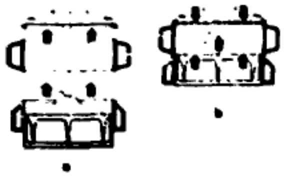


Figure 6. Arrangement of the mixing tools in a Tornado mixer (A. Stotz AG)



a) starting position and raising of pattern and flask against the pattern frame;
b) moving away of pattern and mould as well as separation up to the pattern starting position

Figure 5. Sand compaction by bottom squeezing (Buderus AG)

Instead of the earlier jolt-squeeze machines, FDC Foundry Design Corp., Switzerland, now incorporate shoot-squeeze machines in moulding plants designed by the company. The standard machines are offered for 400 x 400 to 1500 x 800 mm² flasks with different heights.

A. Stotz AG supply their established moulding machines with multi-piston high pressure and shoot-squeeze compaction as the centre piece of their moulding plants.

Fritz Hansberg, Italy, build moulding machines employing shoot-squeeze compaction. The shooting hoppers have a capacity of up to 600 litres, which is also sufficient for large flasks. The machines built up to now have flask dimensions of 450 x 350 mm² to 1600 x 1200 mm² with flask heights of between 115 and 450 mm. The minimum time for the production of a cope or drag is 10 s, i.e. a capacity of 150 moulds per hour.

MECFOND A.G., Italy, also supply shoot-squeeze moulding machines, in which the shouting plate is squeezed. A capacity of 180 moulds per hour is claimed for 1000 x 800 x 200/200 mm³ boxes.

Gisag, GDR, offered a wide range of jolt-squeeze machines as well as rollover machines.

Osborn, France, supplies the established range of jolt-squeeze and shoot-squeeze moulding machines.

Centrozap, Poland, also offered jolt-squeeze machines in both parallel and continuous versions. Additionally, they offered a special machine with round (425 mm) or, if required, rectangular flasks 35 mm high. Compaction is by means of vibrating and squeezing.

Machinoexport, USSR, again showed a model of a plant for the mechanized production of stack moulds.

Machines for production of flaskless moulds

For many years DISA, Denmark, have been building ever more improved machines for the production of flaskless moulds with vertical parting. Types 2013 Mk 4 and 2130 for a maximum of 400 moulds per hour were exhibited on their stand.

In order to also achieve a high output when cores are to be set, this can be achieved with the DISA CSE core setter that operates with the cycle of the machine. A special gripping tool enables the equipment to be used for the manual exchange of pattern plates. For automatic setting the cores are picked up from a horizontal position, they being held in the mask by means of vacuum. The are then swung into the vertical position and set into the mould.

The suction-squeeze process has been systematically developed by Forma-Bühler GmbH. The sand is simultaneously vertically filled and precompacted onto the pattern in the upper and lower mould chambers through the suction-squeeze plates. Because on squeezing, both mould chambers slide over the pattern plate, pressure is applied from the pattern side which correspondingly leads to good compaction around the pattern. The mould removing technique on this machine is worthy of particular note. It is referred to as the air thrust mould removal process, in which compressed air is applied to the nozzles in the pattern plate which are used for the ventilation of air during the filling of the sand.

K. H. Sailer Maschinenbau exhibited their "Haflinger" suction squeeze moulding machine, the development of which was promoted in the humanization of work programme. One of the advantages connected with this technique is the low amount of noise. Particular attention was given to simplicity of construction in order to reduce the repair and maintenance costs. Very simple pattern plates can be used, which are fixed to their supports with a hinged frame through which the air is extracted from the mould chambers. The frame is surrounded with a collar of slit nozzles so that the actual pattern plate only needs to be fitted out in isolated cases. The frame can be undone and fastened on one side with quick action screws which allow for easy changing of the pattern. The machine is offered in two capacities.

The Universal company were represented with the established moulding automat, with which the moulds are the arrangement of the mixing tools in the rotating pan. In preparation plants the mixer is combined with control and monitoring devices, the combination of the units having been developed with Baerbe-Werke[1]).

The W' bac company presented a new feature. In the established Speedmuller with horizontal milling wheels, new sand, bentonite and coal dust is fed in with injection directly from the side. The additives are firstly premixed in a pneumatic aerator and then pneumatically fed to the mixer. The company additionally showed the "on-line control" with which the required amount of bentonite addition is determined by the current absorbed by the mixer motor.

BMD showed a completely different and surprisingly simple solution of the sand preparation problem. The "Contra-Mix" mixer has a stationary mixing-pan in which the slow running mixing tools rotate in opposite directions one above the other in three levels on one axis (Figure 7).

Figure 7. Mixing tools in the Contra-Mix moulding sand mixer (BMD)

The Teka-Maschinenbau GmbH mixers have fixed pans and are equipped with turbines and milling wheels. The range extends from 10 to 125 t/h.

PEMAT-Baumaschinen GmbH offered mixers which are equipped with flexibly mounted mixing tools which are driven from a central shaft. Another series of machines employs additional planetary agitators.

The Gisag, GDR, mixers operate with a combination of rubber-covered milling wheels and additional mixer blades.

Centrozap, Poland, offered the Dasamet mix-muller with different sizes for capacities of 8 to 72 t/hour. The different sizes of pendulum drum mixers have capacities between 18 and 180 t/hour. The MD 1000 "Dynamic" mixer is a new feature and has a capacity of 60 t/hour. On account of its simple method of construction it should not only be low in price but also have a considerably reduced energy consumption.

The Heinrich Herring Maschinenfabrik robust SAMUM mixmuller and sand aerator is suitable for foundries with low and medium degrees of mechanization.

In the H. Paulus sand preparation plants the prepared sand aerator is produced by themselves.

The Swiss Simpson Maschinen AG "Multi-Cooler" can be supplied for capacities up to 300 t/hour. A trough with two opposite rotating transverse arms fitted with mixing blades transports the used sand from the inlet to the outlet so that it is continuously turned over. The required amount of cooling water is determined from the electrical conductivity of the sand. Cold air is blown into the sand from the side. The evaporative cooling brings the temperature of the sand down to around 10 K over ambient. The extracted air passes through a separator that extracts the bentonite carried out in the cooling air so that it can be reused.

For the homogenization and cooling of used sand the French Fondetec company use a combination of a continuous drum, in which the sand is pre-cooled by mixing with water, and a cooling equipment. Here, the sand is cooled on a perforated conveyor, mechanically turned over by agitator arms and cooled by the passage of blown air.

The Uhde GmbH sand cooler operates on the fluidized bed principle with the spraying of cooling water controlled by temperature. The sand can be cooled from 300°C to 35°C in only one minute and then has a residual moisture content of 1 to 2%. The various sizes of machines have capacities ranging from approximately 15 to 200 t/hour throughput.

Paul Lippke KG supply measuring and control devices for the monitoring and control of sand circulation. The required water addition in the mixer is determined by measurements of the residual moisture and temperature in the flow of used sand. Control is effected by the measurement of the sand moisture content after mixing.

GIFA 84: Equipment for moulding and coremaking with chemically bonded sands

Gottfried Schneider, Düsseldorf

In the field of machines that are predominantly used for core and shell core making with cold or hot tools as well as in the area of continuous mixers, the construction of the machines now complies with the regulations concerning the safety of the working area and environmental protection. The focal points of new developments are in:

- introduction of the suction technique for filling, compaction and curing operations,
- programmable controls for the operation and monitoring of the process,
- improvements in design to obtain greater accuracy and reliability in production, combined with flexibility and an increase in output,
- mechanization and automation of tool changing, e.g. core boxes, and the cleaning of machines,
- use of auxiliary equipment and manipulators as well as the linking of production and secondary treatment operations, e.g. gluing, core deflashing and blacking, defined depositing of parts and
- special processes and equipment for specific areas of casting production with the main objective of the humanization of work.

Figure 1. ABC-FLEXIBLO machine for the production of cores from rapid self-setting sand mixtures (Beardsley & Piper, USA)

Dipl.-Ing. G. Schneider, Secretary of the Foundry Machinery and Equipment Committee of the Verein Deutscher Giessereifachleute

By comparison with previous exhibitions, most of the exhibitors restricted their displays to their further and new developments; there was hardly any evidence of machines from established standard ranges that had already been previously introduced to the market.

Together with the WEBAC company, with whom they have enjoyed many years of cooperation, Beardsley & Piper, Chicago (USA) presented the ABC-FLEXIBLO range of machines (Figure 1), which has already been introduced in American foundries. With the relevant equipment it is possible to manually, semi-automatically and automatically produce cores from all rapid self-setting sand mixtures, which are prepared in the quantity required for the cores in the sand mixer that goes with the machine. Low blowing pressures enable the use of existing core boxes, these can also be in wood or plastic. Disposal of waste is not necessary with the ABC process.

Croning & Co offered their established shell moulding machines and gluing presses. With the automatic shell moulding plants further developments included the gas heating system, the control and ancillary equipment, such as automatic gluing and unloading devices.

Georg Fischer AG, Switzerland, who include core shooting machines for all processes as well as shell moulding machines in their range, exhibited a newly developed core deflasher (Figure 2). It is primarily applicable for hatch cores which are deflashed within two seconds by means of being held in a die which is vibrated in defined vertical and horizontal directions. The 2 to 3 minutes required for changing the die allow for fast changing over of

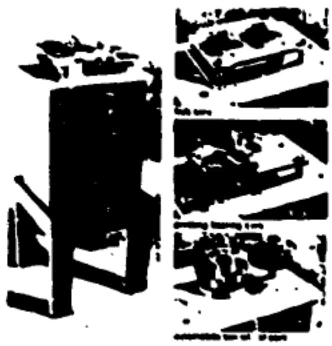


Figure 2. Vibrational deflasher for batch produced cores; operates by vibrating the jig holding the core (Georg Fischer Aktiengesellschaft)

production. It is claimed that, according to the design, the tools have a life of 100000 to 400000 cores.

From a new range of machines the Fomes company, Switzerland, exhibited the PRACTICOR HV25 core shooting machine which has been developed for production with gas curing processes such as CO_2 and cold box. With the sand hopper contents of 25, 38 and 50 l, microcomputer control, hydraulic horizontal and vertical closing of the coreboxes, these machines have a wide range of applications.

Gisag, GDR presented three of their new coremaking machines. The KMAYG 80 special shell core machine with microelectronic control has a rotatable blowing head for the acceptance of two different sizes of corebox. The HEE 12/1 and HEE 25/1 machines exhibited from the

Figure 3. CD 11 core deflashing plant for the continuous secondary treatment of cores (Alfred Gutmann)

Gisecomatic range feature vertical parting of the corebox which allows for the removal of the core by manual methods as well as the depositing of it on a belt.

Alfred Gutmann displayed a newly developed deflasher for the secondary treatment of cores (Figure 3). Deflashing is by means of various sizes of plastic granulate which is blasted through nozzles.

Together with one of the leading European automobile manufacturers, Fritz Hansberg of Italy have developed machines that are suitable for all types of gas curing processes, and have sand hopper contents of 40, 80 (Figure 4)

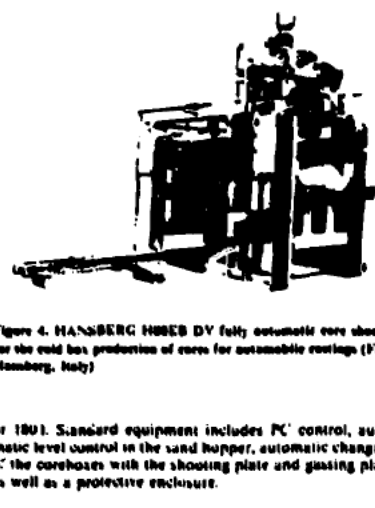
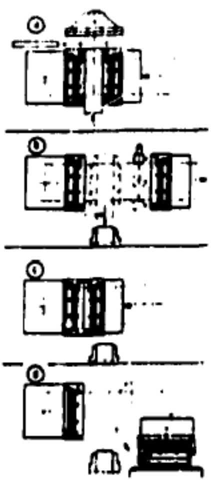


Figure 4. HANSBERG H80EB DY fully automatic core shooter for the cold box production of cores for automobile castings (Fritz Hansberg, Italy)

or 180 l. Standard equipment includes PC control, automatic level control in the sand hopper, automatic changing of the coreboxes with the shooting plate and gassing plate as well as a protective enclosure.

Adolf Hottinger exhibited the new machine concept for the economic production of cores and shell moulds. Above all, this includes a quick core box changing device with an integrated hydraulic lock as well as rapid cleaning of the shooting head and changeover of the sand mixture. This was demonstrated with the Fastcore 22-CB fully automatic vertical parting machine as well as with a model M 1:2.5. The production of completely enclosed hollow cold box or SO_2 cores was shown on the newly developed Fastcore 22-CB-S (Figure 5). The automatic production of complete, extensively recessed transmission housing cores with a 4-part corebox by the hot box or shell moulding process was demonstrated with the Type HS-32-HVA machine. A manipulator integrated with the machine operation removes the core from the machine, immerses it in a blacking bath



a) shooting and glossing of core halves,

b) opening of the tool; moving out of centre part of tool; application of glue on a core shell;

c) tool closes for gluing together of both half core shells,

d) tool reopens and one half rotates to eject core onto unloader belt

Figure 5. Production of completely closed hollow glued cores on the Fastcor 22-CB-B machine (Adolf Hottinger)

and then places it on the corresponding templates for onward transportation.

HPM Corporation, USA, showed a film concerning a machine for the production of cold setting shell cores. This process that is named by the inventor Anatoly Michelson utilizes the advantages of the cold-box process and of shell cores (Croning cores). After the curing of an adjustable depth of the surface layer with gas the corebox is rotated through 180° and the residual uncured sand inside the core is blown out downwards and then reused. In order to obtain the curing of the outer layer it is necessary to use coreboxes made from porous material, e.g. sintered metal, or vents.

From the extensive programme of machines for core sand preparation and coremaking by the established processes, Imafond, Italy, showed new developments in the way of their Type SPR and SPC machines for the automatic and semi-automatic cold box working respectively.

In addition to gravity die casting machines for heavy metals, IMR, Italy, also build coremaking machines. They showed the new FA 2.5 core shooting automat with protective enclosure which has a sand hopper content of 2.5 l for the hot box production of smaller cores.

The Alb. Klein company exhibited their SF process (Spar-Formverfahren, Figure 6). This is a new mouldmaking process for batch casting in which, after the first casting, the mould takes on the function of a "supporting mould" for around a further 20 cycles. After each casting the "burnt" sand layer around the casting itself is removed and renewed with the shooting in of new sand and gas curing in the following moulding operation.

moulding box halves with residual used sand and set pattern,

moulding box with metal filling

Figure 6. SF moulding process for batch casting in chemically bonded sand (Alb. Klein)

Four machines with 2.5, 5, 12 and 25 l sand hoppers were used by Dipl.-Ing. Laempe GmbH to demonstrate their activities in the conversion of existing standard core shooting machines to automatic operation for the cold box, CO_2 and SO_2 processes (Figure 7). The conversion kit offered primarily consists of freely programmable control, a machine table with vacuum clamping of the halves of the corebox, an universal hardening plate and the protective cabin with automatically operating door.

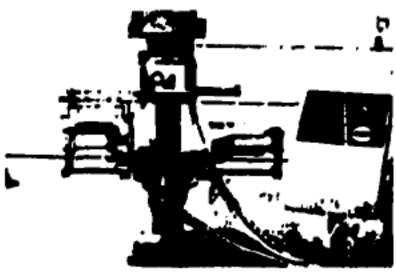


Figure 7. Standard core shooting machine converted to automatic operation on the cold box, CO_2 or SO_2 processes (Dipl.-Ing. Laempe GmbH)

The Spanish Loramendi company showed one machine from each of three newly developed ranges: the S series Type S-25 with a 25 l sand hopper for the shooting and setting of CO_2 and cold box cores, the SVA series Type SVA-40 with a 40 l sand hopper for hot and cold processes and automatic operation with placing of the cores on a belt and the SHA series Type SHA-40 with a 40 l sand hopper for hot and cold processes and automatic operation with placing of the cores on transportation forks. Protective enclosures are standard equipment.

V/O Machinoexport, USSR, again offered the "back plate shell moulding process" for the production of cast iron batch castings, in which the die is lined with a 3 to 8 mm layer of curing moulding material. The A 120 M plant developed for this process works with a 1000 x 1000 x 250/250 mm back plate and achieves an output of 45 to 50 moulds/hour. For the also established "Eclair process" for the production of cores from liquid sand mixtures with heated coreboxes the exhibitor offered complete turntable plants with preparation of the moulding material and stations for filling, curing and parting operations.

Morionair-Druckluftsteuerung GmbH presented a pneumatic manipulation system for the automatic removal of cores from automatically operating machines.

Michel GmbH have expanded their range of automatic gassing equipment. They exhibited 4 generators for the gas setting, cold box (air-amin) and SO_2 processes, with improved metal bellow metering and in some cases electronic control. Particular attention was given to the central supply plants for amin (Figure 8) and SO_2.

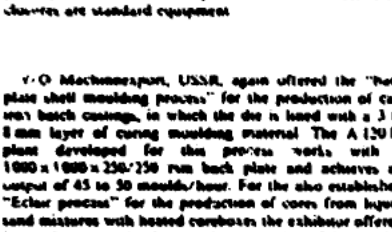
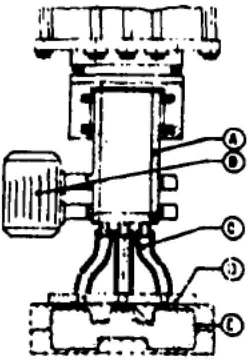


Figure 8. Coremaking shop with central amin supply; the liquid amin is fed by pipe from a storage station to the automatic gassing equipment and converted to the gaseous state (Michel GmbH)

Oukorn, France, have modernized some details on their machines for CO_2, hot box, shell and cold box cores.

The Italian Peterle company exhibited machines for shell cores and cold box cores. The Type 313/800 with a 253 shooting head enables fully automatic production of shell cores and their depositing on a belt. The "cold box compact process" was displayed together with the coldmatic "Sirio" which is equipped with an automatic sand preparation plant with a Klein vibratory mixer. The FLUIDAT shooting head was a new feature (Figure 9) which,



A vibrating head,
B vibrator motor,
C pipeline,
D shooting plate,
core box

Figure 9. FLUIDAT shooting head (Peterle, Italy)

like the vibratory mixer, is based on developments by Prof. D. Boenisch.

The IOU vacuum warm box process (VWB process) was displayed on the Quaker Oats Company stand and is a variant of the already established warm box process. Normal hot box machines are used without any worth mentioning changes to the corebox. The curing process is accelerated by the evacuation of cores in the corebox.

The new features in the Roperwerk EUROCOR machines among others include PC control, sand metering,

Figure 10. MPS monorail manipulator system (Röperwerk)

various methods of core removal and pick-up as well as the fast changing of the corebox equipment and types of sand. From the KV range of machines the company exhibited the KV 4 core shooting and curing automat for vertically parted boxes with the deposit of the cores on a belt as well as the H series RH 36 automat for horizontally parted coreboxes. The MPS manipulators are also new (Figure 10). They are based on a flexible modular construction principle and can be used for many tasks in the handling of cores and castings. One variant was demonstrated as a monorail system for the picking up, deflashing and setting down of automobile component cores.

The Shalco Systems machines for all types of coremaking processes and shell moulds incorporate modernisation of certain details. The company exhibited the Model 4-103 for horizontally parted coreboxes, the MCM 5 for shell moulds as well as a SHALCO-HUTCHINSON shell moulding machine. These machines incorporated protective equipment.

Unimation Incorporated presented information concerning new developments in the use of robots for the automatic gluing of cores.

Together with a complete automatic plant for sand preparation and coremaking (Figure 11), Vogel & Schemmann exhibited a cross-section of their comprehensive range of machines for mould and coremaking with chemically bonded sands. The sand preparation plant consisted of the "Mischka" II GF/C day bin with a charge capacity

Figure 11. Complete plant with sand preparation and two KSM core shooters for automatic production of cores and cored-up moulds (Vogel & Schemmann)

up to 200 kg and the BDA-200-CB-PE 600/600 automatic metering equipment for the addition of two binders. This complete plant supplies the sand for the machines arranged under the platform on which it is mounted. The company also exhibited a working model of the KSM 6.05.00-CO₂/CB core shooter with conveyor belt as well as the KSM 6.40.00-CB core shooter. Both of these machines incorporated pick-up equipment.

Heinrich Wagner Sinto introduced two new developments in coremaking machines from Japan. The Q-process is for the production of moulds and cores from gas curing sands with the use of vacuum. Sand mixture and curing gas are sucked into the core box one after the other. Two

Figure 12. "QVC" coremaker with vertical corebox parting for the Q-process (Heinrich Wagner Sinto)

versions of the machine are offered, one with horizontal parting for the production of moulds and the other with vertical parting for the production of large complicated cores, the latter being designated "QVC" (Figure 12), which was demonstrated in practical operation.

The Swiss WLH-Löher company production range among others incorporates core sand preparation plants, gassing equipment for cold box and SO_2 processes and robots for the handling of cores. The central amin gas preparation plant offered in different sizes is particularly worthy of mention.

GIFA 84: Equipment for the preparation of chemically bonded sands, mould and core making in cold setting sands and sand regeneration

Gottfried Schneider, Düsseldorf

Equipment for the preparation of chemically bonded sands as well as for mould and core making in cold setting sands

Asmann KG and Förder- und Anlagentechnik GmbH offered their TURBOMIX high capacity mixer and the SUPERMIX continuous mixer which are built in stationary and mobile designs with capacities from 2 to 50 t/hour. The TURBOMAT is a complete moulding plant consisting of a combination of the TURBOMIX TMEG high capacity continuous mixer and an 8-station rotary table.

BMD exhibited cold setting moulding plants which can be operated with flasks with variable external dimensions.

Buderus also plan and supply mechanically operated moulding lines for various flask sizes up to 2300 mm and capacities of 3 to 5 moulds/hour. The technologies used in their own foundries and the available know-how are an important base for these activities. Examples of plants supplied for the highly mechanized production of large castings weighing between 200 and 5000 kg (Figure 1) with a sand throughput of 20 to 25 t/hour are two foundries that operate with an organic binder system (furan resin) and inorganic moulding material (sodium silicate/cement) as well as with downstream sand regeneration plants.

Figure 1. Highly mechanized moulding line for large castings up to 5 t; flask size 4000 x 2400 x 800/800 mm; capacity 4 moulds/hour (Buderus AG)

Gustav Eirich also offer their R series intensive mixer (Figure 2) for the preparation of core sand. This can also be incorporated in automatic production as a batch mixer with effective weights of 120 or 240 kg.

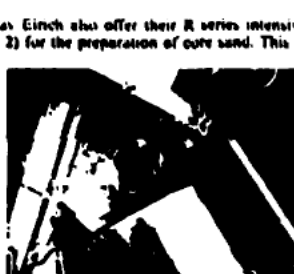
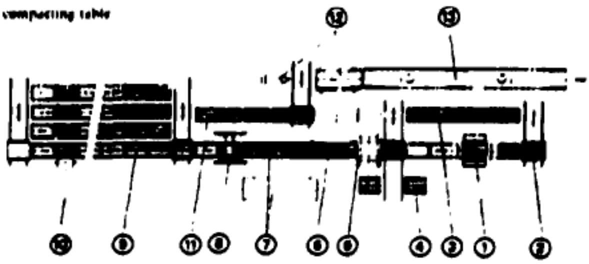


Figure 2. Preparation plant with Type R 15 intensive batch type mixer; also applicable for preparation of core sand (Gustav Eirich)

Together with Fordath, England, the Ekman Engineering company showed a 4-station mould carousel as the basic unit for their no-bake moulding plant, a reversible drum machine with a triangular opening as well as a continuous mixer (20 t/hour) from the Fordath programme Mini-Mix 2 to 4 t/hour, Centurion Plus 6 to 20 t/hour and Pacemaster Plus 1.5 to 30 t/hour. The company has also developed the Ekman cold set mould handler.

For mould and core making with chemically bonding sands, among other items, FM Industrie S.A., France, offered electronically controlled continuous mixers (1 to 36 t/hour) as well as carousel moulding plants with manipulators for the handling of the moulds.



1 filling station with high frequency compacting table
2 transfer car
3 prehardening line
4 pattern changing station
5 turnover stripping equipment
6 washing station
7 core-setting line and core store
8 cope turnover and assembly device
9 casting and storage line
10 casting crane
11 return line
12 high frequency knock-out grid with hydraulic stripper
13 casting cooler

Figure 3. Plant for flexible production of boxless moulds for individual castings and batch production (Foundry Design Corp., Switzerland)

Foundry Design Corp., Switzerland, have developed a boxless moulding plant for single castings and batch production (Figure 3), in which the size, shape and amount of sand can be matched to the individual castings. Automatic paits ~ circulation, additional equipment for the turnover, parting and assembly operations as well as a mould store enable the achievement of flexibility in production.

Karl-Heinz Frank supply core sand batch mixers (200 to 3000 kg/hour, double arm continuous mixers (15 t/hour) and counterflow mixers (30 t/hour; this also as a completely mobile mixing station) as well as plants for mould and core making to the cold setting process with 6 or 8 rotating pattern plate bolsters.

The GFA company build high speed mixers for cold setting sands and exhibited a 3 shaft continuous mixer. Their range of equipment also includes mould and core making plants for cold setting sand with the necessary handling equipment as well as GFA shell moulding plants.

The range of plants offered by Gisag, GDR, also includes continuous mixers (3 to 32 t/hour) for rapid cold setting sands, as well as complete mould and core making plants. Microcomputer control can be incorporated with the Robotron K 1250.

Peter Hammers build cold setting moulding plants for flasks and flaskless moulds.

Imafond, Italy, manufacture batch mixers (25 to 200 l) and continuous mixers (3 to 36 t/hour) for the preparation fo core sand. They also build complete preparation plants for supplying core shooting machines.

I.M.F., Italy, offer high speed continuous mixers, stationary and mobile turbo mixers for rapid setting resins, with plain or articulated arms. Carousel moulding machines are supplied for no-bake moulding shops.

Alb. Klein produce conveyor equipment and moulding lines for synthetic resin bonded sands. The prototype of the Prof. Boenisch type vibratory mixer as presented at GIFA 79 is now manufactured as a compact mixing plant with a batch type vibratory mixer and dosing systems for liquid and powered components.

Among other items Loramendi S.A., Spain, supply stationary and mobile batch mixers (50 or 100 kg) for chemically bonding sands as well as continuous rapid turbo mixers (6 to 30 t/hour). The latter is used in the 8-station carousel cold set moulding plant also offered by the company.

Michel GmbH exhibited a new development in the form of a high capacity ball mixer (Figure 4). This mixer is equipped with volumetric binder dosing and, with a batch size of 30 kg and its short mixing time, it can produce 2400 to 2700 kg of sand per hour.

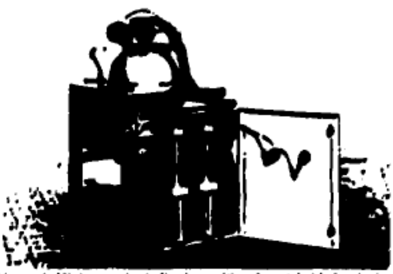


Figure 4. High capacity ball mixer with volumetric binder dosing; 30 kg batches (Michel GmbH)

From their range of sand preparation machines (which also includes the Saturn II continuous mixer) Shalco Systems showed a design of the continuously operating standard mixer with dosing equipment

Simpson Maschinen AG, Switzerland offered the Simpson Promix continuously operating core sand mixer

Within the comprehensive range of their moulding plants A. Stotz AG also build production plants for cold setting resin bonded sands, incorporating all necessary equipment

Vogel & Schemmann have taken up the TRITON high capacity sand mixer in their sales programme for the continuous mixing of cold setting sands (2 to 15 t/hour). The

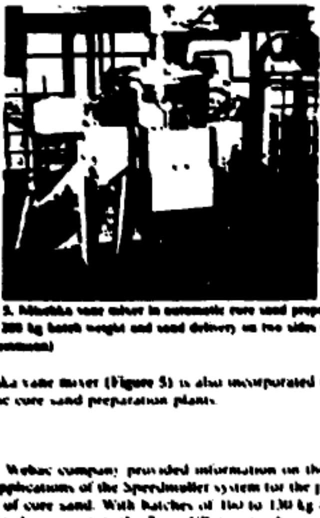


Figure 5. Mischka vane mixer in automatic core sand preparation plant; 200 kg batch weight and sand delivery on two sides (Vogel & Schemmann)

Mischka vane mixer (Figure 5) is also incorporated in automatic core sand preparation plants.

The Webac company provided information on the various applications of the Speedmuller system for the preparation of core sand. With batches of 160 to 130 kg and a modern dosing system the Type CP mixer achieves a capacity of 1500 to 2500 kg/hour. Within a joint arrangement, Webac also market the QUICKSLINGAIR (1 to 50 t/hour) produced by SeTUMAT, France

The six sizes of batch mixers (50 to 500 l) built by W.L.B. Lober, Switzerland, for the preparation of core sand are incorporated as basic units in their preparation plants

Gebr. Wohr manufactures 5 sizes of continuous turbo mixers with capacities from 3 to 30 t/hour. These are incorporated in their cold set moulding plants, frequently in conjunction with sand recovery plants

Sand coating plants

Only a few companies incorporate plants for the production of dry, loosely flowable resin coated sands (shell moulding sands)

The Webac sand coating plant (Figure 6) was offered on the joint stand of Beardsley & Piper, USA, and Webac. It

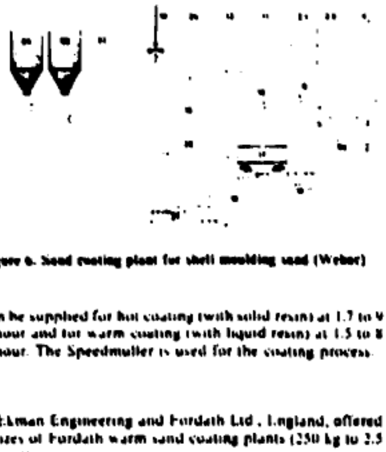


Figure 6. Sand coating plant for shell moulding sand (Webac)

can be supplied for hot coating (with solid resin) at 1.7 to 9 t/hour and for warm coating (with liquid resin) at 1.5 to 8 t/hour. The Speedmuller is used for the coating process.

Ekman Engineering and Fordath Ltd., England, offered 4 sizes of Fordath warm sand coating plants (250 kg to 2.5 t/hour)

Gisag, GDR, showed the AHA 3-2 machine for the hot coating of sand

Shalco Systems market BARBER GREENE hot sand coating plants. Dependant upon the coating time, batch weights from 90 to 1225 kg achieve capacities of 0.9 to 24.5 t/hour.

Sand regeneration equipment

The mechanically operating compact RECUBLOC plant for the recovery of cold setting resin bonded sands is a product of the joint work of Axmann KG and Förder- und Anlagentechnik GmbH. It has a 1800 x 1800 mm knock-out grid and a capacity of 7.5 t/hour

The BMD company offered shot blasting knock-out plants for their cold setting boxless moulding plants. The sand is also regenerated.

Buderus offered a multi-stage mechanical-pneumatic regeneration plant which can handle 25 t/hour of used sand from inorganic moulding material systems, e.g. sodium silicate-cement basis, 85% of which can be reused.

The previously exhibited fluidized bed equipment for thermal sand regeneration is still in the Centrozap, Poland, programme. The system operates with a preheating chamber and a furnace, the sand being heated in the fluidized bed with combustion of the binder.

Gustav Eirich have developed two sand regeneration processes, the mechanical MEREG process and the thermal THERMREG process. The same machine is used for both processes (capacities: 0.5 to 12 t/hour, regeneration times: 3 to 7 min).

Ekman Engineering and Fordath Ltd., England, presented information on their regeneration plants for chemically bonded sands. This embraces thermal plants for shell moulding sands (Fordath-Fluidfire), wet regeneration plants for sodium silicate and bentonite bonded moulding materials, mechanical plants (operating through attrition) for sands from non-ferrous casting that are not effected by heat, mechanical plants for all cold setting moulding materials from the casting of iron and steel as well as chemical-thermal plants for waste sands.

Fata Industriale, Italy, has developed the HOT-REC system for the thermal regeneration of cold setting sands. The plants (Figure 7) work with a fluidized bed furnace, with recovery of heat from the sand and the flue gas, and

Figure 7. HOT-REC thermal regeneration plant for resin bonded sands (Fata Industriale, Italy)

are produced for capacities of 1.2 or 5 t/hour (efficiency: 96 to 98%).

Georg Fischer, Switzerland, produce plants for shot blasting knock-out with integral sand regeneration for flask and flaskless moulding in all mixtures of cold setting moulding materials (process flow diagram in Figure 8).

FM Industrie, France, exhibited the newly developed REGESIL plant for sodium silicate bonded sands. This plant supplements the VIBROJET regeneration plant that is suitable for all chemically bonded moulding materials.

Foundry Design Corp., Switzerland, offer compactly constructed wet regeneration plants for 2 to 100 t/hour with 90 to 95% sand recovery.

Karl-Heinz Frank plans and supplies mechanical recovery plants for used dry sands. Capacities are from 5 to 15 t/hour.

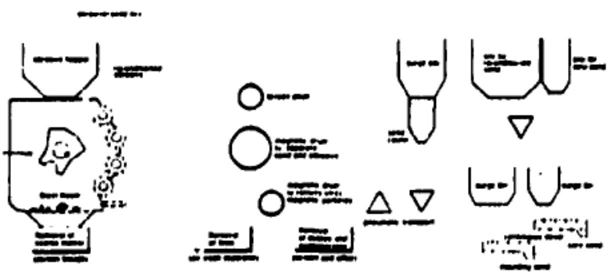


Figure 8. Schematic diagram of integrated knock-out and sand regeneration process, including cooling (Georg Fischer AG, Switzerland)

Equipment for mechanical reclaiming as well as sand after-treatment are built by GFA Giesserei- und Förderanlagenbau.

The long established rebound mill still remains as the central part of the Hazemag company's used sand regeneration plants.

For special applications Hemel KG offer compact used sand recovery plants which operate with mechanical breakers and sifting groups. Capacities are up to 5 t/hour.

KHD Humboldt Wedag presented a combined thermo-mechanical process for the regeneration of used foundry sand with all normal organic and inorganic binders (process flow diagram in Figure 9). The thermal treatment is

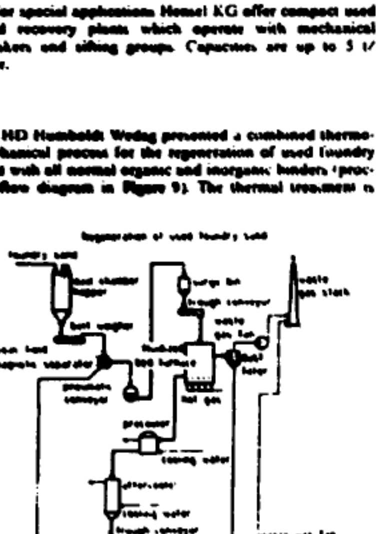


Figure 9. Process flow diagram of combined thermal-mechanical process for the regeneration of used foundry sand (KHD Humboldt Wedag)

carried out in a fluidized bed furnace at a combustion air temperature in excess of 870°C, the after-treatment in a counterflow rebound mill.

Alb. Klein offer two systems for the mechanical regeneration of free-flowing used sands. One has a ball mill equipped with a knock-out grid and tubular vibrating conveyor and a cascade sifter (capacities between 5 and 30 t/hour). The other has a vibrating pot with sieving and sifting equipment in the fluidized bed cooler (capacities of 3 to 12 t/hour). The company exhibited the new SP 25 pressure vessel conveyor for conveying pressures up to 6 bar. This is also applicable for the conveyance of regenerated sands.

For the regeneration of cold setting resin bonded moulding materials the Dr. Küttner company supplies a vibrating crusher for 12 t of sand per hour, in which residual resin adhering to the surface of the sand particle is extensively removed through the scrubbing action caused by the circulation of the material.

Heinz Kulka KG exhibited a compact regeneration machine that simultaneously breaks up the sand lumps and regenerates, cools and sifts sand without loss.

With the aid of a model the H.-G. Lorek company showed the mode of operation of their cleaning and separation process for foundry waste sand (quartz, chromite, zircon), in which regeneration is effected by a hot, wet treatment.

Mechanical and thermal sand recovery and regeneration was also included in the exhibits on the Pangborn (Spencer Halstead), England, and Pangborn Europe, Italy, joint stand.

H. Paulus & Co. manufacture mechanical plants for the regeneration of cold setting resin bonded sands.

Simpson Maschinen AG, Switzerland, supply cellularly constructed pneumatic sand recovery plants which operate on the principle of "grain-on-grain" scrubbing.

A. Stotz manufacture mechanical regeneration plants which, according to the individual case, are equipped with rotating fine crushers or a vibrating scrubbing grid for the treatment of all cold setting and curing as well as cement bonded moulding materials.

Pneu-Reclaim regeneration plants with vertical frictional circulation of the used sand through 2, 4, 6 or 8 cells are manufactured by the Webac company under license from Beardsley & Piper, USA.

Wheelabrator Berger incorporate Pneu-Tek and Mini-Pneu-Tek mechanical-pneumatic regeneration plants in their programme

Gebr. Wohr offer complete mechanically operating recovery plants for cold setting sand

GIFA 84: Die casting machines and accessories for non-ferrous foundries

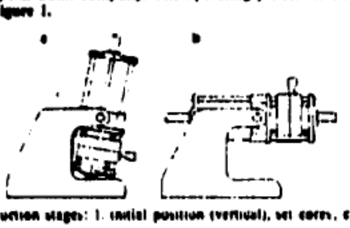
Klaus Malpohl, Düsseldorf

This report presents equipments offered at GIFA for casting processes with permanent moulds, including some of the peripheral equipment. In general, the great progress in automatic control engineering has led to better conditions for the operators and automization of the operating processes.

Gravity die casting and special processes

Hydraulic machines have established themselves for classical die casting operations. Maschinenbau Sprötze GmbH showed their two-station machine model HD2 with a traversable metering device. The automatic operation is prescribed by a microprocessor control.

The large height of fall of the metal in vertically parted dies is considerably lower with tilt pouring; the formation of oxides and dross is largely counteracted and there is a great improvement in the quality of the casting. A working model of a tilt pouring machine was exhibited by the W. F. Poppe & Sohn company. The operating process is shown in Figure 1.



Production stages: 1. initial position (vertical), set cores, close die.
2. start of casting operation (a): filling of melt into pouring spoon; die swings and cavity fills with melt.
3. end of casting operation (b): solidification, unloading of casting and return to initial position.
Figure 1. Schematic of the tilt casting process (W. F. Poppe & Sohn)

The casting machine for the die casting of heavy metals must have particularly short cycle times. The Italian IMR s.r.l. model C40U compact plant achieves an empty running cycle of 14 s and can be used for die weights up to 100 kg. It is also possible to tilt the die on pouring.

The accurate pouring in of the liquid metal by means of an autoladle metering and pouring device under the rotating motion of the die often presents a practical problem. Macchine Automatiche Speciale s.r.l. of Italy showed a solution to this problem. For the pouring operation the autoladle moves to the prepared tilted die where it is mechanically coupled.

Metal Technology RPC, Bulgaria, exhibited a production plant for piston blanks which operates on the gas counterpressure squeeze-casting process, i.e. high pressure compaction (250 bar air pressure). The principle of the process is shown in Figure 2. The method has been specially developed for highly stressed components and can also be used for copper-base alloys.

Figure 2. Gas counterpressure-squeeze casting process (Metal Technology RPC, Bulgaria)

The foundry department of Seri Renault Ingénierie, France, presented equipment designed by their own engineers, amongst others, a semi-automatic machine for the centrifugal casting of aluminium wheels to a maximum diameter of 15" (approx. 38 cm) at a rate of 14 wheels/hour. The machine is also obtainable as a special design for fully mechanized casting.

In the main, the companies shown in Table 1 were represented.

Dipl.-Ing. K. Malpohl is Secretary of the Non-Ferrous Castings Committee of the Verein Deutscher Giessereifachleute

Table 1. GIFA Exhibitors of gravity die casting machines and accessories

E. P. E. Budde GmbH
Centrozap, Poland
Egro AG, Switzerland
Ekmann Engineering GmbH
Fatalominium S.p.A., Italy
Fomet s.r.l., Italy
Foseco Service S.A., France
Foundry Design Cor. Switzerland
IMR s.r.l., Italy
Karrer, Weber & Cie. Aktiengesellschaft, Switzerland
Konkel-Wagner GmbH & Co. KG
Macchine Automatiche Speciali s.r.l., Italy
Maschinenbau Spretze
Metal Technology, Bulgaria
A. W. Plume Ltd., England
Poppe & Sohn KG
Reis GmbH & Co.
Rimas Maskinfabrik A/S, Danmark
Seri Renault Ingenierie, France
Stahl Specialty Company, USA
Urbesalgo S.A., Spain

Low-pressure die casting

Special care must be taken in the production of castings for highly demanding applications, e.g. for power stations or aircraft. In order to meet the high demands with the low-pressure die casting process EDEM Etude et Developpement en Metallurgie, France, have developed a control which accurately regulates the filling of the die.

Röperwerk Rheinische Maschinenfabrik & Eisengießerei Anton Röper GmbH & Co. have taken the development and production of the established Stone Wallwork International "Demo System" for low-pressure die casting machines into their production programme. The further development of this plant was exhibited (Figure 3). The machine has a multi-stage pressure regulating system for low turbulence filling of the die and a level control enables the bath level in the feed tube to be held constant.

Figure 3. Low-pressure die casting machine ND 14.10-500 (Röperwerk)

The Swiss Karrer Aktiengesellschaft company's low-pressure die casting plant for brass fittings achieves high outputs with multiple dies and reduces the heat radiation on the operator.

A fully automatic electrical system for the heating of feed tubes or feed tube distance pieces in low-pressure die casting as developed by Norsk Hydro Magnesiumgesellschaft mbH solves the problems associated with the use of gas. The heating system is equipped with single and multiple heating elements. On account of the good insulation of the heaters it is only necessary to use heating energy at the start of operation or after an interruption of working.

Through the special composition of the raw material and selection of the process the alumina graphite feed tubes offered by the Becker & Piscantor company are dense and resistant against aluminium melts. They have a good resistance to temperature variations and are relatively insensitive to breakage. They have a life of 6 to 8 weeks with two-shift working. The construction of these tubes is shown in Figure 4.

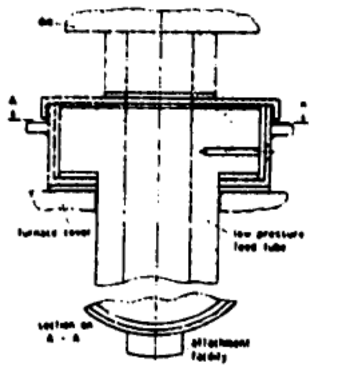


Figure 4. Construction of a graphite feed tube (Becker & Piscantor, Großalmeroder Schmelztiegelwerke GmbH & Co. KG.)

Exhibitors of low-pressure die casting machines and accessories are shown in Table 2.

Table 2. GIFA Exhibitors of low-pressure die casting machines and accessories

Ing. Franz Honitz KG, Austria
Becker & Piscantor
E. P. E. Budde GmbH
EDEM, Frankreich
Egro AG, Switzerland
Ekmann Engineering GmbH
Fatalumninum S.p.A., Italy
Fomet s.r.l., Italy
IMR s.r.l., Italy
International Castings, Spain
Karrer, Weber & Cie. AG, Switzerland
Macchine Automatiche Speciali s.r.l., Italy
Norsk Hydro Magnesiumgesellschaft mbH
A. W. Plume Ltd., England
Reis GmbH & Co.
Rimas Maskinfabrik A/S, Danmark
Roperwerk Anton Roper GmbH & Co. KG
Seri Renault Ingenierie, France
Strike W. Strikfeldt & Koch
Westofen GmbH

Pressure die casting

The continuous and rapid development on the hardware side has enabled the machine manufacturers (Table 3) to equip their plants with comfortable controls and process control.

Table 3. GIFA Exhibitors of pressure die casting machines, accessories and peripheral equipment

Gebr. Buhler AG, Switzerland
Chris Marine AB, Sweden
Colosio s.r.l., Italy
Deutsche Acheson GmbH
Drei-S-Werk Präzisionswerkzeuge GmbH & Co.
Fomet s.r.l., Italy
Fonderes, F. Hodler & Cie, Switzerland
Oskar Frech GmbH
Hasco-Normalien
Huber-Maschinenbau
Idra S.p.A., Italy
International Castings, Spain
Italpresse S.p.A., Italy
M.A.F. Mecanique Assistance Fonderie, France
Müller-Weingarten AG
Metal-Guss GmbH
Regloplas AG, Switzerland
Reis GmbH & Co.
Stahlwerk Stahlschmidt GmbH & Co. KG
Thermco S.A., France
Toshiba Machine Co., Japan
Triulzi R.E.S.S., Italy
UBE Industries Ltd.

Gebruder Buhler AG, Switzerland, showed a fully mechanized horizontal cold chamber pressure die casting plant with 4600 kN locking force which was equipped with the newly developed Datacess control and Processtrol process monitoring (Figure 5). The most essential features of this system are:

- display panel with rapid data access system, i.e. no coded inputs are required, e.g. for the display on the screen of the core pulling programme or the speed of the injection system,
- data storage and programming production data already processed by means of cassette tape or via an external central data station,
- possibility of full production documentation of specific parts thereof.

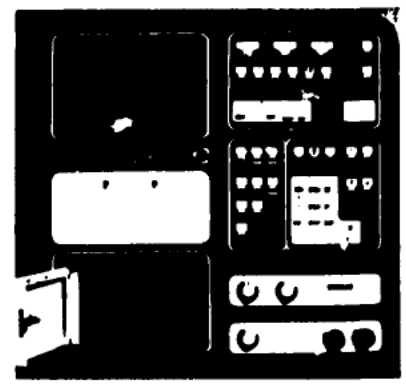


Figure 5. Display screen with foil keyboard for pressure die casting machines (Gebr. Buhler AG)

Buhler showed fast changing of dies as a way of reducing costs by means of shorter setting up times. It was expressly recommended that the measures should not be confined to the actual changing of the die on the machine but must also take into account the conditions in all areas of back-up operations in the pressure die casting foundry, such as the make-up of the tool stores, space relationships, transportation equipment etc.

The well established Optivac system of Fonderes, F. Hodler & Co., Switzerland, for vacuum die casting was further developed by the mechanically operated Mesanovac vacuum valves (Figure 6). The Optivac system ensures optimum evacuation of the die up to the very end of the cavity filling phase. It offers improved operating conditions of the die casting machines, combined with higher quality of the die cast components, e.g. pressure tightness, substantial reduction in porosity.

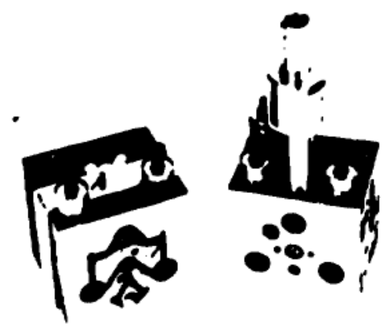


Figure 6. Mesanovac valves for the Optivac vacuum die casting system (Fonderes, F. Hodler & Co., Switzerland)

In addition to the well arranged microprocessor control the Frech GmbH & Co 250 kN hot chamber machine displayed substantial improvements to the mechanics and hydraulics. Among others these consists of

- free space between the columns enlarged to 250 x 250 mm,
- dry shot cycle increased from 1700 to 2000 per hour,
- injection operation via piston type accumulator.

The incorporated hydraulic rapid clamping system (Figure 7) consists of four self-locking clamping elements which are recessed in the platens. The dies are provided with two clamping ledges and centering spigots. Existing dies can be subsequently equipped.

Further remarkable features of the Frech display were a new cold-chamber unit with a locking force of 5000 kN and a range of "medium pressure" machines developed to combine advantages of pressure and gravity die casting.

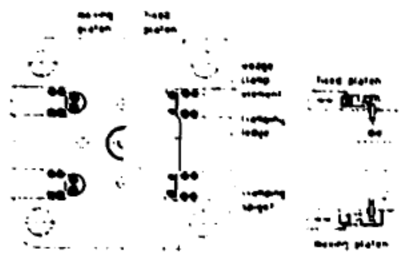


Figure 7. Hydraulic rapid clamping system on the DAW 63 pressure die casting machine (Frech GmbH & Co.)

The Italian Idra S.p.A. company exhibited a medium pressure casting machine which had been developed jointly with the BMW foundry. This type OL-MD 3000 represents a combination of gravity and pressure die casting. The longitudinal axis of the machine has been raised by 5° in the direction of the closing unit, so as to ensure optimum ventilation of the injection chamber during the advance of the piston. The accurate regulation of the force means that sand cores can also be used. The advantages of this process are

- mechanical properties of the material the same as with gravity die casting,
- surface properties as well as tolerances the same as with pressure die casting,
- the castings are weldable,
- low cycle times by comparison with gravity die casting and low-pressure die casting.

Raising of the longitudinal axis of the machine in the direction of the closing unit for improvement of the injection chamber ventilation during the advancement of the piston has also been incorporated in a newly designed Idra horizontal cold chamber machine type OL 220 (Figure 8). Additionally, the machine has a 4-phase injection unit which, according to the manufacturer, Idra S.p.A., allows for "normal pressure die castings" and "heat treatable pressure die castings". In order to avoid the use of a multiplier the machine has a correspondingly larger injection cylinder.

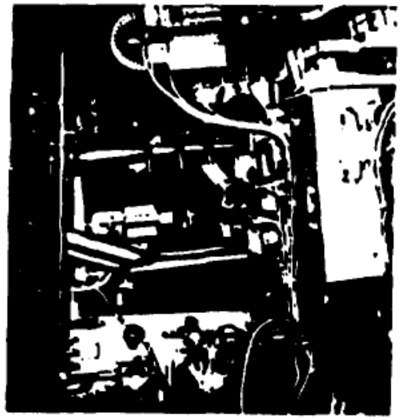


Figure 8. 4-phase injection part of a 5400 kN cold chamber pressure die casting machine with raised longitudinal axis (Idra S.p.A.)

Maschinenfabrik Muller-Weingarten AG also presented solutions for fast die change. Rapid die clamping systems of the platens with hydraulic clamps, and the central ejector couplings point out a practical way also economically equip existing pressure die casting machines with rapid die changing systems.

A vacuum-system equipped pressure die casting machine with horizontal cold chamber (Figure 9) has been developed and brought to production maturity by cooperation between Maschinenfabrik Muller-Weingarten and VAW. Metal from the holding furnace is filled into the casting chamber through a feed tube by means of vacuum, so that the reaction gases from the lubricant vapour are already extracted during the dosing operation. The process strongly reduces porosity and allows e.g. welding and heat treatment.

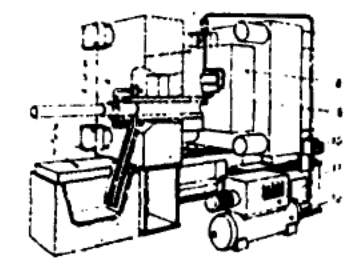


Figure 9. Layout of the VAW-Weingarten Vacural pressure die casting machine

The 3200 kN cold chamber machine exhibited by Metal-Guss GmbH (Figure 10) has retained the established "Multiject" dual circuit filling system. Proportional valves

Figure 10. 3200 kN closing force cold chamber pressure die casting machine (Metal-Guss GmbH)

are employed. The casting parameters are set at the control console. The switching-in of the final pressure can be controlled either by pressure or travel. Amongst further features were larger than normal platen sizes and the longer stroke necessary to accommodate the heavier dies utilized in fully-automatic operation. The control system incorporating a microprocessor provides an immediate display showing the cause and location of malfunctions.

The conventional, economical manipulators for unloading the casting are not suitable for continuously changing production programmes and are in these cases replaced by a robot. Reis GmbH showed an unloading robot to handle up to 15 kg which meets the modern requirements.

The 3-column design of the Reis trimming press has considerably improved accessibility to the press space for tool changing. Microprocessor control, an electronic measuring system for the control of the strokes, positioning and speeds of the main cylinder all contribute to enabling the machine to be adapted to any requested operation (Figure 11).

Figure 11. 3-column trimming press with attached roller conveyors (Reis GmbH)

It is not always possible to rationally supply lubricants from a central plant. Different mixture ratios of die lubricant are required according to the production programme. The Deutsche Acheson "DAG 163 Lube Mix lubricant filling station" provides in each case the currently used or required mixture ratio (Figure 12).

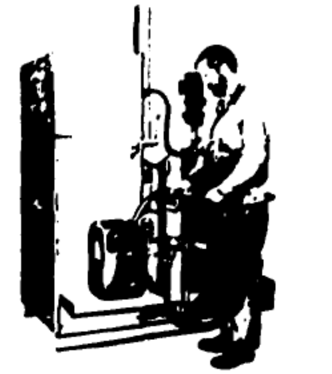


Figure 12. Lubricant supply plant for various mixture ratios (Deutsche Acheson)

Heating and cooling devices are increasingly being used in pressure die casting production. Swiss Regloplas company's equipments incorporate high cooling capacities (11 to 108 kW) so that high casting outputs can also be achieved.

Hasco-Normalien have developed a standard rapid clamping device connection between the die and the machine on small pressure die casting machines (Figure 13). The clamp plate (1) is bolted to the machine. Bolts (3) are mounted in the die and are inserted in the corresponding holes in the clamp plate. An approximately 30° rotation of the excentric bolt (2) clamps the dies.

Figure 13. Ready-made rapid changing device for pressure die casting dies (Hasco-Normalien)

The use of pneumatic control units (Hasco-Pneumat) can considerably simplify the installation of pneumatic equipment. The compact devices can be used to operate pneumatic equipment such as blow-offs on stamping dies, die spraying equipment, cylinders or similar items, for which it has previously been necessary to produce special controls.

GIFA 84: Dosed metal feeds for the casting of aluminium, including pouring furnaces

Wolfgang Büchen, Mettmann

The following report is with reference to the casting of aluminium. Other factors and consequently other solutions exist for the areas of copper, zinc and magnesium alloys; in certain cases the equipment described here may however be used when adapted in an appropriate way.

According to the casting cycle, the gravity and pressure die casting processes require to pour from 0.3 to 30 kg of hot metal into the die or the injection chamber every 1 to 10 min. This requirement has also recently arisen with the highly mechanized sand moulding plants but here frequently with high demands for flexibility with regard to casting weights and alloys. In the low-pressure and tilting crucible gravity die casting processes the filling of the dies is carried out by integrated pouring furnaces.

Mechanical equipment; autoladle systems

A large number of autoladle devices were offered at GIFA 84, some of them with considerable improvements by comparison with earlier designs. Electronic controls enable the easy and rapid adjustment of the movements and times. Autoladle systems were exhibited by the companies shown in Table 1.

Table 1. GIFA Exhibitors of ladling units

Gebruder Buhler AG, Switzerland
Colosio s.r.l., Italy
Elmonta Smelteteknik, Danmark
Fataluminium S.p.A., Italy
Oskar Frech GmbH & Co.
Fondarex, F. Hodler & Cie., Switzerland
Hensel KG
Idra S.p.A., Italy
Maschinenbau Spröße GmbH
Metaullics Systems, USA
Mutal-Guss GmbH
Reis GmbH & Co.
Dr. Schmitz + Apelt, Industrieofenbau GmbH
Wido – Ing.-Büro W. Dobe

For gravity die casting of very high quality castings Reis GmbH & Co. exhibited a genuinely new development in the form of the REIS REIS-ROBOT (Figure 1). The extensive electronic path control and other sensors provide automatic recognition of the bath level and evaluation by means of search functions. The decisive factors are the very sensitively controlled movements and the great advantage of absolute uniformity, which fully simulate the

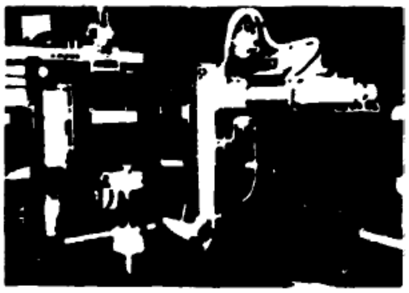


Figure 1. Autoladle system with freely selectable sensitive movement for very high metallurgical requirements (Reis GmbH & Co.)

tried and tested hand pouring technique. Four methods of programming are available. The robot can move up to a distance of 30 m. This "intelligent" gravity die casting robot is already in practical use and has proved to be successful.

As with the previous exhibition, Fondarex F. Hodler & Cie, Switzerland, showed the established "Telemetal" dosing and metal ladling equipment. It operates with a cylindrical-conically shaped ball out and transportation crucible with bottom inlet and stopper valve.

For further information circle

Gebruder Buhler AG Maschinenfabrik AG, Switzerland, offer their Fillmat dosing system.

Up to the end of 1983, Dipl.-Ing. W. Buchen was the Secretary of the Non Ferrous Castings Committee of Verein Deutscher Giessereifachleute

Appendix E.I

Illustration of a foundry investment project

The case shown is the proposed investment of £11 million, of which £4 million will be provided by Government Grants.

Project: Building of a completely new foundry for the production of 15500 tonnes of iron and steel castings per year.

Investment begin: 1977

Production begin: 1980

Level of full production reached: 1984

Foundry location: on a green field site.

Tables E.I/1 to E.I/4 show the basic data for the evaluation, including the capital investment programme and the detailed operating cost and revenues.

Evaluation*: The initial financial evaluation is shown in Table E.I/5. The investment takes place in the first three years, followed by the profits of the assumed ten years life of the foundry. The net cash flow shown is after tax profits, less the capital expenditure and working capital. The cost of finance for this project is 12%. The I.R.R. on the project is calculated to be 21.67% and is based on the assumption that the estimates of sales, sales price, capital costs, material costs and all other costs will be those actually achieved. To enable the management of the company to take the correct decision with the maximum information, a sensitivity analysis is carried out. Each of the variables which make up the estimates of net profit and capital expenditure is varied by 10%, 20% and 30% in both a favourable and unfavourable direction and the I.R.R. calculated for each case. The calculations are shown in Tables E.I/6 to E.I/12 for each factor and the I.R.R for each variation is also shown. Having made these calculations, the results are tabulated giving 43 different I.R.R. The graph showing the results of the sensitivity analysis of this project is shown in Figure E.I/1. The mean value of

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*Note: For the purpose of evaluation only, the life of the foundry is considered to be ten years. It is further assumed that at the end of this period the assets will be sold at their net book value. The period of ten yrars is considered as being conservative estimate which may be reasonably forecast.

Summary of sales value and production cost
***Estimated market price**

Description	t/A	£/t *	£/A
Sales Value			
Iron Castings	13 594.5	420.0	5 709 690
Nodular Castings	594.0	685.0	406 890
C. Steel Castings	198.5	934.0	185 399
S. Steel Castings	1 124.0	2 497.0	2 806 628
Total Sales Value	15 511.0		9 108 607
Total Production Cost			5 064 023

Table E.I/1

Table E.I/2:

Projected annual production and apportionment of costs

Description	Unit	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Net Production	Tons	—	—	—	2 327	5 429	6 980	7 756	15 511	15 511	15 511
	%	—	—	—	15	35	45	50	100	100	100
Moulding Capacity	Shifts	—	—	—	1	1	1	1	2	2	2
Salaries	%	—	20	40	45	50	55	60	100	100	100
Wages	%	—	—	—	40	40	45	50	100	100	100
Materials	%	—	—	—	15	35	45	50	100	100	100
Power and Fuel	%	—	2	4	15	35	45	50	100	100	100
Other Costs	%	—	5	10	25	40	50	60	100	100	100

Table E.I/3:

Projected operating costs (£) 1978-1984 at 1977 prices

	1978	1979	1980	1981	1982	1983	1984
Wages	—	—	451 795	451 795	508 269	563 744	1 129 487
Salaries	44 417	88 833	99 937	111 042	122 146	133 250	223 083
N.H.I	4 886	9 772	60 691	61 912	69 346	76 779	124 243
TOTAL WAGES	49 303	98 605	612 423	624 749	699 761	774 773	1 475 813
Materials	—	—	430 704	1 004 976	1 292 112	1 435 681	2 871 361
Power/Fuel	9 102	18 203	68 262	159 278	204 786	227 541	455 061
Other Costs	13 088	26 177	65 442	104 707	130 884	157 061	261 768
TOTAL COST	71 493	142 985	1 176 831	1 893 710	2 327 543	2 595 056	5 064 023
SALES	—	—	1 366 291	3 188 012	4 098 873	4 554 304	9 108 607
PRE-TAX PROFIT	(71 493)	(142 985)	189 460	1 294 302	1 771 330	1 959 248	4 044 584

Table E.I/4:

Capital investment programme including grant payments at 1977 prices

DESCRIPTION	DESIGN 1977	1977	1978	1979	1980	1981	TOTAL
Land	11 000	11 000	—	—	—	—	—
Site Development	271 920	271 920	—	—	—	—	—
Buildings — Production	2 049 828	50 000	1 900 000	99 828	—	—	—
Buildings — Ancillary	394 108	—	200 000	94 000	100 108	—	—
SUB TOTAL	2 726 856	332 920	2 100 000	193 828	100 108	—	—
Plant and Equipment — Production	8 170 734	—	3 945 000	3 200 000	1 025 734	—	—
Plant and Equipment — Ancillary	14 124	—	—	14 124	—	—	—
TOTAL INVESTMENT	10 911 714	332 920	6 045 000	3 407 952	1 125 842	—	—
Regional Development Grant @ 20%	—	64 384	1 209 000	681 590	225 169	—	—
F.F.I. Grant @ 15%	—	38 630	228 000	11 979	—	—	—
F.F.I. Grant @ 25%	—	—	789 000	640 000	205 148	—	—
TOTAL GRANTS	—	103 014	2 226 000	1 333 569	430 317	—	4 092 900
SELF FINANCE TOTAL	—	229 906	3 819 000	2 074 383	695 525	—	6 818 814

Table E.1/5 **Financial evaluation of foundry project**

	Pre-Tax Profit	Corporation Tax @ 52%	After tax Profit	Capital Expenditure	Grants	Working Capital		Net Cash Flow
1977	—			(332 920)	103 014	—		(229 906)
1978	(71 493)	—	(71 493)	(6 045 000)	2 226 000	—		(3 890 493)
1979	(142 985)	—	(142 985)	(3 407 952)	1 333 569	—		(2 217 368)
1980	189 460	—	189 460	(1 125 842)	430 317	(78 624)		(584 689)
1981	1 294 302	—	1 294 302	—		(108 831)		1 185 471
1982	1 771 330	—	1 771 330	—		(53 869)		1 717 461
1983	1 959 248	—	1 959 248	—		(25 845)		1 933 403
1984	4 044 584	—	4 044 584	—		(271 531)		3 773 053
1985	4 044 584	(310 249)	3 734 335	—				3 734 335
1986	4 044 584	(2 052 489)	1 992 095	—				1 992 095
1987	4 044 584	(2 052 489)	1 992 095	—				1 992 095
1988	4 044 584	(2 052 489)	1 992 095	—				1 992 095
1989	4 044 584	(4 077 577)	(32 993)	2 028 576		538 700		2 534 283
						Rate of Return = 21.6[illegible]%		

Table E.1/6 **Sensitivity analysis variation in sales price**

		−30	−20	−10	+10	+20	+30
CAPITAL COST		6 337 767	6 337 767	6 337 767	6 337 767	6 337 767	6 337 767
NET CASH FLOWS	1980	(960 329)	(835 085)	(709 742)	(459 356)	(334 113)	(208 869)
	1981	274 610	578 231	881 851	1 489 091	1 792 711	2 096 332
	1982	510 570	912 867	1 315 164	2 119 757	2 522 055	2 924 351
	1983	578 498	1 030 137	1 481 768	2 385 038	2 836 674	3 288 308
	1984	1 154 329	2 027 237	2 900 145	4 645 961	5 518 869	6 073 650
	1985	1 312 002	2 222 863	3 133 723	3 484 760	3 235 184	3 303 734
	1986	1 312 002	2 222 863	2 405 069	2 429 308	2 866 521	3 303 734
	1987	1 312 002	2 023 100	1 554 882	2 429 308	2 866 521	3 303 734
	1988	1 312 002	1 117 669	1 554 882	2 429 308	2 866 521	3 303 734
	1989	3 651 563	2 455 342	2 494 813	2 573 753	2 613 224	2 652 694
	Rate of Return	6.38%	11.93%	16.99%	25.99%	30.13%	34.04%

Table E.1/7 **Sensitivity analysis variation in sales volume**

		−30	−20	−10	+10	+20	+30
CAPITAL COST		6 337 767	6 337 767	6 337 767	6 337 767	6 337 767	6 337 767
NET CASH FLOWS	1980	(751 406)	(695 833)	(640 261)	(529 116)	(473 544)	(417 971)
	1981	670 178	841 942	1 013 707	1 357 235	1 529 000	1 700 764
	1982	1 016 755	1 250 324	1 483 893	1 951 030	2 184 599	2 418 168
	1983	1 145 509	1 408 141	1 670 771	1 930 818	2 193 449	2 721 295
	1984	2 256 230	2 761 838	3 267 445	4 278 661	4 784 268	5 289 876
	1985	2 446 302	2 979 063	3 511 823	3 737 841	3 603 434	3 331 115
	1986	2 446 302	2 504 730	2 093 288	2 247 820	2 503 545	2 759 270
	1987	1 694 791	1 480 645	1 736 370	2 247 820	2 503 545	2 759 270
	1988	1 224 920	1 480 645	1 736 370	2 247 820	2 503 545	2 759 270
	1989	2 436 604	2 469 164	2 501 724	2 566 843	2 599 402	2 631 962
	Rate of Return	13.36%	16.27%	19.04%	23.89%	26.31%	28.93%

Table E.I/8

Sensitivity analysis
variation in capital costs

		+30	+20	+10	−10	−20	−30
CAPITAL COST		8 174 754	7 562 425	6 950 096	5 725 438	5 113 109	4 500 780
NET CASH FLOWS	1980	(793 347)	(723 794)	(654 242)	(515 137)	(445 584)	(376 032)
	1981	1 185 471	1 185 471	1 185 471	1 185 471	1 185 471	1 185 471
	1982	1 717 461	1 717 461	1 717 461	1 717 461	1 717 461	1 717 461
	1983	1 933 403	1 933 403	1 933 403	1 933 403	1 933 403	1 933 403
	1984	3 773 053	3 773 053	3 773 053	3 773 053	3 773 053	3 773 053
	1985	4 044 584	4 044 584	4 044 584	3 295 049	2 855 763	2 416 476
	1986	3 014 914	2 570 558	2 126 202	1 987 026	1 981 956	1 976 887
	1987	2 007 304	2 002 234	1 997 165	1 987 026	1 981 956	1 976 887
	1988	2 007 304	2 002 234	1 997 165	1 987 026	1 981 956	1 976 887
	1989	3 181 493	2 965 756	2 750 020	2 318 546	2 102 810	1 887 073
	Rate of Return	17.34%	18.60%	20.04%	23.57%	25.85%	28.64%

Table E.I/9

Sensitivity analysis
variation in material costs

		+30	+20	+10	−10	−20	−30
CAPITAL COST		6 337 767	6 337 767	6 337 767	6 337 767	6 337 767	6 337 767
NET CASH FLOWS	1980	(721 128)	(675 648)	(630 1[illegible])	(539 210)	(493 730)	(448 250)
	1981	874 341	978 052	1 081 7[illegible]	1 289 181	1 392 884	1 496 601
	1982	1 325 008	1 455 827	1 586 644	1 848 278	1 979 095	2 109 914
	1983	1 500 290	1 644 661	1 789 032	2 077 774	2 222 145	2 366 516
	1984	2 887 553	3 182 720	3 477 886	4 068 220	4 363 386	4 658 553
	1985	3 183 176	3 470 312	3 757 448	3 655 660	3 576 985	3 498 309
	1986	2 365 805	2 137 818	1 909 832	2 129 920	2 267 746	2 405 571
	1987	1 578 619	1 716 445	1 854 270	2 129 920	2 267 746	2 405 571
	1988	1 578 619	1 716 445	1 854 270	2 129 920	2 267 746	2 405 571
	1989	2 616 923	2 589 377	2 561 830	2 506 737	2 479 189	2 451 643
	Rate of Return	17.11%	18.67%	20.21%	23.11%	24.53%	25.94%

Table E.I/10

Sensitivity analysis
variation in labour costs

		+30	+20	+10	−10	−20	−30
CAPITAL COST		6 382 140	6 367 349	6 352 558	6 322 977	6 308 185	6 293 395
NET CASH FLOWS	1980	(768 416)	(707 174)	(645 931)	(523 447)	(462 204)	(400 962)
	1981	997 996	1 060 521	1 122 996	1 247 946	1 310 421	1 372 896
	1982	1 507 533	1 577 509	1 647 485	1 787 437	1 857 413	1 927 389
	1983	1 700 971	1 778 448	1 855 926	2 010 880	2 088 358	2 165 835
	1984	3 330 309	3 477 890	3 625 472	3 920 634	4 068 216	4 215 797
	1985	3 601 840	3 749 421	3 812 196	3 656 475	3 578 613	3 500 753
	1986	2 145 656	1 991 053	1 951 256	2 062 934	2 133 773	2 204 612
	1987	1 779 578	1 850 417	1 951 256	2 062 934	2 133 773	2 204 612
	1988	1 779 578	1 850 417	1 951 256	2 062 934	2 133 773	2 204 612
	1989	2 551 993	2 546 090	2 540 186	2 528 380	2 522 477	2 516 573
	Rate of Return	18.94%	19.87%	20.85%	22.57%	23.47%	24.37%

Table E.I/11

Sensitivity analysis
variation in power and fuel costs

		+30	+20	+10	−10	−20	−30
CAPITAL COST		6 345 959	6 343 228	6 340 497	6 335 037	6 332 306	6 329 575
NET CASH FLOWS	1980	(625 647)	(611 993)	(598 341)	(571 037)	(551 385)	(543 731)
	1981	1 110 383	1 135 412	1 160 441	1 210 501	1 235 530	1 260 559
	1982	1 642 373	1 667 402	1 692 431	1 742 491	1 767 520	1 792 549
	1983	1 858 314	1 883 344	1 908 373	1 958 432	1 983 462	2 008 491
	1984	3 568 267	3 636 529	3 704 791	3 841 315	3 909 577	3 977 839
	1985	3 776 003	3 762 113	3 748 224	3 720 446	3 706 557	3 692 668
	1986	1 926 564	1 948 407	1 970 251	2 013 939	2 035 783	2 057 627
	1987	1 926 564	1 948 407	1 970 251	2 013 939	2 035 783	2 057 627
	1988	1 926 564	1 948 407	1 970 251	2 013 939	2 035 783	2 057 627
	1989	2 676 268	2 628 940	2 581 611	2 486 955	2 439 626	2 392 296
	Date of Return	20.79%	21.09%	21.38%	21.97%	22.26%	22.56%

Table E.I/12

Sensitivity analysis
variation in other costs

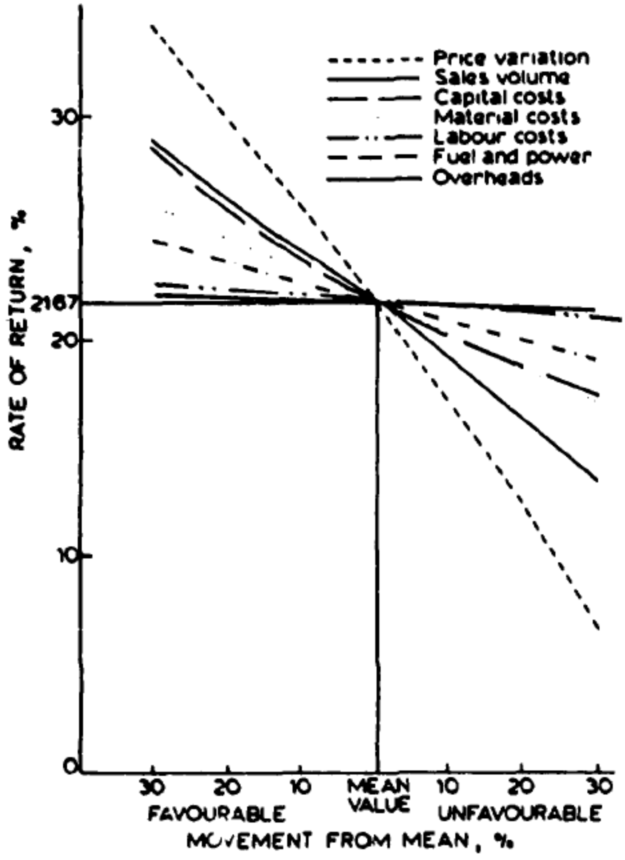
		+30	+20	+10	−10	−20	−30
CAPITAL COST		6 349 546	6 345 620	6 341 694	6 333 840	6 129 914	6 125 988
NET CASH FLOWS	1980	(605 958)	(598 869)	(591 778)	(577 600)	(570 510)	(563 420)
	1981	1 153 077	1 163 876	1 174 673	1 196 269	1 207 066	1 217 865
	1982	1 677 542	1 690 848	1 704 155	1 730 767	1 744 074	1 757 380
	1983	1 885 631	1 901 555	1 917 479	1 949 327	1 965 251	1 981 175
	1984	3 691 905	3 718 954	3 746 003	3 800 103	3 827 152	3 854 201
	1985	3 774 229	3 760 930	3 747 633	3 721 038	3 707 740	3 694 442
	1986	1 954 401	1 966 965	1 979 530	2 004 660	2 017 225	2 029 790
	1987	1 954 401	1 966 965	1 979 530	2 004 660	2 017 225	2 029 790
	1988	1 954 401	1 966 965	1 979 530	2 004 660	2 017 225	2 029 790
	1989	2 543 968	2 540 740	2 537 511	2 531 055	2 527 826	2 524 598
	Rate of Return	21.20%	21.36%	21.52%	21.83%	21.99%	22.15%

21.67% is shown and the curves of all the variables are plotted. The most critical variables to the return on the project are seen to be sales price, sales volume, capital cost and material cost. The project is, however, less sensitive to changes in labour costs. By isolating the critical factors which will affect the profitability of the project, the risks involved may be substantially reduced. The sensitivity analysis shows only the results of movements of a single variable in isolation. To provide the management with the theoretical limits of the profitability, a best and a worst case is calculated. Both the best and the worst case should be based on the practical limits for the variables. These cases result in the following I.R.R.:

Best case	37.22%
Worst case	10.33%

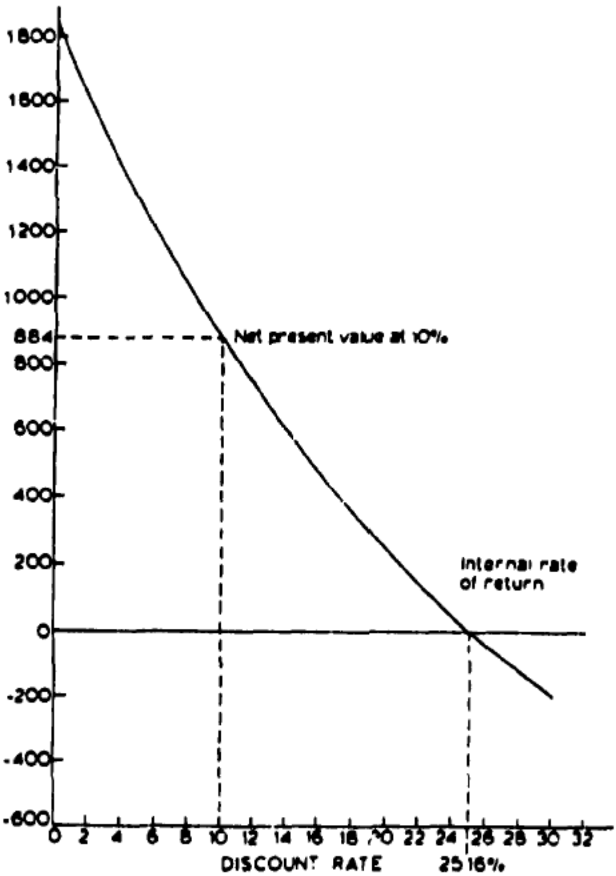
Thus it can be seen that the best possible result of this project is a highly profitable return of 25% above the cost of finance. Whereas the worst possible result is a return of 2% below the cost of finance. This information places the project in perspective as the probale range of outcomes. There is much greater probability that the return on the project will exceed rather than fall below the original rate calculated. Armed with this information and the results of the sensitivity analysis, management is in an informed position to decide that the project is worthwhile and, furthermore, is able to ensure that the risks are minimised by keeping close control over those areas which are shown to have the greatest influence on the success of the project.
Thus, as the cost of capital to the firm is 10%. then the project will give an additional yield over the cost of capital of 15.16%. The principles involved in both methods (I.R.R. & N.P.V.) are, as has been stated, identical. To clarify the results derived from the example quoted are ploted in Fig. E.I/2. The graph shows the net present value calculated for each discount rate from 0 to 30%. It can be seen that the two methods are merely different views of the same principle. The Net Present Value can be seen for each discount rate and if, as the case above, the cost of capital to be used is 10%, the Net Present Value of £884 can be read off the graph. The I.R.R. is the discount rate which results in an N.P.V. of zero and this can be seen as being 25.16%. So the relationship can be seen as giving a different emphasis to the variables in the calculation.

The superiority and the limits of the I.R.R.: An essential characteristic of the type of risk inherent in business is that it is related to time and to the amount of capital outstanding in a capital project at any one time. The advantage of I.R.R., as opposed to N.P.V., is that the result



Graphical representation of sensitivity analysis

<u>Figure E.1/1</u>



Graphical representation of I R R and N P V

Figure E.1/2

is measured in the same dimensions as the risk and this facilitates the task of determining whether the return offered is adequate given the risks involved. The absolute value given by the N.P.V. method does not enable this to be easily assessed. In the simple and most common case of capital investment appraisal, the accept/reject criterion, there is little doubt that the most effective and easily understood method is the I.R.R. There are, however, situations where the superiority of the I.R.R. is brought into question. Where the investment decision is not one of rejection or acceptance but rather the ranking of investment projects in order of profitability, a conflict is possible between the results of the methods. This conflict can be explained by the fact that the I.R.R. gives the rate of return earned on a project and takes no consideration of the size of the actual money return. Thus consideration must be given to the absolute value of the return, in addition to the rate of return on the project. It is obviously more desirable to invest a larger amount for a significant increase in wealth, rather than a small investment yielding a high rate of return but a low absolute increase in wealth. It can be said that the methods are not in conflict but that the whole picture is not shown by the initial analysis of I.R.R., whereas it is shown by the analysis of N.P.V.

Thus in a situation where two projects are mutually exclusive, the use of I.R.R. can lead to the choice of the project which, although giving the grearest return on the investment in %-age terms, does not result in the greatest absolute profit. It is therefore suggested that whereas I.R.R. has many advantages over N.P.V. in the straightforward accept/reject situation, in a situation wherethere is a choice between two projects, only one of which can be accepted both I.R.R. and N.P.V. at the relevant cost of capital should be employed. N.P.V. should in this situation be the more important criterion. The incremental yield may be calculated but as the same result is derived from the N.P.V. method the additional calculation is not seen to yield great benefits other than substantiating the conclusion.

A second situation in which the use of I.R.R. is brought into doubt is a technical oddity and although its occurrence is rare, its existence should not be ignored. The situation arises in circumstances where a project yields cash flows which are uneven and whereby the cash flows in the later life of a project are negative. In the vast majority of cases this presents no problem and results in a meaningful rate of return on the project. There are, however, situations where the negative cash flows in later years may be sufficiently large that during the life the cumulative discounted cash flows become negative. As the rate of return is determined at the point where the N.P.V. is zero, it will be apparent that it is possible to derive multiple rates of return for a project.

In a situation such as this a single I.R.R. has no meaning and the use of N.P.V. is advocated as this gives an unambiguous answer at each rate. Fortunately this situation is very rare in practice and its occurence can be easily predicted. Where a project has cash flows which become cumulatively negative during its life it is possible, but not necessarily certain, that multiple rates of return will result. It would thus be circumspect to use N.P.V. for the evaluation of such an investment project. In the vast majority of appraisals, however, where there is a straightforward accept/reject situation, the use of I.R.R. is strongly recommended.

Appendix E.II

Break-even and productivity

For our illustration let's consider ten varied jobs. Table E.II/1 illustrates the initial product mix. Notice that column 5 in this Table lists the number of moulds presently sold of each part per day. Also, consider that our subject foundry incurs a daily fixed cost of US$6000.- When the problem is solved with a computer, a daily cotribution of US$9524.- is indicated with the suggested optimum product mix shown in Table E.II/2. When comparing columns 5 through 9 of Table E.II/1 with Table E.II/2, a tremendous difference is noted. Notice first that the number of moulds remains constant at 960 per day. (Moulding is the pacing unit). Comparing the results from the data in Table E.II/1 with the data in Table E.II/2 (the same number of jobs) the following differences can be stated:
- total casting weight increased 95%;
- total revenue increased 112%;
- total cotribution increased 67%.

We mentioned that this subject foundry incures US$6000.- per day in fixed costs. From Table E.II/1, column 9 it was shown that the foundry was generating only US$5690.- contribution, not enough to cover fixed costs. In other words, the foundry was loosing money.

The interesting aspect of this problemis that"our" foundry is loosing money while melt capacity was only 22.6% utilized (62,150 lb/275000 lb= = 0.226). The optimum product mix corresponds to 44% melt capacity (121287 lb/275000 lb=0.44). Considering also that the contribution for the foundry in question increased from US$5690.- per day to US$9524.- while the break-even point moved to the left (from 1012 moulds per day to 605 moulds per day).

Break-even will be the farthest to the left and contribution the highest when the optimum product mix for a particular foundry is determined and run. Any other mix of products will be sub-optimal and the subsequent contribution will decrease while the break-even moves to the right.

Part	1 Casting Weight (lb)	2 Selling Price	3 Variable Cost	4 Contribution	5 Number Sold of Each Total Molds	6 Total Weight	7 Total Revenue	8 Total Variable Cost	9 Total Contribution
Manifold	19	$ 16	$ 13	$ 3	100	1,900	$ 1,600	$ 1,300	$ 300
Valve body	15	15	10	5	250	3,750	3,750	2,500	1,250
Lug	4	3	2	1	135	540	405	270	135
Axle housing	410	185	164	21	40	16,400	7,400	6,560	840
Gear Blank	320	134	111	23	45	14,400	6,030	4,995	1,035
Differential case	360	132	105	27	25	9,000	3,300	2,625	675
Wheel hub	66	13	7	6	100	6,600	1,300	700	600
Bearing housing	20	5	3	2	25	500	125	75	50
Brake caliper	49	15	11	4	165	8,085	2,470	1,815	655
Boat anchor	13	4	2	2	75	975	300	150	150
Total					960	62,150	$ 26,680	$ 20,990	$ 5,690

Existing Product Mix

Table E.iI/1

Part	Number of Each (Total Molds)	Total Weight	Total Revenue	Total VC	Total Contribution	Rank By Contribution/lb
Manifold	---	---	---	---	---	---
Valve body	563	8445	$ 8445	$ 5630	$ 2815	1
Lug	---	---	---	---	---	---
Axle housing	178	72,980	32,930	29,192	3738	10
Gear Blank	57	18,240	7638	6327	1311	9
Differential case	44	15,840	5808	4620	1188	8
Wheel hub	---	---	---	---	---	---
Bearing housing	---	---	---	---	---	---
Brake caliper	118	5782	1770	1298	472	7
Boat Anchor	---	---	---	---	---	---
Total	960	121,287	$ 56,591	$ 47,067	$ 9524	

One Shift with Existing Equipment (No Market Constraints)

Table E.II/2

Appendix E.III

Direct costs; Overhead costs; Cost estimate: the preparatory stages

Direct costs

Direct costs, essentiall comprising what might be termed "prime costs" - direct labour and direct materials - are those which can be allocated to cost centres and to actual units of output. Such costs tend to vary in proportion to the volume of production. Foundries must decide just fow far they need to go with cost allocation on the basis of how useful the consequent information may be. Such information is, of course, necessary for control purposes as well as cost estimation.

Direct materials

They may fall into 4 major categories:

(i) materials which comprise the casting
(ii) materials which comprise the mould
(iii) materials which comprise the core
(iv) materials additionally incorporated in individual castings, e.g. inserts and special finishes.

In many instances in practice it may be decided that moulding materials, mainly sand, should be treated as indirect expense.

Metal: metal costs form a significant proportion of total production cost in the typical foundry and as complete as possible an understanding of their determination is desirable. These involve all the elements in a cupola or furnace charge - in the case of ferrous foundries both pig iron and scrap and alloys and scrap in that of non-ferrous foundries. Of the scrap some portion will be own returns, comprising runners and risers, rejected castings and unused or spare metal. The object of collecting metal costs is to determine the cost of good metal at the point of pouring into the mould and consequently to be able to evaluate the metal content of any casting. A problem might arise in the evaluation of internal scrap returns (including castings returned, rejected by customers).

Metal loss: loss on melting is often the most obvious element in metal loss; it is measured by the difference in weight of material charged into the furnace or cupola and the weight of good metal poured from the spout. Other losses generally arise in the course of finishing operations- shotblasting, fettling and machining. Typically on a smaller scale individually than melting losses, they are nevertheless important and must therefore be accounted for in cost calculations.

The total weight of good castings made may be expressed in the form of the equations given in table E.III/1. Table E.III/2 shows the calculation

$$T = M - L - (RRR + RSM + RRC)$$

where T = weight of good castings
M = total weight of metal poured
RRR = weight of returned runner-risers
RSM = weight of returned spare metal
and RRC = weight of returned reject castings

The make-up of metal cost will therefore be expressed by the equation:

$$TC = Mp - Lp - (RRRp + RSMp + RRCp)$$

where TC = total metal cost of good castings
M = total weight of metal poured
RRR = weight of returned runner-risers
RSM = weight of returned spare metal
RRC = weight of returned reject castings
and p = average price of metal charged

Table E.III/1

Table E.III/2 **Example**

(a) Material specification and other relevant information

Composition.

material A	10% @ £60 per ton
material B	20% @ £50 per ton
material C	40% @ £40 per ton
material D	25% @ £40 per ton
material E	5% @ £200 per ton
	100%

Poured weight of casting 40 kg	Melting loss 9%
Rough casting weight 20 kg	Fettling loss 1%
Fettled casting weight 19.8 kg	Spare metal 3%
Reject rate 10%	Returned metal 50%

(b) Composition and disposal of charge

	Tonnes
Total charge	100,000 (for details see (c) below)
Melting and other irrecoverable losses	10,000
Hot metal available	90.000
Spare metal	2.700
Hot metal poured into mould	87.300
Returns (runners and risers etc.)	43.650
Gross castings production	43.650
Rejects	4.365
Good castings production	39.285

Total returned metal = 2.700 + 43.650 + 4.365 = 50.715 tonnes

(c) Cost calculations

Metal cost per tonne of good castings could be calculated in the following way:—

	Tonnes	Price (£)	Value (£)
Material A 10%	4.929	60.00	296
Material B 20%	9.857	50.00	493
Material C 40%	19.714	40.00	789
Material D 25%	12.321	40.00	493
Material E 5%	2.464	200.00	493
Good castings plus irrecoverable losses	49.285	52.02	2564
Returns	50.715	52.02	2636
Total charge	100.00	52.02	5202
Melting and other irrecoverable losses	10.000		—
Hot metal at spout	90.000		5202
Returns:			
Spare metal	2.700	52.02	140
Runners/Risers etc.	43.650	52.02	2271
Rejects	4.365	52.02	227
Good castings	39.285		2564

Metal cost per good tonne $= \frac{2564}{39.285} =$ £65.27 or £3.30 per casting

It will, of course, be seen that any value, including zero, could have been placed on returns. The calculation could, in fact, have been made by deducting the total or irrecoverable losses from the weight of new material (pig iron and bought-in scrap) used the dividing the cost of the latter by that amount (which actually equals the weight of good castings produced).

The cost of metal in some foundries, where the cost variation and the range of alloys is very slight — where, in fact, the range itself is in all likelihood very small — may be arrived at by comparing the net expenditure on bought-in materials with the output of good castings.

of metal cost for a particular type of iron casting.

Moulding: Frequently the material costs of moulding are regarded as an indirect cost, essentially of sand and additives, to any particular casting or group of castings.

The case for regarding materials used in moulding as direct costs or indirect costs rests on the importance of accuracy. Where a relatively high degree of standardisation has been achieved it can be treated as an overhead applied in the form of kg as-cast weight.

Coremaking: If there is a close relationship between the weight of each core produced and the number by overhead recovery unit, and if the cores produced are of standard composition, then the coremaking costs may be considered as overhead cost. If these two conditions are not fulfilled then such treatment is hardly to justify. This is especially likely to be the case in foundries where more than one type of core (e.g. oil sand, CO_2, shell) is made, because the value of the materials used in each type may be substantially different. There is no substantial difference between establishing the direct material cost of a casting and that of a core. See Table E.III/3.

Direct labour

As foundries become increasingly machanised and automated the distinction between direct and indirect labour may tend to decline in significance. Some labour costs are therefore "direct" to the department in which they arise, but "indirect" as far as the calculation of the cost of a particular casting is concerned.

There are two departments, however, where labour activity can be related to the production of specific castings. These departments are moulding and coremaking. Table E.III/4 illustrates a simple case of the calculation of a labour hour rate of moulding. In practice complications may arise because of particular payment etc.

Direct expenses (other than metal and labour)

These include all other costs that are associated with a single product or group of products. It may include some cost, such as pattern or corebox expenditure, special work of an identifiable kind, etc.

Overhead costs

These are the aggregate of indirect materials cost, indirect wages (indirect labour cost) and indirect expenses.

Indirect materials cost: materials cost which cannot be allocated but which can be apportioned to, or absorbed by, cost centres or cost units. For example: protective clothing.

Example

(a) Core mixture specification

Composition:	Material M	150 kg
	Material N	20 kg
	Material O	20 kg
	Material P	20 kg

Coreweight 5 kg
Core blowing loss 5%
Reject rate 10%

A litre of material P is assumed to weight ½ kg

(b) Cost calculation

The direct cost calculation for coremaking will be as follows:—

	Weight (kg)	Price/ kg	Value
Material A	150	0.02	3.00
Material B	20	0.50	10.00
Material C	20	0.30	6.00
Material D (20 × ½ kg)	10	0.40	4.00
TOTAL MIX	200	0.115	23.00
Wastage (irrecoverable @ 5%)	10		—
	190		23.00
	19		—
	171		23.00

Cost per kilo = 23.00 = 13.45 pence
Cost of core = 5 kg × 13.45 p/kg = 67.25 pence

Table E.III/3

Example

Moulder

	Hours	Rate £/hi	Wages £
Normal hours	40	2.00	80.00
*Overtime hours worked	7½	2.00	15.00
	47½	2.00	95.00
Expected bonus earnings	—		25.00
	47½		120.00
Normal idle time	2½		—
	45		120.000

Direct wage rate = $\frac{120}{45}$ = £2.67 per hour

In this example, overtime nremium, treated as overhead, has been calculated as follows:

5 hours @ time and a half = 2½ hours
2½ hours @ double time = 2½ hours

5 hours @ £2 = £10 per moulder
moulder

The above example assumes times quoted on estimates exclude relaxation allowances. Where normal idle (relaxation allowance) is allowed in the time quoted for a job, then:

$$\text{rate/hour} = \frac{120}{47\tfrac{1}{2}} = £2.53/\text{hour}$$

Table E.III/4

Indirect wages: wages which cannot be allocated but which can be apportioned to, or absorbed by cost centres or cost units.

Indirect expenses: expenses which cannot be allocated but which can be apportioned to, or absorbed by, cost centres or cost units.

For example: energy, rates.

Therefore, any cost which cannot be attributed directly to a product or group of products is an indirect expense or overhead.

Generally, the overheads may be classified into the following types:

(i) production or works overhead;

(ii) administration or general overheads;

(iii) selling overheads.

Table E.III/5 shows a summary of total overhead costs analysed by expenditure source.

Overheads in any cost centre fall into three basic categories:

a) those which are directly associated with the cost centre

b) a share of the cost of those departments which serve the cost centre

c) a share of general production overhead.

The accounts in Table E.III/5 are typically treated as general production overhead. Production overhead costs are shown in Table E.III/6. These are apportioned to production and service cost centres according to the benefit received by each cost centre from the particular cost incurred. A schedule of apportionment bases is shown in Table E.III/7. A distribution summary for general production overhead is illustrated in Table E.III/8. All the costs used in the Tables E.III/5 to E.III/8 serve illustrative purposes and are completely fictitious.

Cost estimate: its preparatory stages

Before the detailed preparation of a cost estimate is embarked upon there must be the important decision as to:

a) whether to submit a quotation or to decline it

b) whether in submitting a quotation any qualifications are needed for the customer's requirements.

Such a decision will generally be made by a group representing several functions within the foundry and at the same time it will probably be decided how the casting should be made, bearing in mind both its characteristics and the capability of the foundry. It must be remembered that the technically "ideal" way of making the casting may not, depending on circumstances, be the most cost effective way for a particular foundry. Among the factors this preliminary assessment stage must take account of are the following, which may be expressed in the form of questions:

Cost collection sheet
Source of expense information (in £ sterling)

Account	Stock Materials	Stores Materials	Wages	Salaries	Invoices	Financial Entries	Cash	Total
Indirect labour:								
Cleaners			1416					1416
Sorters			1824					1824
General labourers			920					920
Rent						3246		3246
Rates works						4000		4000
Electricity					4000			4000
Gas					1536			1536
Water						946		946
Fuel for heating		354						354
Hire of equipment					520			520
Protective clothing		216			172		16	404
Fire protection					464			464
Works management salaries				5200				5200
Depreciation — plant						2500		2500
Storekeeping				1279	135			1414
Production planning				3482	625			4107
Security and safety				2897				2897
Drawing office				1282				1282
Canteen			2922	964	3762		(5331)	2317
Weighbridge			480					480
Laboratory		834		1224	300			2358
Employee liability ins.						2970		2970
Fire insurance						2532		2532
Consumable stores		1163						1163
Total:		2567	7562	16328	11514	16194	(5315)	48850

Table E.III/5

Summary cost sheet (in £)

Department	Expenditure source							Total
	Stock Materials	Stores Materials	Wages	Salaries	Invoices	Financial Entries	Cash	
Melting								
Moulding								
Coreshop								
Shotblast								
Heat treatment								
Inspection								
Pattern shop								
Internal transport								
Maintenance								
Compressor								
Fork lift								
Cranes								
Production overhead (see note)	—	2567	7562	16328	11514	16194	(5315)	48850
Selling overhead								
Administration overhead								
Total overhead								

Note: Totals carried over from Table E.III/5

Table E.III/6

General production overhead — basis of apportionment

Basis of Apportionment	Units	Total	Department											
			Melting	Moulding	Core shop	Shot blast	Heat Treat.	Insp.	Patt. shop	Inter trans.	Maint.	Comp-ressors	Fork lift	Cranes
No. of employees	Employees	91	16	8	12	4	4	10	8	3	16	2	3	5
Plant insur. value	£	730000	140000	90000	90000	50000	70000	10000	80000	30000	50000	50000	30000	40000
Floor area	Sq. feet	100400	13600	14000	12500	11000	12500	11500	11500		12000	:1800	—	—
Bulk tonnage	%	100	65	20	10									
Stores issue value	%	100	15	20	10	5	5	—	5	5	20	5	5	

Table E.III/7

General production overhead apportionment — distribution summary

All units expressed are in £'s

Account	Basis of Apportionment	Total Cost	Departmental Apportionment											
			Melting	Mould-ing	Core Shop	Shot Blast	Heat Treat.	Insp.	Patt. Shop.	Inter Trans.	Maint.	Comp-essor	Fork Lift	Cranes
Indirect labour:														
Cleaners	Tech. estimate	1416	142	282	282	142	142	71	71		142	142		
Sorters	Tech. estimate	1824				608	608	608						
General lab.	Tech. estimate	920	138	184	184	138	92	46	46		46	46		
Rent	Floor area	3246	440	453	404	355	404	372	372		388	58		
Rates	Floor area	4000	542	558	498	438	498	458	458		478	72		
Electricity	Tech. estimate	4000			400			400	400		400	2000		400
Gas	Tech. estimate	1536	614		922									
Water	Tech. estimate	946	710	189	47									
Fuel for heating	Floor area	354	48	49	44	39	44	41	41		42	6		
Hire of equip.	Tech. estimate	520		260	260									
Protect. clothing	No. employees	404	71	36	53	18	18	44	36	13	71	9	13	22
Fire protection	No. employees	464	82	41	61	20	20	51	41	15	82	11	15	25
Works Man. sal.	No. employees	5200	915	457	686	229	229	571	457	171	914	114	171	286
Deprec. plant	Tech. estimate	2500	500	1000	500	250	250							
Storekeeping	Store issue val.	1414	212	283	141	71	71		70	70	283	71	71	71
Security & safety	No. employees	2897	509	255	382	127	.127	318	255	96	509	64	96	159
Drawing office	Tech. estimate	1282							641		641			
Canteen	No. employees	2317	408	204	305	102	102	255	204	76	407	51	76	127
Weighbridge	Bulk tonnage	480	360	48	48	24								
Laboratory	Tech. estimate	2358	1886	236	236									
Employers Lia. Ins.	No. employees	2970	522	261	392	131	131	326	261	98	522	63	98	163
Fire Insurance	Plant ins. value	2532	487	312	312	173	243	35	277	104	173	173	104	139
	Sub total	43580	8586	5108	6157	2865	2979	3596	3630	643	5098	2882	644	1392
Prod. planning	% sub total	4107												
Consumable stores	% sub total	1163												
	GRAND TOTAL	48850	9624	5726	6902	3211	3339	4069	4069	721	5714	3231	722	1560

Table E.III/8

(i) material specification: is it within the foundry's usual range and if not what are the consequences of taking it on as a "special"?

(ii) quality standard: are the standards of properties and finish required within the foundry's capability?

(iii) size and weight: are these within the normal capability of the foundry, bearing in mind such things as box size, melting and fettling capacity?

(iv) complexity: is the casting of a kind appropriate to the production facilities of the foundry?

(v) quantity: what are the implications of the total quantity, and the rate of production called for? how will it affect the balanced utilization of the foundry's capacity? what type of pattern equipment will be required?

(vi) policy: are there any general policy factors that should be taken into account, or revised, for example, in the light of enquiry?

When above decisions have been taken the enquiry will then pursue the normal channels applying in the particular foundry; yhis may involve such a progression as weight estimation, determination of production methods and calculation of production rates.
Decisions have to be made as to yield (determining how much metal will require to be melted), feeding and running systems, coring,size of box and number of castings per box, type of moulding sands and core materials and magnitude of fettling and scrap rates. It is important to establish a system which will ensure that all points that might be significantly relevant to cost are given consideration. The possibility of comparing alternative production strategies must also be taken into account. Care must be also taken to see that any special requirements of the enquiry have been included in the composition of the quotation. A list of factors that must be taken into account or assessed follows.

Basic information:
- customer's name
- description and part number
- material
- quantity required
- delivery schedule
- inspection requirements
- special instructions
- pattern equipment requirements
- sample requirements

This information would be expected to be contained in the customer's enquiry and on the drawing.

<u>Production information:</u>

- casting weight-as cast and finished
- material specification
- melting method
- production method (e.g. machine, floor etc.)
- design of feeder/runner system
- number per box, box size
- production rate (moulding)
- type of sand
- cores required-material, weight and time
- heat treatment - type and weight
- scrap rate estimates
- fettling - process and time
- inspection details
- special finishing details
- carriage - packing and transportation
- pattern and corebox - time and materials

<u>Cost information:</u>

- melting cost
- metal loss rate
- direct labour rate - moulding
- moulding scrap overhead rates
- core material cost
- direct labour rate - core scrap
- core scrap overhead rates
- direct labour rate - fettling
- fettling scrap overhead rate
- general overhead rate
- specific costs for heat treatment, special finishes, carriage etc.
- mark-up for profit

The sample of cost estimate performed in Table E.III/9 is not intended to represent an ideal or complete way of approaching the task, but it demonstrates a way in which the major elements of expense can be incorporated in a cost estimate.

A SIMPLE COST ESTIMATE SHEET

Customer	Smith's E..gineering	Enquiry date and reference no.	3/2/84 P1381
Casting details			
Description	Body	Part no.	3335
Material	Aluminium BSS 1490 LM6M		

Estimated weights: Fettled 2.00 kg Unfettled 3.50 kg

	Output per hour	Direct labour rate	Direct cost per casting	Shop overhead	Total cost	Cost per casting £
1. Metal cost	2.00 kg @ £1000 per tonne					2.000
2. Metal loss	7½ % of melt x £1000 per tonne .2625 kg					0.263
3. Melting cost	3.50 kg @ £150 per tonne					0.525
4. Coremaking	200	2.50	0.0125	150% - 0.0188	0.031	
5. Moulding	40	3.50	0.0875	200% - 0.1750	0.262	
6. Fettling	60	3.00	0.0500	200% - 0.1000	0.150	0.443
7. Reject allowance	= 10% of 2, 3, 4, 5 & 6					0.123
8. Works overhead	= 50% of 3, 4, 5 & 6					0.485
9. Admin/Sales overhead	= 45% of 3, 4, 5 & 6					0.437
0. Carriage & packing	= £0.05 per kg					0.100
1. Special processes & tests						
a) heat treatment	– per kg					
b) pressure test	– each					
c) X-ray	– each					
d) machining	1.150 each					1.150
Total cost						5.526
"Normal" mark-up (20%)						1.105
"Normal" selling price						6.631
Total cost (less works, admin, sales overheads)						4.604
Total cost (less admin, sales overheads)						5.089

Estimator's remarks ....

Actual quoted price ....

Table E.III/9

Appendix F

Bibliography of some British Standard Specifications relating to the design, manufacture and inspection of castings

PART I. SPECIFICATIONS FOR CASTINGS AND CASTING ALLOYS

Note 1: *Contents*. Chemical compositions are specified except where otherwise stated.
Most specifications give values for mechanical properties including tensile strength and elongation; proof or yield stress, impact, bend, hardness and other test values are given in appropriate cases.
General clauses cover, in varying degree, inspection and sampling requirements for freedom from defects, rectification practice and dimensional tolerances. Special requirements in certain Specifications include microstructure and machinability.

Note 2: *Other B.S.S. for castings*. In addition to the Specifications listed below, specialised cast products, for example cast iron pipes and rainwater goods and cast steel valves, are covered by separate Specifications.*

Alloy group	*Specification and subject*	*Content*
Aluminium base	B.S. 1490 *Aluminium and aluminium alloy ingots and castings for general engineering purposes*	21 alloys variously suitable for sand casting, gravity and pressure die casting. Main alloying elements Cu, Mg, Si, Mn, Fe, Ni, Zn. Designation *LM* (additional symbols indicate condition or temper)
	B.S. L Series (Aerospace)	Includes 11 specifications for Al base castings
Copper base	B.S 1400 *Copper and copper alloy ingots and castings*	High conductivity copper: HCCI Cu–Cr alloy: CC1-WP Phosphor-bronzes: Series PB (3 compositions). Tin bronze: CT1 Leaded phosphor-bronze: LPB1; Leaded bronzes: Series LB (4 compositions); Gunmetals: Series G and G-WP (3 compositions);

* Refer to Subject Index, British Standards Yearbook

Alloy group	Specification and subject	Content
		Leaded gunmetals: Series LG (3 compositions); Aluminium bronzes: Series AB (2 compositions); Cu-Mn-Al alloys: Series CMA (2 compositions); Brass sand castings: Series SCB (4 compositions); Brass die castings: PCB1 and Series DCB (2 compositions); High tensile brasses: Series HTB (2 compositions);
	B.S. B Series (Aerospace)	Includes one specification for phosphor-bronze bearing castings
Magnesium base	B.S. 2970 *Magnesium and magnesium alloy ingots and castings for general engineering purposes*	7 alloys, sand and chill cast. Main alloying elements Al, Zn, Zr, Mn, rare earths. Designation MAG (additional symbols denote condition or temper)
	B.S. L Series (Aerospace)	Includes 8 specifications for Mg base castings
Cast iron	B.S. 1452 *Grey iron castings*	7 grades designated numerically from 10 to 26 by tensile strength tonnage obtained on 1.2 in dia test bar. No composition specified. Guide to variation of strength with section thickness
	B.S. 2789 *Iron castings with spheroidal or nodular graphite*	6 grades, designated numerically from 24/17 to 47/2 by tensile tonnage elongation combination obtained. No composition specified
	B.S. 309 *Whiteheart malleable iron castings*	2 grades, designated W22/4 and W24/8 by tensile tonnage/elongation combination. No composition specified
	B.S. 310 *Blackheart malleable iron castings*	3 grades, designated B18/6 to B22/14 by tensile tonnage elongation combination. No composition specified
	B.S. 3333 *Pearlitic malleable iron castings*	2 grades, designated P28/6 and P33/4 by tensile tonnage elongation combination. No composition specified
	B.S. 3468 *Austenitic cast iron*	8 grades, various compositions. Main alloying elements Ni, Cr, Cu, Si. 4 grades, designated AUS101-105, of flake graphite type. 4 grades, designated AUS202-205, of spheroidal graphite type
	B.S. 1591 *Acid resisting high silicon iron castings*	Composition 14.75% Si, 0.35-1.0% C
	B.S. K Series (Aerospace)	Two specifications for piston ring pots, cylinders, etc.

Alloy group	*Specification and subject*	*Content*
Steel	B.S. 3100 *Steel castings for general engineering purposes*	20 separate standards for cast steels These include: B.S. 592: Carbon steels (3 compositions); B.S. 1398: Low alloy steels for elevated temperatures (5 compositions); B.S. 1458: Higher tensile strength alloy steels (3 compositions); B.S. 1630: Corrosion resisting 13% Cr steels (2 compositions); B.S. 1631: Corrosion resisting austenitic Cr-Ni Steels (4 compositions); B.S. 1632: Corrosion resisting austenitic Cr-Ni-Mo steels (6 compositions); B.S. 1648: Heat resisting alloy steels (11 compositions); B.S. 4238: Close composition high alloy steels for high temperature use (5 compositions); 12 further individual standards are included, mostly covering special-purpose carbon and alloy steel compositions
	B.S. 1504-1506 *Steels for use in the chemical, petroleum and allied industries*	Includes B.S. 1504: Carbon and alloy steel castings
	B.S. 3146 *Investment castings in metal*	Part 1: Carbon and low alloy steels (12 types); Part 2: High alloy steels, nickel and cobalt alloys (18 types)
Nickel base	B.S. 3071 *Nickel-copper alloy castings*	Main alloy content 30% Cu 3 compositions, designated NA1-3, containing 1-4% Si.
	B.S. 3146 *Investment castings*	Part 2: High alloy steels, nickel and cobalt alloys (18 types)
Zinc base	B.S. 1004 *Zinc alloys and alloy die castings*	Main alloy content 4% Al, 0.05% Mg 2 compositions, designated A and B, containing 0.1% max and 1% Cu respectively

PART 2. FURTHER SPECIFICATIONS RELATING TO THE INSPECTION OF CASTINGS

Field	*Specification and subject*	*Content (further notes)*
Inspection procedure	B.S. 1367 Code of procedure in inspection of copper base alloy sand castings	Inspection and service classification. Chemical analysis and mechanical tests. Recommended procedures for non-destructive tests. (Since embodied in B.S. 1400)
	B.S. 2L 101 Inspection and testing procedure for aluminium base and magnesium base ingots and castings (Aerospace)	
	C.P. 3001 Zinc alloy pressure die casting for engineering	Recommendations for materials, design of components, inspection, mechanical properties and dimensional stability
Non-destructive testing	B.S. 3683 Glossary of terms used in non-destructive testing	Part 1. Penetrant flaw detection. 2. Magnetic particle flaw detection. 3. Radiological flaw detection. 4. Ultrasonic flaw detection. 5. Eddy current flaw detection
	B.S. 4080 Methods for non-destructive testing of steel castings	Visual examination, acid pickling, pressure testing, magnetic particle inspection, ultrasonic inspection, radiographic inspection
	B.S. 3971 Image quality indicators for radiography and recommendations for their use	Dimensional requirements for wire type and step hole types of penetrameter for radiographs of materials from 3–250 mm thick
	B.S. 2704 Calibration blocks and recommendations for their use in ultrasonic flaw detection	
	B.S. 4069 Magnetic flaw detection inks and powders	
	B.S. 1134 Centre line average height method for the assessment of surface texture	
	B.S. 2634 Roughness comparison specimens	For ground, turned and milled surfaces
Mechanical testing	B.S. 18 Methods for tensile testing of metals	
	B.S. 131 Methods for notched bar tests	5 parts. Izod and Charpy tests
	B.S. 1369 Impact test for grey cast iron	

Field	*Specification and subject*	*Content*
	B.S. 1639 Methods for bend testing of metals	
	B.S. 427 Method for Vickers Hardness Test	2 parts: testing; machine verification
	B.S. 240 Method for Brinell Hardness Test	2 parts: ditto
	B.S. 891 Method for Rockwell Hardness Test	2 parts: ditto
	B.S. 3846 Methods for calibration and grading of extensometers for testing of metals	
	B.S. 3500, 3688, 3228, 3920, 3518	Describes elevated temperature, creep and fatigue tests not customarily used for inspection purposes
Chemical analysis	B.S. 1728 Methods for the analysis of aluminium and aluminium alloys	15 parts treating determination of 8 individual elements by chemical methods
	B.S. 1748 Methods for the analysis of copper alloys	12 parts treating determination of 9 elements by chemical methods
	B.S. 1121 Methods for the analysis of iron and steel	50 parts treating determination of individual elements or compounds by chemical methods
	B.S. 1121B Method for the spectrographic analysis of low alloy steels	Apparatus, procedure standardisation, typical spectra
	B.S. 1499 Sampling non-ferrous metals	Sampling of liquid and solid metals
	B.S. 1005 Sampling and analysis of high purity zinc and zinc alloys for die casting	

Appendix G

Process control system; Production control system for a foundry; CAD/CAM: aspects, applications and developments in the foundry industry; Maintenance operations.

Process control system: its functions and components

The notion of a process control system is not yet precisely defined. A process control system has more functions other than the control of a process. It has not to perform the basic control functions by itself. It can be limited to the transmission of proper instructions to the controlling units of an installation. On the other hand the process control system may carry out those instructions by itself. The range of functions of a process control system is determined by the size and structure of an installation as well as by the economy of the controlling hardware. Table G/1 shows the possible functions of a process control system. They include control and interlocking of running processes and regulation of data to present values or to such values as determined by higher level aspects for the optimization of the process.

This also includes the preparation of information concerning a running process, with a clear display of the operational data with alerting the operators at the reaching of critical situations and with memorizing and/or recording of the most essential operational data.

A process controlsystem has to assist, among others, the operator in the organization of a process by administering the actual production program and by assisting in the choice of the most convenient materials. By doing so the works management, and maybe the process control system itself, can improve their knowledge of the process through the analysis of past process variations. The process control system can also perform the functions of failure detection in system components. These functions are then best resolved when the failure detection gives direct indication of the cause of failure to maintenance personnel and is able to point out the corresponding remedies. Through failure detection it should also be possible to determine the weak points in an installation by recording the frequency of any given failure. Quite a few devices are available today for the dedign of a process controlsystem, if the task -as above outlined- is considered in the widest sense (table G/2). In any case signal transmitters and transducers, local control panels and a motor control centre are needed. The choice of dependable signal transmitters and transducers is of foremost importance for a troublefree function of the installation.

The traditional automation equipment of a melt shop consisits of a control cabinet with the contactors for the motors of blowers and pumps in the gas

Table G/1

The functions of a process control system have to be defined in every specific case

- process control
- control of operational variables
- display of operational variables
- warning of critical situations
- recording of operational data
- storage of operational data
- management of the operational program
- selection of favourable working stock
- analysis of process variations
- fault display
- weak point detection

Table G/2:

A wide range of components is available for a process control system

- signal transmitters, local control panels
- transducers and transmitters
- motor control centre
- programmable process control systems
- microcomputers, personal computers
- black and white or colour terminals
- keyboards
- floppy or fixed disk storage units
- matrix or ink jet printers

Table G/3

Summary of production control reports

Report	Used by	Frequency
Forward load reports	Production Control Foundry Manager Purchasing	Weekly or on demand
Work centre load analysis	Production Control Shop supervision	Daily or on demand
Foundry performance	Senior Management	Monthly
Overdue deliveries	Production Control Foundry Manager Sales Department	Weekly or on demand
Work in progress	Production Control Foundry Manager	Monthly
Scrap Analysis	Foundry Manager Quality Control	Daily
Operator performance	Shop supervision	Daily

circuits, and the motors of the transport devices in the changing system. Pushbuttons, indicators for pressures, flows and temperatures, and signal lamps to indicate running motors complete the typical cabinet front plate. An example of process control in a melt shop is given at the end of Appendix G.

<u>Production control system for a foundry</u>

Foundries, although usually viewed by their managers as a "special - case" are clearly of the production system process type. In this form of production, a single "mass" of material is used to manufacture either a single product or a range of products (several casting types may be produced from a single "melt" of metal). Where foundries do usually differ from other process type industries (e.g. paper, glass, etc) is in the variety of their products and the relatively small batch sizes often involved.

Production control in foundries is often difficult to implement for a variety of reasons -lack of data, wide variations of production process yields, casting rework resulting in split-batches, and even a seemingly inherent inability to count castings. Nevertheless no foundry is too small to reject the transfer to a computerized production control system.

<u>Objectives and functions of a production control system</u>: The major objectives of production planning and control necessary to assist in achieving both adequate profitability and customer satisfaction in foundries are:

(i to plan and monitor the execution of production activities in order to offer and to maintain reliable delivery performance;

(ii) to provide a balanced flow of work through the various production centres to utilize resources efficiently;

(iii) by efficient use of resources to provide the required level of service at the lowest possible manufacturing cost;

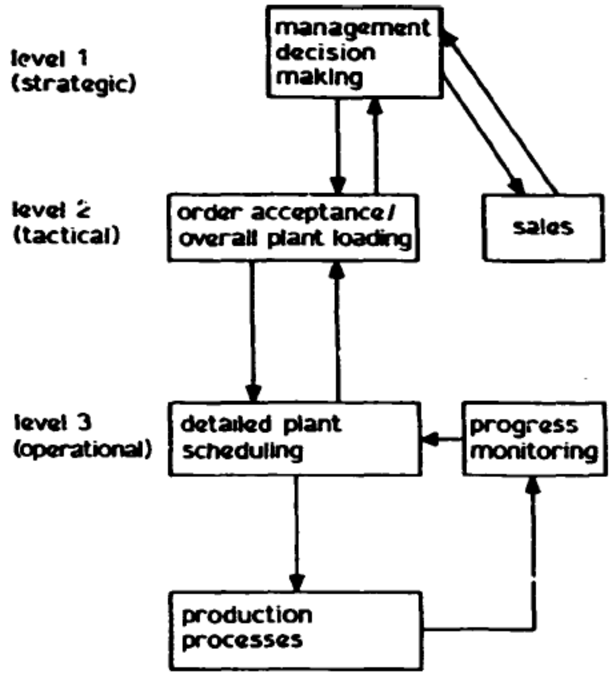
(iv) to monitor production achieved in relation to that planned;

(v) to provide a permanent record of production, deliveries, scrap etc.

The planning and controlling of production in a foundry can be considered as comprising three levels of decision making (Figure G/1) combined to give an overall approach by which strategy and tactics can be planned and then used as a basis for control.

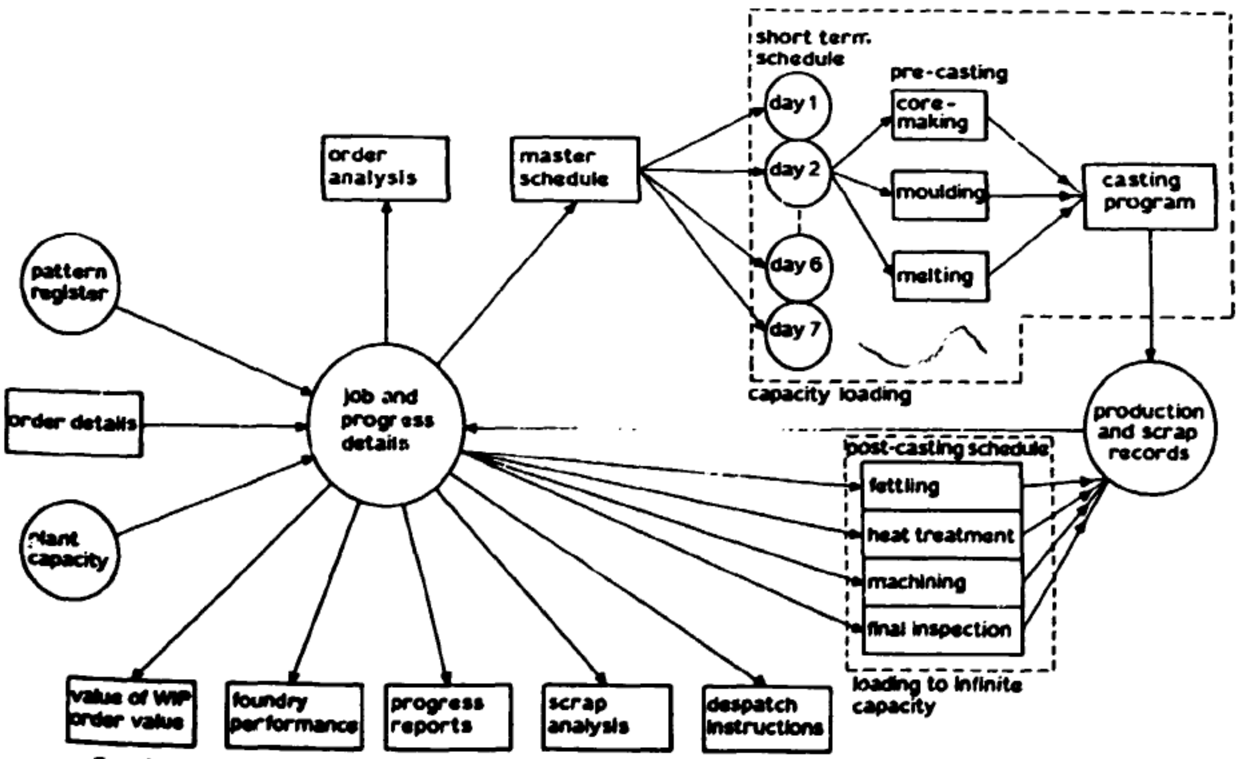
In pursuing the objectives above outlined, a foundry production planning and control system should incorporate the following activities:

a) order acceptance and forward plant loading;
b) detailed plant scheduling, encompassing the issue of work instructions;
c) monitoring the progress of work and taking immediate decisions concerning modifications to schedules to react to divergence from plans;
d) preparation of management reports.



Levels of decision making

Figure G/1



Foundry production control system

Figure G/2

Figure G/2 shows the relationship existing between the various phases and features of production planning and control in a foundry. Table G/3 illustrates a summary of production control reports.

Production control systems should be flexible. The plans made at one level of controlshould not unduly resrict decision making at other levels when local difficulties arise. Flexibility to react to new information or disturbance must be built in to the system. System flexibility does not eliminate all problems but should facilitate better control.

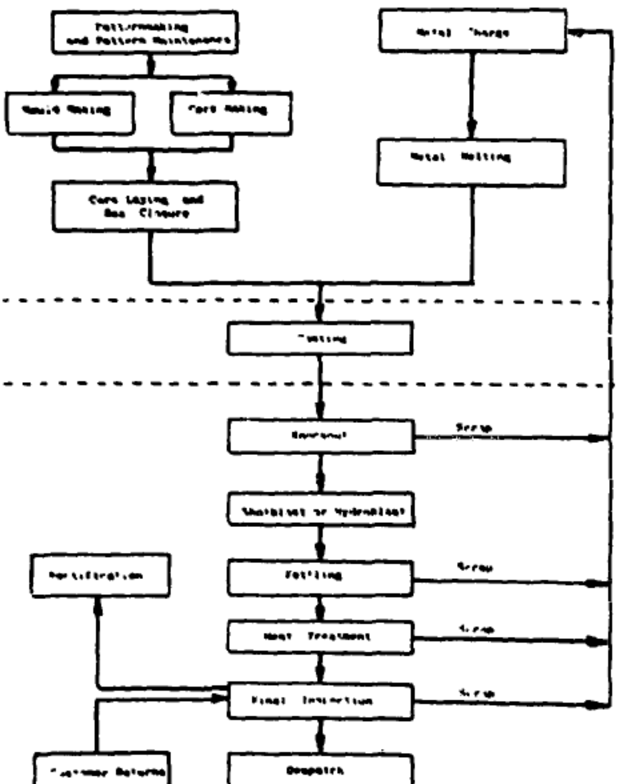
A model of foundry production: Foundry production may perhaps best be modelled as a "cascade" of stages. manufacture of moulds and cores occur on the top step, castings are poured on the next lower and subsequent processes occur lower down up to the despatch section. When products pass through a process stage they fall to the next lower stage. Rework involves going back several stages, and scrap products produce a call for additional products at the top of the flowsheet.

The number of steps at which castings can be monitored depends upon the nature of production. An indication of the relative complexity demands can be gained from comparison of Figures G/3, G/4, and G/5, although even within broad groupings (e.g. sand casting) there are substantial differences. In general these should never need to be more than ten monitoring stages. Operations occuring between of the monitoring stages should be involved within one of the stages before or after. Die casting production requires approximately 4 or 5 monitoring stages, sand casting between 4 and 7 depending whether iron or steel, and precision casting between 6 and 10 stages. Iron foundries generally have simpler process sequences than either steel or non-ferrous foundries. Therefore the need for close monitoring is restricted to fewer process stages -typically casting, fettling, and despatch.

Regarding the effect of order pattern all three basic types such as discrete orders on a non-repeating basis, discrete orders on a repeating basis, semicontinuous or continuous production of running lines have their own peculiarities and place different demands upon a production control system. Two case staudies are reported at the end of Appendix G.

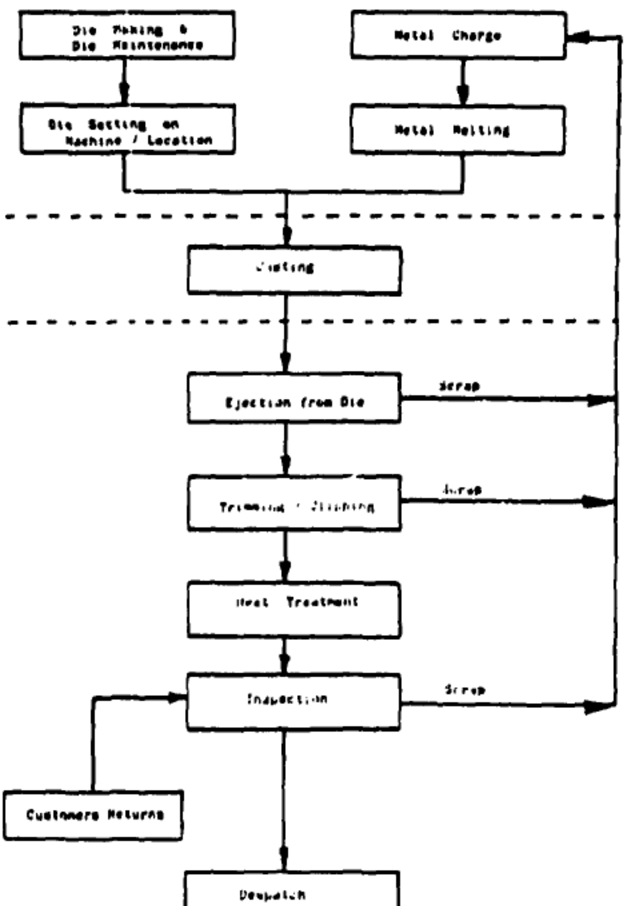
CAD/CAM: aspects and developments in foundry operation

Rising claims on quality levels consequently imposed increased pressure on delivery dates and costs in the casting industry. The only answer is continuous rationalization in commercial and technical departments by introducing modern technologies like electronical data processing (EDP) and CAD/CAM to remain competitive in the market. Working with CAD



Foundry production flow in a sand foundry.

Figure G/3



Foundry production flow in a die/permanent mould foundry.

Figure G/4

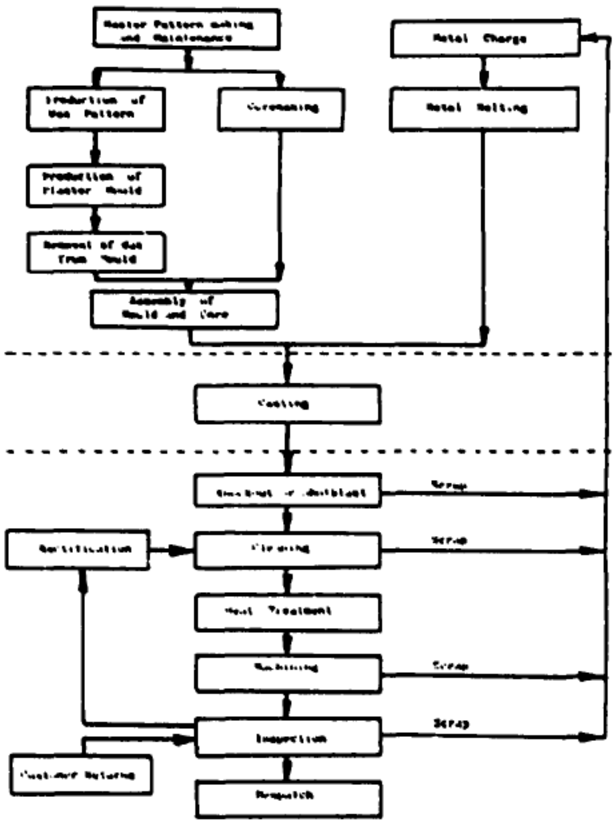
(Computer Aided Design) and CAM (Computer Aided Manufacturing) in production starting with product design right up to the parts manufacturing, offers optimal opportunities for rationalisation. CAD/CAM technology has the objective of improving the speed and accuracy with which a design concept can be translated into a finished product. Companies with the right attitude and readiness towards calculated risks will surely be ahead of their competitions in the near future when adopting these new technologies.

When introducing a CAD/CAM system one should proceed in logical steps that can be followed by all persons concerned in the company. It is absolutely necessary that the CAD/CAM concept is prepared systematically and then logically interpreted into CAD/CAM application programmes. The flow diagram shown in Fig. G/6 outlines the interaction between CAD/CAM and the casting production process. An essential requirement of the dedicated foundry CAD/CAM system is an effective solidification model.

Solidification simulation: Solidification is a unique feature of the casting process, and it exerts a fundamental influence on the structure and properties of a casting. The macroscopic aspects of the casting process: heat transfer; thermal stress; and fluid flow are receiving considerable attention and are the most likely aspects to be incorporated in process control and process design models. Research to develop an understanding of the solidification phenomena continues to be an important topic of research and the mathematical modelling or simulation of solidification is a prerequisite of a dedicated casting CAD system. As a casting solidifies, heat transfer occurs in three ways: conduction; convection; radiation. A number of factors representing physical properties are of primar importance and must be taken into consideration in attempting a successful computer simulation of solidification. These factors include the following transport phenomena and/or state properties:

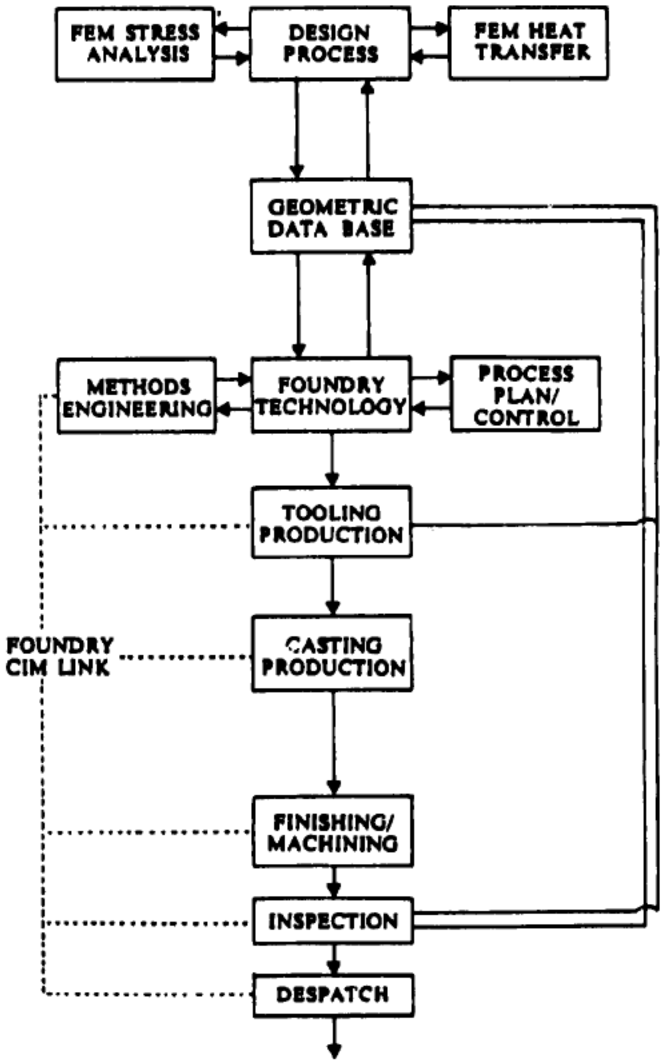
- latent heat of fusion
- thermal properties of the metal/alloy
- thermal properties of the mould
- heat transfer from the metal to the mould
- convection in the melt

Heat transfer at the interface between the casting and the mould is complicated by the formation of an air gap. This occurs whether a refractory aggregate mould or metal die is involved, and is a manifestation of the contracting casting and the expanding mould. Metal in a mould cavity is subject to convection and this causes deviation from the concept of a steady state. It is only recently that this aspect has received detailed



Foundry production flow in a precision foundry (e.g. lost-wax process).

<u>**Figure G/5**</u>



Flow diagram for foundry CAD/CAM.

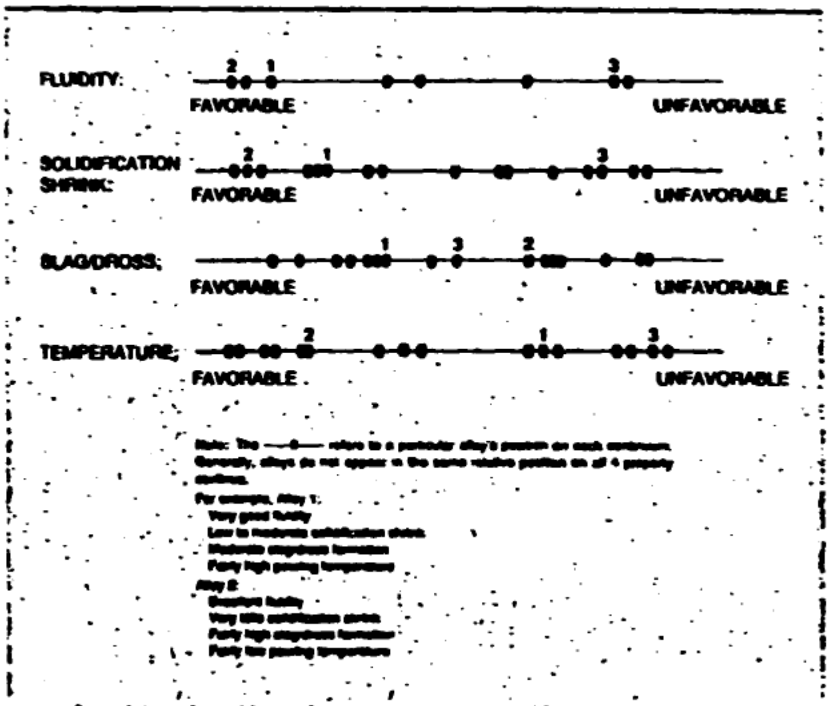
Figure C/6

investigation. In numerical computation for solidification simulation the two most important procedures are the finite difference method (FDM) and the finite element method (FEM). For the elaboration of a solidification model it is necessary to take into account the four physical characteristics affecting the castability of metal alloys. Considering each alloy's characteristic as a continuum a respective model can be illustrated as in the Figures G/7a and G/7b depicted. by means of a model like this the designer can clearly see several different design considerations for the alloys in question (in the example of Figures G/7a & G/7b are three) and taking full advantage of computer assistance it is possible to optimize machine productivity and product itself.

Other CAD/CAM interfaces with foundry: (i) Patternmaking: in order to provide an effective casting CAD system, solidification simulation must be complemented and supported by an unambiguous means of specifying the casting geometry and by the production of good patterns and tooling as well. CAD/CAM applications in foundry pattern tooling are in their first generation. However this is just the beginning of what will become the way of life for patternmakers in the foundry industry.

(ii) Mould filling simulation: the simulation of mould filling has not received as much attention as the simulation of solidification, due to the complexity of the problem. Metal flow and heat loss during this flow is of importance when solidification is rapid or a large temperature loss occurs during mould filling.

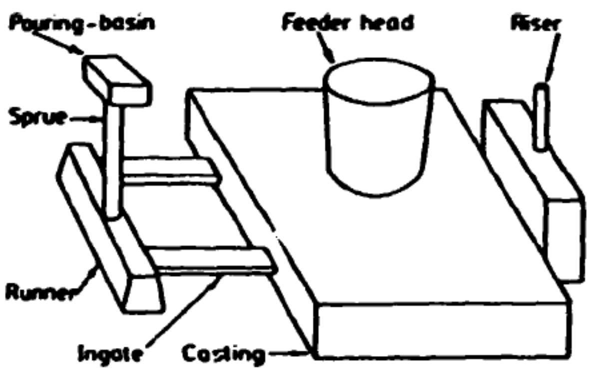
Currently, the standard assumption of instantaneous mould filling is made. The significance of the gating system goes beyond its influence on solidification, as it is well known that many casting defects can be attributed to poor gating system design. To be of any practical value a simulation model must be carefully validated by checking its predictions with experimentally determined results. Table G/4 shows the results of a computer program used to analyse the flow conditions in the gating systems of grey iron castings in the size range 5 to 10 kg. Forty different castings were studird. The results show that all the systems used fall into three main groups, depending on the location of the choke. Eight of the 40 systems were choked at the ingates. The calculated velocities show that the largest cross section in the gating system, that of the runner (see Figure G/8), had the lowest velocity to allow for slag-separation. The computer also calculated the smallest cross section on the joint line necessary to form the choke, together with the velocity through it. An examination of these results and the dimensions of the castings enabled a pouring rate to be selected which was suitable for the foundry.



A model, such as this continuum concept, can provide the designer with a graphical representation of the favorable/unfavorable characteristics of any given alloy.

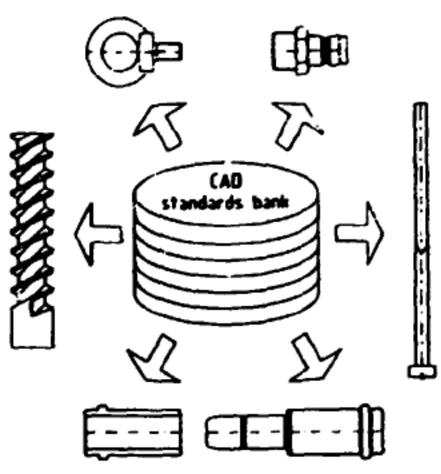
Figure G/7a

Figure G/7b: see next page!



Components of gating systems as used by BCIRA.

Figure G/8



Calling-up of various standard components from the CAD-standards data bank

Figure G/9

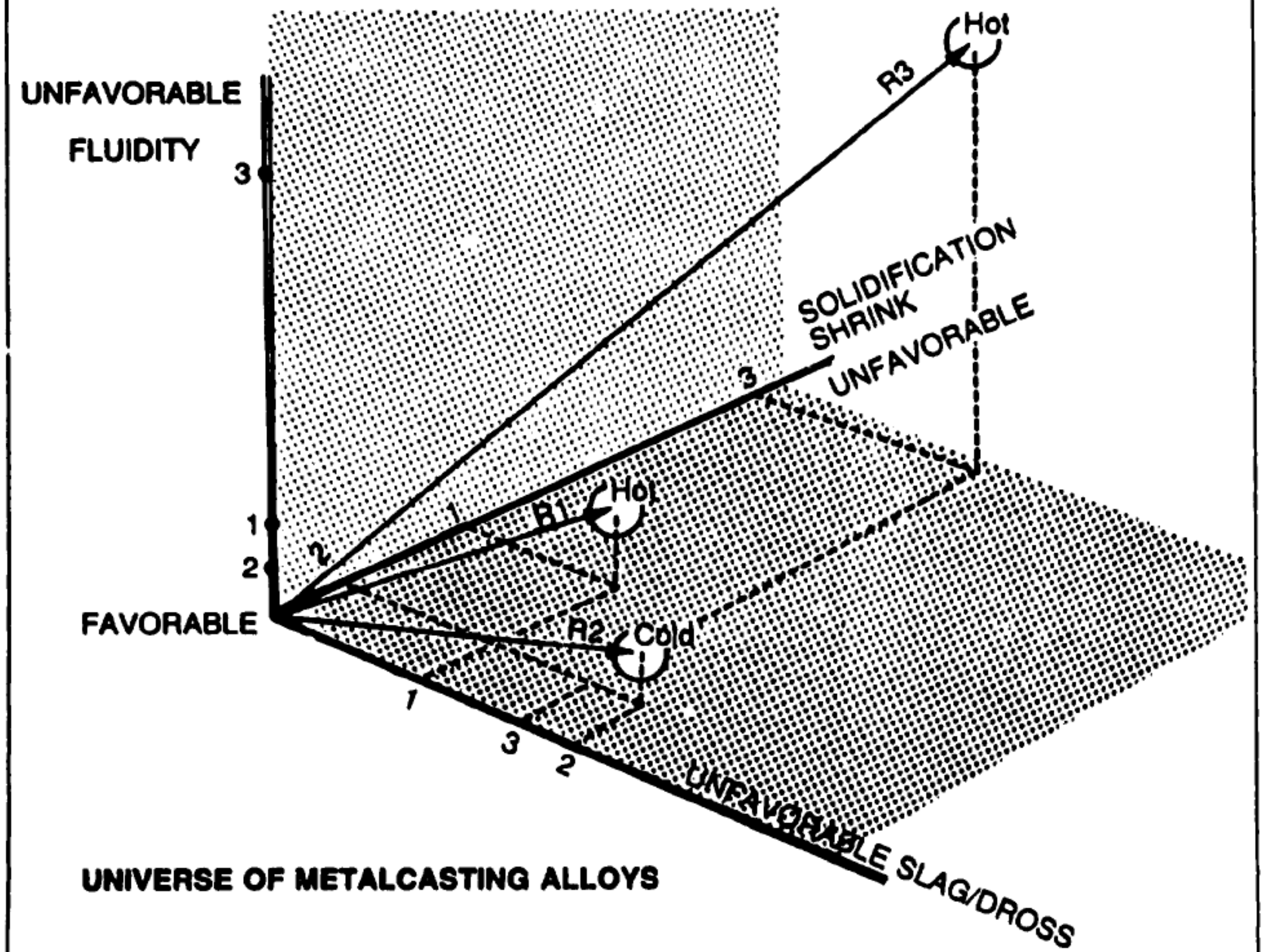


Figure G/7b

A four-dimensional model can be helpful for the design engineer in determining the castability and proper application of a metal alloy. Note that the length of Resultants R1, R2 and R3 as they relate to temperature are a relative measure of the need for system-wide thinking when designing a casting in each alloy shown.

Table G/4

Gating system type	*Location of choke*	*Computer Calculations* — *Velocities cm/sec* — *Runner*	*Runner choke*	*Ingates*	*Joint line head cm*	*Filling time seconds*	*Discharge coefficient*	*Number of castings in box*
ingate controlled	Ingates	28.1		177.2		7.45	.86	4
	Ingates	no						
	Ingates	runner		126.5		6.89	.77	1
	Ingates	23.2		123.8		16.62	1.1	1
	Ingates	30.7		141.8		12.59	.74	2
	Ingates	67.93		140.1		8.78	.62	1
	Ingates	76.9		140.1		11.04	.71	2
	Ingates	38.4		102.8		18.79	.65	4
	Ingates	31.1		107.5		14.72	.62	2
runner controlled	Runner	43.9	100.7			21.5	.95	4
	Runner	45.6	99.8			26.9	1.05	1
	Runner	35.2	135.0			26.7	.9	4
	Runner	38.5	146.9			16.7	1.0	2
	Runner	65.5	148.6			7.2	.67	1
	Runner	63.6	145.6			13.42	.56	6
	Runner	48	153.4			9.31	.65	5
	Runner	33.9	145.2			10.45	.46	2
sprue top controlled	Sprue top	45.8	75.4		2.89	14.1	.79	2
	Sprue top	45.6		86.1	3.78	20.69	.68	1
	Sprue top	64.3		109.4	6.1	5.65	.57	4
	Sprue top	142.8	142.8		10.4	17.95	.7	1
	Sprue top	44.6	89.5	107	4.07	11.44	.84	4
	Sprue top	35.1		54.5	5.83	6.11	.57	4
	Sprue top	22.4			1.51	17.59	.94	1
	Sprue top	33.8	72.8	81.9	2.7	16.73	.88	4
	Sprue top	33.3		65.5	3.42	6.93	.61	4
	Sprue top	38.1			2.19	17.98	.76	1
	Sprue top	57.7	121.5	47.8	7.52	4.63	.69	2
	Sprue top	45.1		49.2	1.73	6.92	.44	1
	Sprue top	17.6	71	5.30	1.23	34.4	.98	1
	Sprue top	31.7		41.6	1.56	3.58	.25	9
	Sprue top	47.5	104.42	59	2.57	2.91	.34	16
	Sprue top	18.4			.88	13.62	.96	8
	Sprue top	25.5		113.8	1.78	7.52	.59	6
	Sprue top	41.1		43.3	5.56	7.52	.72	2
	Sprue top	45.3	·99.1	101.7	6.60	7.23	.63	4
	Sprue top	39.1		22.2	.95	7.02	.7	4
	Sprue top	38.6			5.27	8.51	.51	6
	Sprue top	21.9		70.2	7.66	7.66	.79	4
	Sprue top	44.7			5.00	14.84	.51	5
	Sprue top	23.8			2.51	5.54	.74	4

It was proposed that the best yield would be obtained with a filling gate system if both the sprue top and ingates formed equal chokes. The results also indicated a suitable runner velocity to give slag separation.

(iii) Modular system for die-casting die: today it is common practice world-wide to use standard elements in the die-making industry. At least 25% of the in-house capacity for the die construction can be eliminated by using standard elements. Some additional work on the die (approx. 20%) can often be carried out by the manufacturer of the standard elements, together with the provision of accessories. Thus, an average of 45% of the capacity required for the production of a die can be served by using bought-in parts. Extensive programmes of standard elements are available off-the-shelf. All items are listed in a catalogue (Figure G/9) and can be combined individually according to a modular system contributing to a more economical production in general. Considering the fact that many diemaking shops work directly or indirectly as subcontractors for large companies, it is very obvious that CAD/CAM cannot be ignored. Their introductory period is over; it is time for medium- and small-scale makers to study CAD/CAM. But attention must be given to appropriate introduction. It is important to introduce an optimum system corresponding to the foundry's production scale, type of dies and software technological ability so as no to leave it unused.

Maintenance operations

In the cast metals industry the maintenance department is often used as a corrective department, only putting equipment right when it fails, and the only routine maintenance function being carried out is that of oil changing and machine cleaning. However, this department can make a major contribution to a foundry's profitability. Proper planning of the maintenance foundry plant and equipment in conjunctionwith production requirements will go a long way to avoiding unnecessary stoppages. The principles of condition monitoring can be used as an aid to establishing maintenance routines and fault-diagnosis. By choosing a parameter which reflects the condition of a plant and by observing changes, it is possible to diagnose trouble at an early stage. The objective of applying condition monitoring is to pinpoint a problem before it occurs. It is claimed that maintenance based on this method is now recognised to be the most efficient and versatile approach to the operation of plant and machinery. The cost of carrying this out is offset by improved control maintenance, reduceed labour costs, avoiding failures and reducing the amount of money tied up in the holding of spares long before they are required. Table G/5 gives the advantages provided by condition monitoring. Possible areas which may be utilised for condition monitoring are given in the Tables G/6 and G/7. Table G/8 gives a comparison of general purpose condition monitoring techniques.

There is an almost unlimited variety of maintenance data which is possible to analyse. Analysis of the maintenance function is of no use unless the information is acted upon promptly. The secret of operating any successful scheme lies in retaining simplicity, whereby only essential data is analysed on a routine basis.

With objective quantitative analysis based on historical records it is possible to prove that a decision on a machine will have to be made:

(i) Accept the present level of downtime, as modifications are impractical or too costly. (Downtime analysis will show the frequency of occurance and the cumulative downtime hours, plus repair time man hours and material costs).

(ii) Modify of a plan for a major overhaul of the equipment to bring it to an accepatable standard. (Cost analysis will show the reccuring cost of maintenance).

(iii) Dispose of the failing asset and purchase replacement machinery of improved design. (Defect analysis will show what pifalls to avoid).

Table G/9 illustrates a weekly analysis of maintenance labour. An example of a monthly comparative analysis of machine costing by labour and material is produced in Table G/10. Results from subsequent periods indicate whether or not maintenance is being efficiently applied. Reduction of emergency and corrective maintenance indicate that the foundry approaches the optimum economic maintenance level.

Now that the industry is becoming more automated it is considered an essntial requirement for a foundry to back up the maintenance trades with advanced training and a large degree of "in house expertise". Many maintenance schemes fail because management do not provide the necessary resources (spare parts schedules, technical information, training etc.). It is the responsibility of the employer to train maintenance personnel to maximise machine availability at optimal cost to the company. Training and particularly in-plant training should be regarded as an on-going process. Also the increasing importance and adaptability of computers (micro- and mini-) within the framework of maintenance operations should not be omitted. This is significantly enh[illegible] by the fact that much cheaper hardware is available.

Table G/5

Advantages provided by condition monitoring

Advantages obtained			*Methods by which condition monitoring gives these advantages* — *Trend monitoring*	*Condition checking*
Safety	Reduced injuries and fatal accidents to personnel caused by machinery		Enables plant to be stopped safely when instant shutdown is not permissible	Machine condition, as indicated by an alarm is adequate if instant shut-down is permitted
Output	Increased machine availability	More running time	Enables machine shutdown for maintenance to be related to required production or service, and various consequential losses from unexpected shut downs to be avoided	Allows time between planned machine overhauls to be maximised and, if necessary, allows a machine to be nursed through to the next planned overhaul
		Less maintenance time	Enables machine to be shut down without destruction or major damage requiring a long repair time Enables the maintenance team to be ready, with spare parts, to start work as soon as machine is shut down	Reduces inspection time after shut-down and speeds up the start of correct remedial action
	Increased rate of net output			Allows some types of machine to be run at increased load and/or speed. Can detect reductions in machine efficiency or increased energy consumption
	Improved quality of product or service		Allows advanced planning to reduce the effect of impending breakdowns on the customer for the product or service, and thereby enhances company reputation	Can be used to reduce the amount of produce or service produced at sub-standard quality levels

Table G/6

Areas which may be utilised for condition monitoring

Gases, fluids (including lubricants
Flow, pressure and temperature of water cooling systems
pH, chemical analysis (microsiemens/cubic centimetres), gases, flue gas analysis, CO: CO_2 ratio, temperature pressure cupolas etc.
Moisture, dust content, viscosity
Flow, pressure and temperature of lubricants

Mechanical — noise, temperature, vibration
Temperature (cooling system, casings etc)
Loading (strain gauges etc), cranes, silos, rotation speed of driving mechanisms (e.g. gearboxes)
Vibration noise

Energy
Light emission
Earth leakage
Current/power drawn by motors etc.
Combustion and flame control
Power factor
Fuel combustion efficiency
Temperature monitoring, insulation temperature monitoring
Flow/pressure

Table G/7: **Summary of condition monitoring techniques**

Method	*On/off load*	*Location of fault*	*Equipment costs (1977 level)*	*Skill required of operator*	*Comments*
1. Visual	On	Surface only	nil	Predominantly experience	Covers a wide range of *ad hoc* methods
	Off	Can be extended to interior components provided method was considered at design stage	Optical probes about £500 £2000 television	No special skill required	Extensively used in aero engine industry for 'turn round' inspections
2. Temperature (General purpose technique)	On	Surface or internal	Varies widely	Little skill required for most methods	Instruments range from direct reading thermometers to infra-red scanners
3. Lubricant monitoring (General purpose technique)	On	Any lubricated component - via magnetic plug, filters or oil samples	<£50 except for ferrography and spectrography equipment	Skill is required to distinguish between damage debris and normal wear debris	Spectrographic and ferrographic analysis services are available to show what elements are present
4. Leak detection	On and Off	Any pressure-containing component	<£1000	Skill in use of the specialized equipment readily acquired	
5. Crack detection					
(a) dye penetrant	On and Off	At clean surface	<£50	Some skill required	Only detects cracks breaking surface
(b) magnetic flux	On and Off	Near to clean smooth surface	<£50	Some skill required. Easy to miss crack	Limited to magnetic materials. Sensitive to crack orientation
(c) electrical resistance	On and Off	At clean smooth surface	<£100	Some skill required	Sensitive to crack orientation. Useful for estimating crack depth
(d) Eddy current	On and Off	Near to surface. Closeness of probe to surface affects results	£100–£1000	Skill essential	Detects a wide range of material discontinuities, cracks, inclusions, hardness, etc.
(e) Ultrasonic	On and Off	Anywhere in any component to which there is access via a clean smooth surface	£500–£1000 (Battery operated)	Skill essential if cracks not to be overlooked	Directional sensitivity, therefore general searches lengthy. Used to back up other diagnostic techniques
(f) Radiography	Off	Access to both sides necessary	>£1000	Considerable skill required in setting up and interpreting radiographs	Covers a large area at one time. Security required because of radiation hazard. Limited to sections less than 50 mm (steel)
6. Vibration monitoring (general purpose technique), total signal, band frequency analysis, or peak level	On and Off	Any moving component. Any object containing moving parts. Transducer placed in path of vibration transmission, e.g. bearing housing	>£500	Some skill required	Methods vary from the simple to the sophisticated. Routine measurements taken rapidly and do not affect operation of the machine
7. (a) Corrosion monitoring		In pipes and vessels			
(b) Corrosometer (electrical element)	On		Potentiometer <£200	Some skill required	Will detect 1 μm corrosion loss
(c) Polarisation resistance and corrosion potential	On		Meters £500	Some skill required	Only indicates that corrosion is occurring
(d) Hydrogen probe	On		£100	No skill	Hydrogen evolved diffuses into thin walled probe tube and causes pressure rise
(e) Probe indicator holes	On		-	Skill required in drilling to exact depth	Indicates when preset amount of corrosion has occurred
(f) Weight loss coupons	Off		-	-	Monitored when plant stripped down.
(g) Ultrasonics	Off		£500–£1000	Skill essential	Will detect 0.5 mm thinning

Table G/8: Comparison of general purpose condition-monitoring techniques

	Thermal monitoring	*Lubricant monitoring*	*Vibration monitoring*
Medium for transmission of information through machine	*Solid* – casing, shaft body *Fluid* – lubricant, cooling water or air Depends on thermal conductivity	Oil used for lubrication and/or cooling Depends on lubricant being pumped round the machine	Any solid part of machine Depends on elastic and mass characteristics of solids
Components monitored	Any heat generating devices (combustion in cylinder or electrically generated heat in motor). Condition of bearings. Fluid flow in heat exchangers (fouling of passages)	Any component which is lubricated; bearings, transmission components (gears, couplings, cams), lubrication pump	Any component that moves, surfaces between components with relative motion, clearances
Faults detected	Failure of drives, blockage of ducts, loss of cooling, fouling of coolers, over-use (e.g. overloading motors)	Any form of wear or failure that results in lubricated surface failure. Leakage of other contaminants into lubricant	Change in any moving components, wear or failure of bearings, misbalance, change in clearances
Monitoring equipment	Fluid or bimetallic thermometers, thermocouples, resistance thermometer, thermistor plus associated instruments, temperature paints/crayons, infra-red detectors, optical pyrometers, infra-red scanning camera	On-load removable filters, magnetic plugs for visual examination of debris using microscope, spectroscope for analysis of material in suspension, ferroscope for separating debris, pressure gauge across filters	Accelerometer plus electronic processing equipment to display time averaged values. Frequency filters and recorders for analysis of vibrations
Frequency	Continuous and periodic	Primarily periodic	Periodic but also continuous

Table G/9:

	Pure Maintenance									Project Engineering						Production			Non Maint			Total
Week No. 51	Inspection			Corrective			Emergency			Modifications			Capital									Hours
Dept.	Mech	Elect	Civil	Mech	Elect	Civil	Mech	Elect	Civil	Mech	Elect	Civil	Mech	Elect	Civil	Mech	Elect	Civil	Mech	Elect	Civil	Booked
Foundry	199	63	—	31	13	70	2	6	—	125	117	184	8	18	—	45	1	1	—	—	—	883
Dressing	11	6	—	18	10	—	—	9	—	4	—	—	—	—	—	3	—	—	—	—	—	61
New Mill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	5	—	—	—	—	7
Assembly	14	—	—	11	3	9	37	—	—	—	—	—	—	—	—	10	—	—	—	—	—	84
Sheet Met.	—	21	—	3	2	—	—	23	—	—	—	—	—	—	—	10	—	—	—	—	—	59
Maintenance	—	—	—	—	2	—	—	—	—	—	—	—	—	—	42	—	—	—	126	47	2	218
Services	38	3	—	—	—	—	—	—	—	—	14	—	—	2	—	—	—	—	—	—	—	57
Other Depts	1	—		6	5	38	—	—	—	—	—	15	—	—	—	—	—	4	—	—	—	63
Spares	—	—	10	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13
							39			129	—		8	—		70	—		126			
Totals								38		—	133		—	20		—	6			47		
Mech	262			79						—	—	—	—	—	—	—	—	—				713
Elect		93			36				—			—			—			—				373
Civil			—			117			77			199			42			5			2	365
Total Hours			355			232						461			70			81			175	1451
Hours spent on pure maintenance																						
			355			115			77													
%			65%			21%			14%													

Labour analysis chart. All units are hours.

Plant Item No.	Inspections		Corrective		Emergency		Pure Maint. Mat'l.	Production			Modifications			Totals			Down Time
	No. of Jobs	Labour	Jobs	Labour	Jobs	Labour		Jobs	Labour	Mat'l	Jobs	Labour	Mat'l	Jobs	Labour	Mat'l	
1219	1	2½						13	12¾					14	15¼		6½
Group Total	138	732½	19	49¼	65	36¼	286.60	24	20¼	36.80	32	216¼		278	1054¼	323.40	29
Sand Plant																	
1300F			1	6¾			1.10				54	1006¼	94.69	55	1013	95.77	
1300	31	72									3	4¼		34	76¼		
1301	1	6												1	6		
1302	2	6						1	6					3	12		1½
1303	1	2												1	2		
1309	1	2					4.40							1	2		
1310	1	2			1	¼	6.29							2	2¼		¼
1312	1													1	2		
1313			1	1¾	2	1	30.56	1	¼					4	3		1
1314		2½													2½		
1315	2	5½			2	17		1	¾					5	23¼		9½
1316	1	6												1	6		
1317	2	8						1	¼					3	8¼		¼
1321							7.04										
1322	4	32												4	32		
Group Total	48	146	2	8½	5	18¼	49.39	4	7¼		57	1010½	94.67	116	1190½	144.06	12½
Core Machine																	
1405	4	4½	2	5	2	5½		2	11½		1	24		11	50½		5½
1406	11	19	2	4										13	23		
1407	11	19½	6	30¼	1	3½					1	22		19	75¼		1¼
1411	3	3						1	2					4	5		
1412	4	4½			1	1								5	5½		½

Four weekly direct maintenance costs

Table G/10

Example 1:

Melting with process control

The melt facility at Valley Mould was designed to produce 900 tpd using two 55 ton coreless induction furnaces, each with 16MW power supply. As a result of process control, the shop can comfortably and economically produce 1000 tpd with two furnaces. With all three furnaces available in use, it has been possible to produce in excess of 1200 tpd.

The plant may melt either 100% scrap or 100% direct reduced iron (DRI) pellets or any combination of the two. The induction furnaces are supported by a preheater and a unique alloy addition system.

The alloy addition system consists of two, three bin groups, with each bin having a weigh feeder. The weigh feeders supply material to cross and indexing conveyors, which feed directly into the furnaces. The materials, presently graphite, 50% ferrosilicon and granulated pig iron, are precisely weighed out as directed by the control room supervisor. Adding alloys in this method not only saves manpower, but gives a very high recovery rate as the alloys are added slowly while the melt power is on. Bin groups are refilled once each turn.

Charge makeup and bucket charging follow traditional methods. Typical charge makeup consists of broken ingot molds, pig iron, various types of steel scrap and foundry returns. Tap sizes range from 30-35 tons with four recipe type backcharges per heat.

Valley's melt shop departs from traditional coreless induction facilities in that the melt deck is elevated 20 ft above the operating floor. The deck is elevated to this level to allow tapping into hot metal mixer cars (torpedo cars), required because of the design of the building.

Process control: The foundry, using three supervisors and 11 hourly workers per turn, has produced as much as 30,000 tpm of molten metal that is in specification. Much of the success of this installation is due to the process control systems. Without the process control systems in place today, the shop could not run as economically with respect to raw materials, energy use or manpower, nor would it be able to maintain precise chemistry standards and delivery schedules. The facility is equipped with data gathering, data processing and automatic control systems. The table on the next page lists the hardware in the plant. The devices are in constant communications with each other. Data transfer to the IBM System 36 computer occurs only on command, however.

Applications of process control:

- Raw materials tracking
- Charge makeup control

- Alloy additions
- Furnace tapping
- Furnace operations
- Record keeping of products
- Power demand control
- Management information

While the technical expertise is available to fully automate a melt facility and the processing hardware is on the shelf, the sensing equipment available today is either too expensive or will not stand up to the harsh melt facility environments. There are many conditions that may occur in coreless induction furnace that require immediate skilled evaluation and action and it would be difficult to program all of these conditions into control systems.

Use of the process control systems to operate subsystems, advise operating personnel and gather data has been demonstrated in this facility described above. Considerable savings may be generated by prudent use of raw materials and energy and use of the systems in product quality control cannot be disputed. Canned programmes for personal computers (PCs) lead to the next step in programmable control-operational control for smaller shops. In large melt shops today, process control systems are a must, but large and small shops alike need to look for ways to cut costs. A well designed and implemented system can save large amounts of labour, materials and energy for the whole foundry industry.

Hardware for Data Gathering, Processing, Control and Reporting

DATA INPUT DEVICES

- truck and track scales
- three hot metal scales
- two raw material scales
- six alloy feeding scales
- maxi lab
- spectrometer
- furnace control systems
- Ohio Edison electric meter (kwh and time sync pulse)

PROCESSING AND CONTROL

- three programmable controllers (furnace)
- one programmable controller (alloy system and auxiliary data)
- PDP 11 computer with two disk drives
- six integrator controllers (alloy feed)

INFORMATION OUTPUT

- control room displays
- five printers
- six CRTs
- data transfer to Valley IBM System 36 computer

Example 2:

Sand foundry system on single user micro-computer

This foundry, part of a large engineering group had assessed many 'assembly industry' systems over a 4 year period, deciding that none were suitable, in every case.

In 1982 a single-used microcomputer was installed with the sole function of planning, recording and reporting upon stock, work in process, orders in hand.

After 3 months negotiation and system design discussions, an order was placed. The system, total cost about £8000 was delivered in late July 1982 and was fully operational by late August/early September 1982.

About 1000 live orders are held upon the system at any time (limited by the use of small 'floppy-disc' data storage), and any number of master records (i.e. pattern numbers and full processing details) can be accommodated. Currently the system has some 2500 'methods' stored on disc.

In use the production control system is operated by one individual who receives production returns from the foundry at the end of each shift. The system processes this data immediately and produces a printout of the updated production programme for issue to the shop floor on the following morning.

Management reports are also produced -overdues, valuation of order file, loading on each work centre, production programme, metals requirements over any given period etc.

Entry of new orders to the system requires only input of order number, required date and quantity ordered. The remainder of the information on each pattern number is stored on floppy disc and is automatically transferred to the order file when the pattern number ordered, is given to the computer.

The systems has been working since November 1982 continuously and has reduced the manning required in production monitoring/control from 4 persons to 2.

The major system limitations are the rather slow search routines used and when creating reports -this leads to lengthy (half hour) delays while waiting for order book printouts. In addition the foundry has now filled the order file, and despite rigorous removal of orders from the file as soon as they are complete, there is no expansion available should business volume increase and the order book be extended.

Example 3:

Precision castings foundry using hard disc microcomputer

This foundry uses fairly exotic alloys in its castings, so that strict control of materials flow and material stocks is essential.

The production control system also acts as a materials ledger, booking material out to sub-contract machinists and back into stock from the machinists. In this way all material ia accounted for, including machining swarf. The system has now been operational for about five months, having taken about ten weeks to install, modify and commission with all basic data.

Again a 'package' solution was used, although one with considerable modifications.

The experience in using the system to date has been good, with a single operator coping with all daily production recording. Initially the need to import production figures from eight separate stages caused problems for the limited period in the day when the computer was available. Program improvements to speed access time to disc files, involving 'compiling' the BASIC programme, have now cured this problem.

Appendix H

Environmental control and recycling

Introduction

In recent years the foundry industries in various countries have encountered growing problems, in connection with the disposal of their wastes. In some countries, the situation has led to the initiation of special investigations relating to the disposal of foundry wastes, in most cases initiated and financed by the foundry industry.

Input materials in a foundry

When a foundry is in equilibrium, the annual input of purchased refractories and moulding materials balances the output of waste gases, dust and waste as a rule. It follows that by monotoring the input materials one can estimate the output of foundry wastes. In general, the incoming materials can be classified into the following categories:

i) refractory materials
ii) unbonded moulding materials (silica, chromite and olivine sands etc)
iii) clay-bearing moulding sands
iv) bentonite and clay binders
v) moulding sand additives
vi) inorganic moulding sand binders
vii) organic moulding sand binders
viii) hardeners, hardening accelerators
ix) miscellaneous

By far the greatest proportion of these materials is inorganic in nature, and no combustion of them takes place in the foundry. Consequently an equivalent amount must leave the foundry again in solid form. Moreover, all the inorganic materials are inert (with the exception of the two binders, cement and sodium silicate). Only the organic binders, moulding sand additives and hardeners can produce critical waste materials. See Table H/1.

Foundry waste outgoings

Depending on the operational factors such as class and nature of products output in tpy, type of melting equipment, type of moulding and coremaking equipment, a foundry can contribute a wide range of contaminants to its waste outgoings and checks on the amount of waste material leaving most foundries are very approximate because exact weighing is seldom practised. Consequently, the available data must be less accurate than those on incomong materials. Before the recycling of foundry wastes can be considered, effective sorting is required. By understanding the specific make-up of the foundry waste solids and conducting proper bench testing and plant trials, a successful programme can be developed to remove these regulated chemicals from the wastewater. In a typical iron foundry melting with a cupola, the gases leaving the cupola are CO, with small amounts of CO_2 and SO_2 if the coke was made with sulphurbearing coal. The discharge from the cupola is high in suspended solids, because the weaker coke lumps break loose and there is an initial surge of cokes fines into the exit gases when the charge is dumped to the burden. These suspended solids also include iron oxide from the bars of pig iron. The dust may be collected by bag filtration or wet scrubbers. The later are usually installed and become the principal use of water in foundry opeartions.

In the scrubber water, suspended solids are usually quite high and the pH is acidic. after the quenching spray the cooled gas moves through the venturi with the scrubbed gases going out the stack and the scrubbing liquid to the clarifier.

Dust is also a problem in foundries. The dust comes basically from the sand molds in the casting preparation and finishing operations. In the preparation step, sand is mixed with a variety of chemicals to produce green sand moulds. Dust is generated in both the sand preparation and moulding operations here, as well as the subsequent knockout, cooling, cleaning and finishing operations. Individual venturi scrubbers can be used at each operation, with all water flows being directed to a common clarifier. As already mentioned above Table H/1 gives the amount of the ancillary materials used in the foundries of the countries listed. The average figures represent the portions of waste materials produced by these foundries.

Table H/2 lists results of an enquiry about waste disposal from the foundry industry. The disposal of waste from foundries related to the production of cast iron varies between .4 (Japan) and 1.5 (USA). Related to the ancillary materials only Japan is under 1.0, ie. in all countries the output of waste is greater than the amount of ancillary materials purchased. The elements lead, arsenic, cadmium and chromium were measured most of all. In some cases results for mercury, copper, zinc, cyanide, phenol, hydrocarbons and formaldehyde were given.

Wastewater treatment and regulative aspects

With proper planning and evaluation in the conceptual engineering stage, the design engineer can determine the most effective treatment method for a facility. An organized, syepwise approach to find the best solution

Table H/1 **Input of ancillary materials, Point 7 of the Enquiry**

	Quest No.	Unit	BRD	DDR	GB	F	J	CH	USA
Refractories	1	% Average (% range)	3.8 (0.4 - 16)	8.9	6.9	0	6.8	6.5	2.5
Moulding sands	2 + 3		85.2 (61 - 96)	78.8	84.2	99	76.7	79.9	85.6*
Binder Clay Bentonite	4		6.3 (0.5 - 22)	5.0	3.8	0.6	12.1		9.0
Additives	5		2.5 (0.1 - 6.6)	1.4	3.4	0.2	0.7	8.6	2.9
Inorganic binders	6		2.0 (0.02-6.8)	2.7	1.0	0	1.6		*included in 2 + 3
Organic binder.	7		1.6 (0.03 - 4.8)	2.2	0.9	0.2	2.0	2.9	*included in 2 + 3
Others			0.3 (0.02 - 0.9)	—	—	—	—	2.1	—
Total per foundry		t/year	42,210	15,970	49,180	208,600	14,950	4,190	24,300
Related to iron production		t/t	0.68	1.00	1.36	8.88	0.57	0.84	0.3

*The values for iron casting production were calculated partly from data given in the enquiry (BRD, DDR, F, J, USA) and partly from estimations (GB, CH).

Table H/2: **Foundry waste (waste outgoing, waste sorting, method of removal, chemical analysis)**

	Unit	BRD	DDR	GB	F	J	CH	USA
Amount of waste per foundry	1 000 t/y	4.5 ... 160	0.1 ... 71	19.5 ... 127	4.3 ... 32	0.1 ... 76	—	9 ... 68
Average	1 000 t/y	51	22	60	18	9.7	5.1	35
In proportion to Iron production	t/t	0.8	1.4	0.6	0.9	0.4	1.0	0.5
In proportion to ancillary materials	t/t	1.2	1.4	1.2	1.2	0.6	1.3	1.6
Waste sorted:								
YES	No/foundries	8	7	1	1	46	9	—
NO	No/foundries	4	17	8	1	25	27	—
Waste removal:								
	No/foundries	8	22	9		66	mostly	—
by lorry	No/foundries						by lorry	
by container	No/foundries	2	2	—	2	2	—	—
other means	No/foundries	—	—	—	—	1		
Chemical analysis:								
YES	No/foundries	10	7	1	2	57	16	118*
NO	No/foundries	2	17	8	0	11	20	382*

*Also non-iron foundries

for an individual foundry will minimize both cost and wasted effort. Compliance with the effluents guidelines can be achieved using methods that include various options for both wastewater collection and treatment.

Currently, foundry wastewater treatment varies greatly, depending on the size and location of a plant. However, treatment of process water falls into one of three basic options or modes of operation. These are:

(i) central treatment of combined flows;

(ii) individual wastestream treatment;

(iii) a combination of these two.

Alternatively, a foundry may utilize a dry baghouse systen with no direct contact water use.

The most common method of wastewater treatment for foundries is a combination of central and individual treatment, i.e., cooling waters may be separate, but all dust collection systems are routed to a common pond or clarifier.

Many systems inadvertently mix nonregulated and regulated wastestreams. The mixing of wastes can either assist or hinder treatment and recycle, depending on the nature of the wastewater systems snd noncontact cooling water systems. It is important to recognize the existence of nonregulated wastes and the effect they will have on treatment alternatives. The design engineer usually has several alternative solutions to consider for achieving compliance with the effluent guidelines. These alternative solutions have to include a factor of flexibility in their lay-out, because, unfortunately, in foundry wastewater treatment it is rare for a plant to have a consistent stream to treat in terms of quantity and quality. Variations in flow, particle size, feed solids content, pH, temperature and chemical constituents can adversely affect clarification efficiencies. Table H/3 presents a selection of common system upset symptoms, their likely causes and recommended remedies.

Air Pollution

Air pollution control regulations must also be taken into consideration during the design phase of new or modified effluents treatment facilities.

Sources of emission from electric arc furnaces

Emissions from electric arc furnaces can be divided into three categories:

i. Those originating from the charge materials

ii. Those generated during melting and refining

iii. Those emitted during furnace tapping.

Some increase in furnace emission may be noted immediately following the addition of some alloys and slag forming materials but their quantity is

Table H/3: *Troubleshooting Clarifier Problems*

UPSET	POSSIBLE CAUSE	REMEDY
Low underflow density	Excessive hydraulic load	Reduce flow
	Underflocculated	Increase chemical dose, revise addition points
	Channeling	Decrease polymer dosage or revise rake mechanism
Poor settling rate	Excessive hydraulic load	Reduce flow
	Excessive rake speed	Reduce speed
	Chemical problems	Inspect chemical feed system and dosage levels
	Poor internal mixing	Inspect and adjust agitator mechanism
Excessive solids carryover or turbid overflow	Excessive hydraulic load	Reduce flow
	Underflocculated	Increase chemical dose, revise addition points
	Overflocculated	Reduce chemical addition
	Qualitative shock load	Equalization basin needed
	Septic sludge	Increase sludge withdrawal
	Excessive fines	Recirculate some underflow back to clarifier feed
Floating solids	Entrained air	Deaerator trough or repair leaky pump seals
	Foaming	Defoamer addition
	Septic sludge	Increase sludge withdrawal
	Solids or oils lighter than water	Skimmer
Excessive rake torque	Scale buildup	Clean and use scale inhibitors
	Large, heavy solids	Screen clarifier influent
	Over flocculation	Decrease flocculant addition
	Poor design	Consult with manufacturer
Corrosion	pH upset	Check pH adjustment system
	Improper materials of construction	Consult with manufacturer
	Use of corrosive inorganic coagulants	Switch to an organic program

Table H/4

Effect of various methods of dust and smoke control during different parts of the melting cycle

	Charging		Melting		Additions		Holding/ superheating		Slagging		Pouring	
System	Control	Value to operators	Control	Value to operators	Control	Value to operators	Control	Value to operators	Control	Value to operators	Control	Value to operators
General Ventilation	Poor	Little	Poor	Little	Poor	Little	Poor	Little	Poor	Little	Poor	Little
General ventilation with roof baffles	Can be good	Little	Can be good	Little	Can be good	Little	Can be good	Little	Poor	Little	Poor	Little
Canopy hood	Poor	Little	Poor	Little	Poor	Little	Poor	Little	Poor	Little	Poor	Little
Lip extraction	Poor	Little	Good	Good	Reasonable	Some	Good	Good	Poor	Little	Poor	Some
Combined lip extraction and canopy hood	Poor	Little	Good	Good	Reasonable	Some	Good	Good	Poor	Little	Poor	Some
Box enclosure	Good	Fairly good	Fairly good	Good	Good	Fairly good	Good	Good	Good	Fairly good	Good	Good
Side draught hood	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	May be good	May be good
Swing aside hood	Can be good	Can be good	Good	Good	Normally good	Normally good	Good	Good	Normally poor	Normally poor	Can be good	Can be good
Side draught hood with blower duct	Reasonable	Some	Good	Good	Good	Good	Good	Good	Reasonable	Reasonable	Poor	Some
Total enclosure hood	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	May be good	May be good
Extracted charge bucket	Good	Good	Good	Good	Can be good	Can be good	None	None	None	None	None	None
Telescopic duct	Good	Good	None	None	None	None	None	None	None	None	None	None

small and duration short. When the heat is completed, some small quantities of emission will be given off as metal is tapped into the pouring ladle or run into a holding furnace. Table H/4 illustrates some individual methods of capturing emission-materials and compares their effectiviness.

Recycling

As a result of the rising costs of raw materials, transport and dumping charges, and the uncertainties relating to the dumping of used sand increasing attention has been devoted in recent years to the reclamation of used sands. Various methods already exist and have been proved sound in practice. The economics of sand reclamation naturally depend greatly on the dumping costs and the specific costs of transporting both new and used sand. A central reclamation installation can be considered for certain regions, to increase the profit margin by operating at maximum capacity.

Waste material: Used foundry sand is usually made up of a mixture with a ratio varying from 0 to 100% of moulding sand to core sand. By testing these thoroughly, it has been found that only dust and the so called "dead clays" are actually unusable. The balance is made up of sand grains which are perfectly integral and usable, provided that it is possible to free them from the clay and binder residues.

Regeneration plants: Regeneration is possible with combined plants where, by means of different treatments a clean and completely usuable sand is obtained. Figure H/1 illustrates the general layout of these plants for mixed sands, indicating the four main stages

Operating plants - Energy consumption - Product: There are currently worldwide several plants in operation for regeneration of used foundry sand on the lines shown in Figure H/1. Figure H/2 shows one of these plants operating in Japan. The plant treats a mixture (80% green sand and 20% shell sand), obtaining a sand with .4% clay and .05 L.O.I. (loss on ignition). Consumption in propane gas (10970 cal/kg): 17.1 kg/t, electric power:23.4 kWh/t.

Further improvements are necessary, especially from the energy consumption point of view.

Economic considerations: The economics of regeneration plants will be justified in cases where

$$R \leqq S + D$$

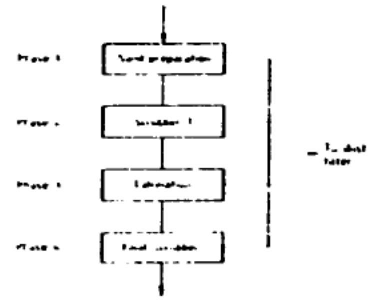
where:

R = cost per ton of regenerated sand

S = cost per ton of new sand ex-foundry

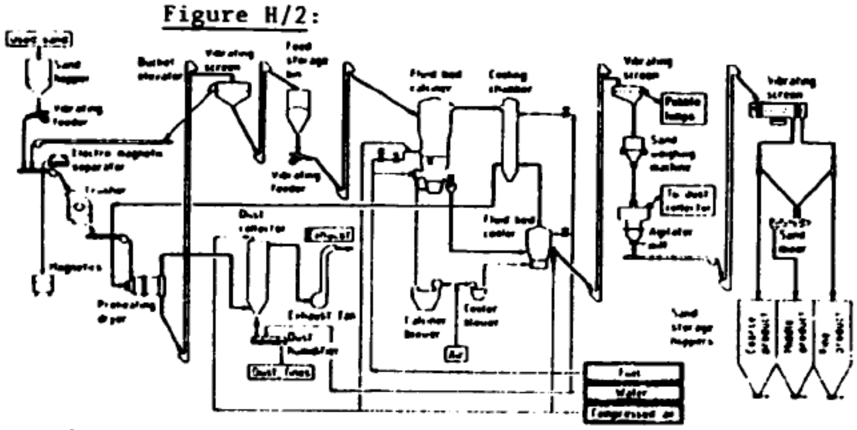
D = cost per ton of disposal, transport included.

Figure H/1



General block scheme of sand regeneration plant

Figure H/2:



Flow of mixed sand reclamation plant

Example for the determination of cost saving by installing a plant for the regeneration of used foundry sand at a rate of 5 t/h (Based upon the Federal Republic of Germany). (see Fig. H/3).

Operating expenses per year

Labor costs (3-shift operation)

0,5 man/shift

Average yearly salary including social security contributions of approx. DM 50.000,00 — DM 75.000,00

Energy costs

Based upon 22 h/d at 5 d/We

50 We/a = 5.500 operating hours/year

Natural gas

(significant calorific value Hu = 8.500 Kcal/m³ and 3 % combustible substance in the used sand)

(7 m³ natural gas/t sand; 0,630 DM/m³; at 5 t/h approx. 35m³ natural gas/h)

35 m³/h x 5.500 h/a x 0.630 DM/m³ — DM 121.275,00

Electric power

(Power rating: 295 kW, rate of utilization: 80 %, 0,175 DM/kWh)

295 kWh x 0.175 DM/kWh x 5.500 h/a x 0,80	DM 227.150,00

Cooling water

(Consumption: 2,0 m^3/h, 1,698 DM/m^3)

2,0 m^3/h x 1,698 DM/m^3 x 5.500 h/a	DM 18.678,00

Pressure air

(Consumption 60 m^3/h, 0,031 DM/m^3)

60 m^3/h x 0,031 DM/m^3 x 5.500 h/a	DM 10.230,00

Used materials

Spare parts, parts subject to wear, lubricating agent, furnace lining, impingement type, nozzles etc.

approx.	DM 80.000,00

Gross operating costs/year	DM 532.333,00

Recoverable energy for example

for the hot water supply

Admission:	Sand at 900°C
Cooling process:	to 150°C
T:	750°C
Cp Sand:	0,22 kcal/kg°C

Quantity rating: 5.000 kg/h Sand

Transfer price: 0,08088 DM/Kcal x 10^{-3}

Duration: 15 h/d, 250 d/a = 3.750 h/a

750°C x 0,22 kcal/kg°C x 5.000 kg/h x 3.750 h/a x 0,00008088 DM/kcal

---

Recoverable energy/a approx. DM 250.223,00

Net operating cost = gross operating costs - recoverable energy

DM 532.333,00/a
DM 230.223,00/a

DM 282.110,00/a
===============

Cost of capital per year
========================

Capital investment		DM	5.400.000,00
Starting cost from project to commissioning	approx.	DM	80.000,00
Capital costs/year		DM	5.480.000,00

Depreciation per year
=====================

$$K = \frac{A}{100} \left(\frac{100}{n} + p * \frac{(n+1)}{2n} \right)$$

K = depreciation/year

A = capital costs/year

n = projected period of depreciation in years

p = interest rate

$$K = \frac{5.480.000}{100} \left(\frac{100}{12} + 9 * \frac{(12 + 1)}{24} \right)$$

K = 723.963,00 DM/a

Insurance costs per year

(approx. 1 % of the capital costs/year) DM 55.000,00

Production costs per year

Operating costs	DM 282.110,00/a
Depreciation	DM 723.963,00/a
Insurance	DM 55.000,00/a
Production costs	DM 1.061.073,00/a

Throughput capacity

5 t/h x 5.000 h/a = 27.500 t/a used sand resulting in 75 % regenerated clean sand

27.500 t/a x 0.75 = 20.625,00 t/a

Specific sand costs

$$\frac{\text{Production costs (DM/a)}}{\text{Throughput capacity (t/a)}}$$

$$\frac{1.061.073,00 \text{ DM/a}}{20.625 \text{ t/a}} = \text{DM } 51,45\text{/t clean sand}$$

Investment Requirements and Unit Production Costs

Cost saving from installing a regeneration plant

(Based upon the Federal Republic of Germany, operation with a required sand quantity of 27.500 t)

Without regeneration plant

Provision of fresh sand as well as transportation and disposal of 27.500 t used sand per year including dumping costs (115 DM/t, estimated)

27.500 t/a x 115,00 DM	DM 3.162.500,00/a

With regeneration plant

Provision of fresh sand as well as transportation and disposal of 6.875 t used sand per year including dumping costs

6.875 t/a x 115,00 DM/t	DM 790.625,00/a
Regeneration costs (production costs) of 27.500 t used sand per year	DM 1.061.073,00/a
Total costs	DM 1.851.698,00/a

Cost saving of the foundry

Without regeneration plant	DM 3.162.500,00/a
With regeneration plant	DM 1.851.689,00/a
	DM 1.310.802,00/a

Without regeneration the costs for 1 t of sand including provision, transportation and dispcsal are:

$$\frac{3.162.500 \text{ DM/a}}{27.500 \text{ t/a}} = \text{DM } 115{,}00/\text{t}.$$

With a regeneration plant the costs for 1 t of sand including provision, transportation and disposal are

$$\frac{1.851.698 \text{ DM/a}}{27.500 \text{ t/a}} = \text{DM } 63{,}33/\text{t}.$$

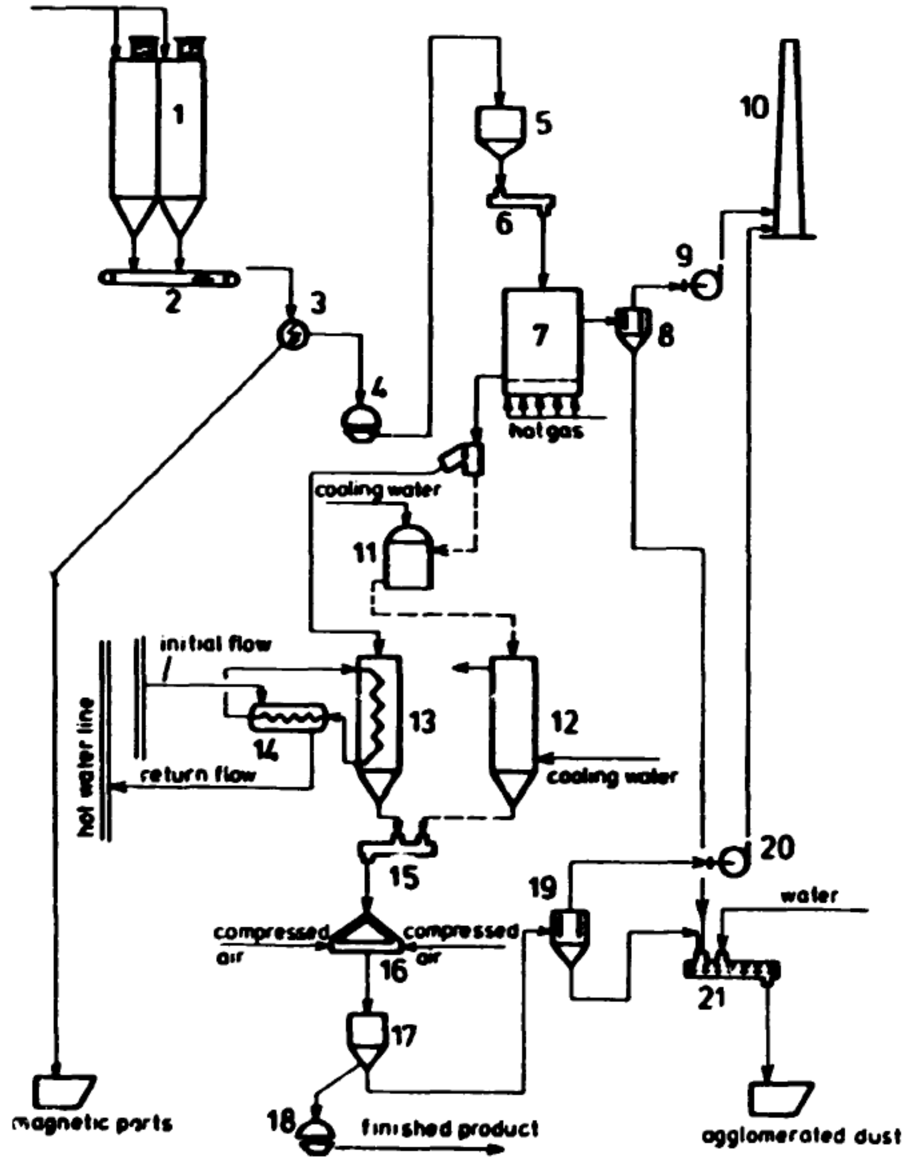
Saving: DM 47,67/t

Figure H/3: Regeneration of Used Foundry Sand. Flow Sheet.

Reporting organization:
KHD Humboldt Wedag AG
D-4630 Bochum 1

Materials and energy requirements for regeneration of used foundry sand:

Rate of used sand admission:	5 tph,	coolong water: 5 m^3/t used sand
Regenerated sand:	3.8 tph,	pressure air: 30 m^3/t used sand
Dust:	1.2 tph (by-product)	
Natural gas:	7	cub. meter p.t. used sand
Electric power:	55	kWpt used sand



1 silo
2 belt weigher
3 low intensity magnetic separator
4 pneumatic handling
5 surge bin
6 screw conveyor
7 fluidized bed furnace
8 dust filter
9 exhaust gas fan
10 exhaust gas stack
11 primary cooler
12 secondary cooler
13 impact cooler
14 heat exchanger
15 screw conveyor
16 counter-flow impact mill
17 classifier
18 pneumatic handling
19 dust filter
20 exhaust gas fan
21 mixer

IDA DATA BASE: UNIDO PAPERS ON FOUNDRY

31 AUGUST 1987

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	001052
DOCUMENT DATE:	1973
CALL NUMBER:	
PERSONAL AUTHOR:	Lalkaka, Rusi
CORP. AUTHOR:	UNIDO ECAFE
TITLE:	(R) INDIA. MODERNIZATION OF FOUNDRIES AND RE-ROLLING MILLS IN THE SMALL SCALE SECTOR. ADVISORY SERVICES REPORT.
SOURCE:	Vienna, 1973. 1 vol. (various pagings). tables, diagrams, map.
DOC. NUMBER:	::::
ABSTRACT:	‹UNIDO pub›. ‹Final report› on modernization of ‹foundry›s and re-‹rolling› mills in ‹India› - covers (1) ‹small scale industry› in the ‹metallurgy› sector; proposed ‹modernization› programme (2) upgrading the technology at foundries for various ‹casting› and for ‹steel› foundries (3) improving re-rolling operations (4) ‹raw material›s; ‹financing›, ‹training›, ‹management›; ‹marketing› (5) implementation of modernization. ‹Recommendations›, ‹factory layout›s, ‹maps›, tables. Additional references: ‹iron›, ‹fuel›, ‹metal scrap›. ‹Restricted›.
LANGUAGES:	ENGL
COUNTRY CODE:	204

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	002386
DOCUMENT DATE:	1970
CALL NUMBER:	OA220TOG(4)
PERSONAL AUTHOR:	MALVAUX RG
CORP. AUTHOR:	UNIDO
TITLE:	(R) INSTALLATION D'UNE FONDERIE DE PETITES DIMENSIONS. RAPPORT FINAL.
SOURCE:	VIENNA, 1970. 36 P. TABLES, DIAGRAMS, ILLUS.
DOC. NUMBER:	UNIDO-UNIDO/TCD.35
ABSTRACT:	/UNIDO PUB/. /EXPERT REPORT/ ON THE ESTABLISHMENT OF A SMALL /FOUNDRY/, INITIALLY FOR /NONFERROUS METALS/, IN /TOGO/ - CONTAINS (1) /MARKET INFORMATION/ AND /INVESTMENT/ ESTIMATES (2) TECHNICAL AND /ECONOMIC ASPECTS/ OF THE PROJECT, INCLUDING /RAW MATERIAL/ ASSESSMENT, /PRODUCTION CAPACITY/ AND /PRODUCTION COSTS/ (3) /TRAINING ASSISTANCE/ REQUIRED AND GENERAL /RECOMMENDATIONS/. /STATISTICS/, /FACTORY LAYOUT/, PHOTOGRAPHS. /RESTRICTED/.
LANGUAGES.	FREN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	003416
DOCUMENT DATE:	1972
CALL NUMBER:	420IRA(2-5)
PERSONAL AUTHOR:	KENTISCHER A
CORP. AUTHOR:	UNIDO
TITLE:	(R) FINAL REPORT. (FOUNDRY IN IRAN).
SOURCE:	VIENNA, 1972. 12 P.
DOC. NUMBER:	::::
ABSTRACT:	/UNIDO PUB/. /EXPERT REPORT/ ON ASSISTANCE TO A /FOUNDRY/ AND ATTACHED /METALLURGY/CAL /LABORATORY/S OF THE /INDUSTRIAL ESTATE/ AHWAZ IN /IRAN/ - CONTAINS /RECOMMENDATIONS/ AND DESCRIBES WORK DONE WITH REFERENCE TO /FACTORY LAYOUT/, PRODUCTION OF CAST /IRON/ AND /ALUMINIUM/, /TRAINING/ OF /COUNTERPART PERSONNEL/ AND SMALL SCALE /ENTREPRENEUR/S, ORGANIZATION OF EXTENSION SERVICES AND /COMMON SERVICES/ FACILITIES, /MANAGEMENT/, PROCUREMENT OF /RAW MATERIAL/S AND /EQUIPMENT/, ETC. /RESTRICTED/.
LANGUAGES:	ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 003810
DOCUMENT DATE: 1972
CALL NUMBER: 420IRA(2-12)
PERSONAL AUTHOR: LUTON CE
CORP. AUTHOR: UNIDO
TITLE: (R) FINAL REPORT. ORGANIZATION FOR SMALL SCALE INDUSTRIES AND INDUSTRIAL ESTATES OF IRAN.
SOURCE: VIENNA, 1972. 10 P.
DOC. NUMBER: ::::
ABSTRACT: /UNIDO PUB/. /EXPERT REPORT/ ON /SMALL SCALE INDUSTRY/S AND /INDUSTRIAL ESTATE/S OF /IRAN/ - (1) DESCRIBES WORK CARRIED OUT WITH RESPECT TO /TRAINING PROGRAMMES/; /INDUSTRIAL EXTENSION/ SERVICES, INCLUDING EXISTING LIMITATIONS; MODEL SCHEMES FOR AN /ALUMINIUM/ SAND CAST /FOUNDRY/ AND WOOD PATTERN SHOP, AND FOR PRODUCTION OF AUTOMOTIVE TYRE CHAINS, SAFETY SEAT BELTS; FEASIBILITY AND /MARKET/ STUDIES FOR THE DEVELOPMENT OF THE /AUTOMOBILES/ ANCILLARIES INDUSTRY (2) LISTS VARIOUS TECHNICAL BULLETIN ISSUED. /RESTRICTED/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 004239
DOCUMENT DATE: 1971
CALL NUMBER:
CORP. AUTHOR: UNIDO IDB, 5TH SESSION, VIENNA, 1971
SENEGAL
TITLE: ROLE OF UNIDO IN CO-ORDINATION OF ACTIVITIES IN INDUSTRIAL DEVELOPMENT: CO-ORDINATION AT THE COUNTRY LEVEL. ADDENDUM 2. EVALUATION REPORT: SENEGAL.
SOURCE: VIENNA, 1971. 48 P.
DOC. NUMBER: UNIDO-ID/B/83/ADD.2
ABSTRACT: /UNIDO IDB PUB/. /EVALUATION REPORT/ ON /TECHNICAL ASSISTANCE/ TO /SENEGAL/, WITH REFERENCE TO THE /ROLE OF UNIDO/ - CONTAINS (1) /STATISTICS/ REGARDING /OPERATIONAL PROJECT/S, BY /SOURCE OF FUNDS/; DETAILS OF ASSISTANCE PROVIDED TO /SMALL SCALE INDUSTRY/S, TO THE NATIONAL INDUSTRIAL STUDIES AND PROMOTION COMPANY (SONEPI) AND THE 'SOCIETE AFRICAINE DE FONDERIE D'ALUMINIUM' (/ALUMINIUM/ /FOUNDRY/S) (2) /COMMUNIQUE/S, /RECOMMENDATIONS/ AND /LONG TERM/ /COOPERATION/ PROGRAMME.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	004402
DOCUMENT DATE:	1972
CALL NUMBER:	220-MLI(12)
PERSONAL AUTHOR:	DELARUELLE J
CORP. AUTHOR:	UNIDO
TITLE:	(R) RAPPORT FINAL. (ALUMINIUM FOUNDRY, MALI).
SOURCE:	VIENNA, 1972. 12 P.
DOC. NUMBER:	::::
ABSTRACT:	/UNIDO PUB/. /EXPERT REPORT/ ON TECHNICAL ASSISTANCE RENDERED IN SETTING UP A SMALL /ALUMINIUM/ /FOUNDRY/ IN /MALI/ - (1) DEALS WITH INSTALLATION OF /EQUIPMENT/ AND TECHNICAL ASPECTS OF ALUMINIUM /CASTING/ AND /MOULDING/ (2) CONTAINS /RECOMMENDATIONS/ ON FOLLOW-UP ASSISTANCE IN /TRAINING/ OF /COUNTERPART PERSONNEL/, IN /MANAGEMENT/ AND /MARKETING/. /RESTRICTED/.
LANGUAGES:	FREN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	004794
DOCUMENT DATE:	1973
CALL NUMBER:	220-MLI(2)
PERSONAL AUTHOR:	MALVAUX R
CORP. AUTHOR:	UNIDO
TITLE:	(R) MISSION AU MALI. RAPPORT FINAL. (ALUMINIUM, IRON AND STEEL INDUSTRY).
SOURCE:	VIENNA, 1973. 15 P.
DOC. NUMBER:	::::
ABSTRACT:	/UNIDO PUB/. /EXPERT REPORT/ ON /ALUMINIUM/ AND /IRON AND STEEL INDUSTRY/ IN /MALI/ - (1) DESCRIBES PROGRESS OF A SMALL ALUMINIUM /PILOT PLANT//FOUNDRY/ (2) ANALYSES FEASIBILITY STUDIES WITH RESPECT TO SETTING UP AN IRON AND STEEL INDUSTRY (ESPECIALLY /ROLLING/ MILL), AND AN /ALUMINA/ AND /ALUMINIUM INDUSTRY/ BASED ON VALUABLE /BAUXITE/ DEPOSITS (3) CONTAINS NOTE ON /HANDICRAFT PROMOTION/ FOR /EXPORT ORIENTED INDUSTRY/. /RECOMMENDATIONS/. /RESTRICTED/.
LANGUAGES:	FREN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 004870
DOCUMENT DATE: 1972
CALL NUMBER:
PERSONAL AUTHOR: BERGEAUD F
CORP. AUTHOR: UNIDO
TITLE: (R) CREATION D'UNE FONDERIE DE DEUXIEME FUSION AU LAOS. ETUDE D'AVANT-PROJET. (SEPT. 1971 - MAI 1972).
SOURCE: VIENNA, 1973. 148 P. TABLES, DIAGRAMS, ILLUS.
DOC. NUMBER: UNIDO-UNIDO/TCD.213
ABSTRACT: /UNIDO PUB/. /EXPERT REPORT/ ON THE FEASIBILITY OF ESTABLISHING A SMALL DEMONSTRATION /FOUNDRY/ TO PROVIDE /IRON/ /CASTING/S FOR /METALWORKING INDUSTRY/ IN /LAOS/ - COVERS /DEMAND/ FOR CASTINGS; AVAILABILITY, IDENTIFICATION AND COLLECTION OF LOCAL /METAL SCRAP/, WITH ATTENTION TO /COSTS/; /ENERGY SOURCE/S, /SAND/, /CHARCOAL/, /MANPOWER/, /FINANCING/; TECHNICAL AND /ECONOMIC ASPECTS/, AND ASSESSMENT OF /PRODUCTION COSTS/; POTENTIAL FOR A /STEEL/ FOUNDRY, ETC. /RECOMMENDATIONS/, /STATISTICS/, /DIAGRAM/S, ILLUS. /RESTRICTED/.
LANGUAGES: FREN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 005014
DOCUMENT DATE: 1973
CALL NUMBER:
PERSONAL AUTHOR: MANUKULASURIYA B
CORP. AUTHOR: UNIDO
INTERREGIONAL SYMPOSIUM ON THE IRON AND STEEL INDUSTRY, 3D, BRASILIA, 1973
TITLE: THE SRI LANKA IRON AND STEEL INDUSTRY.
SOURCE: VIENNA, 1973. 9 P. TABLES.
DOC. NUMBER: UNIDO-ID/WG.146/71
ABSTRACT: /UNIDO PUB/ ON THE /IRON AND STEEL INDUSTRY/ OF /SRI LANKA/ - COVERS (1) OPERATIONS OF THE 'CEYLON STEEL CORPORATION' (A /PUBLIC ENTERPRISE/) WITH RESPECT TO /ROLLING/, /WIRE/ PRODUCTION, /STEEL//FOUNDRY/, /MACHINE TOOLS/, /TRAINING/, /RESEARCH AND DEVELOPMENT/, ETC. (2) OPERATIONS OF A SMALL RE-ROLLING MILL IN COLOMBO (/PRODUCTION COOPERATIVE/). /STATISTICS/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 005756
DOCUMENT DATE: 1974
CALL NUMBER:
PERSONAL AUTHOR: Maneck, Arno
CORP. AUTHOR: UNIDO
TITLE: (R) CONSULTATIONS AT UNDP HEADQUARTERS, NEW YORK, CONCERNING UNIDO'S PROGRAMME IN AFRICA, 28-31 MAY 1974.
SOURCE: VIENNA, 1974. 23 P.
DOC. NUMBER: UNIDO-UNIDO/TCD.317
ABSTRACT: /UNIDO PUB/ ON CONSULTATIONS WITH /UNDP/ CONCERNING /UNIDO/'S PROGRAMME IN /AFRICA/ - COVERS TALKS ON (1) PROJECTS IN VARIOUS COUNTRIES (/DEVELOPMENT CENTRE/S, /WATCHMAKING/, /INDUSTRIAL PROMOTION/, /QUALITY CONTROL/, /ENGINEERING/, /TEXTILE INDUSTRY/, /MAINTENANCE AND REPAIR/, /STANDARDIZATION/, /BRICKS/, /AGRO-INDUSTRY/, /ALUMINIUM//FOUNDRY/, /SMALL SCALE INDUSTRY/, /CEMENT/, /PYRETHRUM/, /NATURAL GAS/, /GYPSUM/, /PUBLIC SECTOR/ INDUSTRIES, /VEGETABLE OILS/, /TRACTORS/, /FRUIT/ AND /VEGETABLES/ PROCESSING, /MINING/, CAT-/FISH/ PROCESSING, ETC.) (2) /REGIONAL/ PROJECTS. /RESTRICTED/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 005858
DOCUMENT DATE: 1974
CALL NUMBER:
PERSONAL AUTHOR: CHAKRABARTI NG
CORP. AUTHOR: UNIDO
WORKING GROUP ON EXCHANGE AND EXPERIENCE IN THE FOUNDRY INDUSTRY BETWEEN SELECTED DEVELOPING COUNTRIES IN ASIA AND THE FAR EAST, INDIA, 1974
TITLE: ESTABLISHMENT AND OPERATION OF SMALL CAST IRON FOUNDRIES: INDIAN EXPERIENCE.
SOURCE: VIENNA, 1974. 127 P. TABLES, DIAGRAMS.
DOC. NUMBER: UNIDO-ID/WG.195/1
ABSTRACT: /UNIDO PUB/ ON SMALL /IRON//CASTING//FOUNDRY/S IN /INDIA/ - (1) DISCUSSES PRESENT STATUS OF FOUNDRY ACTIVITIES IN TERMS OF /PRODUCTION CAPACITY/, ASSISTANCE RENDERED BY THE GOVERNMENT, /TRAINING/, /RESEARCH AND DEVELOPMENT/ FACILITIES, /STANDARDIZATION/, GROWTH IN /CONSUMER GOODS/ INDUSTRY, DEGREE OF /MECHANIZATION/ (2) COVERS BASIC FACTORS IN THE CREATION OF FOUNDRIES, FUTURE /REGIONAL COOPERATION/, APPENDING /CASE STUDY/S ON ESTABLISHMENT OF SMALL FOUNDRIES. /STATISTICS/, /RECOMMENDATIONS/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	006189
DOCUMENT DATE:	1974
CALL NUMBER:	
CORP. AUTHOR:	UNIDO WORKING GROUP ON EXCHANGE AND EXPERIENCE IN THE FOUNDRY INDUSTRY BETWEEN SELECTED DEVELOPING COUNTRIES IN ASIA AND THE FAR EAST, INDIA, 1974
TITLE:	EXCHANGE OF EXPERIENCE IN THE FOUNDRY INDUSTRY BETWEEN SELECTED DEVELOPING COUNTRIES IN SOUTH-EAST ASIA. REPORT OF A WORKSHOP. CALCUTTA, JAMSHEDPUR, RANCHI, INDIA.
SOURCE:	VIENNA, 1974. 11 P.
DOC. NUMBER:	UNIDO-ID/144 UNIDO-ID/WG.195/2
ABSTRACT:	/UNIDO PUB/. /REPORT/ OF A /MEETING/ ON /FOUNDRY/ (/CASTING/) INDUSTRY IN /SOUTH EAST ASIA/ - (1) PRESENTS CONCLUSIONS AND /RECOMMENDATIONS/ WITH RESPECT TO IMPROVEMENT IN PRODUCTION OF CASTINGS, ESPECIALLY IN THE SMALL-SCALE SECTOR (2) COVERS SIGNIFICANCE OF FOUNDRY OPERATIONS, /REGIONAL/ REQUIREMENTS IN /KNOWHOW/, /TRAINING/, /RESEARCH/ AND /TECHNICAL ASSISTANCE/.
LANGUAGES:	ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	007931
DOCUMENT DATE:	1978
CALL NUMBER:	
PERSONAL AUTHOR:	NDAM SN
CORP. AUTHOR:	UNIDO
TITLE:	(R) REPORT ON MISSION UNDERTAKEN TO THE REPUBLIC OF MALI, UNITED REPUBLIC OF CAMEROON, REPUBLIC OF BURUNDI, UNITED REPUBLIC OF TANZANIA AND REPUBLIC OF ZAMBIA.
SOURCE:	VIENNA, 1978. 86 P. TABLES.
DOC. NUMBER:	UNIDO-UNIDO/IOD.165
ABSTRACT:	/UNIDO PUB/. /MISSION REPORT/ REGARDING VISITS TO /MALI/, /CAMEROON/, /BURUNDI/, /TANZANIA/ AND /ZAMBIA/ - (1) COVERS: /ROLE OF UNIDO/; PROBLEMS OF /INDUSTRIAL DEVELOPMENT/; /TREND/S IN UNIDO ACTIVITIES; /TECHNICAL ASSISTANCE/ (2) REVIEWS UNIDO PROGRAMMES, I.A. REFERRING TO: /FOOD INDUSTRY/, /FOUNDRY/, /AGRO-INDUSTRY/, /SOLAR ENERGY/, /CHARCOAL/, /BRICKS/, /BAGASSE/, /POLLUTION CONTROL/, /TRAINING/, /INDUSTRIAL RESEARCH/, /APPROPRIATE TECHNOLOGY/, /EXPORT PROMOTION/, /INVESTMEN PROMOTION/, /PROJECT SELECTION/, /SMALL SCALE INDUSTRY/, AID TO /NAMIBIA/. /RECOMMENDATIONS/. /STATISTICS/. /RESTRICTED/.
LANGUAGES:	ENGL

RECORD NUMBER:	008843
DOCUMENT DATE:	1978
CALL NUMBER:	
PERSONAL AUTHOR:	DAS K
CORP. AUTHOR:	UNIDO INTERNATIONAL FORUM ON APPROPRIATE INDUSTRIAL TECHNOLOGY, NEW DELHI AND ANAND, INDIA, 1978
TITLE:	LIGHT ENGINEERING WORKSHOPS FOR RURAL AREAS.
SOURCE:	VIENNA, 1978. 83 P. TABLES, DIAGRAMS.
DOC. NUMBER:	UNIDO-ID/WG.282/61 UNIDO-ID/232/11
ABSTRACT:	/UNIDO PUB/ ON LIGHT /ENGINEERING/ /WORKSHOP/S FOR /RURAL AREA/S - COVERS (1) /DEFINITION/ OF SCOPE; /RURAL INDUSTRY/, /LIGHT INDUSTRY/ (2) STRUCTURAL FEATURES OF /DEMAND/ AND POSSIBILITIES (3) BROAD /INDUSTRIAL PROMOTION/ POLICIES: RURAL /INDUSTRIAL ESTATE/S, /INDUSTRIAL EXTENSION/, /CREDIT/, /SUPPLY/, /MARKETING/, /COOPERATIVE/S, /TRAINING/ (4) A SKELETON DEMAND MATRIX BY SECTOR (/AGRICULTURE/, /HANDICRAFT/, /TRANSPORT/, /CONSTRUCTION INDUSTRY/, ETC.) (5) SKELETON PATTERNS OF WORKSHOPS AT (A) CENTRAL VILLAGE (B) RURAL MARKET TOWN. ADDITIONAL REFERENCES: /SMALL SCALE INDUSTRY/, /FOUNDRY/, /FORGING/, /WOOD PRODUCTS/, /MAINTENANCE AND REPAIR/, /APPROPRIATE TECHNOLOGY/. /DIAGRAM/S. /STATISTICS/.
LANGUAGES:	ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 009026
DOCUMENT DATE: 1979
CALL NUMBER:
CORP. AUTHOR: UNIDO
SOLIDARITY MEETING OF MINISTERS OF INDUSTRY FOR CO-OPERATION IN THE INDUSTRIAL DEVELOPMENT OF HAITI, PORT-AU-PRINCE, 1979
TITLE: PROJECT PROPOSALS. (HAITI).
SOURCE: VIENNA, 1979. 80 P. TABLES, DIAGRAM.
DOC. NUMBER: UNIDO-UNIDO/EX.90
ABSTRACT: /UNIDO PUB/ ON /INDUSTRIAL DEVELOPMENT/ IN /HAITI/, WITH PROPOSALS FOR /INDUSTRIAL PROJECT/S - COVERS (1) THE /INDUSTRIAL SECTOR/ (2) /INTERNATIONAL COOPERATION/ AND /TECHNICAL ASSISTANCE/ AGREEMENTS WITH OTHER DC'S (3) PROJECT PROPOSALS UNDER THE HEADING OF /INFRASTRUCTURE/, /TECHNOLOGY TRANSFER/ AND ADAPTATION, AND SECTORAL /INVESTMENT/. ADDITIONAL REFERENCES: /SMALL SCALE INDUSTRY/, /FREE ZONE/, /STANDARDS/, /LABORATORY/, /PACKAGING/, /INSTITUTIONAL FRAMEWORK/, /SOLAR ENERGY/, /BIOGAS/, /CEMENT/ /TILES/, /FUEL/ /ALCOHOL/, /FIBREGLASS/, /RICE BRAN/, /STEEL/, /FOUNDRY/, /SHIPS/, /FURNITURE/, /MEAT INDUSTRY/, /TEXTILES/, /CASSAVA/ /FLOUR/, /PHARMACEUTICALS/, /SALT/, /FERTILIZER/, /PESTICIDES/, /MINERAL WATER/. /MAPS/.
LANGUAGES: ENGL FREN SPAN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 009333
DOCUMENT DATE: 1979
CALL NUMBER:
PERSONAL AUTHOR: SWAMY RAO AA
CORP. AUTHOR: UNIDO
TITLE: RAPPORT DE MISSION AUPRES DE LA REPUBLIQUE UNIE DU CAMEROUN. DEVELOPPEMENT DES PETITES ET MOYENNES ENTREPRISES.
SOURCE: VIENNA, 1979. 6 P.
DOC. NUMBER: UNIDO-UNIDO/IOD.292/ADD.2
ABSTRACT: /UNIDO PUB/. /MISSION REPORT/ REGARDING ASSISTANCE TO /CAMEROON/ IN DEVELOPMENT OF /SMALL SCALE INDUSTRY/ - COVERS PROPOSED /TECHNICAL ASSISTANCE/ TO THE "CENTRE NATIONAL D'ASSISTANCE AUX PETITES ET MOYENNES ENTREPRISES" (CAPME) IN /COOPERATION/ WITH THE "SERVICE ARTISAN RURAL" (SAR), WITH A VIEW TO IMPROVING /INDUSTRIAL SERVICES/ AND WITH ATTENTION TO PROJECTS (/ELECTRIC MOTORS/, /FOUNDRY/, /PAPER/ AND /CARDBOARD/, /MOLASSES/-BASED /ALCOHOL/). ADDITIONAL REFERENCES: /INDUSTRIAL INSTITUTIONS/, /INDUSTRIAL PROMOTION/.
LANGUAGES: FREN

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	009366
DOCUMENT DATE:	1979
CALL NUMBER:	
PERSONAL AUTHOR:	MEYERS H JENNINGS RF
CORP. AUTHOR:	UNIDO
TITLE:	CHARCOAL IRONMAKING. A TECHNICAL AND ECONOMIC REVIEW OF BRAZILIAN EXPERIENCE.
SOURCE:	VIENNA, 1979. 289 P. TABLES, GRAPHS, DIAGRAMS.
DOC. NUMBER:	UNIDO-UNIDO/IOD.228/REV.1
ABSTRACT:	/UNIDO PUB/. /EXPERT REPORT/ ON USE OF /CHARCOAL/ IN /IRON/-MAKING (BASED ON EXPERIENCE IN /BRAZIL/) - COVERS (1) UP-TO-DATE PRACTICE IN MANUFACTURE OF PIG IRON, FOR /FOUNDRY/S AND /STEEL/-MAKING USING CHARCOAL AS /FUEL/ IN BLAST /FURNACE/S (2) TECHNICAL AND /ECONOMIC ASPECTS/ OF VIABLE SMALL-SCALE MANUFACTURE IN /DEVELOPING COUNTRIES/ HAVING ADEQUATE /WOOD/ SUPPLY AND SUITABLE /IRON ORE/. ADDITIONAL REFERENCES: /FORESTRY/, /COKE/, /COSTS/, /CAPITAL INVESTMENT/, /ENGINEERING DESIGN/, /IRON AND STEEL INDUSTRY/, /CARBONIZATION/, /METALLURGY/, /FACTORY ORGANIZATION/. /DIAGRAM/S, /STATISTICS/, /BIBLIOGRAPHY/.
LANGUAGES:	ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	009509
DOCUMENT DATE:	1973
CALL NUMBER:	
PERSONAL AUTHOR:	HAJDU BJ
CORP. AUTHOR:	UNIDO
TITLE:	(R) STUDY ON THE DEVELOPMENT OF ZAMBIAN AGRICULTURAL MACHINERY AND ON THE POSSIBILITIES OF CREATING A NEW AGRICULTURAL MACHINERY FACTORY.
SOURCE:	VIENNA, 1973. 76 P. TABLES, DIAGRAM.
DOC. NUMBER:	UNIDO-UNIDO/ITD.161
ABSTRACT:	/UNIDO PUB/. /FINAL REPORT/ REGARDING /AGRICULTURAL MACHINERY/ PRODUCTION IN /ZAMBIA/ - COVERS (1) PRESENT STATE OF /AGRICULTURE/; CREATING AN AGRICULTURAL MACHINERY INDUSTRY; PROMOTION OF /AGRICULTURAL MECHANIZATION/ (2) RELEVANT /ECONOMIC ANALYSIS/ (3) PROPOSED DEVELOPMENT OF /HAND TOOLS/, /AGRICULTURAL EQUIPMENT/ AND /MACHINERY/ (4) /ECONOMIC ASPECTS/ OF PROPOSED /FACTORY/; /COSTS/ AND /PROFITABILITY/ CALCULATIONS (5) /FORGING/ /WORKSHOP/, SMALL /FOUNDRY/, /STEEL/ /CASTING/; /CHOICE OF TECHNOLOGY/, TECHNICAL ASPECTS, REQUIRED /EQUIPMENT/. /STATISTICS/. /RESTRICTED/.
LANGUAGES:	ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 009602
DOCUMENT DATE: 1980
CALL NUMBER:
PERSONAL AUTHOR: CHAKRABARTI NG
CORP. AUTHOR: UNIDO
TITLE: (R) ESTABLISHMENT OF A MULTI-PURPOSE MINIFOUNDRY CUM ROLLING MILL AT THE DOCKYARD OF THE GAMBIA PORTS AUTHORITY, BANJUL.
PROJ. NUMBER: SI/GAM/79/802
SOURCE: VIENNA, 1980. 8 P. TABLES, DIAGRAMS.
DOC. NUMBER: ::::
ABSTRACT: /UNIDO PUB/. /FINAL REPORT/ ON THE FEASIBILITY OF SETTING UP A SMALL /FOUNDRY/ WITH /METALS/ /ROLLING/ PLANT IN /GAMBIA/ - COVERS (1) A PROJECT TO MEET DEMAND FOR SHAPED /CASTING/S AND FOR BILLETS FOR SUBSEQUENT ROLLING INTO /STEEL/ BARS AND RODS (2) /FACTORY LAYOUT/ AND /MACHINERY/ /SPECIFICATIONS/ (3) /SMELTING/, /MOULDING/ AND COREMAKING, FETTLING AND /HEAT TREATMENT/; INGOTS AND ROLLED PRODUCTS; /TESTING/ /LABORATORY/; (4) /RAW MATERIAL/S: FERROUS /METAL SCRAP/ AND /NONFERROUS METALS/, ETC. (5) /CHOICE OF TECHNOLOGY/, /FURNACE/S, /FORGING/; /ELECTRIC POWER/ (6) /ECONOMIC ASPECTS/, /COSTS/. ADDITIONAL REFERENCES: /IRON AND STEEL INDUSTRY/. /RECOMMENDATIONS/, /PROJECT DOCUMENT/. /RESTRICTED/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 009781
DOCUMENT DATE: 1979
CALL NUMBER:
PERSONAL AUTHOR: MITRA AK
CORP. AUTHOR: UNIDO
TITLE: (R) COUNTRY REPORT. BASIC METAL AND ENGINEERING INDUSTRIES DEVELOPMENT PROGRAMME. UGANDA. FIELD MISSION, DECEMBER 1976.
SOURCE: VIENNA, 1979. V, 101 P. TABLES, CHART.
DOC. NUMBER: ::::
ABSTRACT: /UNIDO PUB/. /MISSION REPORT/ ON DEVELOPMENT OF BASIC /METALS/ AND /METALWORKING INDUSTRY/ IN /UGANDA/ - COVERS (1) MEETINGS AND /FACTORY/ VISITS; /INSTITUTIONAL FRAMEWORK/ (2) /ECONOMIC CONDITIONS/; RELEVANT /INDUSTRIAL DEVELOPMENT/; /ENGINEERING/ AND ALLIED /METAL PRODUCTS/ INDUSTRIES; /SMALL SCALE INDUSTRY/, /IMPORT/S, /EMPLOYMENT/ (3) PRESENT STATUS, /DEVELOPMENT PLAN/; /IRON AND STEEL INDUSTRY/, /FOUNDRY/; /TECHNOLOGY/ LEVEL; /IRON ORE/ (4) CONSTRAINTS; PROPOSED INTEGRATED DEVELOPMENT AND /INDUSTRIAL PROJECT/S. ADDITIONAL REFERENCES: /FINANCING/, /TRAINING/, /MANAGEMENT DEVELOPMENT/, /INFRASTRUCTURE/. /RECOMMENDATIONS/, /STATISTICS/, CHART. /RESTRICTED/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 009802
DOCUMENT DATE: 1979
CALL NUMBER:
PERSONAL AUTHOR: ARIZABAL AV
CORP. AUTHOR: UNIDO
TITLE: THE LIGHT ENGINEERING INDUSTRIES OF THE PHILIPPINES.
SOURCE: (IN 'APPROPRIATE INDUSTRIAL TECHNOLOGY FOR LIGHT INDUSTRIES AND RURAL WORKSHOPS'. VIENNA, 1980. PP.102-112) TABLES.
DOC. NUMBER: UNIDO-ID/232/11
ABSTRACT: /UNIDO PUB/ ON /LIGHT INDUSTRY/ IN THE /PHILIPPINES/ (REFERENCE: /METALWORKING INDUSTRY/) - COVERS (1) BACKGROUND AND STATUS OF /ENGINEERING/ INDUSTRY IN GENERAL; /MACHINERY INDUSTRY/; STRUCTURE, /EMPLOYMENT/, /CAPITAL/, LOCAL PRODUCTION, /SMALL SCALE INDUSTRY/, /SERVICE INDUSTRY/ (2) LIGHT ENGINEERING: METAL PRESSING, /FORGING/, /ROLLING/, /METAL CUTTING/, /MACHINING/ AND /CASTING/ (3) /INDUSTRIAL ENTERPRISE/S, /WORKSHOP/S, /FOUNDRY/S (4) PROBLEMS OF THE INDUSTRY. ANNEXES A RELEVANT /CLASSIFICATION OF INDUSTRIES/. /STATISTICS/.
LANGUAGES: ENGL

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 010570
DOCUMENT DATE: 1980
CALL NUMBER:
PERSONAL AUTHOR: HOESNI BN
CORP. AUTHOR: UNIDO
CONFERENCE: SEMINAR-WORKSHOP/STUDY TOUR IN THE DEVELOPMENT AND APPLICATION OF TECHNOLOGY FOR MINI-HYDRO POWER GENERATION (MHG), 2ND, HANGZHOU AND MANILA, 1980.
TITLE: MINI-HYDRO IN MALAYSIA.
SOURCE: Vienna, 1981. 5 p. table.
DOC. NUMBER: UNIDO-ID/WG.329/10
ABSTRACT: ‹UNIDO pub› on mini-‹hydroelectric power› development in ‹Malaysia› - covers (1) present status of relevant construction projects; large ‹development potential› (2) process of ‹project implementation› (3) ‹management› and operation of stations (4) technical and ‹economic aspects› (5) local small ‹foundry› capacity for production of ‹equipment›; ‹training programmes›. ‹Statistics›.
LANGUAGES: ENGL
COUNTRY CODE: 270
CLASSIFICATION: 34.20

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 010815
DOCUMENT DATE: 1981
CALL NUMBER:
PERSONAL AUTHOR: WIJENAIKE EM
CORP. AUTHOR: UNIDO
TITLE: (R) TERMINAL REPORT ON THE DEVELOPMENT OF SMALL-SCALE INDUSTRY IN PAPUA NEW GUINEA.
SOURCE: Vienna, 1981. 44 p.
DOC. NUMBER: ::::
ABSTRACT: ‹UNIDO pub›. ‹Final report› on assistance to ‹small scale industry› in ‹Papua New Guinea› - covers (1) formulation and implementation of an integrated programme, particularly for small ‹rural industry› (2) advising in ‹industrial administration› and ‹industrial promotion› (3) promoting ‹entrepreneurship› (4) ‹social aspects›, ‹economic aspects›; ‹industrial policy›, ‹training›, ‹infrastructure›, ‹industrial estate›s, ‹pilot project›s. ‹Recommendations›. Additional references: ‹silk›, ‹salt›, ‹rubber› goods, ‹wood products›, ‹leather›, ‹coconut fibres›, ‹foundry›, ‹handicraft›s. ‹Restricted›.
LANGUAGES: ENGL
COUNTRY CODE: 649
CLASSIFICATION: 21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 010993
DOCUMENT DATE: 1981
CALL NUMBER:
PERSONAL AUTHOR: BANESCU A
CORP. AUTHOR: UNIDO
TITLE: (R) PROJET DE FONDERIE A KIGALI, RWANDA, CAPACITE ANNUELLE 300 TONNES. RAPPORT DE MISSION.
PROJ. NUMBER: RP/RWA/80/002
SOURCE: Vienna, 1981. 86 p. tables, graphs, diagrams, illus.
DOC. NUMBER: UNIDO-UNIDO/IO.474
ABSTRACT: ‹UNIDO pub›. ‹Expert report› on assistance in setting up a small ‹foundry› and grey pig ‹iron› ‹casting› in ‹Rwanda› - covers (1) ‹domestic market› for casting products (2) availability of ‹metal scrap› ‹raw material› (3) ‹capital costs› and ‹production costs› (4) ‹production capacity›, ‹product mix› (5) ‹financial aspects›; ‹profitability›. ‹Recommendations›, ‹statistics›, ‹maps›, illustrations. Additional references: ‹training›, ‹furnace›s, ‹smelting›. ‹Restricted›.
LANGUAGES: FREN
COUNTRY CODE: 375
CLASSIFICATION: 36.30

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 011777
DOCUMENT DATE: 1982
CALL NUMBER:
PERSONAL AUTHOR: Wijenaike, E.M.
CORP. AUTHOR: UNIDO
TITLE: (R) REPORT ON A MISSION TO PAPUA NEW GUINEA ON THE PROMOTION OF SMALL SCALE INDUSTRY.
PROJ. NUMBER: DP/PNG/74/039
SOURCE: Vienna, 1982. 31 p.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub>. <Expert report> regarding assistance to <industrial promotion> in <Papua New Guinea> (reference: <small scale industry>) - covers (1) present situation of various <technical assistance> projects involving <silk> (<weaving>), <salt>, <leather goods>, <ceramics>, <wood products>, <coconut fibres>, <industrial estate>s, moulded <rubber> goods, cane <furniture>, <machining>, <maintenance and repair>, <foundry>, <handicraft>s (2) need for <UN> volunteers for <training assistance>. <Recommendations>. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 649
CLASSIFICATION: 21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 011960
DOCUMENT DATE: 1982
CALL NUMBER:
PERSONAL AUTHOR: Vijay, S.R.
CORP. AUTHOR: UNIDO
TITLE: (R) IDENTIFICATION OF PARTNER ENTERPRISES IN SWEDEN FOR UNITS SELECTED FOR THE TRANSFER OF TECHNOLOGY PROGRAMME IN KARNATAKA STATE AND A DETAILED PLAN OF OPERATION.
SOURCE: Vienna, 1982. 50 p.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub> on a programme of <cooperation> for <technology transfer> between <industrial enterprise>s in <Sweden> and <India>, with special reference to <metalworking industry> - covers identification of partner enterprises in Sweden for mainly <small scale industry>s in Karnataka State, considering (1) <forging> units, <machine tools>, precision products, <foundry>, <measuring instruments>, <electrical equipment>, <wood products>, etc. (2) problems; supporting services. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 204
411
CLASSIFICATION: 24.30

RECORD NUMBER:	012269
DOCUMENT DATE:	1982
CALL NUMBER:	
PERSONAL AUTHOR:	Lindblad, Lars
CORP. AUTHOR:	UNIDO
TITLE:	(R) SURVEY OF TECHNOLOGY TRANSFER FROM INDIA TO SMALL-SCALE INDUSTRIES IN NEPAL. TECHNOLOGY SELECTION VISIT OF SIX NEPALESE ENTREPRENEURS.
PROJ. NUMBER:	AR/RAS/80/006
SOURCE:	Vienna, 1982. 34 p.
DOC. NUMBER:	UNIDO-UNIDO/IS/R.3
ABSTRACT:	<UNIDO pub>. <Expert report> regarding potential <technology transfer> from <India> to <small scale industry>s in <Nepal> - covers (1) situation of such industry in Nepal: <market>, <infrastructure>, <financing>, <training>, technology used (2) visits of the consultant; <industrial administration> and <development centre>; <industrial services> (3) survey of six <industrial enterprise>s, manufacturing i.a. <bricks>, <rice> <rubber> rolls, <metal products>, small <turbines>. Annexes an outline <project document>. <Recommendations>. Additional references: <casting>, <foundry>, <industrial estate>. <Restricted>.
LANGUAGES:	ENGL
COUNTRY CODE:	297
204	
CLASSIFICATION:	24.30

RECORD NUMBER:	012410
DOCUMENT DATE:	1983
CALL NUMBER:	
CORP. AUTHOR:	UNIDO
TITLE:	UNIDO FOR INDUSTRIALIZATION: FOUNDRY INDUSTRY. - ONUDI ET INDUSTRIALISATION: L'INDUSTRIE DE LA FONDERIE. - ONUDI AL SERVICIO DE LA INDUSTRIALIZACION: LA INDUSTRIA DE LA FUNDICION.
SOURCE:	Vienna, 1983. 15 p. illus.
DOC. NUMBER:	UNIDO-PI/87 UNIDO-PI/87/Corr.1
ABSTRACT:	‹UNIDO pub› on the ‹role of UNIDO› in promotion of ‹foundry› industry in ‹developing countries› - (1) gives information on ‹financing› for UNIDO activities (2) covers (a) UNIDO ‹technical assistance›: small jobbing foundry; small foundries for ‹least developed countries›; foundry with integrated ‹rolling› mill and ‹forging› shop; ‹TCDC› (b) project proposals for UNIDO assistance (c) some possible projects and their scope. Illustrations. Additional references: ‹casting›, ‹training›, ‹choice of technology›, ‹standardization›, ‹coke›, ‹coal›.
LANGUAGE:	ENGL FREN SPAN
CLASSIFICATION:	36.30

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	013142
DOCUMENT DATE:	1982
CALL NUMBER:	
PERSONAL AUTHOR:	Thompson, William Miles
CORP. AUTHOR:	UNIDO
TITLE:	(R) INDUSTRIAL DEVELOPMENT CENTRE - OSHOGBO, NIGERIA. FINAL REPORT.
PROJ. NUMBER:	DP/NIG/73/014
SOURCE:	Vienna, 1982. 15 p.
DOC. NUMBER:	::::
ABSTRACT:	‹UNIDO pub›. ‹Final report› on assistance to a ‹development centre› in ‹Nigeria›, especially in promotion of ‹small scale industry› - covers (1) setting up of ‹training programmes› to upgrade ‹skills› of ‹entrepreneur›s and government ‹counterpart personnel› in the fields of: ‹marketing›, ‹maintenance and repair›, ‹product design›, ‹production control›, ‹tools› manufacture, ‹factory layout›, ‹purchasing› (2) establishment of ‹credit policy›s; ‹work organization›, need for ‹project evaluation›. ‹Recommendations›. Additional references: ‹wood processing›, ‹leather goods›, ‹textiles›, ‹foundry›, ‹engineering›, ‹management development›, ‹electrical engineering›. ‹Restricted›.
LANGUAGES:	ENGL
COUNTRY CODE:	321
CLASSIFICATION:	21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	013377
DOCUMENT DATE:	1983
CALL NUMBER:	
PERSONAL AUTHOR:	Harper, J.D.
CORP. AUTHOR:	UNIDO
TITLE:	(R) TURKEY. TRAINING PROGRAMME IN THE IDENTIFICATION AND PREVENTION OF FERROUS CASTING DEFECTS. TERMINAL REPORT.
PROJ. NUMBER:	DP/TUR/77/024
SOURCE:	Vienna, 1983. 45 p.
DOC. NUMBER:	::::
ABSTRACT:	<UNIDO pub>. <Final report> on assistance to <foundry>s in <Turkey>, with special reference to ferrous <casting> - covers (1) <training programmes> for <engineers> concerning problems in cast <iron> castings, pattern design, <moulding> machine operations, <sand> and <slag> intrusion, etc. (2) visits to <factory>s and <small scale industry>s; assistance in <standards> and <quality control>, <maintenance and repair>, <management>, <planning> methods, sand <testing>, <raw material> inspection, <metallurgy>cal <specifications>. <Recommendations>, <job description>, <list of participants>. Additional reference: <steel>. <Restricted>.
LANGUAGES:	ENGL
COUNTRY CODE:	435
CLASSIFICATION:	36.30

RECORD NUMBER: 013724
DOCUMENT DATE: 1984
CALL NUMBER:
PERSONAL AUTHOR: Schulze, Manfred J.
CORP. AUTHOR: UNIDO
TITLE: (R) TURKEY. EQUIPMENT SPECIFICATION FOR FOUNDRY LABORATORIES AT ANKARA FOUNDRY DEVELOPMENT CENTRE AND DETERMINATION OF ASSISTANCE TO BE PROVIDED THROUGH THE CENTRE. TECHNICAL REPORT.
PROJ. NUMBER: DP/TUR/80/010
SOURCE: Vienna, 1984. 39 p. tables.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub>. <Expert report> on assistance to a <foundry> <laboratory> in <Turkey> - covers (1) <small scale industry> structure of the foundries, their <production capacity> and <product mix>; <equipment> in use (2) <industrial extension> and services to be provided by the Ankara Foundry <Development Centre> and its <research> and <training centre>; <technical personnel> requirements; equipment <specifications> and <prices>; <testing> facilities and <instruments> in laboratory. <Recommendations>, tables. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 435
CLASSIFICATION: 36.30

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 013844
DOCUMENT DATE: 1984
CALL NUMBER:
PERSONAL AUTHOR: Mitlaender, W.
CORP. AUTHOR: UNIDO
TITLE: (R) TURKEY. SURVEY ON THE ACTIVITIES OF KUSGET AND RECOMMENDATIONS FOR THE IMPROVEMENT OF THE WORKSHOP AND THE EXTENSION SERVICE SECTION.
PROJ. NUMBER: DP/TUR/80/010
SOURCE: Vienna, 1984. 64 p. tables, graphs.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub>. <Expert report> on <industrial extension> services to <small scale industry> in <Turkey> - covers (1) proposals for improvement of a <workshop> serving <metalworking industry> in an <industrial estate>; its structure and the condition of <equipment> in <laboratory>s, mechanical <foundry> and <heat treatment> sections (2) <staff>; consultations fees (3) technical <common services> provided to small scale <entrepreneur>s for design and manufacture of <tools> and <spare parts>; need for <training> of <technical personnel>. Lists <machinery> on hand. <Recommendations>, <statistics>. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 435
CLASSIFICATION: 21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 014207
DOCUMENT DATE: 1984
CALL NUMBER:
PERSONAL AUTHOR: Bishop, L.R.
CORP. AUTHOR: UNIDO
TITLE: (R) INDONESIA. ASSISTANCE TO THE DEVELOPMENT OF SMALL-SCALE INDUSTRIES. FINAL REPORT.
PROJ. NUMBER: DP/INS/78/078
SOURCE: Vienna, 1984. 17 p. tables.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub>. <Final report> on assistance to <small scale industry> in <Indonesia> - covers (1) project objectives (2) small <industrial estate>s; <common services> (3) <foundry>s; <industrial extension>, <training>; <subcontracting>; <product mix>. Additional references: <entrepreneurship>, <workshop>. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 207
CLASSIFICATION: 21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER: 014446
DOCUMENT DATE: 1984
CALL NUMBER:
PERSONAL AUTHOR: Hakka, Mikko J.
CORP. AUTHOR: UNIDO
TITLE: (R) NIGERIA. INDUSTRIAL DEVELOPMENT CENTRE OSHOGBO. TERMINAL REPORT.
PROJ. NUMBER: DP/NIR/73/014
SOURCE: Vienna, 1984. 79 p. tables, diagrams.
DOC. NUMBER: ::::
ABSTRACT: <UNIDO pub>. <Final report> on assistance to an industrial <development centre> serving <small scale industry> in <Nigeria> - covers (1) organization of <seminar>s, <training programmes>, <fellowships>; <in-plant training> for small scale <entrepreneur>s; <industrial extension> regarding <maintenance and repair>, manufacture of <spare parts> and <prototype>s; <engineering design>; <workshop>s; <credit policy>s (2) <raw material>s, <energy>, <manpower>; the <development potential> of <foundry>s (3) the use of <charcoal> for melting cast <iron> (4) the role of technology in African <industrialization>. <Recommendations>, <diagram>s. <Restricted>.
LANGUAGES: ENGL
COUNTRY CODE: 231
CLASSIFICATION: 21.40

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	014449
DOCUMENT DATE:	1984
CALL NUMBER:	
PERSONAL AUTHOR:	Wanjun, Wang Hongshu, Liu
CORP. AUTHOR:	UNIDO
CONFERENCE:	EXPERT GROUP MEETING ON THE DEVELOPMENT OF MULTI-PURPOSE AGRICULTURAL MACHINERY PLANTS, GUANGZHOU, CHINA, 1984.
TITLE:	DESIGN AND STUDY OF MULTIPURPOSE AGRICULTURAL MACHINERY PLANTS. - ETUDE ET CONCEPTION D'USINES POLYVALENTES DE MACHINES AGRICOLES.
SOURCE:	Vienna, 1985. 40 p. tables, diagrams, illus.
DOC. NUMBER:	UNIDO-ID/WG.449/2
ABSTRACT:	<UNIDO pub>. <Expert report> on design of multipurpose <agricultural machinery> plants (based on experience in <China>) - covers (1) organization of medium and <small scale industry>s for the production of <hand tools>, <animal power> and <tractors>-drawn <agricultural equipment>, <pumps>, mills (2) <factory layout> and <factory organization> with reference to <foundry>, <forging>, <heat treatment>, <welding>, <machining>, <casting>, <assembling>, <maintenance and repair>; <metrology>; <management>; <choice of technology>; <capital costs>. <Recommendations>, <diagram>s, illustrations.
LANGUAGES:	ENGL FREN
COUNTRY CODE:	086
CLASSIFICATION:	37.20

RECORD NUMBER:	015528
DOCUMENT DATE:	1986
CALL NUMBER:	
PERSONAL AUTHOR:	Graf, Karoly
CORP. AUTHOR:	UNIDO
TITLE:	(R) BURUNDI. ETUDE SUR LA RECHERCHE DES POSSIBILITES DE RECONVERSION D'UNE USINE DE FABRICATION DE MATERIEL AGRICOLE. RAPPORT TECHNIQUE.
PROJ. NUMBER:	DP/BDI/81/008
SOURCE:	Vienna, 1986. 39 p. diagrams.
DOC. NUMBER:	::::
ABSTRACT:	<UNIDO pub>. <Expert report> on assistance in re-establishment of a <workshop> for production of <hand tools> in <Burundi> - covers (1) existing and required <equipment> (2) <utilities>, overhead and <production costs> (3) <choice of product>s for a <metalworking industry> (mainly <agricultural equipment>); <technicians> and <skilled workers> required (4) possibility of setting up a small <foundry> in support of workshop activities. <Recommendations>, <factory layout>. Additional references: cast <iron>, <spare parts>. <Restricted>.
LANGUAGES:	FREN
COUNTRY CODE:	061
CLASSIFICATION:	37.10

INDUSTRIAL DEVELOPMENT ABSTRACTS

RECORD NUMBER:	015618
DOCUMENT DATE:	1986
CALL NUMBER:	
PERSONAL AUTHOR:	Bal, Ergun Bertsch, Heinz de Groot, Adrie
CORP. AUTHOR:	UNIDO
TITLE:	(R) TURKEY. EXTENSION SERVICES FOR SMALL INDUSTRY. REPORT OF THE EVALUATION MISSION.
PROJ. NUMBER:	DP/TUR/80/010
SOURCE:	Vienna, 1986. 47 p. diagram.
DOC. NUMBER:	UNIDO-DP/ID/SER.C/7
ABSTRACT:	<UNIDO pub>. <Mission report> on evaluation of a project promoting <industrial extension> services to <small scale industry> in <Turkey> - covers (1) objectives of the project; <social aspects>, <economic aspects>, the <institutional framework>; project design (2) delivery of inputs; implementation of activities (3) project results: activities of the Gaziantep <regional development> centre, the Ankara <foundry> <development centre>, and of other <consulting> centres. <Recommendations>, <diagram>. Additional references: <industrial services>, <quality control>, <skills>, <management development>. <Restricted>.
LANGUAGES:	ENGL
COUNTRY CODE:	435
CLASSIFICATION:	14.70

DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

1545368 87-511547
Dumbbell Ingot for Simulation of V-Shaped Streaks on a Small Scale.
Trans. Iron Steel Inst. Jpn. 25, (11), 1187 Nov. 1985
ISSN: 0021-1583
Journal Announcement: 8709
Document Type: ARTICLE
Language: ENGLISH
For studies on formation of segregation streaks, small scale experiments simulating the solidification process taking place in large ingots and continuous casting strands were made. However, it was difficult to give the solidifying conditions from which segregation streaks were formed in a small ingot. A dumbbell ingot with a necked zone in the middle was found to be suitable for the object to have V-shaped streaks quite easily.--AA
Descriptors: Ingot casting; Continuous casting; Segregations; Solidification; Ingot molds, Design; Simulation
Section Headings: 51 .(FOUNDRY)

1541813 87-511361
Effect of Mould Coatings on the Surface Defects in Ingots.
Wada, T ; Honda, M
Tetsu-to-Hagane (J. Iron Steel Inst. Jpn.) 73, (6), 684-690 Apr. 1987 ISSN: 0021-1575
Journal Announcement: 8708
Document Type: ARTICLE
Language: JAPANESE
This work was carried out to obtain data on the function of mould coatings most necessary to reduce surface defects in ingots. Thermobalance and differential thermal analysis and small scale casting experiments were carried out so that splash boxes and splash like scabs could be related to the thermal decomposition temperature of mould coatings. It concluded that water soluble resin coatings cause a so called rolling reaction of hot metal at the first stage of pouring and promote a smooth hot metal rise in the moulds and ingot surfaces appear to be the best. Coal tar and graphite of low and high thermal decomposition temperature are the causes of many surface defects in ingots. 14 ref.--AA
Descriptors: Carbon steels, Casting; Castings, Quality control; Surface finish; Surface defects; Molds, Coating; Differential thermal analysis; Coal tar, Coatings; Graphite, Coatings
Section Headings: 51 .(FOUNDRY)

1530221 87-510799
Study of Slab Bulging in Continuous Caster.
Lamant, J Y ; Larrecq, M ; Birat, J P
Continuous Casting '85, London, UK, 22-24 May 1985
Publ: The Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB, UK, 1985
37.1-37.5
Journal Announcement: 8708
Document Type: BOOK

Language: ENGLISH
In order to quantify the influence of the main casting parameters on slab bulging, three different studies have been conducted. First a mathematical viscoplastic model of bulging between two rolls, using the results of tensile tests carried out for the matter, has been developed. Then, in order to check the validity of this model a physical modelling with a small scale model using plasticine has been operated. Moreover, measurements of bulging intensity and profiles on actual continuous casters have been made. They show that the bulging deflections depend also on the defects in geometry and the deformations induced in the upper part of the caster. Finally all these results are discussed and applied to the design of the continuous caster supporting system. 21 ref.--AA
Descriptors: Steels, Casting; Slab casting; Continuous casting; Bulging; Viscoplasticity; Mathematical models; Casting defects
Section Headings: 51 .(FOUNDRY)

1526522 87-460053
Laboratory Study on the Recycling of Nickel Base Superalloy Foundry Scrap.
Rupp, S ; Bienvenu, Y ; Massol, J
High Temperature Alloys for Gas Turbines and Other Applications, 1986. I, Liege, Belgium, 6-9 Oct. 1986
Publ: D. Reidel Publishing Company, Spuiboulevard 50, P.O. Box 989, 3300 AZ Dordrecht, The Netherlands, 1986
787-797
Journal Announcement: 8704
Document Type: BOOK
Language: ENGLISH
Three French laboratories collaborated within the COST 50 programme to understand the generally inferior foundry performance of revert alloys and to improve the recycling procedures of Ni base superalloys. The influence of recycling on the solidification behaviour of two turbine blade alloys, IN-100 and Mar-M002, was studied. Only with IN-100 could significant differences be evidenced between virgin and recycled material, in agreement with industrial experience on the relative influence of recycling for both alloys. Thermodynamic investigation of the behaviour of nitrogen and oxygen in Ni based melts centered on the interaction between these impurities (usually linked with recycling) with Cr, Ti, Al. Laboratory studies also included the denitriding of Ni--20Cr melts by the bottom blowing of Ar and the continuous induction cold hearth remelting of IN-100. Trials indicated that both processes look quite promising on a small scale (a few kg) and owe their improved recycling performances to the purging action of inert gases or to the removal of inclusions by eddy currents and entrapment in a slag. 12 ref.--AA
Descriptors: Nickel base alloys, Recovering; Superalloys, Recovering; Metal scrap, Recovering; Recycling; Induction melting
Alloy Index(Identifier): IN-100, Mar-M002, NI, SP

(cont. next page)

DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

Section Headings: 46 .(NONFERROUS ALLOY PRODUCTION)

992315 86-511636
Solar Furnaces for Small Scale Aluminium Melting.
Seshan, S
International Conference on Aluminium-85 (INCAL), New Delhi, India, 30 Oct.-2 Nov. 1985
Publ: Indian Institute of Metals, Chatterjee International Centre, A-1 Flat, 15th Floor, 33A, Chowringhee Rd., Calcutta, 700 071, India, 1985
426-439
Journal Announcement: 8611
Document Type: BOOK
Language: ENGLISH
Experimental trials on (i) drying/baking of foundry sands, (ii) heat treatment of steels and (iii) melting and casting of Al and its alloys have been accomplished satisfactorily using the prototype solar furnace. A maximum temperature of 1190 deg C has been recorded on a sunny day. This and the melting of Al alloys are positive achievements of this investigation. The castings produced using the solar melted metals exhibit freedom from defects and possess better mechanical properties compared to the conventionally melted metals. A cost benefit analysis has been made for the melting operation and it has been found that solar melting results in approx 14% savings in cost/kg of Al melted. This type of furnace could be a very useful and economical tool for certain metallurgical operations, and has tremendous potentials in tropical, urban and rural areas of India for small scale metallurgical industries. 2\ ref.--AA
Descriptors: Aluminum, Melting; Energy conservation; Solar furnaces
Section Headings: 51 .(FOUNDRY)

989006 86-511456
Consideration of Pattern Costs in the Design of Castings.
Ehrlenspiel, K ; Pickel, H
Schweiz. Maschinenmarkt 86, (19), 73-75 14 May 1986
Journal Announcement: 8610
Document Type: ARTICLE
Language: GERMAN
Costs connected with making the wood patterns may constitute a considerable part of the overall costs of castings, especially in the case of single units or small scale production runs. In these cases cost effective designs of the patterns are essential. A number of examples of different wood pattern designs and tooling are presented. Both good and bad designs are shown diagrammatically. The designs are categorized according to their size and shape complexity, and a relationship to cost is established. 15 ref.--C.G.G.
Descriptors: Pattern making; Sand casting
Section Headings: 51 .(FOUNDRY)

975540 86-510974
Refining of Equiaxed Crystals and Change in Substructure by Stirring at Early Stage of Solidification.
Morikawa, H ; Yamauchi, T ; Hasegawa, M
Nisshin Steel Tech. Rep. (53), 10-16 Dec. 1985 ISSN: 0387-3427
Journal Announcement: 8606
Document Type: ARTICLE
Language: JAPANESE
The effect of stirring modes on the refining of equiaxed crystals was studied, simulating in-mold stirring by using a small-scale linear motor-type stirrer. In addition, the relation between size of equiaxed crystals and morphology of substructures was investigated. The results obtained are summarized as follows: (1) With a constant frequency and electric current, stirring modes affected the flow velocity of molten steel, V sub Fe , estimated from the deflection of dendrites. (2) The ratio of equiaxed zone and the size of equiaxed crystals were closely related to V sub Fe . (3) The morphology of substructures was changed from large branched columnar dendrites to globular crystals mixed with fine dendrites, at a V sub Fe of about 35 cm/s. 8 ref.--AA
Descriptors: Stainless steels, Casting; Solidification; Electromagnetic stirring; Structures (crystalline); Equiaxed structure
Alloy Index(Identifier): 310S, SSA/ Fe-0.65C-13Cr, SS
Section Headings: 51 .(FOUNDRY)

972041 86-510699
New Solutions for Efficient Production of Rotation-Symmetrical Parts From Ferrous Materials in Unit- and Small-Scale Production.
Ambos, E ; Lichtenberg, H ; Geszler, W ; Beier, H M
Fertigungstech. Betr. 35, (8), 458-460 1985 ISSN: 0015-024X
Journal Announcement: 8605
Document Type: ARTICLE
Language: GERMAN
It is shown that small-scale production of rotation-symmetrical parts can be efficient by using cast parts. A comparative table of material and energy costs for 1 ton production of steel and cast iron parts, respectively, shows that the total cost of the latter was 5726 DM against 9203 DM for the former. Steps in the planning of components production are explained with the help of a heirarchical chart. Use of CAD/CAM is an essential part of the modern rational production. Use of flexible model assemblies for casting the final product is discussed with illustrations. 7 ref.--R.N.
Descriptors: Cast iron, Castings; Steels, Forgings; Economics; Computer aided design
Section Headings: 51 .(FOUNDRY)

DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

962251 86-510320
Evaluation of Centrifugally Cast TiAl5Fe2.5 Alloy for Implant Material.
Zwicker, U ; Breme, J
Titanium--Science and Technology. Vol. 1, Munich, FRG, 10-14 Sept. 1984
Publ: Deutsche Gesellschaft fur Metallkunde, Adenauerallee 21, D-6370 Oberursel 1, FRG, 1985
171-178
Journal Announcement: 8602
Document Type: BOOK
Language: ENGLISH
An installation for the centrifugal casting of stems of hip prostheses of the alloy TiAl5Fe2.5 was constructed and used for small scale melting and casting under an argon atmosphere. Two stems each of about 250 g can be cast simultaneously. Since the mechanical properties of the cast stems compared with a forged stem were diminished by pores of included gas and/or shrinkage cavities an attempt was made to improve the properties by hot isostatic pressing (3 h 950 deg C/1000 bar) and by remelting the lateral side of the stem by tungsten inert gas welding. In the hipped stem the maximum bending stress of the as cast stem could be improved from 580 to 600 N/mm exp 2 compared with 620 N/mm exp 2 of the > 99% hot forged stem under service conditions. A hot deformation of 25% of cast rods (14 mm 0). In the (alpha + beta)-temperature region at 800 deg C after casting and annealing for 5 minutes 1000 deg C/H sub 2 0 improved the rotating fatigue strength of cast rods to 97% of the values of the fatigue strength which was obtained with > 99% hot worked material. Therefore it is recommended to produce the final shape of centrifugally cast stems of hip prosthesis by a deformation process of about 25% at 800 deg C. 5 ref.--AA
Descriptors: Surgical implants; Titanium base alloys, Casting; Centrifugal castings, Mechanical properties; Bend strength, Deformation effects; Fatigue strength; Hot isostatic pressing; Hot forging
Alloy Index(Identifier): TiAl5Fe2.5, Ti
Section Headings: 51 .(FOUNDRY)

962184 86-510253
A Continuous Caster for Research.
Trans. Iron Steel Inst. Jpn. 25, (5), 44[illegible] May 1985
ISSN: 0021-1583
Journal Announcement: 8602
Document Type: ARTICLE
Language: ENGLISH
A small scale experimental continuous caster has been evolved to study the effect of casting parameters on the friction force generated in the mould, an important factor in the quest for increases in casting speeds. The caster comprised a vertical withdrawal unit and a sinusoidal mould oscillation device. The vertical mould was mounted on to load cells attached to the mould oscillation table so that the friction force between mould wall and strand during casting could be measured. The friction force was determined from the apparent mould weight by substracting the mould inertia force. The friction force decreased by about 50% with the aid of mould powder. Friction force during negative stripping period appeared at the range of negative strip time ratio more than 50%. The powder consumption rate decreased with increase in oscillation cycle.--S.M.F.
Descriptors: Continuous casting machines; Research; Friction ; Molds
Section Headings: 51 .(FOUNDRY)

962113 86-510182
Induction Furnaces for Melting Aluminum Alloys in Small-Scale Production Shops.
Bogin, V S ; Zhudinov, M I ; Ilyutochkin, V V ; Nizov, N N
Liteinoe Proizvod. (5), 29-31 1985 ISSN: 0024-449X
Journal Announcement: 8602
Document Type: ARTICLE
Language: RUSSIAN
The conditions of small-scale production place certain demands on the operation of melting furnaces, such as fast startups, easy transitions from one alloy to another, and high melting rates. Two high-frequency induction furnaces with a crucible capacity of 400 and 2500 kg, respectively, specially designed for small-scale production, are described. It is shown that the use of high rather than commercial current frequencies (1200-2400 Hz) makes it possible to increase the power of the furnace by a factor of at least two (and therefore reduce the melting time) while retaining optimum mixing intensity. 6 ref.--V.L.
Descriptors: Aluminum base alloys, Melting; Induction melting; High frequency induction furnaces, Design; Furnace liners, Materials selection; Refractories, Materials selection
Section Headings: 51 .(FOUNDRY)

959020 86-510070
Technological Innovation in a Lost Wax Casting Small Scale Industrial Unit.
Vishnu, T
Indian Foundry J. 31, (6), 19-22 June 1985 ISSN: 0379-5446
Journal Announcement: 8601
Document Type: ARTICLE
Language: ENGLISH
A modernisation programme is described, conducted in a small scale industrial unit, making investment mould castings of traditional brass and bell metal castings. The programme included development of a wax blend which can be finished by machining, replacing the mud-cover-mould by coats of investment slurry, developing a new feeder head and a new scheme of finishing the products. The programme was successful. This not only improved the quality of reproduction but also the surface finish. The rejection percentage also came down from around 30% to 10%.--AA
Descriptors: Brasses, Casting; Investment casting; Plants;

(cont. next page)

Modernization; Quality; Surface finish; Feeders, Design
Section Headings: 51 .(FOUNDRY)

955957 85-511636
Study on the Straightening Process of the Strand in Continuous Casting Plant. II.--Straightening Test by Small Scale Model Machine With Aluminium Strand. (Synopsis).
Tsune, K ; Yoshii, A ; Kihara, S ; Kobayashi, T ; Mishima, T
Trans. Iron Steel Inst. Jpn. 24, (9), B-298 Sept. 1984
ISSN: 0021-1583
Journal Announcement: 8512
Document Type: ARTICLE
Language: ENGLISH
A model continuous casting machine was developed, with a casting radius of 1500 mm, a roll pitch of 60 mm, a casting speed of 53.5-352 mm/min, and from 1 to 6 straightening points. Al strands of thickness 35 mm and width 15 mm were straightened on the machine while the roll reaction forces and strand surface strains were determined. Reaction forces downstream of the last straightening point were found to be very high when either the leading or trailing end of the strand was passing through, reducing to values of approximately 20-30% of this when the bulk of the strand was being straightened. Optimum distance between straightening points to achieve uniform strains was 2-3 roll pitches, with surface strain values of <= 0.4% per straightening point.--T.W.
Descriptors: Continuous casting machines, Design; Straightening; Continuous casting; Strain
Section Headings: 51 .(FOUNDRY)

955956 85-511635
Study on the Straightening Process of the Strand in Continuous Casting Plant. I.--Bending Theories of Hot Strand and an Analysis of Straightening Process in Continuous Casting Plant. (Synopsis).
Yoshii, A ; Kihara, S ; Tsune, K ; Kobayashi, T ; Mishima, T
Trans. Iron Steel Inst. Jpn. 24, (9), B-297 Sept. 1984
ISSN: 0021-1583
Journal Announcement: 8512
Document Type: ARTICLE
Language: ENGLISH
A mathematical model of strand bending was developed and used to calculate roll reaction forces during continuously-cast beam straightening. Good agreement was obtained between the model and the results of experimental studies on a small-scale model caster and observations on a service plant.--T.W.
Descriptors: Mathematical models; Continuous casting; Bending; Rolls; Strain; Straightening
Section Headings: 51 .(FOUNDRY)

952182 85-511420
A Combined Eulerian--Lagrangian Three-Dimensional Finite-Element Analysis of Edge-Rolling.
Huisman, H J ; Huetink, J
J. Mech. Work. Technol. 11, (3), 333-353 July 1985
ISSN: 0378-3804
Journal Announcement: 8511
Document Type: ARTICLE
Language: ENGLISH
After edge-rolling (heavy width-reduction), the cross-section of a continuously-cast steel slab may be non-rectangular, whereas what is desired is that it should be exactly rectangular. The deformed shape results in an increased number of heavy width- and thickness-reductions having to be imposed on the slab. Since edge-rolling is clearly a three-dimensional forming process, use of plane-strain analysis would be insufficient: a three-dimensional finite-element formulation, based on elastic--plastic material behaviour, has therefore been developed. This three-dimensional formulation has been incorporated into the existing special purpose FEM programme DIEKA, developed at Twente University of Technology. The former two-dimensional programme DIEKA has already been successfully applied to plane-strain processes such as the cold rolling of strip-material, and axi-symmetric processes such as wire drawing. Using the extended three-dimensional programme, calculations have been made to investigate the influence of roller-radii on the resulting cross-section of the slab after a width reduction. Experiments for verification and small-scale simulation of the real production process have been carried out using plasticine as a model material. 17 ref.--AA
Descriptors: Steels, Casting; Continuous casting; Continuous cast shapes, Rolling; Finish rolling; Hot rolling; Plastic flow; Mathematical models
Section Headings: 51 .(FOUNDRY)

- 281 -

929813 85-510536
The Integrated Melting and Horizontal Casting of a Boron Steel.
Heard, R A ; Mountford, N D G ; McLean, A ; Haissig, M
Iron Steelmaker 12, (1), 10-16 Jan. 1985 ISSN: 0097-8388
Journal Announcement: 8505
Document Type: ARTICLE
Language: ENGLISH
A B--0.5%Mo alloy steel was inductively melted and horizontally cast in a small-scale industrial facility. Particular emphasis was given to the advantages of an integrated system. The influence of melting conditions on chemical composition and physical properties has been demonstrated. Factors investigated include furnace atmosphere, refractories, fluid flow, and temp. In addition, the effects of stroke rate, stroke length, pushback, ferrostatic pressure, and superheat on surface quality have been documented. 8

(cont. next page)

ref.--S.K.B.
Descriptors: Boron steels, Casting; Continuous casting; Induction melting; Deoxidizing; Casting defects
Section Headings: 51 .(FOUNDRY)

919835 85-510239
Stability of Molten Metal Free Surface in the Presence of an Alternating Magnetic Field.
Garnier, M ; Moreau, R
Metallurgical Applications of Magnetohydrodynamics, Cambridge, England, 6-10 Sept. 1982
Publ: The Metals Society, 1 Carlton House Terrace, London SW1Y 5DB, England, 1984
211-216
Journal Announcement: 8502
Document Type: BOOK
Language: ENGLISH
In many electromagentic devices the equilibrium shape of the free surface of a molten metal is magnetically controlled. In this paper the stability requirements are discussed. Two kinds of disturbances are distinguished: those with a length scale of the same order as the size of the inductor or the gap between the inductor and the molten metal, and those with a small length scale for which the external magnetic field may be considered as uniform. It is shown that an AC magnetic field may stabilize a free surface against gravity (levitation) if the surface is flat enough; if the slope of the free surface is too steep, it necessarily evolves towards another shape (constricted jet) easily stabilized. On the small scale an AC magnetic field tends to stabilize the deformations of the surface, but it can excite some internal stirring underneath the free surface. 14 ref.--AA
Descriptors: Liquid metals; Shaping; Levitation; Magnetohydrodynamics
Section Headings: 51 .(FOUNDRY)

919829 85-510233
A New Approach to Electromagnetic Stirring During Continuous Casting of Steel. (Abstract Only).
Norris, T S ; Armstrong, G R
Metallurgical Applications of Magnetohydrodynamics, Cambridge, England, 6-10 Sept. 1982
Publ: The Metals Society, 1 Carlton House Terrace, London SW1Y 5DB, England, 1984
163
Journal Announcement: 8502
Document Type: BOOK
Language: ENGLISH
During continuous casting of steel, improvement in product quality can be obtained by electromagnetic stirring of the melt either in or beneath the casting mould. It is generally accepted that there are metallurgical advantages for stirring in the mould but the commercial equipment available for achieving this requires a special mould assembly and a low frequency electrical supply. TI Research Laboratories has

developed a novel device for stirring molten steel in the continuous casting mould without the need for a low frequency electrical supply and using equipment which can easily be fitted to an existing mould. In this device, high current conductors are used to generate the rotating magnetic field which induces the stirring motion in the melt. The theory of the stirrer design is presented in terms of magnetic flux generation, penetration of the flux into the melt and mould structure and the interaction of the flux with the melt to produce the stirring motion. During the development work on this stirrer, small scale working models were used extensively to support the theory, and the value of this approach is also discussed. The effects of stirring on steel structure obtained in the laboratory are shown. This stirrer has been installed in a steelworks where it is now in successful operation.--AA

Descriptors: Steels, Casting; Continuous casting; Electromagnetic stirring; Magnetic flux

Section Headings: 51 .(FOUNDRY)

896019 84-510897

Electromagnetic and Hydrodynamic Measurements in Aluminum Continuous Casting. (Pamphlet).

Vives, C ; Ricou, R · Forest, B

Publ: The Metallurgical Society/AIME, 420 Commonwealth Dr., Warrendale, Pa. 15086, U.S.A., 1984

Pp 15

Report No.: TMS Paper No. A84-9

Journal Announcement: 8407

Document Type: REPORT

Language: ENGLISH

The use of new local measurement techniques of velocity, magnetic field, current density and phase difference by small-scale probes, which allow the experimental investigation of the flow in molten metal (up to 700 deg C) in the presence, or absence, of an induction magnetic field is described. These methods are applied to the study of electromagnetic and hydrodynamic phenomena in Al industrial processes, such as in electromagnatic castings, inside the sumps of both rectangular and circular cross-section ingots. Comparisons relative to macrosegregation, grain size and secondary dendrite arm spacing were made between conventional and electromagnetic continuous casting of Al alloys (7049). The important shield effect is also discussed as a function of the screen location by means of a Hg pool simulating the electromagnetic casting. 9 ref.--AA

Descriptors: Aluminum base alloys, Casting; Continuous casting; Electromagnetic stirring; Flow measurement

Alloy Index(Identifier): 7049, AL

Section Headings: 51 .(FOUNDRY)

DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

851113 83-580542
Hot Dip Galvanizing as a Finish for Cast Irons--Problems and Remedies.
Pugazhenthy, L
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1982
Pp 8
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
The causes for corrosion and the magnitude of corrosion losses in India, U.S. and U.K. are indicated. Universally, galvanizing is the most popularly adopted method for combating corrosion of iron and steel products. The main types of galvanizing processes and the relative merits and demerits are noted. Galvanizing of cast irons poses special difficulties because of the adhering foundry sand. The common methods for overcoming these difficulties are pickling with hydrofluoric acid, shot blasting and pickling with a fused alkali; these methods are discussed in detail. The economic considerations, when viewed with a small-scale galvanizer, arising out of these special pretreatment methods, are analyzed.--AA
Descriptors: Cast iron, Coating; Hot dip galvanizing; Surface pretreatments; Corrosion, Coating effects
Section Headings: 58 .(METALLIC COATING)

850373 83-510561
Melting and Rolling of Stainless Steel With Particular Reference to Small-Scale Sector.
Varshneya, K K
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1981
Pp 19
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
The development in India of small-scale units for the manufacture of stainless steel (sheets, rounds, slabs and ingots) is reviewed. To improve quality in these units information on the technical problems of melting and rolling AISI 304 stainless steel are given. The metallurgy includes: stabilization, melting equipment, including refractory lining materials, melting techniques and teeming practice; the solidification process including top-pouring, bottom pouring, selection of pouring method and ingot molds; the rolling processes including preparation of material, reheating, hot rolling, cold rolling, defects in cold rolling, annealing and pickling.--M.G.S.
Descriptors: Austenitic stainless steels, Melting; Ingots, Rolling; Billets, Rolling; Hot rolling; Cold rolling
Alloy Index(Identifier): 304, SSA
Section Headings: 51 .(FOUNDRY)

850372 83-510560
Industry Oriented Research and Development Work in Aluminum Technology at NML.
Kumar, R ; Savens, B K ; Lal, K
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1981
Pp 17
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
Some results of industry-related research and development work carried out at India's National Metallurgical Laboratory are described. Included are: a process capable of reducing the rejection rate in the country's small-scale Al utensil industry from 30-35% to 5-7%; a ceramic "reactive filter" for removing hydrogen or submicroscopic dross and oxide particles from Al alloys; development of 5% Mg filler wires/rods for use in Al alloy welding which are suited to indigenous resources; inoculants for Al and its alloys in the form of pellets (NML-PM120) and wire (NML-PM 121 and 122); development of an Al-bearing alloy as substitute for bronze.--M.G.S.
Descriptors: Aluminum base alloys, Melting; Filtration; Welding wire; Inoculation; Research
Section Headings: 51 .(FOUNDRY)

850371 83-510559
Small-Scale Aluminum Industries and Energy Conservation.
Murthy, B K
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1981
Pp 9
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
Sources of energy waste in the melting process of Al are considered. Methods of minimizing heat loss include choice of heat source and melting furnace, careful control of charge (particularly separating scrap) and good melting practice. During melting, recommendations include: avoid overheating, avoid stewing, leave molten surface undisturbed, provide good temp. control using iron--constantan thermocouple and good degassing and fluxing practices.--M.G.S.
Descriptors: Aluminum, Melting; Energy conservation; Charge preparation

(cont. next page)

DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

Section Headings: 51 .(FOUNDRY)

850370 83-510558
Controlling the Metal Quality f. the Production of Malleable and Ductile Castings.
Ghatak, A
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1981
Pp 6
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
The effect of various elements on the production of malleable and ductile Fe castings is considered. The black and white heart processes for production of malleable Fe castings and the effect of carbon, Si, sulfur, phosphorus and Mn in each case are described. The molding and annealing processes and mottling are considered. The effects of C, Si, S, P, Mn, Mg and Ce on ductile Fe castings are described.--M.G.S.
Descriptors: Malleable iron, Melting; Nodular iron, Melting Quality control
Section Headings: 51 .(FOUNDRY)

850369 83-510557
Important Role of Inoculant in Cast Iron.
Karkhanis, S S ; Taskar, V G
All India Seminar on Small Scale Metallurgical Industries in India--Scope for Development in Techniques and Processes, New Delhi, India, 10-11 Sept. 1981
Publ: Indian Institute of Metals, 2, Sambhunath Pandit St., Calcutta, India, 1981
Pp 8
Journal Announcement: 8306
Document Type: BOOK
Language: ENGLISH
The role of graphite in structure and properties of cast iron is reviewed. The effect of inoculant is to promote formation of Type A graphite and reduce incidence of Type D and E graphite which cause a chilled and mottled structure. The effect of inoculant on section sensitivity, mechanism of inoculant and different types of inoculant are discussed. A comparison of the inoculating effect of ferrosilicon, calcium silicon, SM sub 2 alloys, metallic Ca and Al is given. Factors to be considered include carbon equivalent of the Fe, section thickness of casting, quantity of metal, type of inoculation and temp. of liquid Fe.--M.G.S.
Descriptors: Gray iron, Melting; Graphitic structure, Alloying effects; Inoculation
Section Headings: 51 .(FOUNDRY)

822935 82-450654
A Survey of Oxygen Sensor Uses in Steel Foundries
Goto, K
Met. Technol. (Jpn.) 51, (11), 33-37 Nov. 1981
Journal Announcement: 8210
Document Type: ARTICLE
Language: JAPANESE
A survey of use of oxygen sensors in steel foundries (five major steel corporations and two companies of special steels) was made. Results are given for the number of O sensors being used, purposes of their use and methods of applications. In steel refining, the use of the O sensor helped to improve the quality of steel such as the constant O concentration, the suppression of void formation on the slab surface, etc. The manufacturers of special steels are not using O sensors because of the interference of additive elements in special steels in correlating an O concentration with the e.m.f., the small-scale production of the steels, etc. 9 ref.--T.T.
Descriptors: Steels, Refining; Liquid metals, Chemical analysis; Oxygen probes
Section Headings: 45 .(FERROUS ALLOY PRODUCTION)

807391 82-720209
Small Scale Foundries for Developing Countries: A Guide to Process Selection.
Harper, J D
Publ: Intermediate Technology Publications, 9 King Street, London, WC2E 8HN, England, 1981
Pp iv + 66, 25 x 18 cm, illustrated (U.K. pounds sterling 4.95, overseas pounds sterling 6.20); ISBN 0-903031-78-7
Journal Announcement: 8205
Document Type: BOOK
Language: ENGLISH
Descriptors, Foundries; Casting
Section Headings: 72 .(SPECIAL PUBLICATIONS)

779123 81-450724
The Manufacture of Reduced Iron Using the SL/RN Process.
Yatsunami, K
Nippon Kokan Tech. Rep. (Overseas) (27), 21-30 Sept. 1979
ISSN: 0546-1731
Journal Announcement: 8109
Document Type: ARTICLE
Language: ENGLISH
The design and operation of a small scale direct reduction plant to utilize foundry dust and several sorts of solid fuel as reductant, is described. A new dolomite desulfurizing process renders the reduced iron pellets obtained suitable for BOF use, instead of scrap.--R.D.P.
Descriptors: Iron and steel plants, Design, Direct reduction ; Dust; Fuels; Iron ores, Reduction (chemical); Desulfurizing Pellets, Reduction (chemical)
Section Headings: 45 .(FERROUS ALLOY PRODUCTION)

771644 81-510725
A Method of Dispersing Graphite Powder in Aluminum Alloy Castings.
Yuasa, E ; Morooka, T
Imono (J. Jpn. Foundrymen's Soc.) 52, (7), 394-399 July 1980
ISSN: 0021-4396
Journal Announcement: 8107
Document Type: ARTICLE
Language: JAPANESE
Some foundry techniques for adding Ni-coated graphite particles to molten Al alloys were investigated. The first method was that of introducing graphite particles by injecting argon gas stream from the bottom of the molten bath (injecting method). The second method was that of plunging pellets prepared from a mixture of aluminum powder and graphite into the melt (pellet method) and the third method was that of pouring graphite particles directly into a deep vortex of the melt created by an impeller mixer in the melt (vortex method). The vortex method was judged to be the most suitable technique of graphite dispersion for the small scale production of graphite--aluminum alloys. Using the vortex method, up to 17 wt.% graphite can be dispersed into the aluminum alloy. Coarse graphite particles (420-840 mu m) with continuous nickel coating of about 6 mu m thickness were successfully introduced into the melt of Al--Si alloys. Optimum mixing temp. of the melt for the addition was about 50 deg C higher than the liquidus of the alloy. There is a flotation of the graphite particles in sand mold casting, but a uniform distribution of the particles is obtained in water-cooled chill casting. 10 ref --AA
Descriptors: Aluminum base alloys, Casting; Graphite, Alloying additive; Dispersion; Sand casting; Powders; Nickel, Coatings
Alloy Index(Identifier): Al-8Si, AL
Section Headings: 51 .(FOUNDRY)

758927 81-510306
The Continuous Horizontal Casting of Steel.
Sugitani, Y
Bull. Jpn. Inst. Met. 18, (12), 834-836 Dec. 1979
Journal Announcement: 8103
Document Type: ARTICLE
Language: JAPANESE
The problems associated with the continuous horizontal casting of steel are discussed based on the results obtained with a small scale experimental unit. Some solutions to the various problems are proposed. For example, in the case of the casting of 18-8 stainless steel, the resistance inside the mould is high and drawing is difficult without a lubricant. This problem was solved by using a Ni plated mould with a lubricant (CF) in the plating. Results obtained with this experimental unit indicate that the continuous horizontal casting of a small cross section products is possible on a practical basis but further research is necessary for the casting of larger products. --V.T.S.
Descriptors: Carbon steels, Casting; Stainless steels,

Casting; Continuous casting; Lubrication
Alloy Index(Identifier): SUS304,SUS316,SUS310,SUS321, SSA/ SUS430, SSF/ SBOC, SCH
Section Headings: 51 .(FOUNDRY)

656473 79-450081
The Development of a Small Scale Cupola.
Fahy, F W ; Leong, K H
Castings (Sydney) 24,(3/4), 21,25,28 Mar.-Apr. 1978
ISSN: 0008-7521
Journal Announcement: 7902
Document Type: ARTICLE
Language: ENGLISH
After reviewing earlier attempts to develop a 75 mm dia. cupola to study the effect of the various elements in Fe upon the ability of cast iron to absorb C, a description is given of work undertaken more recently in this field. A study was first made of the operation of cupolas in two foundries, and from this various lines of development were determined. A description of the final experimental procedure adopted is presented together with illustrations of the cupola used, indicating its important parameters. Data were obtained from a run in which operating conditions had been stabilised and a limited heat balance produced. It is concluded that from the basic data obtained an experimental heat balance can be constructed and as such provides a very basic experimental unit.--P.M.D.
Descriptors: Cupola Design; Heat balance
Section Headings: 45 .(FERROUS ALLOY PRODUCTION)

506806 76-510155
Simulation of Metal/Mould Reactions in a Small-Scale Laboratory Test.
Frawley, J J ; Moore, W F ; Kiesler, A J
Fonderia Ital July-Aug. 1975, 24, (7-8), 222-232 (Italian).
Journal Announcement: 7603
Document Type: ARTICLE
Language: ITALIAN
Descriptors: Steels, Casting; Vacuum casting, Alloying effects; Molding materials, Reactions (chemical); Reactions (chemical)
Alloy Index(Identifier): 1Cr-0.5Mo, SACM
Section Headings: 51 .(FOUNDRY)

415864 74-510336
Some Aspects of Small-Scale Continuous Casting Plants.
Takehara, Eiro; Nishimura, Osamu
UN-IDO Third Interreg Symposium Iron Steel Ind Preprint Brazil, Oct. 1973, ID/WG/146/45), 25 p.
Journal Announcement: 7408
Document Type: ARTICLE
Language: ENGLISH

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DIALOG File 32: Metadex 66-87/Sep (Copr. 1987 ASM International)

Descriptors: Continuous casting; Slab casting
Section Headings: 51 .(FOUNDRY)

050206 67-067325
COMPLEX MICROALLOYING OF CUPOLA MALLEABLE IRON FOR SMALL-SCALE PRODUCTION
TALANOV, P I ; KUKINA, R A
LITEINOE PROIZV NO 5, MAY 1966, P 29-32
Journal Announcement: 6701
Document Type: ARTICLE
Language: ENGLISH
Descriptors: MALLEABLE IRON, MICROSTRUCTURE; GRAPHITIZATION BORON, ALLOYING ADDITIVE; INOCULATION; CASTINGS
Section Headings: 66-06 . (FOUNDRY)

Appendix K

Research and Development activities in the non-ferrous metallurgy

RESEARCH AND DEVELÓPMENT IN DEVELOPING COUNTRIES

Research and Development in Latin America

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Argentina	INTI	0.5	Extraction of Ni and Co.	14
Brazil	CEPED	13.0	Beneficiation, biological leaching of Cu ores. Review of environmental conditions in Cu mining and ore dressing. Development of Cu alloys for coin fabrication.	160
Brazil	CETEM	2.0	Pilot plant studies of Cu, Pb and Zn ore treatment. Processing of Sn ore fines. Cu and Ni minerals bulk flottation. Electrorefining of Cu with pulsating current.	149
Brazil	CTP	0.5	Environmental control in the Cu and Ni industries.	10
Brazil	IPT de S. Paulo	0.04	Extraction of Cu from complex oxidized ores.	2,600
Chile	CIMM	2.0	Cu ore dressing and metallurgy. Au processing methods for "small mines". Separation of Mo and As. Recovery of rutile from copper tails. Hydraulic transportation systems for solid materials.	300
Chile	INTEC	1.0	Heap leaching Cu-ores, of Au and Ag Gravitational concentration and tailing recovery Cu, Au, Co, W, etc.	72
Chile	INACAP	8.5	Training on process control and automation in the copper industry.	121
Chile	Sociedad Minera Pizarro Lida	n.a.	Exploration and beneficiation of Pb deposits. Alternative Al and Pb technologies. Pb alloying.	6
Chile	Universidad de Tarapaca	0.05	Non-destructive testing, standardization and quality control of metal products.	52
Colombia	CIDI	0.12	Recovery of Zn in an iron and steel plant.	15

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Costa Rica	Instituto Tecnologico	0.04	Extraction of Al minerals. Recycling and refining of Al alloys.	8
Ecuador	Politecnica de Litoral	0.06	Al alloying. Scrap recycling and refining. Pure Ni electroforming Zn and Cu alloys.	7
Jamaica	Jamaica Bauxite Institute	n.a.	Improving the processability of Jamaican boehmitic and goethitic bauxites.	26
Mexico	Instituto Politecnico Nacional, Esiquie, Laboratorios pesados de Ingenieria Metalurgica	0.23	Leaching of concentrates of non-ferrous metals. Substructures produced at high temperatures. Optimization of flat rolling sequences.	50
Peru	INGENMET	1.708	Exploration and evaluation of deposits (Cu, Pb, Zn, Ag); (Sn, W, Au). Problems of underground mining, beneficiation of ores. Polymetallic minerals flottation. Bacteriological leaching of Cu minerals.	75
Trinidad and Tobago	Caribbean Industrial Research Institute	6.0	Experimental casting prototype development.	60

LIST OF ABBREVIATIONS

Research Institutes

CEPED	Centro de pesquisas e desenvolvimento
CETEM	Centro de Tecnologia Mineral
CTP	Centro de Tecnologia Promon
IPT	Instituto de pesquisas tecnologicas de Estado de Sao Paulo S/A
INTI	Centro de Investigación para las industrias minerales
CIMM	Centro de Investigación Minera y Metalurgica
INTEC	Comite de Investigaciones Technologicas de Corfo
INACAP	Instituto Nacional de Capacitacion Profesional
CIDI	Centro de Investigaciones para el desarrollo integral
INGEMMET	Instituto Geologico Minero y Metalurgico
CMRDI	Central Metallurgical Research and Development Institute

Research and Development in Africa

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Egypt	ASSIUT University Department of Mining and Metallurgy	0.15	Production of Al-Ti, Al-Si alloys. Beneficiation of nepheline-cyanite. Recycling of materials in the Al industry.	28
Egypt	CMRDI	0.7	Activation of bentonites. Cryolite regeneration. Alloy and surface protection development. Cu refining. Pb recycling.	72
Egypt	TABBIN Institute for Metallurgical Studies	1.0	Production of high quality Al castings. Corrosin resistance of Al-alloy castings. Anodizing. Heat treatment of brasses.	50
Kenya	Kenya Industrial Research and Development Institute	0.98	Analysis of metal contamination in canned fruit and vegetable products.	45
Morocco	Direction de la Geologie	2.45	Exploration of deposits of non-ferrous metals. Investigations on precious metals associated with Cu and Pb.	300

Research and Development in Asia

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
China	General Research Institute for Non-Ferrous Metals	n.a.	Beneficiation of ores, process and quality and environmental control, alternative technologies, manufacture of Al and Cu products. Recycling.	1,200
China	Institute of Metal Research, Academia China	3.5	Development of Al- and Ni-based alloys, copper tubes and wire. Quality control in the production of Al and Ni.	1,200
China	Shenyang Aluminium and Magnesium Research Institute	n.a.	Exploration and beneficiation of diaspore bauxite. Surface mining. Engineering for Al industry including main and auxiliary utilities for processing.	900
India	College of Engineering, Department of Metallurgy PUNE	1.8	Ni-Ti shape memory alloys. Liquid forging of Al alloys. Al/Al and Al/Cu rollbonding.	12
India	Indian Institute of Science	0.9	Mechanical alloying of Ni, Cr, ThO_2; Al alloys containing Mn and Li. Al, Cu, Zn castings. Bacterial leaching of lean sulphide ores.	350
India	India Lead PVT Ltd.	0.0126	Improvement of refining process. Desilverization. Pb-Sc, Ca-Pb alloy.	15
Indonesia	Mineral Technology Development Center, Department of Mining and Energy	2.0	Beneficiation of fine and sulphide complex ores. Flotation of galena. Production of Al-sulphate. Scope stability study on primary Sn ore.	106
Republic of Korea	Korea Institute of Energy and Resources	0.14	Origin and exploration of non-ferrous metals deposits in the country.	10
Republic of Korea	Korea Institute of Machinery and Metals	19.0	Development of Ni-base super-alloy castings for gas turbine application.	620

Country	Name of the institution	Resources in million US$, 1985	Activities	Staff
Malaysia	Geological Survey Department	5.39	Mineral exploration and assessment.	127
Pakistan	Metal Industry and Development Centre	n.a.	Development of alloys of non-ferrous metals. Melting and casting processes. Moulding sands.	7
Pakistan	Minerals and Metallurgy Division PCSIR	n.a.	Substitution of imported minerals and mineral-based products. Beneficiation of antimonial Pb ores.	34
Philippines	Metals Industry Research and Development Centre	1.2	Al, Cu castings. Electroplating.	128
Thailand	The Metalworking and Machinery Industries Development Institute	n.a.	Colours of jewellery, centrifugal casti..g.	7
Thailand	Regional Centre of Mineral Resources	0.027	Exploration and beneficiation of Pb, Zn, Sn, Ni ores.	9

Note: More information regarding R+D activities and Training opportunities in industrialized and developing countries can be obtained from reference Nr. 75.

Appendix L

UNIDO Concept of the Pilot Demonstration Foundry in a developing country *)

This discussion will treat two aspects, (a) the role of foundry in an economy and (b) the pilot foundry, in order to present a clear picture of the role of foundry, which will serve as background and to indicate how the pilot foundry, seen as a productive unit, fits into practically any scheme of development.

a. The role of foundry in an economy

The foundry is an industrial service industry. A foundry provides intermediate goods to equipment users, manufacturers or builders; it does not provide a 'final product' in the sense that a casting may be directly acquired or used by a member of the public. It has become fashionable to speak of spare parts which are required in order to keep industry and many agricultural activities in operation; the basis of spare parts manufacture is of course the foundry. It may be asserted in passing that almost all parts produced by forging and by machining may also be produced by the casting process. The reverse is rarely true and where small volumes of production are involved, the casting process is selected, over forging.

Modern casting processes can produce castings very close to final shape. This not only reduces the cost of final machining but may frequently also reduce the requirement for investment in machine tools, and for scarce machine tool operators. However, the most important factor concerning the foundry industry is its availability; i.e. it can respond rapidly to local requirements and occasionally to an emergency order for a part required to keep a process in operation. In this sense, one does not enquire as to the cost of the foundry but rather the cost to the economy of not having a foundry.

The above comment must be qualified. A large automotive foundry producing for assembly plants is a somewhat different concept, to that of the true service foundry. The automotive foundry supplies large volumes to the assembly plant for incorporation into vehicles. The service - or jobbing - foundry supplies the parts to keep the assembly plant's machines and equipment in operation. The price of the castings from the automotive parts foundry is of great importance; this is not the case with the products of the service foundry. Here, the opportunity cost is the predominating factor and the service foundry must provide high quality products, of all types, shapes and sizes whenever they are required. Thus, availability is the applicable criterion, not cost.

There is a limiting size for a foundry and this depends upon the types of products which it offers. An automotive foundry in a developed economy can melt 400 tons per day. A specialized service foundry (also in a developed country) may melt 2.5 tons per day. Whereas the former will melt continuously one or two alloys, the latter may process five heats per day, each widely different in composition and properties. The size of the foundry will depend upon the type of market which is to be addressed. Thus the shorter the production runs, the smaller the foundry and clearly the 'service' foundry is directed at those products which have shorter production runs and frequently 'one off' castings in order to keep a client's equipment in operation.

*) Prepared by A. Buckle, Metallurgical Industries Branch, Department of Industrial Operations, UNIDO

The smaller, and one may assert, more metallurgically capable operation charges much higher prices, because the costs of short run production are high, and the rejects are proportionally greater. Whereas the automotive foundry will work at a reject rate of below 1%, certain jobs in a service foundry may result in a rate of over 20%.

The technical requirements of such a varied production lead to a proportionally high overhead cost and an annual production of 600-2000 tons per annum of good castings, implies that overhead per kilo is high. This may lead some to argue that, in such a case, the size of the foundry should be increased; this size is however limited by the average size of orders for the special alloys, which in turn dictates the size of the furnace, which fixes the production capacity. There is also an administrative restriction in that to handle thousands of small orders is not easy, from either the administrative or technical position and if the foundry grows, it will inevitably abandon the smaller and more complicated orders, to a smaller foundry! Thus the small foundry is the inevitable and eternal adjunct to progress, and even when, in the developed economies the larger foundries have been displaced by imports from the developing world, the service foundry is to be found, supplying the critical requirements of local industry and other, and being very profitable.

b. The Pilot (Demonstration) Foundry

The first affirmation is: that it is unacceptable to install productive equipment in a developing economy and allow it to be under-utilized or not utilized at all.

The structure of Government-administered, and frequently, of Government-owned plants is that the bureaucratic and operative restrictions are such as to cause them to be a nett financial load to the economy. The problems of purchasing raw materials, selling finished products, paying competitive salaries are too well known to merit further discussion and thus experience indicates that it is most reasonable to assert that the plant must be installed only where such conditions are allowed as to offer a high guarantee of success.

Where the Government of a developing country is required to include a pilot plant, an institute or industry in the national budget as the recipient of what is in fact a subsidy, there is little doubt that after a period of time, no subsidy will arrive. Such monies as may be available, will be required for education. health, agriculture and similar basic requirements, and the above mentioned institutions should be expected to contribute to these activities, not drain resources from them.

The pilot foundry, if allowed to operate within a correct state administrative structure, can operate as a 'service foundry'. Its size is adjusted to the type of market to be expected and this is a profitable market. It is relatively easy to ensure that the plant be self-sustaining, and that it contribute considerably to the proper operation of industry (as noted in section a.) whilst offering a source of excellent training for a reduced number of persons at all levels of responsibility. The professional characteristics of the metallurgists, engineers and analytical chemists who will work with or in co-operation with the foundry, must become such that their knowledge will be of considerable use to industry, given that the operation of a 'service foundry' includes of necessity a consultancy service.

The foundry must help its clients determine their requirements, i.e. is the spare part made of stainless steel? If so, which and at what hardness - heat treatment? (It should be clear from this that without a good foundry, it is nonsense to speak of a 'capital goods industry', for if good spares cannot be manufactured, neither can machines be produced.)

It is a characteristic of the foundry industry in developing countries, that, after some 5-10 years, employees leave the plant to set up their own operation. In general, these second operations are not of a good standard because the original plant where they learned their trade, was abysmal. This can be detected in many countries, but if the plant is a properly operated, technically adequate unit, then the young metallurgists and engineers will clearly be in a better position to progress themselves to the benefit of the economy.

As a final note, it is affirmed that without outside assistance, it is practically impossible for a developing country to assemble all the skills and experience required to ensure that a service foundry will operate properly.

A carefully programmed training schedule, organized and overseen by experts from the service foundries, a clear selection of products of steadily increasing complexity of manufacture to be produced on traditional, well-tested equiment, backed by an unsophisticated laboratory service of the type that has proven its worth in hundreds of similar foundries in Europe and North America - will ensure the proper functioning of the plant.

It has been asserted that the market for specialized (non-automotive) short production run parts is profitable. Experience in South America indicates that such parts can be sold (i.e. including profit) at a price of some 50% of FOB factory price for equivalent imports. The limiting factor will be the total market size.

<u>Conclusions</u>

It has been shown that the service or pilot foundry is an essential element within an economy. It has been stated that, given a market of adequate characteristics and the proper administrative structure, such a foundry can be easily self-supporting and that, if a sufficient market exists for castings, it can be a source of properly qualified personnel to start their own operation. Where a foundry industry already exists, the pilot foundry can be a source of training opportunities and, in the natural course of events, other foundries who wish to progress, will look to the pilot foundry as a source of qualified personnel.

It is proposed that the pilot foundry which the Government of Ethiopia wishes to establish, will fulfill these objectives.

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