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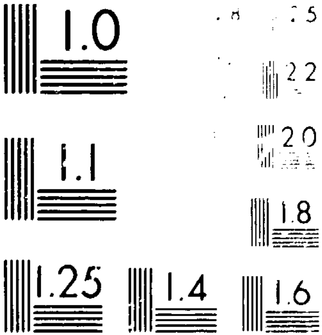
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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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Development and Transfer of Technology Series

No. 16

METAL PRODUCTION DEVELOPMENT UNITS

UNITED NATIONS

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

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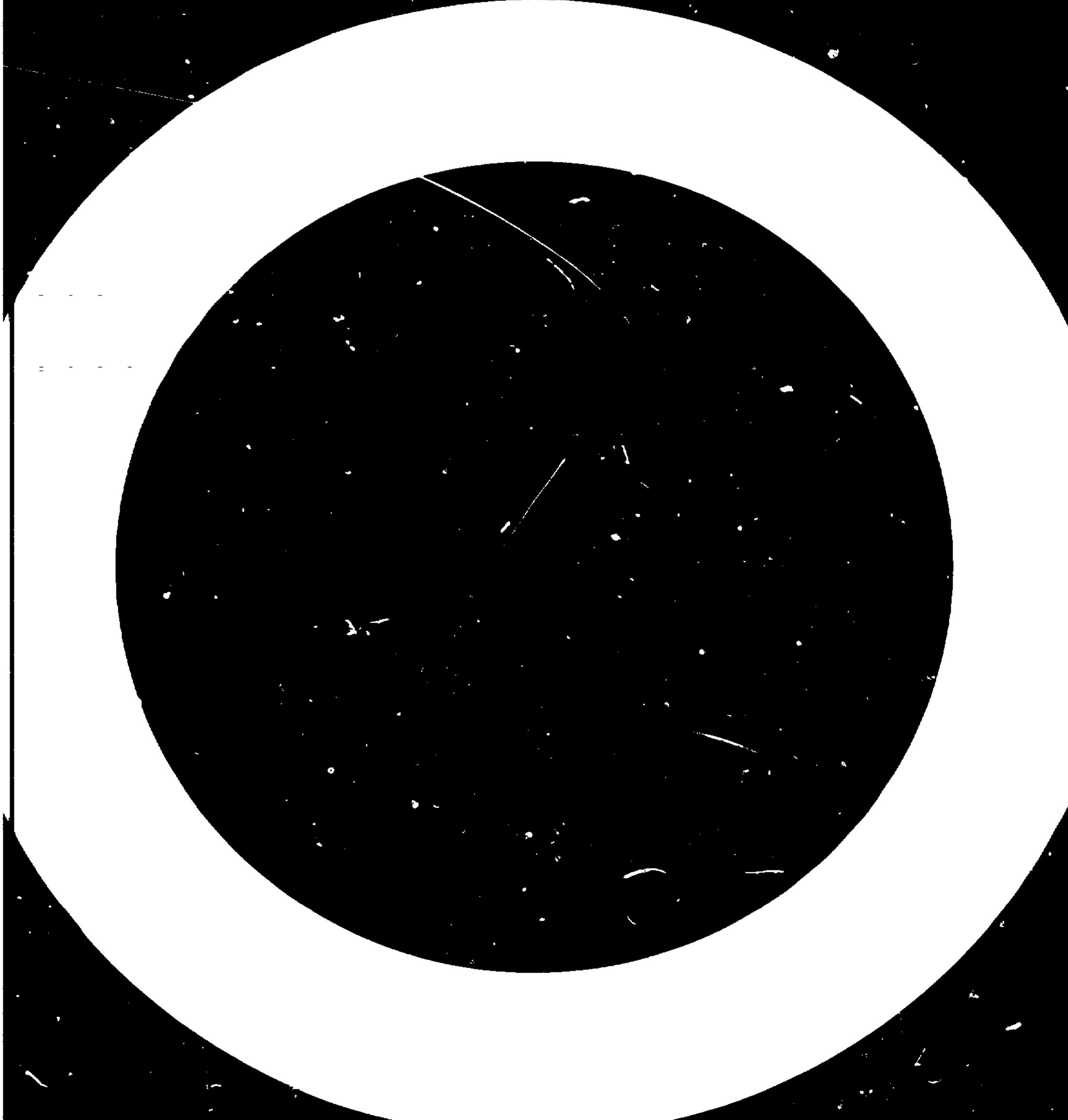
UNITED NATIONS
New York, 1982



Preface

The strengthening of metalworking capability in developing countries is fundamental to supporting their efforts in industrial development. Without this capability, one can hardly imagine a viable technological independence of the developing countries from the industrialized countries.

To provide an option for developing countries to build up and strengthen such capabilities, the United Nations Industrial Development Organization (UNIDO) has undertaken, with financial support from the Government of Italy, to develop a prototype facility referred to as a metal production development unit (MPDU). The work was carried out by UNIDO and FIAT Engineering S.A., Turin, Italy. The main objectives of the MPDU are to:

(a) Create the capacity to produce, as well as adapt and eventually substitute imported metal products, components and spare parts;

(b) Provide tools and moulds for metal-transforming operations carried out within the country;

(c) Assist in creating the materials required for metalworking machinery construction;

(d) Be the base for a capital industry.

The MPDU has been conceived to reduce the level of economy-of-scale for the production of metal products, components and spare parts to suit the requirements of the country. It applies both traditional and modern metal-transforming techniques, with sufficient flexibility to take into consideration the specific needs of the country, such as the available labour forces, size of market and orientation of demands. MPDUs are modular units that include forging, casting, metal-forming and machine installations. In addition, they include the facilities necessary for training cadres of engineers, skilled and semi-skilled technicians, and operators for the metal-transforming sector of industry.

The present publication would be used first by planners and decision-makers to assess the priority an MPDU project should have in their national development plans. The next step would be the preparation of a technical implementation plan based upon a technical market survey, which would tailor the project to the country's specific plans, needs and financing possibilities. The plan would then be elaborated flexibly so that it could respond to the needs of the future. In other words, the MPDU should be promoted on a modest, not too ambitious scale and should function as a kind of development pole of the metal-transforming sector, particularly in remote areas where it is often difficult to obtain the services of a larger, centralized unit.

Anyone interested in further examining the possibility of the design and establishment of an MPDU for their country's metal-transforming sector should contact the Head, Development and Transfer of Technology Branch, Technology Programme, Vienna International Centre, P.O. Box 300, A-1400 Vienna, Austria, directly or through the local resident representative of the United Nations Development Programme (UNDP).

EXPLANATORY NOTES

Costs, unless noted, are those estimated for September 1979.

References to dollars ($) are to United States dollars.

Use of a hyphen between dates (e.g. 1960-1965) indicates the full period involved, including the beginning and end years.

A full stop (.) is used to indicate decimals. Thousands, millions etc. are set off by spaces unless a symbol for a monetary unit precedes the number.

References to tons are to metric tons (tonnes), unless otherwise specified.

The following notes apply to tables:

Three dots (. . .) indicate that data are not available or are not separately reported.

A dash (—) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

Totals may not add precisely because of rounding.

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used:

Technical symbols

CO_2	carbon dioxide
O_2	oxygen
SiO_2	silica

Organization

EEC	European Economic Commission

Other

MPDU	metal production development unit

CONTENTS

Tables

Page

Figures

I. The concept of metal production development units (MPDU)

A. The need for industrial infrastucture

The metalworking industry is the centre-piece of any attempt at sophisticated industrialization because it supplies all tools and tool systems to the entire manufacturing industry. At the same time, the metalworking industry supplies essential consumer durable goods and capital goods in general.

For the metalworking industry to serve as the backbone of industrial infrastructure, the following are necessary:

(a) Specialized technological institutes;

(b) Tool, die and mould making factories;

(c) Manufacturing and product engineers;

(d) Parts manufacturers for industrial users. These require facilities such as a foundry or forge;

(e) Stocks of parts for production and of tools and equipment;

(f) Services to industry, including machine-tool repair and provision for further training of skilled workers.

Although much effort has been spent in developing the metalworking industry in developing countries, the core of the developmental problem, namely the need for the facilities above, has most often only been attacked in a superficial manner by setting up general workshops and foundries which serve only common maintenance needs and cannot provide a qualified service for the manufacturing industry. The result has been that most often engineering is imported along with parts. Even if some parts are locally made, the tools are usually imported.

The purpose of the MPDU programme is to overcome these shortcomings by creating metal-working units which will provide the basis of a local parts and components industry and assist in creating new industries, new product lines and tool making facilities. In addition the MPDU will provide a sophisticated maintenance and repair service for the manufacturing industry. To a greater or lesser extent, in various areas, the MPDU can thus provide, on a long-term basis, much of the industrial infrastructure needed for the metalworking industry.

Basic processes

Casting and metal forming are the basic processes of the MPDU. These two basic processes make all specially formed parts and components from the products of cast-iron and non-ferrous metal foundries, from sheet-metal stamping and forming shops, steel-fabricating shops, and from forging, hot-stamping and machine shops. The tools, moulds, dies and patterns that give the individual components their shape are common to these shops. Highly experienced engineering talent is required to create the designs for the patterns and dies. To make the tools, superior craftsmanship is needed and is provided by tool-makers and pattern-makers.

Adapted technology

Technological sophistication may increase product quality and may reduce labour consumption through mechanization and automation. Sophistication may reduce the need for higher skills in mass production; however, this often requires a very large capital investment.

For developing countries it is essential to manufacture with low capital investment. It is also usually necessary to produce products which may be adapted to local conditions. Thus, it is frequently not possible to justify a high level of mechanization or automation for the relatively small volumes which prevail in developing countries.

To obtain high product quality from low-volume production it is necessary to have production skills and to have the ability to design and make the basic tools and dies. This is because tools adapted to the requirements of developing countries are difficult to have made abroad. They usually have to be specially fitted and may require reconditioning, sharpening etc. The manufacture of these tools is very labour intensive and manufacture can thus eventually be made competitive in the developing countries. Furthermore, products can often be redesigned to accomodate far less capital intensive production. Thus it is essential to pay due attention to in-depth skill development and to engineering, and not simply to think in terms of operator training.

The multiplier effect

Most metalworking factories set up in developing countries use tools and product design bought in developed countries. The factory has usually started to make simple products which require short-term operator training. This is because many, if not all parts have been imported. Such production rarely creates any industrial development. That is, the existing production rarely increases as there is no development of in-depth training of workers and engineering capability.

In the developed countries, the facilities for engineering and tool making come from various specialized companies. The transnational companies have self-sufficiency in this respect. For developing countries it is rarely commercially justified to have a company that will be self-sufficient in these faculties, nor is it justified to have specialized companies provide these services. For this reason, the initial nucleus of such services must be a central unit, to which technical assistance has been provided. The technical assistance will develop skills in engineering and tool making, and provide facilities for this training. Initially it is not possible to fully exploit the facilities; however, a facility can be created that will have a multiplier effect and be able to assist existing industries to develop themselves and to create new industries and product lines. Most important, the presence of the MPDU will create infrastructure and facilitate overseas investment. The MPDU may assist the investor and assist the Government in screening and adapting proposals. These proposals should use technology appropriate to local conditions.

A modular approach to MPDUs

To create all the basic facilities for development of metalwork in one unit at one time would be very costly and is not always initially necessary. This is because few countries are able to utilize all the facilities simultaneously. For this reason, only two basic modules, to which optional modules can be attached, are suggested. The basic two modules are the cast-iron foundry and the metal-forming factory. These two inherently different modules may be able to support a viable operation by themselves. Each of these modules should have a special engineering department and precision workshops to provide tools and to support the main operation. In the case of the foundry, a machine shop to machine the castings and provide an in-depth maintenance and repair service is necessary. In the case of the sheet-metal factory a tool and die making shop with sophisticated machine tools and equipment and maintenance facilities is needed.

In both cases these basic units will support the industry with an output of quality parts and components. The units will provide essential services in manufacturing engineering and for maintenance of auxiliary facilities. This will improve the economic base of the MPDU. A non-ferrous metal-casting facility and a forging and hot-stamping plant may be added to the casting and metal-forming units respectively. Steel casting may be added later to the casting unit. These additional manufacturing facilities are difficult to justify on their own (without the other MPDU units) in developing countries except in special cases.[1]

The production of parts

The main production should be of cast or stamped parts for other manufacturers, so as to not compete with assembled products. The parts may be for the following product groups:

- Agricultural implements (ploughs, carts)
- Building components (windows, hinges, locks, louvers)
- Pots, pans, cookers, heaters
- Food-processing and other plants (beverages, meat)
- Drain, sewer and road fittings (signs, fencing, posts)
- Railway, truck and hoisting equipment
- Pumps, engines, brassware (eventually machine tools)

B. Justification for technical assistance for training and implementation

The training of tool- and pattern-makers and the development of manufacturing and product engineering capability is extremely costly. The development of these skills and capabilities in the developed world is borne by technical institutions and by large companies which train engineers and precision workers with on-the-job training programmes. This is impossible in the developing countries, as there are no factories at which young engineers and precision workers can be trained by senior engineers and tool-makers. New facilities must have workshops that are equipped for training and for manufacture of tools and patterns. Staff that can provide the training and

[1]Developing countries in the context of this paper do not include partly-industrialized countries.

guidance both for the workshop and the engineering department must be available. A tool-maker or a pattern-maker needs seven to eight years of training before being able to work without guidance. A manufacturing or product engineer is not of real value until after five years of senior guidance. It may take longer to develop a tool designer. Table 1 indicates the training required for the MPDU.

It is also beneficial to have selected local engineers, foremen and managers who can undertake several months of familiarization training with companies in developed countries. Training in specialized subjects such as cast-iron product design may be done by short-term (four to six months) in-plant fellowship training. In-depth training should be provided for precision workers. This will require technical expertise and equipment, and entail costs for maintenance allowances for trainees and counterpart instructors. Trained machinists cannot easily become precision workers as the discipline for precision work has to be taught early in the training process.

As the MPDU will initially not have a developed market, production by the units will develop gradually. Marketing and engineering will be essential to create demand for production. Tools and patterns must be designed and made during the initial period. This period will comprise training, production implementation, and the opening and development of markets. The local government may be expected to help finance this stage. These costs are of such a nature tha they may also justify soft loans or grants for capital investment.

Activities and output

Marketing and manufacturing engineering

The objects of marketing and manufacturing engineering are to:

(a) Identify production alternatives for cast components and for forged or for sheet-metal components;

(b) Produce a technical and economic analysis of those new industrial ventures that may be future users of the output of the MPDU. This includes screening technology transfer proposals, license negotiations, and undertaking viability analysis;

(c) Design tools and patterns as may be needed by the MPDU and by industrial clients.

An overview of viable production alternatives for the MPDU is in the appendix to this chapter.

Production

The object of production is to start actual production of parts and components for the industry in the second or third year of operation, so as to reach full production for one shift after four years.

Training

The object of training is to train 15 precision-worker-trainees per year and thus to produce

TABLE 1. TRAINING REQUIRED FOR THE MPDU[a]

Type of training	*Years required*	*Cumulative years*	*Comments*
Basic	2.25		Training in precision work for 4 000 h. Courses include 800 h theory and 2 000 h machine tool study
Basic specialized	1.25	3.50	Trainees will separate into three groups. Machine tool fitters will have 2 200 h including 200 h theory, precision machinists will have 2 200 h machine tool operation, tool sharpening and setting, including 200 h theory. Tool and pattern makers will have 2 200 h training including 350 h of theory
Senior specialized	1.00	4.50	Trainees will continue in three groups, production technicians will be drawn from machine tool fitters; tool and die designers will be drawn from the precision machinists; advanced tool and pattern makers from the tool and pattern makers. All groups will have 1 800 h. The pattern makers will have 100 h theory. The other two groups will have 200 h theory
Journeymanship	1.50	6.00	
Supervisory	1.00	7.00	The supervisory course will include 1 day per week formal training, and 4 days per week on-the-job training

[a]Trainees will have prior O-level mathematics or equivalent.

within four to five years journeymen, tool makers and pattern makers. It is assumed that 10 such trainees should graduate per year for every 15 accepted for training. Some of these graduates may later become trainers, technicians and designer draftsmen.

It is also planned to train production workers, machine-tool operators, moulders, casting and melting operators for two to three years to enable them to work as skilled workers. Training is also planned for counterpart trainers and foremen. Counterparts should be trained by each expert working for the project. A further feature is on-the-job training of engineers who, after five years, may be able to operate on their own in some operations. Engineers can be trained by engineering experts with two trainees per expert.

Long-term multiplier effect

Fully experienced engineers and technicians may eventually become factory managers or technical supervisors in other companies. On the basis of studies made by the engineering department, subsidiary companies may be established with participation of the MPDU itself, as well as of private industries and overseas investors who may also supply overseas market outlets and know-how.

Inputs

Capital costs

Capital costs should be financed by:

(a) Government or local equity funding for buildings;

(b) Soft loans (at least for training) or commercial finance (from equipment-supplier countries, or from local finance institutions).

Training assistance

Local training costs in the form of maintenance allowances for trainees and instructor costs are to be subsidized by the Government. Non-local experts may be financed either through the UN or EEC or bilateral funds. This is also true for non-local fellowship training.

Pre-operational costs and working capital

Basic working capital is to be financed by soft loans. In addition these funds may be needed to cover the initial pre-operational costs. These funds may be raised by the sale of shares or by the Government from other grants.

Promotional costs

Capital may be needed to be invested in promotion of the local engineering services of the MPDU. This promotion can be financed by the Government or by other grants and will encourage small entrepreneurs to buy engineering services from the MPDU rather than from abroad.

C. Work plan

Table 2 is a work plan for both basic MPDUs, casting and metal forming. It shows activities over a five-year period. A more detailed work plan will be made for each of the MPDUs in the technical implementation plan or final project document.

Effective participation by industry

It is anticipated that an MPDU should become economically self-sustaining. It is therefore essential that the MPDU be able to sell its services and products through trade and distribution systems. It will also be an advantage if the MPDU produces products with characteristics accepted in the market areas which are to buy the products. It is thus necessary to have either agreements or ties to the local manufacturers.

As one of the essential aspects of the engineering will be to create a basis for new industries, it may be important to have local investors and also have foreign participation. This may provide markets or technical know-how that the MPDU cannot yet create itself.

Organization

The following methods of organization are possible:

(a) A government-funded institution;

(b) A wholly government-owned company, operated as a business;

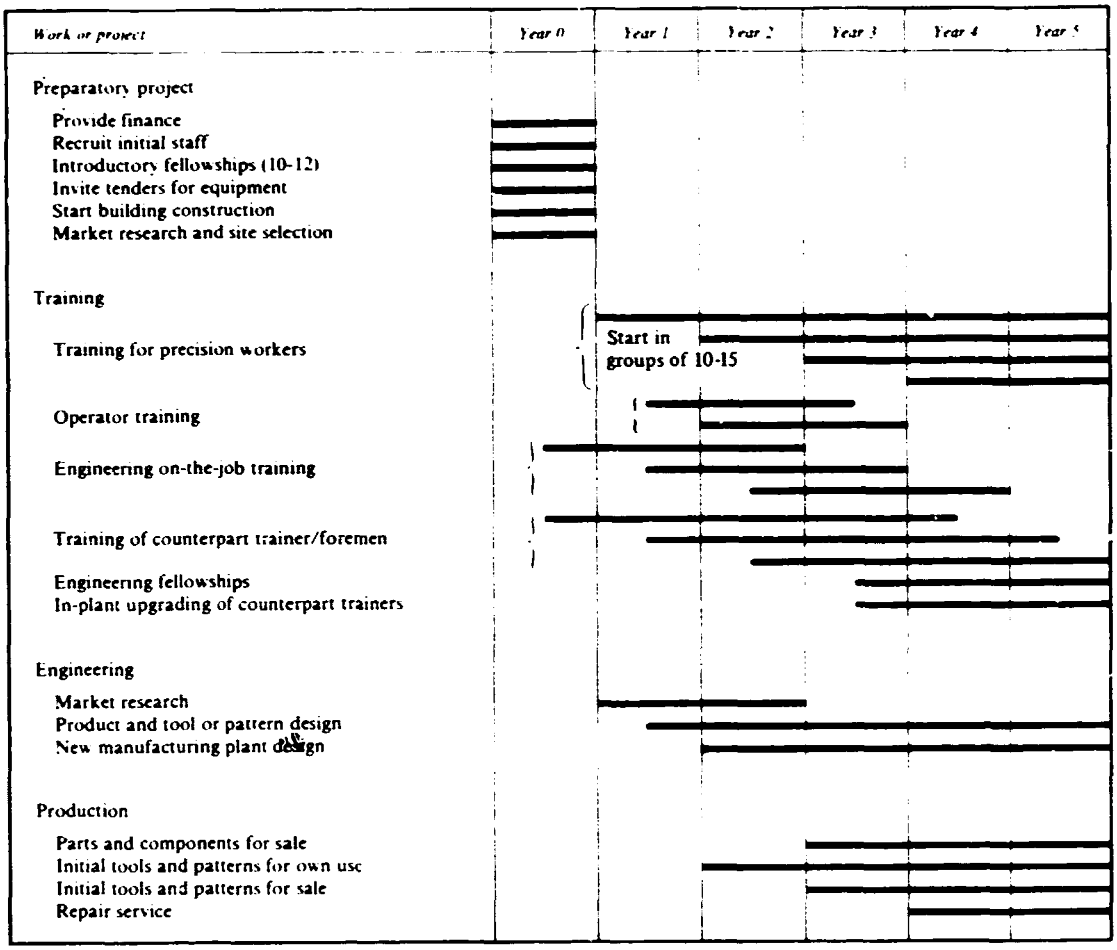
(c) A government-controlled company, with financial participation by industry. Participants will preferably also be future buyers of products and services;

(d) Separation into two organizational parts. One part is institutional and undertakes initial basic training. The other part is commercially oriented, and may be operated as *(b)* or *(c)* above;

(e) A co-operative.

Experience with government-funded institutions for this type of operation is one of low efficiency. Such institutions are subject to government regulations that may not make it possible to

TABLE 2. WORK PLAN FOR MPDU OPERATIONS



retain the best people or may, for example, require shorter working hours than customary, and hamper efficient development.

Possibility *(c)*, above (a government-controlled private company with participation by industry), seems the best solution. This is because a private company would be able to secure some future revenue from purchases by shareholders. Participation from these industries in the overall direction of the company could be beneficial for the company's development. The controlling government shareholding would ensure that the technical assistance programmes, and the training subsidy provided by government were spent so as to secure in-depth development rather than to benefit only the industrial participants.

Solution *(d)* (separation into two parts) is a feasible one. It is important that precision-worker training not be subjected to business pressure to develop efficiency.

The type of operation described under *(c)* has been tried by UNIDO and proved successful under conditions wherein the Government was prepared to leave the control of the company to its board and prepared to provide the necessary training subsidies.

D. Capital and ot[illegible]ents

Capital investment

The estimates for capital requirements are based on a number of assumed conditions and on the ability of the local market to absorb the plant production. The general requirements are summarized in table 3.

The Government should subsidize training for engineers and technicians in their first year. The local training subsidy costs may amount to $100,000 per year over a five-year period. Pre-operational expenses of the order of $100,000 to $200,000 may be paid by the Government.

TABLE 3. CAPITAL REQUIREMENTS FOR MPDU DIVISIONS[a]

(Thousands of dollars)

Nature of investment	*Foundry*		*Metal stamping*	*Other forging*
	Cast iron	*Non-ferrous*		
Buildings	900	–	500	–
Equipment, including installations	2 960	140	3 090	610
Total	3 860	140	3 590	610

[a]Costs are for mid-1970s.

Technical assistance

The technical assistance consists of managers, tool-making instructors and engineering and marketing experts who will initially perform as general managers and shop managers. This programme is suggested to cost a total of $3.8 million for each project. This will be a five-year programme plus an initial preparatory project of one year.

Overseas fellowship training for engineers, technicians and foremen for a five-year period will cost $312,000 for each project. The total technical assistance cost for each project will be approximately $4.1 million.

Simple viability analysis

Some preliminary analyses have been made for the cast-iron foundry including machine shop and engineering, and the tool-making (precision worker) services, including engineering and sheet-metal production.

In summary, a production unit, by itself, will break even earlier, and use less technical expertise than the entire MPDU.

Sheet-metal production will develop in a similar fashion but somewhat slower than foundry production. This is because the money and time requirements for tools is much greater for sheet-metal production than for foundry production. It is difficult at this stage to produce a highly detailed viability analysis for sheet-metal parts. An advantage is that for engineering there are no capital investment costs other than those for building. Thus the sheet-metal department may earn revenue equivalent to salaries by sales or provision of engineering services. After four to five years the engineering services should be able to provide a revenue of two to three times salaries. This income will partially cover overheads.

Appendix

GENERAL MARKET OVERVIEW

A market survey must be conducted to define the market opportunities. The following are general market areas which may be supplied with the products of the MPDU:

- Agriculture
- Off-road transportation
- Vehicle components industry
- Metalworking and mining industries
- Food and related industries
- Construction
- Household appliances
- Valves for industrial use
- Power- and telephone-line fittings

Agriculture

Despite remarkable progress in the mechanization of agriculture, there still remains a need for equipment for animal traction and manual work. An estimate of the need is detailed below.

Manual agriculture

Manual agricultural equipment must have surface hardness, toughness and high elasticity. The basic material is steel, and the main technology is forging with some use of shaped, sharpened and treated plate.

Animal traction equipment

Animal traction equipment is usually a machine on wheels with blades to work the ground. The main technology is assembling of section iron and plate for the supporting structure (with the possible use of modular cast-iron castings). Forging is always essential in the farm equipment field but there is also need for cast iron, especially nodular cast iron.

Items to be produced may include:

Traditional ploughs (forgings and structural steel work)

Rotary-blade harrows (forgings, castings and structural steel work)

Ring rollers (forgings and structural steel work)

Zigzag harrows (forgings and structural steel work)

Seeders with dispenser (shaped plate and cast-iron castings)

Bearings and other parts for animal-drawn carts

Animal-drawn carts

Equipment for power traction cultivators

Popular equipment such as harrows, seeders, graders, clod smashers and sowing machines have been chosen for production. These items contain cast as well as forged and machined parts. Welding is often necessary. It is assumed that household supply is important. The items include:

Spare parts for power cultivators (mainly forgings)

Wood-processing machines (cast parts or forgings)

Ground graders (mainly plate assembly)

Rollers (mainly plate assembly)

Seeders, harrows and cultivators (plate stamping, casting and structural steel work)

Components for sprayers (aluminium casting)

Irrigation equipment

More complex technologies are involved in producing irrigation equipment. Among the technologies are the casting of non-ferrous metals and production of special cast iron.

Typical products are:

Components for centrifugal pumps (all MPDU technologies are involved)

Connections and bends (mainly aluminium technologies)

Components for hand pumps

Components for sprayers

Panels for water reservoirs and roof tanks

Off-road transportation

Off-road transportation includes rail and water transportation. Of the 30 components selected, brake shoes for railway cars are of major importance as there is considerable wear and consequently need for frequent replacement. Some marine spare parts have been considered.

The products are:

Parts for railway cars, and rail transport (forgings, castings, plate)

Bushings and covers (nodular cast iron)

Traction components (forged or shaped metalwork)

Brake components (cast iron)

Boat propellers (non-ferrous alloys)

Parts for moorings (nodular cast iron)

Hooks, turnbuckles, clamps and other fastenings (mainly forged)

Vehicle components industry

Vehicle components include spare parts for motorcars, trucks, tractors, earth-moving machines and industrial conveying and hoisting equipment. Vehicle components subject to easy breakdown, such as pulley systems, fans and traction hooks, have also been included.

The following are representative items:

Brake discs and drums (pig iron)

Oil-tight covers, oil sumps, pistons (aluminium alloys)

Fans (aluminium alloys and stamped plate)

Lights and tool kits (aluminium alloy and stamped plate)

Trolley roofing (stamped plate and structural steel work)

Hubs for tractors and trolley wheels (cast iron)

Trailer traction components, articulated joints (mainly forged nodular cast iron with plate components)

Track lines (forged)

Metalworking and mining industries

The metalworking and mining industries require metal containers, conveyors, gears, supplies for tracks and cars, pulleys and electric motor casings. Typical products are:

Plate bins (shaped plate)

Components for rolling conveyors (plate or cast-iron castings)

Components for overhead conveyors (forgings)

Pulleys and gears (iron castings and forgings)

Equipment for ingot moulds (iron castings)

Blacksmith or smelter equipment (uses all technologies)

Miscellaneous tools (mostly forged)

Food and related industries

Different levels of technological processes in different countries, and from plant to plant within the same country, require an approach to product type on a case-by-case basis. Among the products are:

Components for cereal crushers (mainly plate)

Components for seed-oil presses (cast-iron)

Containers for food liquids (normally stainless-steel stamped parts)

Dies for glass (cast-iron and special alloys)

Stainless-steel vats, tables, containers, for food-processing plants

Wire products (baskets, shelves, dish drainers)

Metal hanging panels

Cookers, water-heaters, solar heaters

Construction

The products considered are products generally of simple castings imported in whole or in part from abroad. Building yard machines and tools are essential items where domestic production may replace imports. The following are construction products:

- Building yard equipment (mostly forgings)
- Scaffolding material (mostly cast)
- Mason tools (mostly forgings)
- Components for building-yard machines
- Implements for rolling shutters or window screening (shaped plate)
- Components for door framing (cast or stamped plate)
- Indoor or other reflectors (cast in aluminium or stamped in plate)
- Drain covers, grates, road-drain wells (cast iron)
- Piping, elbows and unions for drains (cast iron)
- Components for valves, gate valves, unions, for potable or other water (cast iron)
- Street and road signs, road fencing
- Fire hydrants

Household appliances

Household appliance products for the MPDU are:

- Bath-tubs, showers and sanitary equipment (mostly cast-iron)
- Taps (non-ferrous casting)
- Miscellaneous household fixtures and equipment (cast-iron and aluminium castings and shaped sheets)
- Brassware for fittings, stop-cocks, water taps

Valves for industrial use

Valves for industrial use include products that are almost exclusively nodular cast iron. Components include those of gate valves and fittings for gas and oil pipelines. Also included are components of small rotary compressors and radial fans which mostly use shaped-plate castings. Cast-iron pipes, centrifugally or statically cast, must also be considered.

Power- and telephone-line fittings

Possible MPDU items are:

- Connection, support and mooring clamps for power lines (cast-iron and aluminium castings)
- Accessories for overhead line supports (aluminium castings and forgings)
- Cable junction boxes (cast-iron and aluminium castings)
- Waterproof feeder boxes (cast-iron and aluminium castings)

As many countries will soon increase installed power capacity, these items should be the subject of a market survey.

II. Metal forming

A. General considerations related to tool, die and metal pressing units for developing countries

The main goals of the MPDU are:

(a) Production of an adequate level of pressed metal capital goods and spare parts;

(b) Design and production of dies, tools and fixtures to support production of pressed metal parts and to be sold in local markets;

(c) Development of local professional capabilities in administration, marketing, engineering and technology;

(d) Training of workers, for production and for skilled tasks such as pattern-making, precision machining, maintenance and general installation control.

Thus the unit will become self-sufficient and independent of non-local know-how, and it will be possible to supply local industries with engineering, workshop and die-making services. These activities will earn revenue for the factory. The MPDU is, generally speaking, profit and market oriented. This aspect is only one of the components of a broader and more important goal, namely social improvement and auxiliary training.

B. Basic forming technologies

Sheet-metal cold forming

In forming or "drawing", a sheet is subjected to one or more physical transformations by the use of pressing dies to obtain a given geometrical shape. This process normally uses mechanical or hydraulic presses. In more advanced methods other sources of energy are involved. Explosive forming, electrohydraulic or electromagnetic forming, hydrostatic forming, ultrasonics forming (deepdrawing) and other forming methods exist. The drawing tool consists of three main parts: the punch, the die and the blank holder. The punch and die make the inside and outside contours of the stamped item, and the blank holder, which presses the metal against the die, prevents creases and controls the motion of the sheet, which slides along the punch.

During drawing, the metal stretches when it is pressed between the die and the blank holder. During this process the metal expands due to the punching action. The metal then shrinks when the punch is removed. The blank holder may also be used to strain the flowing metal on only a part of the surface. A die for drawing is shown in figure 1.

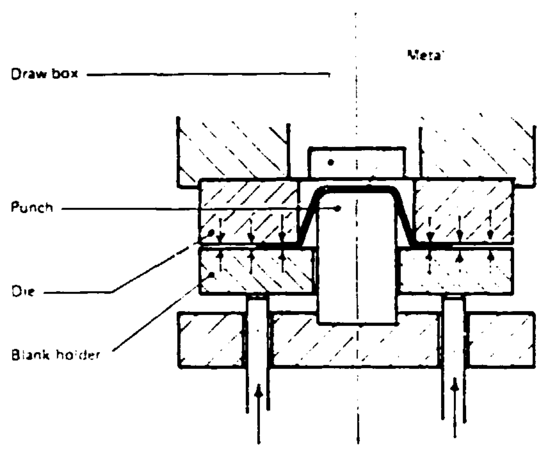


Figure 1. A tool for drawing metal

Detailed studies of different types of deformation have indicated the following important considerations:

Tolerances in forming
Economics of choices of materials
Die design and lubrication
Forming speeds
Deformation paths and strain analysis

A typical operating sheet-metal sequence is: blanking, forming, trimming, punching, beading, flanging, coining and checking. Pieces may be joined together by rivets, snap-rivets, welds or spot welds to make components of more complex products. Some components may alternatively be obtained from pipes or from section irons, which have been processed by first cutting then shaping (carried out with press and suitable dies) and rolling or bending. These process steps are shown in figure 2.

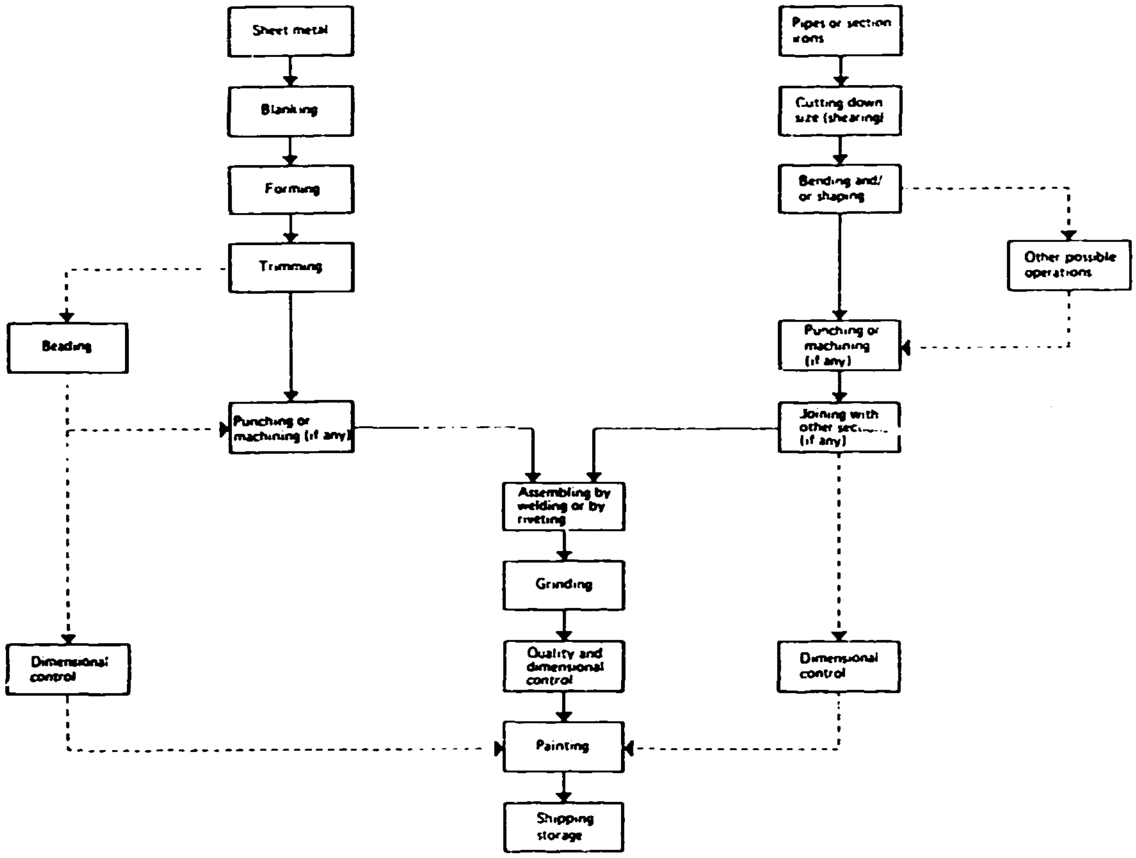


Figure 2. Process steps for sheet-metal operations

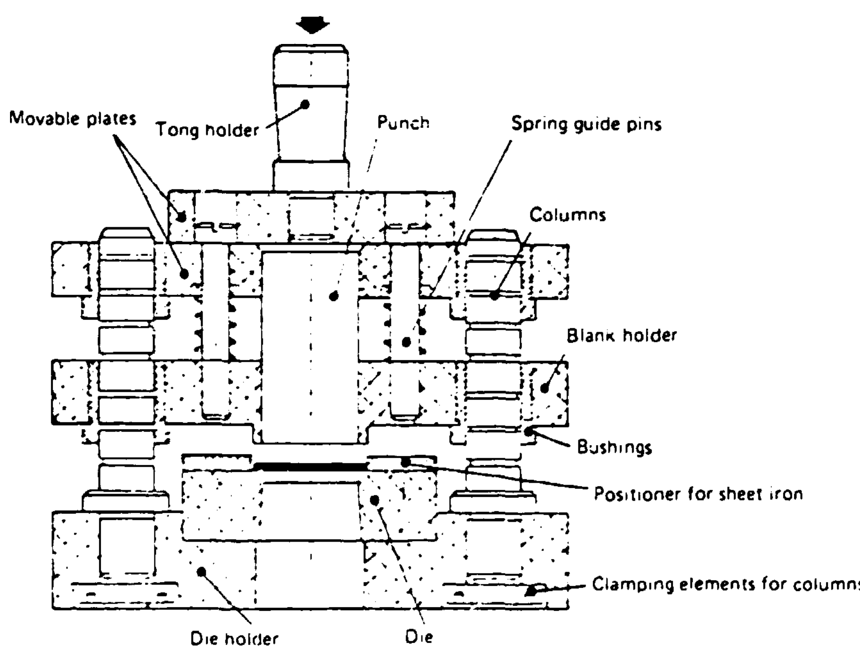


Figure 3. Schematic drawing of a die assembly

TABLE 4. OPERATIONS NEEDED FOR DIE MANUFACTURE

	Operation needed												
Part	*Lathe turning* *1*	*Milling* *2*	*Drilling* *3*	*Boring* *4*	*Tapping* *5*	*Heat treating* *6*	*Grinding* *7*	*Vertical grinding* *8*	*Outside diameter grinding* *9*	*Inside diameter grinding* *10*	*Sharpening* *11*	*Marking* *12*	*Spark erosion machining* *13*
Movable plates		X	X	X	X		X	X		O		X	
Tong holder	X	O		O		X			X		O		O
Punch	X	O				X	O		O	O	X		O
Spring guide pins	X	X											
Columns	X					X			X				
Blank holders		X	X	X	X	X	X	X				X	
Bushings	X	X							X	X			
Positioner for sheet iron		X	X			X		X					
Clamping elements	X		X				X						
Die		X	X	O		X	X	X	O	O	X	X	O
Die holder		X	X	X	O	X	O	X			X	X	O

Note. X = operation required; O = operation may be required.

Stamping technology

Dies are a very broad class of tools, designed to give shape to materials (mainly metals or plastics). The die material may be of rubber, sintered carbide or steel. Raw material and machinery costs are generally high.

Tool design is important for all forming operations. Design requires determination of workpiece size, materials, accuracy, the number of pieces to be produced by one set of dies, the required productivity, and assessment of the skill of the personnel involved in cold forming.

Figure 3 shows a schematic drawing of a die assembly. The operations needed to manufacture the various parts of the die are shown in table 4. It is interesting to note that the operations required are those which can be performed by a mechanical equipment workshop. With such a workshop it is possible to manufacture not only dies but also other tools and fixtures. The workshop can carry out most of the maintenance operations and manufacture fixtures, for internal use and for outside sale. Figure 4 is a flow diagram showing the steps in manufacturing dies. Figures 8-10 (in appendix I to this chapter) show types of dies and die products.

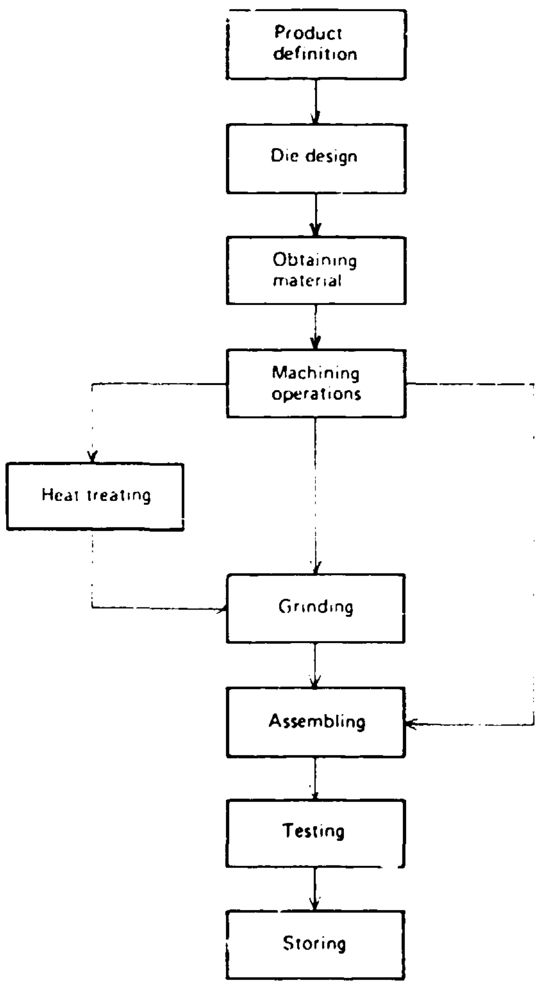


Figure 4. Steps in die manufacturing

Forging

Forging occurs when metal is heated to maximum plasticity temperature and subjected to force. The force deforms the metal. After a short period of elasticity the deformation becomes permanent. Shaping may be done by hammers, presses, skilled hand-work or by dies, to achieve a desired final product. Forged steel has an internal structure which yields better mechanical properties than the structure of rolled steel as the internal structure of rolled steel consists of fibres which are parallel to the direction of rolling.

Strains acquired during forging include those acquired by:

(a) Impact-pressure which carries strains due to the forging hammer. The extent depends on the velocity and weight of the falling mass;

(b) Push-pressure which causes strains by hydraulic presses. The extent of the strain is limited by the metal's increasing resistance to deformation;

(c) A combination of impact- and push-pressure, normally imparted by high-speed mechanical-forging presses used on closed-die forging work.

Forging operations may be grouped into two general types of processes, smith-die forging and impression-die forming. Smith-die forging includes many forging techniques using flat-faced dies in combination with other tools. The result largely depends on the skill of the smith. This method is also known as open-die forging, or hand- or hammer-forging and normally requires skilled workers.

Impression-die forging (or closed-die forging, drop forging) uses cavities in matching metal dies to form the workpiece. The metal to be shaped, usually red-hot steel, is cut to a length prior to forging which provides the needed size plus some size allowance for flash.

The number of forging steps is dependent on the size and shape of the part, on amounts needed and on the type of metal to be worked. The process consists of cutting billets to size, pre-heating them to the forging temperature, forming them by press or hammer, and trimming. In most cases the forged item is later machined. The main steps of the process are shown in figure 5.

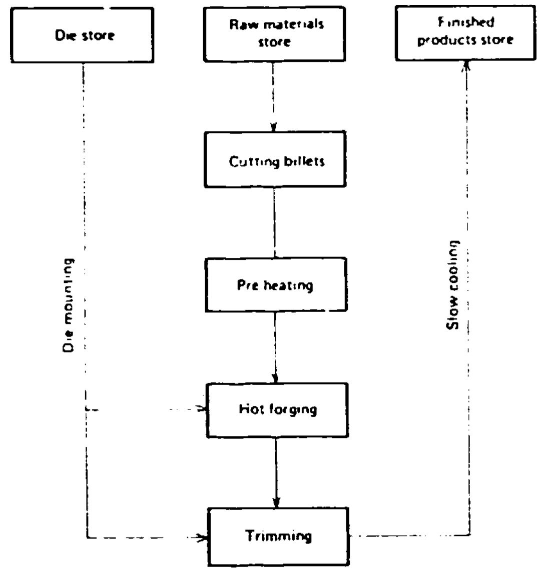


Figure 5. Steps in impression-die forging

C. Products

Sheet-metal cold forming is one of the fundamental operations for many products such as shovels, buckets, hinges, stators and rotors for electric motors, silencers for motor vehicles, and components for electrical instrumentation. Product types include: agricultural machines (carts, wagons, wheelbarrows, harrows, sowing machines); building industry needs (locks, hinges, padlocks), household utensils (casseroles, stoves, fans); street and road elements (panels, signals); railroad and lifting systems.

D. General design criteria

The production unit

The production unit for sheet-metal items is fundamentally mechanical. It contains two departments, sheet forming (with structural work and assembling of parts) and tool manufacturing, dies, fixtures and machinery maintenance.

The unit is well balanced and the two departments are integrated. However, the plant may be enlarged by the installation of hot-forging equipment. Near the tool and die department is a workshop for training workers and technicians. Theory is taught in the office building.

Plant characteristics

Among the characteristics of the plant are that the investment required per worker is relatively modest, especially in comparison to the investment per worker needed for rolling plants. The training needs are short-term compared to training needs for hot-forging and machine-tool training. The products are suitable for industry or direct marketing and have a wide range. The unit is labour intensive. The problem of supply of dies can be met by a special tool department.

The tool and die department

Tool and die manufacture is indispensable for a sheet-metal pressing unit. It requires experienced workers and technicians. The high cost of training pesonnel is justified by:

(a) The large number of dies required (two, three, four dies may be necessary for the same component);

(b) The high cost of the dies (an average size die costs $4,000 to $5,000);

(c) The need for rapid construction to assure rapid deliveries;

(d) The needs for rapid repair and for machinery maintenance;

(e) The potential benefit obtainable by selling engineering, and modified tools and dies to other industries, including the usual buyers of pressed items.

The production unit needs two types of training. The first type is for "sheet-metal pressing" workers and the second for "tool and die department" workers.

The hot-pressing department

High-performance mechanical properties are generally obtained from hot-pressed steel which has then been heat treated to give high yield strength, in addition to resistance to torsion, bending, compression, and other dynamic stresses.

Although at the present stage of this study it is not possible to make an overall economic calculation, the following characteristics should be noted:

(a) The estimation and calculations of costs are not influenced by and may be made separately from other costs for the unit;

(b) Investments and personnel employed are quite minimal and do not significantly affect the entire investment;

(c) The area occupied is relatively small and can also be used for temporary storage.

E. The production plant

The assumed general conditions for implantation are that:

(a) The ground is levelled;

(b) Road transportation is available;

(c) Water and electric energy are available. High voltage electricity is available and a transforming station is available or at least planned for the region;

(d) No legal restrictions exist regarding noise and vibration;

(e) The eventual installation of a power hammer for the hot-pressing department will necessitate the creation of foundations which can absorb the vibrations (in order to maintain the production quality of the tool machines).

Water purification and drainage needs and requirements have not been included in this study.

Buildings and installations

The offices are located in a separate building and have an area of about 1,000 m². The inner patio comprises 100 m². The offices include (figure 6): the entrance, waiting room, management and secretarial area, book-keeping department, engineering department, records, two halls for classroom training, offices for the instructors, canteen, surgery and other staff services.

The workshop (figure 7) has an area of about 3,000 m². Nearly half of the area is for the tool and die department. This area is in turn divided into two sections by a wide aisle which allows space for fork-lift trucks.

The first section includes the machine-tools and the die-fitter's benches. Next to the die-fitter's benches some space is set aside to store dies and equipment being made or repaired. As usual in tool and die workshops, machines with similar characteristics have been placed together in a group. The second section is set aside for the training of newly-hired workers. There is less free space in this section because there are fewer products to be handled. At the front of this section a little room is set aside for instructors. A tool distribution centre has been placed near the sharpening machinery. Large areas, accessible from both departments, are used for storing the new dies, repaired dies and dies to be reconditioned.

The pressing department has the presses and the other machines for sheet-metal machining. The aisles are wide because of the large quantities of materials moved and because of the large stocks of pieces near the machines. For reasons of appearance and surface protection, the pressed pieces must often undergo surface treatment. Therefore, there is a room for phosphatizing, painting and degreasing.

The handling of the pieces is done manually, with small hoist machines (for the heavier pieces) or with mechanical or magnetic grips (for safety reasons).

In-plant transportation is by fork-lift trucks carrying containers or wooden pallets. The trainees may make those containers or wooden pallets during a training exercise. A compressed-air system (600 kgf/cm²) feeds the presses and all other machine tools as well as the fitting benches.

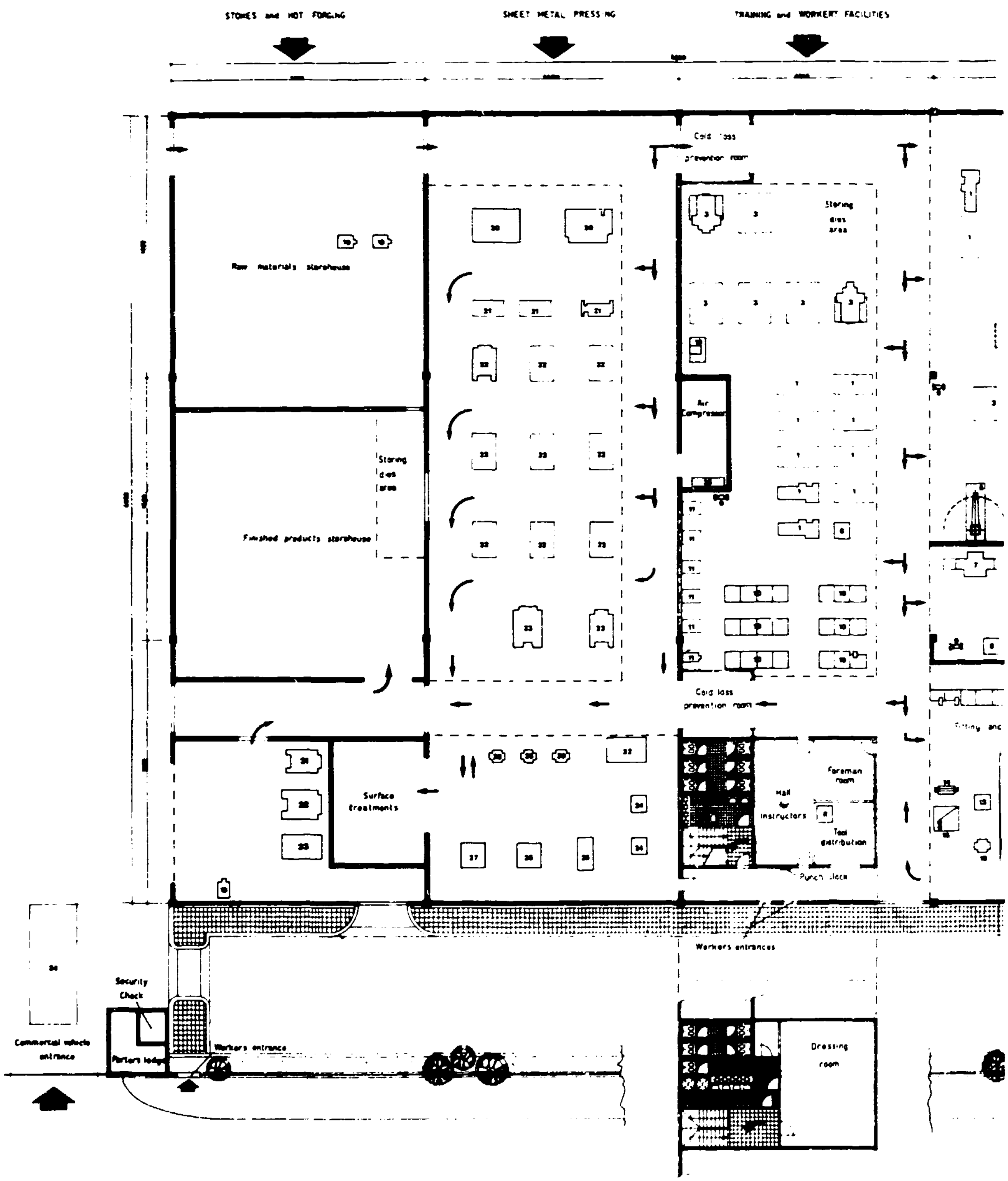


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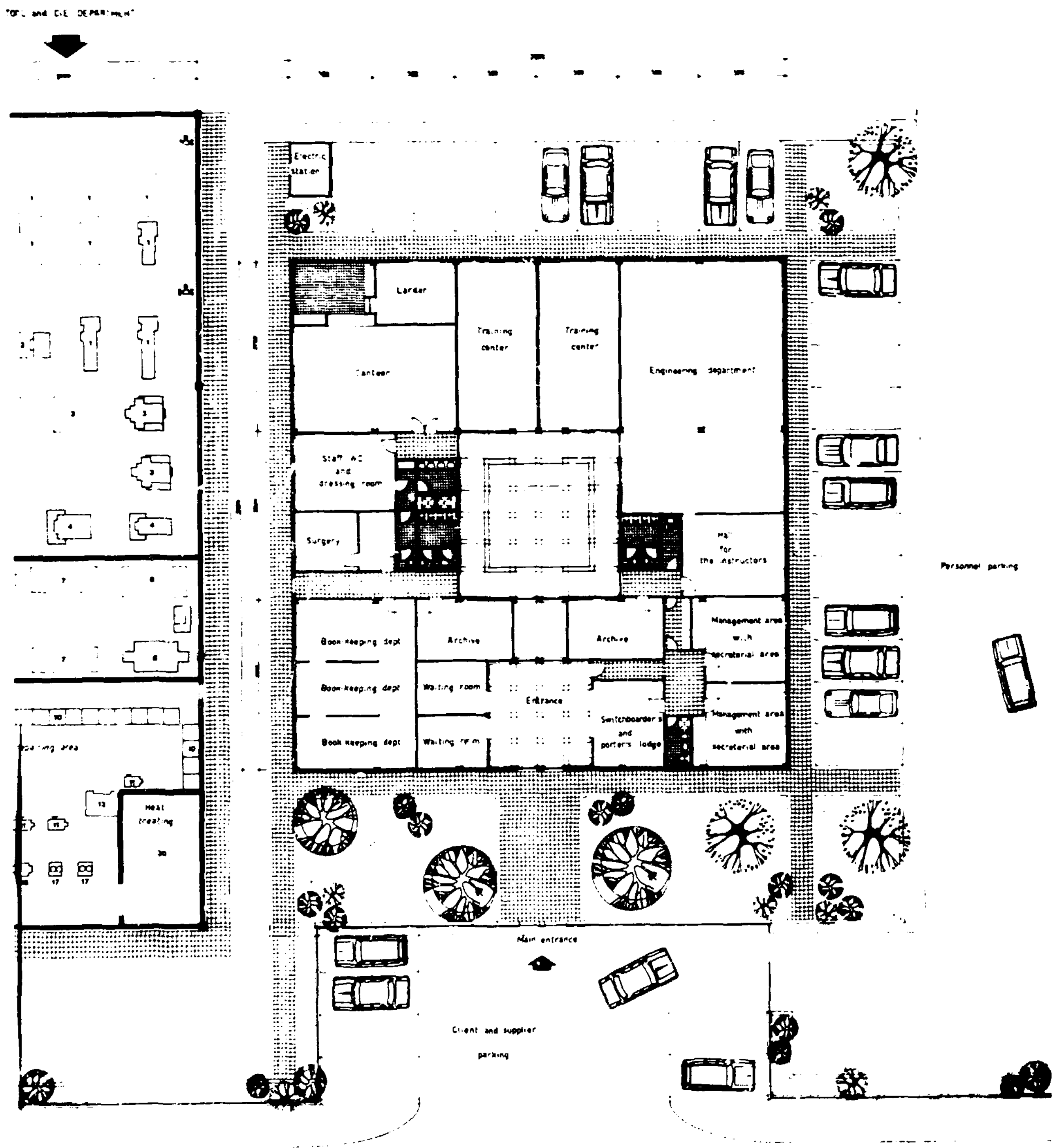
Figure 6. General floor plan

SECTION 1



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for a metal-forming plant

SECTION 2

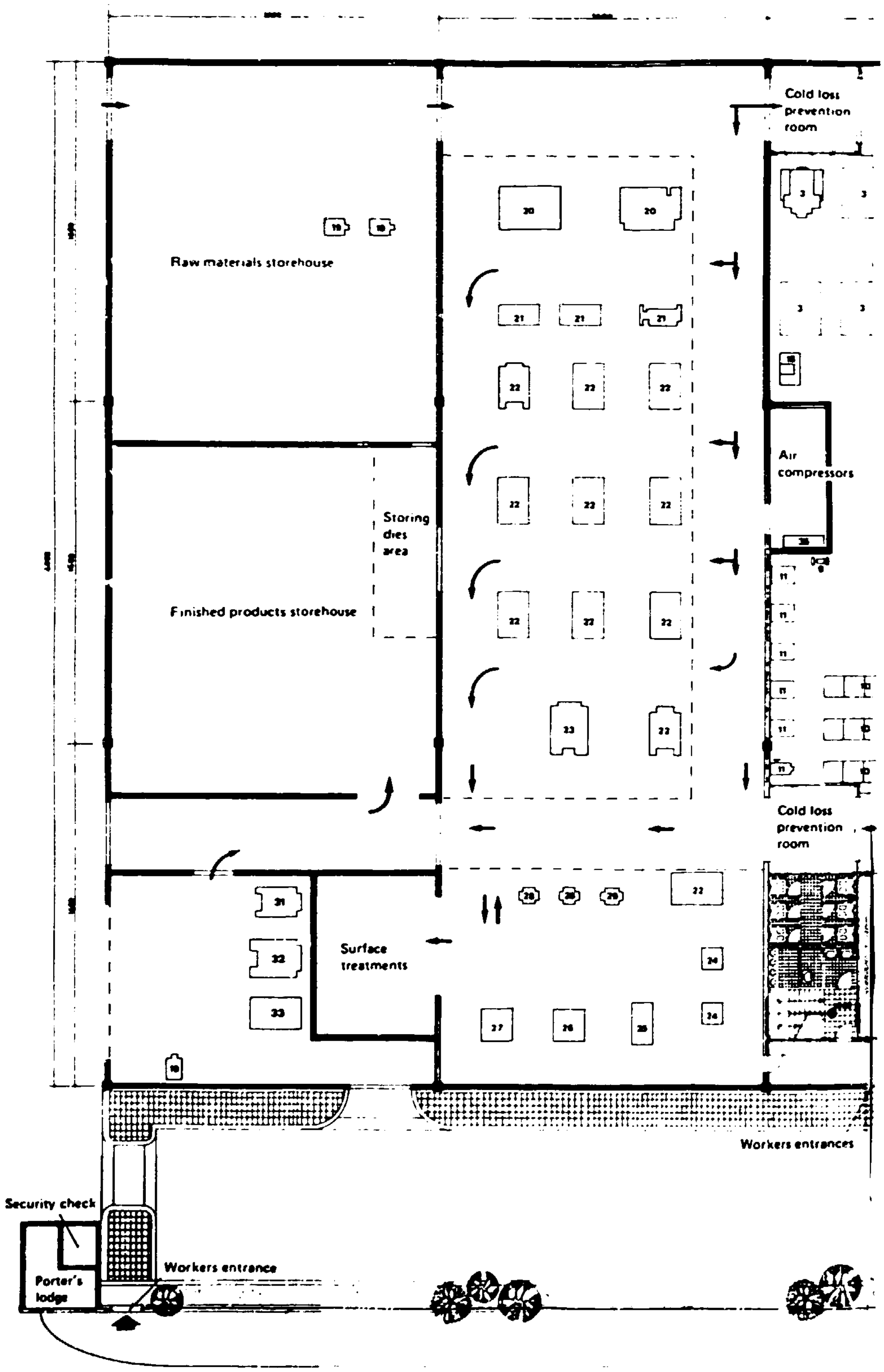
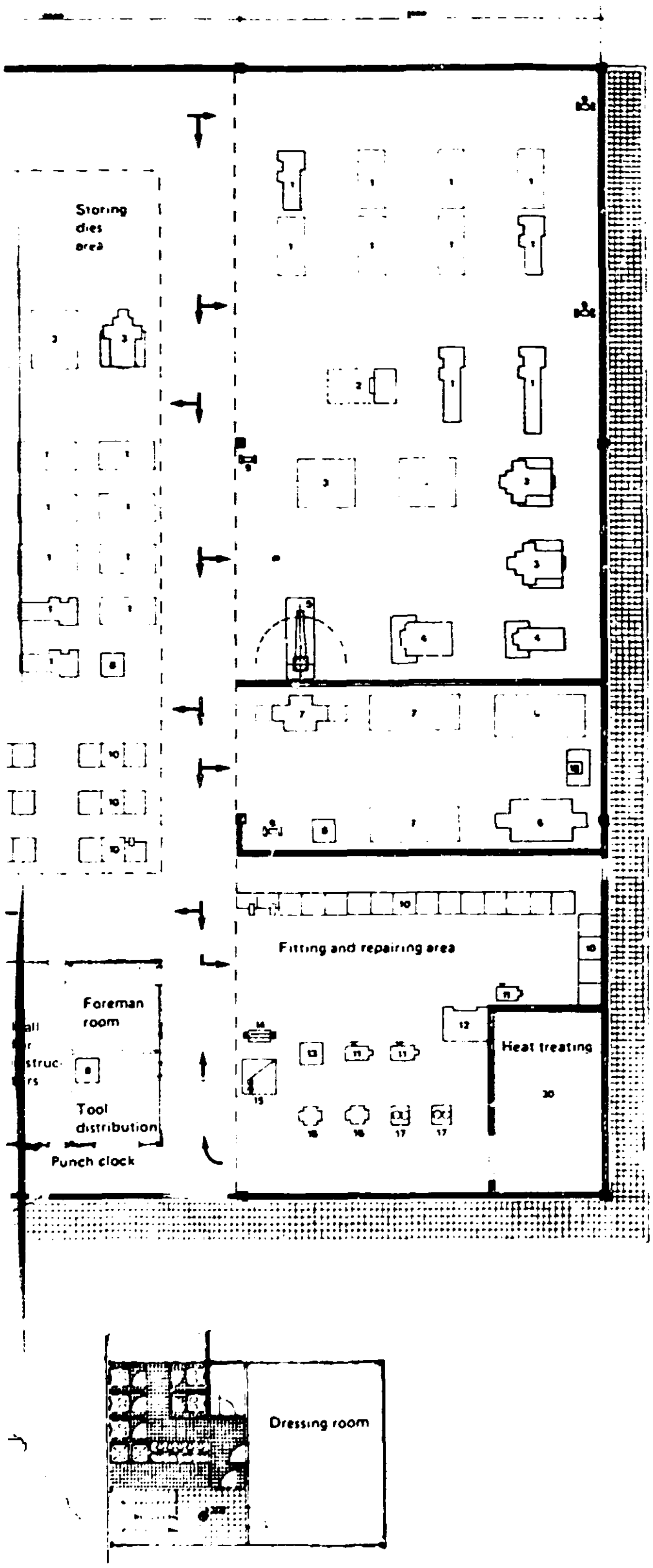


Figure 7. Floor plan of a

SECTION 1



Key:

1 Parallel lathe
2 Facing lathe
3 Milling machine
4 Horizontal boring machine
5 Radial drilling machine
6 Cylindrical grinder
7 Surface grinder
8 Universal sharpening machine
9 Upright twin wheel grinder
10 Fitting bench
11 Hand operated drilling machine
12 Plunging spark erosion machine
13 Profile optical comparator
14 Hand operated screw press
15 Pantograph marking machine
16 Arc welding set
17 Blowpipe soldering set
18 Honing machine
19 Hack sawing machine
20 Guillotine shears
21 Folding press
22 Mechanical press
23 Hydraulic press
24 Pipe bending machine
25 Hotching machine
26 Three rolls bending machine
27 Disc shearing machine
28 Spot-welding machine
29 Submerged arc welder
30 Heat treating furnaces
31 Trimming press
32 Press hammer
33 Preheating furnace
34 Weighbridge
35 Battery charger

0 1 2 3 4 5 6 7 8 9 10 m

metal-forming workshop

SECTION 2

The electrical system and the lighting system use fixed ducts with safety sockets. To reduce the voltage for safety, an electric station with two transformers (one for service and a smaller one for supply) is located outside the building. The tool and die department and the offices have an air-conditioning system to guaranteee comfortable working conditions and to control thermal changes which might affect the machines.

Easily accessible powder and foam fire extinguishers are provided. The painting room has a small automatic sprinkler system because of highly inflammable vapours.

The plant structure permits eventual enlargement. Any individual department may be enlarged by the addition of a 16 m × 16 m shed; or the entire plant may be enlarged by the addition of a 64 m × 16 m shed, built behind the plant.

Departmental area requirements

Table 5 shows areas of departments of the MPDU. These areas are divided into three production departments.

TABLE 5 AREAS OF VARIOUS DEPARTMENTS OF THE METAL-FORMING MPDU

(m^2)

Function	*Pressing*	*Tool and dies*	*Hot forging*	*Total*
Pressing	640	—	—	640
Tool and dies	—	720	—	720
Hot forging	—	—	80	80
Training	—	420	—	420
Stores	450	90	20	560
Painting	60	—	—	60
Heat treatment	—	55	—	55
Other	270	345	—	615
Offices	300	650	—	950
Total	1 720	2 280	100	4 100

Personnel

The number of personnel increases yearly until the plant becomes fully operational in the fifth year. The distribution of personnel at that time is as shown in table 6.

TABLE 6 DISTRIBUTION OF PERSONNEL DURING THE FIFTH YEAR OF PRODUCTION

(Number of persons)

Job category	*Total*	*Cold pressing*	*Tool and dies*
Management and secretarial staff	11	5	6
Engineers	14	—	14
Foremen and surveyors	14	6	8
Sheet pressing	34	34	—
Toolmakers	50	—	50
Unskilled	15	7	8
Total	138	52	86

Worker safety is a basic consideration. All machines which may pose any risk to personal safety have been systematically excluded. For example friction-clutch presses are preferred to dog-clutch presses. All presses have two push-button commands to avoid squashing fingers. The lathes have a cover on the self-centring chucks, and all lathes, milling and drilling machines have plastic screens for chips.

Machine equipment and attachments (vices, tail stocks, indexing heads, fixed and moving rests, and three- and four-jaw self-centring chucks) must be considered so as to make the machines more universal and adaptable. Specific equipment (dies, pliers, special jaws) has not been specified, as it is first necessary to know the shape and dimension of the machined piece, and the economic status of current labour costs.

F. Machinery

An attempt has been made to limit over-mechanization and over-sophistication for reasons of cost, ease of maintenance, and wide applicability.

Sheet-metal machines

Table 7 shows the installation of sheet-metal machines by year. The details of the equipment and space needed for the MPDU pressing unit are in appendix II.

In addition the following are necessary:

(a) Demagnetizer device;

(b) Fly press;

(c) Measuring and checking instruments;

(d) Safety equipment (pliers, gloves etc.);

(e) Transpallets;

(f) Fire extinguishers;

(g) Metal containers.

Tool and die machines

Table 8 shows the installation of machines by year for the tool and die department.

TABLE 7. INSTALLATION OF MACHINES BY YEAR

(Number of machines)

Machine	*Total*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Presses	12	1	6	3	2	—
Guillotine shears	2	1	—	1	—	—
Disc shear	1	—	—	—	—	—
1 000 mm arm shape-notching machine	1	—	—	—	1	—
Bending machine	2	1	—	—	1	—
Rolling machine	1	1	—	—	—	—
Pipe-bending machine	2	—	1	—	1	—
Spot-welding machine	2	1	—	1	—	—
Submerged-arc welding	1	—	—	—	1	—

TABLE 8. SCHEDULE OF MACHINE INSTALLATION FOR THE TOOL AND DIE DEPARTMENT

(Number of machines)

Machine	*Total*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Lathes	19	11	6	—	1	1
Milling machines	10	—	3	6	1	—
Drilling machines	9	5	4	—	—	—
Boring machines	2	—	—	1	1	—
Surface grinders	3	1	2	—	—	—
Round grinders	2	1	1	—	—	—
Sharpeners	3	—	2	—	—	1
Spark erosion machine	1	—	—	—	1	—
Benches for toolmakers	40	10	10	10	10	—
Furnaces	3	3	—	—	—	—
Miscellaneous	20	6	9	3	—	2

In addition the following are necessary:

(a) Shelves for tools and fixtures (one for every machine);

(b) Portable grinding wheels and drilling machine;

(c) Tools, wheels, band saw;

(d) Gauges, measurement instruments, surface plates;

(e) Safety equipment (safety glasses etc.);

(f) Transpallets and a jib crane;

(g) Fire extinguishers.

Machines for the hot-forging department

For the hot-forging department, it is necessary to have a power hammer, and a trimming press, each to be installed in the fourth year of unit operation. In addition, a disc saw, pre-heating furnace, measurement and check instruments, safety equipment (pliers, safety gloves, safety glasses), transpallets, fire extinguishers and metal containers are necessary.

G. Investments

Planned investments are summarized in tables 9 through 12. Table 10 does not take land cost into account. In table 11 it is assumed that the power and water supplies reach the plant's boundaries.

Estimates are based on use of standard quality machines of different reliable firms. The prices are for September 1979 and include "tropicalization" design for high-temperature environments.

TABLE 9. TOTAL INVESTMENT REQUIRED FOR THE MPDU

(Thousands of dollars)

Facility	*Cold-pressing department*	*Tool and die department*	*Hot-forging department*
Buildings	225	315	15
General facilities	135	203	12
Operating machinery and equipment	1 200	1 500	480
Total	1 560	2 018	507

The cold-pressing and tool and die departments together require an investment of $3,578,000.

TABLE 10. INVESTMENT IN WORKSHOP AND OFFICE FACILITIES

(Thousands of dollars)

Facility	*Pressing department*	*Dies and fixtures department*	*Hot-forging department*	*Total*
Workshop	180	217	15	412
Offices	45	98	—	143
Total	225	315	15	555

H. Training

One of the most important aims of the unit is training, so as to make the plant as independent as possible of overseas expertise and know-how. Overseas training technical assistance programmes (using overseas experts and counterpart trainers, during the first stages of unit production) and in-plant training for upgrading personnel must be considered. Different training programmes include those for managers, engineers and counterparts, counterpart trainers (future technicians or foremen) tool makers, mechanics and sheet-metal and forging workers.

Table 13 summarizes training costs as detailed in tables in appendix III.

TABLE 11. COSTS TO INSTALL EQUIPMENT

(Thousands of dollars)

Installed equipment	*Total*	*Pressing department*	*Dies and fixtures department*	*Hot-pressing department*
Air compressor system	90	45	40	5
Electric energy system (includes electric station)	110	45	60	5
Lighting	30	10	18	2
Air cooling system (office facilities, and tool and die department	35	5	30	—
Sprinkler system (only painting facilities)	5	5	—	—
Furniture	55	25	30	—
Transport	25	—	25	—
Total	350	135	203	12

I. Preliminary viability plan

The viability study compares the estimated production revenues to the operating costs. The plan is based on the following elements estimated for the five start-up years of the factory:

- Production implementation
- Estimated material cost
- Personnel, wages and salaries
- Training costs
- Investments and depreciations schedules
- Estimated product prices; revenue
- Operating costs
- Net income statement and cash result

Cost figures for materials have been estimated to be 20% higher than European costs.

It is assumed that employees will be hired over a period of five years, with the full quota to be reached in the fifth year. The employee cost has been calculated by summing the costs of the different job grade levels. These costs vary in the years as shown in the tables in appendix IV. Production income starts in the second year. Local training costs are added to operating costs, but it is envisaged that a training subsidy will be paid by outside sources and this subsidy is considered as income. The cost of non-local experts and fellowship training abroad are not included in the operating costs. Supposedly these expenses will be financed through EEC or bilateral funds.

To estimate investment depreciation, interest rates of 4% per year for buildings; 5% per year for general systems and 10% per year for machinery and equipment have been used (see tables in appendix V).

Financial charges have been added to operating costs. Cash financing is estimated to be

TABLE 12. MACHINERY COSTS FOR THE MPDU

(Thousands of dollars)

Operation	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Cold-pressing					
Machines	71	175	275	285	192
Set-up	19	35	55	55	38
Total	90	210	330	340	230
Cumulative total	90	300	630	970	1 200
Tool and die department					
Machines	242	396	308	170	66
Set-up	63	104	92	40	19
Total	305	500	400	210	85
Cumulative total	305	805	1 205	1 415	1 500

Note The cost for the hot-forging department is $480,000 in the fourth year, only.

TABLE 13. SUMMARY OF TRAINING COSTS

(Thousands of dollars)

Type of training	*Cost*
Non-local	
In-plant for managers, engineers, counterpart trainers	156
Continuing training (engineers, counterpart trainers)	156
Technical assistance for 45 person-years over a five-year period	3 771
Local training for	
Sheet-metal shop	142
Tool and die shop	298
Hot-forging department	19
Total	4 542

5% of operating costs. Financial charges on investment have been added to the net income statement and are estimated to be about 2% of the total investment.

Prices of the local markets have been estimated to be 30% higher than European prices (September 1979) for sheet metal and hot pressing.

Financial projections for the sheet-metal pressing department

Production begins at the end of the second year as the first two years are dedicated to training. Estimated average sheet-metal production is 19.5 kg/h per machine. This average can be reached after gradual improvement of efficiency. Sheet-metal production in years two through five should be as follows:

Year	*Production (t)*
2	98
3	323
4	610
5	835

Employees will be hired over a period of five years. In the fifth year there will be 5 management and staff, 6 foremen and surveyors, 34 line workers and 7 unskilled workers.

Local training costs have been estimated by assuming that staff and management are trained in the first year only; that foreman counterpart sheet-metal employees are trained during all five years; that sheet-metal workers are trained during the first three years and that general workers are trained in the first two years.

Depreciation estimates are separately detailed in appendix V. Revenue from the sheet-metal shop is estimated by assuming a market price of $2 per kg. Table 14 is a breakdown of operating costs for years one through five; these are compared with projected income to yield profit and loss projections in table 15.

Financial projections for the tool department

Tool shop production will begin in the second year. The first two years are devoted to training. From the second year on, time spent on production will be as follows:

Year	*Production time (h)*
2	7 200
3	21 600
4	43 200
5	72 000

Personnel will be hired over a period of five years. By the fifth year it is assumed that there will be 6 management and staff; 14 engineers, 8 foremen and surveyors, 50 tool-makers and 8 unskilled workers.

Local training costs are estimated for training staff and management in only the first year; training counterpart engineers for one year; tool-makers for two years; and the general work force unskilled labour in the first year. Depreciation is detailed in appendix V.

TABLE 14. SHEET-METAL PRESSING DEPARTMENT: OPERATING COSTS

(Thousands of dollars)

Item	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Raw materials	23	124	406	704	876
Auxiliary and expendable materials	2	12	40	70	87
Power	1	4	14	25	35
Direct labour	5	17	35	52	68
Auxiliary labour	8	15	23	32	43
Managers and employees	11	15	20	27	28
General costs	4	18	50	91	110
Other	2	8	22	42	60
Total	56	213	610	1 043	1 307

TABLE 15. SHEET-METAL PRESSING DEPARTMENT: PROFIT AND LOSS

Item	*Amount (thousands of dollars)* Year 1	Year 2	Year 3	Year 4	Year 5
Income					
Sales of production	–	205	678	1 281	1 753
Training subsidy	24	32	33	23	30
Total income	24	237	711	1 304	1 783
Costs					
Operating costs	56	213	610	1 043	1 307
Depreciation charges	26	47	80	114	137
Loan interests	12	25	25	25	25
Total costs	94	285	715	1 182	1 469
Profit (loss)	(70)	(48)	(4)	122	314
Net cash	(44)	(1)	76	236	451

TABLE 16. TOOL AND DIE DEPARTMENT: OPERATING COSTS
(Thousands of dollars)

Item	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Auxiliary and expendable materials	7	14	21	34	57
Power	3	6	8	13	22
Direct labour	12	32	57	88	125
Auxiliary labour	15	24	32	43	54
Managers and employees	47	66	89	114	136
General costs	8	14	21	29	40
Finance department cost	4	7	10	15	20
Total	96	163	238	336	454

TABLE 17. TOOL AND DIE DEPARTMENT: PROFIT AND LOSS

Item	*Amount (thousands of dollars)* Year 1	Year 2	Year 3	Year 4	Year 5
Income					
Production sales	—	57	173	346	576
Engineering services sales	—	29	54	87	126
Training subsidy	74	50	50	58	66
Total income	74	136	277	491	768
Costs					
Operating costs	96	163	238	336	454
Depreciation charges	55	105	145	166	174
Loan interests	15	30	30	30	30
Total costs	166	298	413	532	658
Profit (loss)	(92)	(162)	(136)	(41)	110
Net cash	(37)	(57)	9	125	274

As a raw materials are not part of cost estimates, estimated revenue is calculated from the marketable production hours. These hours are valued at a market price of $8 per hour (about $12,000 per year per person per machine).

Revenues from service are the product of working hours of the engineers multiplied by a value of $10 per hour (about $18,000 per year per person).

Table 16 is a breakdown of operating costs for years one through five; these are compared with projected income to yield profit and loss projections in table 17.

Financial projections for the hot-forging department

Production will begin in the fourth year and is estimated to be 60 kg/h per machine. This will be attained gradually. In the fourth year, 29 t of forgings will be produced. In the fifth year 86 t of forgings will be produced. Due to the high investment costs, production uses two shifts of the power hammer.

Personnel, wages and salaries are detailed in appendix IV. One foreman and five forge workers will be required. The training costs will be $7,000 in the fourth year and $12,000 in the fifth year.

Figures for depreciation during the five years are given in appendix V.

Revenue is valued at a market price of about $2 per kg of produced forgings.

The operating costs of the hot-forging department are shown in table 18. The costs are compared with income to yield profit and loss projections in table 19.

TABLE 18. HOT-FORGING DEPARTMENT: OPERATING COSTS

(Thousands of dollars)

Item	*Year 4*	*Year 5*
Raw materials	20	60
Auxiliary and expendable materials	2	7
Power	7	10
Direct labour	4	8
Auxiliary labour	3	4
Managers and employees	—	—
General costs	4	10
Finance department cost	2	5
Total	42	104

Note There are no costs in the first three years.

TABLE 19. HOT-FORGING DEPARTMENT: PROFIT AND LOSS

(Thousands of dollars)

Item	*Year 4*	*Year 5*
Income		
Sale of production	58	172
Training subsidy	7	12
Total income	65	184
Costs		
Operating costs	42	104
Depreciation charges	50	50
Loan interests	9	9
Total costs	101	163
Profit (loss)	(36)	21

Appendix I

TYPES OF DIES AND DIE PRODUCTS

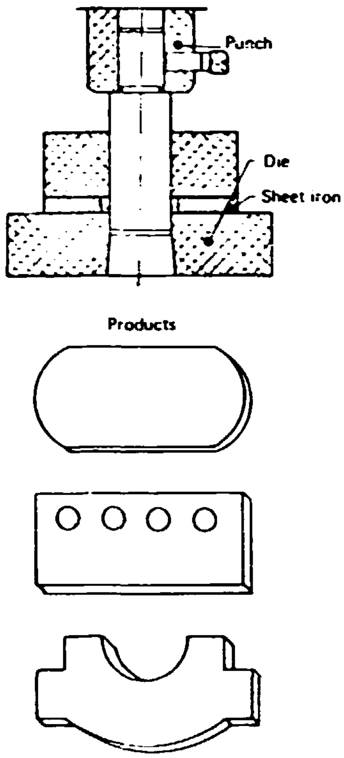


Figure 8. Sectional view of a blanking die. The "male punch" fits the die hole; die and punch can have various shapes

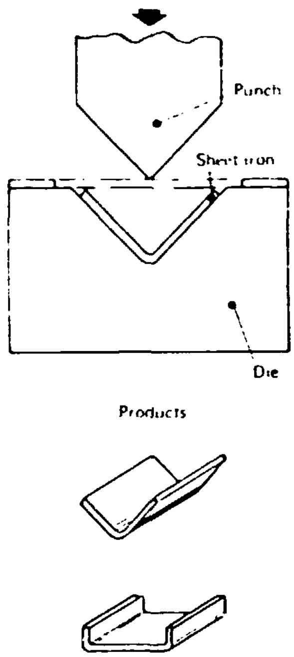


Figure 9. Sectional view of a bending die. The die has a groove. The punch bends the sheet iron

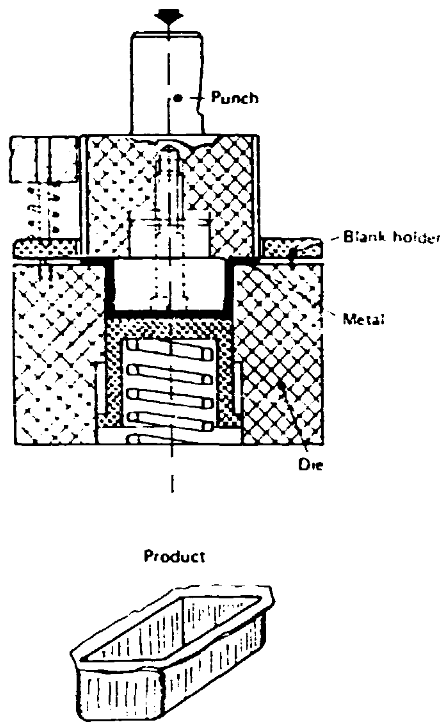


Figure 10. Sectional view of a drawing die. The die has a cavity of a suitable depth. The process requires that the metal sheet be put on the die and clamped by the blank-holder spring. The punch reproduces the entire die profile on the sheet iron

Appendix II

DETAILS OF EQUIPMENT AND SPACE NEEDED FOR THE MPDU PRESSING UNIT

Selection of machines for the pressing department

The area and power requirement for the pressing department are shown in table 20.

TABLE 20. AREA AND POWER REQUIREMENTS FOR THE PRESSING UNIT

Machine	*Number*	*Requirement for each machine* *Area (m²)*	*Power (kW)*	*Total* *Area (m²)*	*Power (kW)*
250 t hydraulic press	1	12	49	12	49
100 t mechanical press (table 1 000 × 550 mm)	2	8	13	16	26
80 t mechanical press (table 880 × 480 mm)	3	8	11	24	33
50 t mechanical press (table 880 × 500 mm)	5	7	9	35	45

Machine	Number	Requirement for each machine: Area (m²)	Requirement for each machine: Power (kW)	Total: Area (m²)	Total: Power (kW)
30 t mechanical press (table 382 × 700 mm)	1	5	9	5	9
Guillotine shears 2 050 mm	2	18	5	36	10
Bending press	2	9	6	18	12
Hand-operated bender	1	3	—	3	—
Pipe-bending machine	2	12	39	24	78
Spot-welding machine	2	2	22	2	22
Notching machine	1	2	3	2	3
Disc-shearing machine	1	3	1	3	1
Three-roll bending machine	1	4	5	4	5
Inert-gas welder	1	4	25	4	25
Total				188	318

Advantages and disadvantages of various sheet-metal presses are shown below.

Type	*Advantages*	*Disadvantages*
Hydraulic press	Force applied is constant. Many types of drawing are possible. Easily controlled	High cost Ramming at end of run is not positive Few cycles per minute
Friction-clutch mechanical press	Good for bending and blanking	Work speed varies during operation Drawing is difficult
Dog-clutch press	Same advantages as friction-clutch mechanical press	Disadvantages same as friction-clutch mechanical press Ratched gear clutch and clamp wear easily and slide might fall down at end of run (safety)

The friction-clutch mechanical press is the press of choice as it is safer than the dog-clutch press. Hydraulic presses are to be used for drawing operations.

The operating principles and application of sheet-metal equipment are shown below.

Machine	*Operating principle*	*Applications*
Guillotine shear	A cutter (the same length as the machine) shears the sheet metal into two sections in one step	All straight-line shearing done on standard sized sheets
Disc shear	Two touching sharp discs shear the sheet metal fed to the cutter	Sheet metal may be cut into discs, concentric rings, and profiles with wide radii
Notching machine	Opposed cutters, a few mm in length, make a sequence of small notches, cutting the sheet metal which is manually fed	Irregular profiles or corners can be made
Folding machine	A male punch and female die fold the metal	Folds, corrugated forms, straight ribs are made by a sequence of operations
Bending machines for pipes and profiles	A manually or mechanically driven pushing device moves the piece against the forming block and bends it	Tubes of up to 50 mm diameter can be bent
Spot-welding machines	Two metal sheets are pressed together between two electrodes. The current passing through them melts the metal and spot welding occurs	Final joining of pressed, profiled or formed pieces
Inert-gas welding	A continuous-wire inert-gas welder's electrode, protected from oxidation by an inert gas	Welding of stainless steel, alloyed steels and non-ferrous metals

These machines can produce pieces larger than those produced by presses. They machine small batches, in cases when a die would be too costly. The machines can shape pipes and sections for mounting on complex products, for example, handles for wheelbarrows. The machines can also assemble various items.

Selection of machines for the tool and die department

Table 21 shows the area and power requirements for the tool and die department. The selection of machines for this department is based on the following:

(a) Lathes, milling and drilling machines are basic machines for training a skilled worker;

(b) In all machining operations, lathes, milling and drilling machines always carry out the initial basic operations. Possible working overloads can be easily absorbed as there are many machines. In high accuracy operations such as borings and post heat-treatment such as grinding, two working shifts per day can be used;

(c) It is possible to modify these basic machines so as to produce medium-volume batch products by simple and inexpensive methods. Thus, as an example, it is possible to add a copying device to the lathe, or to add special gears to the cam milling machine. The large number of machines provides a buffer reserve.

TABLE 21. AREA AND POWER REQUIREMENTS FOR THE TOOL AND DIE DEPARTMENT

		Requirement for each machine		*Total*	
Machine	*Number*	*Area (m^2)*	*Power (kW)*	*Area (m^2)*	*Power (kW)*
Parallel lathe (250 × 2 000 mm)	2	6.7	9.0	13.4	18.0
Parallel lathe (180 × 800 mm)	5	2.7	3.8	13.4	18.8
Parallel lathe (180 × 1 200 mm)	1	4.0	3.8	4.0	3.8
Parallel lathe (100 × 500 mm)	10	1.7	3.8	16.8	37.5
Facing lathe (830 mm diameter × 1 120 mm length)	1	5.0	15.7	5.0	15.7
Reproducing milling machine (table 1 200 × 280 mm)	1	2.0	9.1	2.0	9.1
Toolroom milling machine (table 1 100 × 250 mm)	8	10.2	4.6	81.6	36.9
Vertical milling machine (table 680 × 2 000 mm)	1	22.5	17.4	22.5	17.4
Radial drilling machine (30 mm diameter bore)	1	6.6	4.1	6.6	4.1
Hand-operated drilling machine (40 to 50 mm diameter bore)	2	0.9	2.4	1.8	4.8
Hand-operated upright drilling machine	6	0.3	0.5	1.9	3.0
Small jig borer die-sinker	1	7.4	2.9	7.4	2.9
Horizontal boring machine (table 1 000 × 500 × 500 mm)	1	28.9	7.5	28.9	7.5
Horizontal spindle surface grinding machine (table 400 × 1 000 mm)	1	20.9	4.5	20.9	4.5
Vertical spindle surface grinding machine (table 280 × 600 mm)	1	18.0	4.5	18.0	4.5
Tool room grinding machine (table 200 × 300 mm)	1	11.2	2.3	11.2	2.3
Cylindrical grinding machine (180 × 1 000 mm)	1	24.0	12.0	24.0	12.0
Cylindrical grinding machine (120 × 700 mm)	1	20.0	10.5	20.0	10.5
Universal sharpening machine	2	13.2	2.0	26.4	4.0
Small universal sharpening machine	1	12.2	1.1	12.2	1.1
Spark erosion machine (table 500 × 500 mm)	1	10.5	24.0	10.5	24.0
Fitting-bench (table 1 000 × 700 mm)	40	2.1	—	84.0	—
Upright twin-wheel grinding machine (250 mm diameter × 30 mm width)	5	0.4	0.2	1.9	1.2
Pantograph marking machine	1	6.0	1.3	6.0	1.3
Electric etcher	1	—	1.0	—	1.0
Honing machine (350 mm diameter table)	1	—	1.0	—	1.0
Automatic tapping machine	1	3.0	4.0	3.0	4.0
Hack-sawing machine	2	2.5	2.0	5.1	4.0
Over-finishing machine	1	2.8	2.0	2.8	2.0
Trichloroethylene degreasing furnace	1	2.6	5.0	2.6	5.0
Hand-operated screw press	1	1.0	—	1.0	—
Arc-welding set	2	—	15.0	—	30.0
Blow-pipe soldering set	2	—	—	—	—
Salt-bath furnace with pyrometric equipment	1	—	100.0	—	100.0
Muffle furnace with pyrometric equipment	1	—	35.0	—	35.0
Tempering furnace with pyrometric equipment	1	—	35.0	—	35.0
Profile optical comparator	1	6.0	0.2	6.0	0.2
Total	111			460.9	462.0

The operating features of several types of lathes are shown below.

Type of lathe	*Operating features*	*General comments*
Centre lathe	The workpiece revolves about its axis. The workpiece is mounted between points or locked by a self-centring chuck. The controls are mechanical, and are manually operated	The simplest and most universal of lathes. The centre-lathe machines cast, forged or machined billets and blanks.

Type of lathe	Operating features	General comments
Face lathe	Same as the centre lathe, but used for wide and short pieces	Same as above but more expensive because of the larger headstock
Copying lathe	Hydraulically-driven stylus follows the profile of a master piece and controls the tool, which machines the profile on the workpiece	Copying device requires regular maintenance. The copying lathe is used for medium size batch production. This lathe is limited with respect to size of workpiece
Capstan lathe	Construction is similar to that of a centre lathe. The capstan lathe has a hexagonal turret which rotates around a vertical axis. This turret has various tools on it, each for a different operation. The turret is operated manually	A sophisticated, complicated and expensive medium size production machine
Numerically controlled lathe	Saddle movement, speed and feed are electronically controlled by punched cards or magnetic tapes	Very expensive, sophisticated and delicate machine for small or medium size production
Automatic bar lathe	Long bars machined by it pass through a set of spindles. A set of tools and cams are needed to produce each piece. The last cam cuts the piece off from the bar	Only used for large size production. Each workpiece requires expensive equipment. Only small diameter pieces can be obtained from bars
Multi-spindle automatic lathe	Six or eight revolving bars each face a tool station where an operation is performed. A revolving bar drum shifts the bars to a new tool station for the subsequent machining operation	For very large size production. The multi-spindle automatic lathe uses very costly tools and equipment and only machines workpieces from bars. The machine is very expensive

Multi-spindle automatic lathes and automatic bar lathes are not chosen for the MPDU because of the small volume of production. The numerically controlled lathes are too sophisticated and require a staff of programmers.

The medium volume production lathes, the copying and capstan lathes, are not suitable.

The traditional centre lathes were chosen due to their flexibility and economy. The face lathe is indispensable for the two operations, of producing die carrying plates and of refinishing wheels and fly wheels for maintenance purposes.

Operating features of milling machines are shown below.

Type of milling machine	Operating features	General comments
Horizontal milling machine	Milling cutters mounted on a horizontal spindle	Needed for flattening and producing straight tunnels in various forms
Universal milling machine	Developed from the horizontal milling machines. Uses horizontal and vertical spindle mounted cutters	Makes many different milled forms including helicals
Vertical milling machine	Has a swinging vertical spindle	Used for straight or circular tunnels, for forming and for flattening. Less costly than other milling machines but limited in operations performed
Universal tool-room milling machine	A development of the universal milling machine	
Planer-type milling machine	Operates with one or more cutters mounted on one or more shafts	Used for large production, very strong
Copying milling machine	Copying from a master to the workpiece	Can mill complex and irregular profiles

The universal tool-room milling machine was chosen for its wide application. The horizontal milling machine was not chosen because of its limited field of application. The planer-type is used for large-scale production and was not chosen. A vertical milling machine with quite a large-size table (680 × 2,000 mm) is indispensable for heavy-duty flattening because of its rigidity. A copying milling machine is needed to produce hot-forgings and to produce chilling moulds and moulds for plastic.

A universal-type grinder is used for medium- to small-scale production.

The circular and surface grinding machines for the MPDU have been designed with a hydraulically driven travelling table (for precision) and a manually driven feed and dressing device (for economy).

Circular grinders use a rapid hydraulic approach mechanism because the batch runs are small (sometimes only for the piece) and measuring operations are frequent.

Control systems are needed to grind pieces with close tolerances and fine surface finishes. The characteristics of such systems are as follows:

	Type of system		
Movement controlled	*Hydraulic*	*Mechanical*	*Manual*
Table travel	Precise, reliable, continuous speed control	Precise, reliable speed control. Obsolete because of maintenance difficulties and step-by-step speed control	Movement may be irregular and table may vibrate
Rapid return to workpiece (only on circular grinders)	Precise, very fast		Takes a long time to approach workpiece. Difficulties arise when measuring operations are frequent
Feed	Precise, continuous control. Expensive	Precise	Inexpensive
Wheel dressing	Movement is uniform and regular	Precise	Quite precise and cheap

The two precision boring machines (one small, the other with a 1,000 × 500 mm table) are needed in a precision machine shop. These machines bore holes with limited tolerances, bore holes at closely defined distances and machine surfaces at closely defined separations. Die holders and various flat items can be manufactured, repaired or reconditioned.

The universal sharpeners come with a wide range of equipment including tail stocks, indexing heads, swivelling vices, concave and convex radius dressing devices. These machines groove, form chamfers and do other operations.

The spark erosion machine produces punches and dies with remarkably complex profiles that otherwise could not be produced. These profiles are for spare parts, dies, profiles with an undercut, and concave shapes with small radii. The machine is quite sophisticated and can increase the production range and also acquaint workers with the possibilities of modern technology.

A compressed-air spray gun is used to paint the workpiece. The spray booth will include a water curtain with two exhaust fans for vapours. Degreasing is done manually in six tanks of 590 × 600 × 600 mm. The entire floor area will be covered by a wooden platform. A tank for hot degreasing is also provided.

Die components are heat treated. There are three furnaces. One furnace is a salt-bath type and the other two are muffle types. These are used for box-carburizing, hardening, tempering, stress-relief, normalizing and annealing.

Selection of machines for the hot-pressing department

Table 22 gives the area and power requirements for the hot-pressing department.

TABLE 22. AREA AND POWER REQUIREMENTS FOR THE HOT-PRESSING DEPARTMENT

		Requirement for each machine		Total	
Machine	*Number*	*Area (m^2)*	*Power (kW)*	*Area (m^2)*	*Power (kW)*
Press hammer (1 500 kg)	1	10	45	10	45
Trimming press	1	8	20	8	20
Preheating furnace	1	6	35	6	35

The hot-forging department may be fully operational in the fourth or fifth year. It has a guided press hammer (1,500 kg ram) for the production of small- to medium-size pieces (up to 2.5 kg). The ram is a fully equipped machine with attachments. A trimming press is used to finish the pieces. Heating is done by an electric furnace, as an oil furnace would require installation of a fuel tank. Machines which are able to use dies are chosen instead of an open-frame power hammer which needs highly skilled workers.

The advantages and disadvantages of various presses are shown below.

Press types	*Operating features*	*Advantages and disadvantages*
Eccentric press	An eccentric delivers thrust to the ram	High cost, limited versatility, rapid die wear. Difficulties in mounting dies. Low speed. Heat generated shortens die life
Friction press	The friction press has lower piece and die contact time than the eccentric press. This makes die mounting easier. To obtain desired thickness it is possible to ram the same piece several times	Moderate cost, limited versatility, die wear is irregular
Hydraulic press	The hydraulic system makes the use of multi-ramming dies and production diversification possible. It is an independent work centre in the plant	Rather high cost, excellent versatility, low die cost

The trimming press chosen has the same characteristics as the hydraulic forging press, but is less powerful.

Other equipment and transport

The electric furnace has greater temperature control, is less complex and produces less oxidation than the oil furnace. However, the electric furnace uses more energy and is subject to power failures. The hack saw machine is a traditional machine, and can be found on the market.

Material handling is carried out by manually operated transportation pallets in the various departments, by a 5 t jib crane which lifts heavy pieces in the tool department and by two fork-lift trucks which transport production materials to and from stores and production departments. The plant will also have a pick-up truck.

Appendix III

DETAILS OF TRAINING COSTS

TABLE 23. NON-LOCAL TRAINING COSTS

(Dollars)

Item	*Cost per trainee*	*Total cost*
Travel	3 000	72 000
Per diem expenses	4 000	96 000
Training	6 000	144 000
Total		312 000

TABLE 24. TECHNICAL ASSISTANCE PROGRAMME FOR THE SHEET-METAL MPDU

Job or function	*Duration (years)*	*Cost by year (thousands of dollars)* Year 1	Year 2	Year 3	Year 4	Year 5	*Total cost (thousands of dollars)*
Project manager (three years acting as general manager)	5	80	90	90	100	100	460
Chief workshop trainer and manager	4	35	80	80	90	45	330
Sheet-metal plant engineer	2	70	80				150
Sheet-metalwork trainer	3	30	70	70	40		210
Precision worker and toolmaker trainer	3	30	70	70	40		210
Precision worker and toolmaker trainer	3		70	70	80		220
Precision worker and toolmaker trainer	3		35	70	80	40	225
Precision (machine tool) instructor	3			80	90	90	260
Sheet-metal product designer	3	35	80	80	45		240
Tool and die designer	3	35	80	80	45		240
Tool and die designer	3		40	80	90	45	255
Industrial engineer and economist	3	35	80	80	45		240
Marketing engineer	2	70	80				150

TABLE 24. (continued)

Job or function	Duration (years)	Cost by year (thousands of dollars) Year 1	Year 2	Year 3	Year 4	Year 5	Total cost (thousands of dollars)
Short-term (4 to 6 months) engineering experts (quality control, heat treatment, specialist plant and tool design) (for 5 person-years)	5		40	120	135	135	430
Preparatory cost for equipment purchasing, local construction activity and recruitment							150
Total	45 person-years	420	895	970	880	455	3 770

TABLE 25 LOCAL TRAINING COSTS FOR THE SHEET-METAL DEPARTMENT[a]

Job or function	Cost by year (thousands of dollars) Year 1	Year 2	Year 3	Year 4	Year 5
General manager	8 (1)				
Assistant accountant	2.5 (1)				
Supervisor and counterpart trainer	6 (2)	10.5 (3)	16 (4)	22.5 (5)	30 (6)
Sheet-metal workers	5 (5)	16.8 (14)	16.8 (14)		
Auxiliary unskilled workers	2 (2)	4.8 (4)			
Total	23.5	32.1	32.8	22.5	30

[a]The figures in parentheses indicate the number of jobs.

TABLE 26. LOCAL TRAINING COSTS FOR THE TOOL AND DIE DEPARTMENT[a]

Job or function	Cost by year (thousands of dollars) Year 1	Year 2	Year 3	Year 4	Year 5
General manager	8 (1)				
Company secretary and accountant	6 (1)				
Assistant accountant	2.5 (1)				
Foremen and counterpart trainer	12 (4)	17.5 (5)	24 (6)	31.5 (7)	40 (8)
Counterpart engineers and technicians	30 (6)	10 (2)	10 (2)	10 (2)	10 (2)
Sheet-metal workers, toolmakers and mechanic	12 (10)	16 (20)	16 (20)	16 (20)	16 (20)
Auxiliary unskilled workers	3 (3)	6 (5)			
Total	73.5	49.5	50	57.5	66

[a]The figures in parentheses indicate the number of jobs.

TABLE 27. SUMMARY OF TRAINING COSTS

(Thousands of dollars)

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Total
In-plant group training (non-local)	156			4		156
Upgrading of engineers and counterpart trainers (non-local)	156					156
Technical assistance	570	896	970	880	455	3 771
Local training						
Tool and die shop	74	50	50	58	66	298
Sheet-metal	24	32	33	23	30	142
Forging				7	12	19
Total training cost	980	978	1 053	968	563	4 542

Appendix IV

PERSONNEL AND PERSONNEL COSTS

TABLE 28. PERSONNEL FOR THE SHEET-METAL PRESSING DEPARTMENT[a]

(Number of persons)

Job or function	Year 1	Year 2	Year 3	Year 4	Year 5
General manager	1	1	1	1	1
Assistant accountant	1	2	3	4	4
Supervisor and counterpart trainer	2	3	4	5	6
Sheet-metal workers	5	14	23	29	34
Auxiliary unskilled workers	2	4	5	6	7
Total	11	24	36	45	52

[a]Partial list.

TABLE 29. PERSONNEL FOR THE TOOL AND DIE DEPARTMENT[a]

(Number of persons)

Job or function	Year 1	Year 2	Year 3	Year 4	Year 5
General manager	1	1	1	1	1
Accountant	1	1	1	1	1
Secretary and accountant	1	2	3	4	4
Supervisor and counterpart trainer	4	5	6	7	8
Counterpart engineers and technicians	6	8	10	12	14
Toolmakers and mechanics	10	20	30	40	50
Auxiliary unskilled workers	3	5	6	7	8
Total	26	42	57	72	86

[a]Partial list.

TABLE 30. COST OF PERSONNEL FOR THE SHEET-METAL PRESSING DEPARTMENT

(Thousands of dollars)

Personnel	Year 1	Year 2	Year 3	Year 4	Year 5
General manager	8	9	10	11	12
Assistant accountant	2.5	6	10.5	16	16
Supervisors and counterpart trainers	6	10.5	16	22.5	30
Sheet-metal workers	5	16.8	34.5	52.2	68
Auxiliary unskilled workers	2	4.8	7	9.6	12.6
Total	24	47	78	111	139

TABLE 31. COST OF PERSONNEL FOR THE TOOL AND DIE DEPARTMENT

(Thousands of dollars)

Personnel	Year 1	Year 2	Year 3	Year 4	Year 5
General manager	8	9	10	11	12
Accountant	6	7	8	9	10
Secretary and accountant	2.5	6	10.5	16	16
Supervisor and counterpart trainer	12	17.5	24	31.5	40
Counterpart engineers and technicians	30	44	60	78	98
Toolmakers and mechanics	12	32	57	88	125
Auxiliary unskilled workers	3	6	8.4	11.2	14.1
Total	74	122	178	245	315

Appendix V

INVESTMENT AND DEPRECIATION

TABLE 32. SHEET-METAL PRESSING DEPARTMENT INVESTMENT AND DEPRECIATION

(Thousands of dollars)

Item	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Buildings					
Investment	258				
Depreciation	10	10	10	10	10
General Systems					
Investment	135				
Depreciation	7	7	7	7	6
Machinery					
Investment	90	210	330	340	230
Depreciation	9	30	63	97	120

TABLE 33. TOOL AND DIE DEPARTMENT INVESTMENT AND DEPRECIATION

(Thousands of dollars)

Item	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Buildings					
Investment	342				
Depreciation	14	14	14	14	14
General Systems					
Investment	203				
Depreciation	10	10	10	10	10
Machinery					
Investment	305	500	400	210	85
Depreciation	31	81	121	142	150

III. Casting

The main objects of the present study are:

(a) The identification of the present and the expected market demand for iron and non-ferrous castings and for the supply of specialized services;

(b) The development of professional capabilities in the fields of administration, marketing, engineering and technology by local people;

(c) The training of workers for production and for highly specialized tasks such as pattern making, precision machining, maintenance, and general installation control;

(d) The production of capital goods including spare parts using high-quality machined castings.

The unit will thus become self-sufficient and independent from overseas know-how. The unit will also be able to supply local industries with engineering and machine tools or pattern-making services, thus generating additional income for the factory. The unit should also be, generally speaking, profit and market oriented. This is one aspect of other broader and more important goals such as social improvement and generation of spin-off activitivies.

The study is in two parts: *(a)* a detailed description of the proposed foundry unit, including an analysis of what is needed in money, people and machines to make it viable, and *(b)* a discussion of the adaptation of casting processes for use in developing countries.

A. Description of the proposed foundry unit

The foundry unit 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 following steps:

(a) Production of the pattern. This step translates the idea of the designer into a pattern. The pattern maker must take into account the physical-chemical and metallurgical characteristics of the raw material, of the refractory materials, and of the processes of casting;

(b) Production of the mould;

(c) Preparation of sand and bonding elements forming the mould;

(d) Preparation of cores. Cores are required if the casting is hollow. The template shaping the core is called a "core box";

(e) Preparation of the metal. This involves melting and also proper control of composition;

(f) Assembling the cores and clamping the moulds;

(g) Introducing liquid metal into the mould;

(h) Removing the solidified casting from the sand (knock-out);

(i) Final conditioning. This includes removing supplementary parts, sandblasting, grinding, chipping and heat treatments;

(j) Inspection, which is carried out both "in line" and on the finished products.

In some cases the mould is made of metal and is permanent. Such moulds are used for die casting. Figure II shows the main steps of the process. The foundry's final products are rough castings. Normally these castings are later machined in another process.

Product types

The plant consists of a casting unit producing mainly grey and nodular iron parts with a small shop for non-ferrous castings. Its is estimated that full production (about 80% of the capacity) will be reached within five years, with some production beginning during the second year of operation. The capacity of the plant is 2,000 t/a of useable iron castings and 36 t/a of "good" non-ferrous castings. The following calculations are based on 225 working days of 8 hours each per year. Production of rough grey iron castings will be 1,360 t/a; of rough nodular iron castings, 240 t/a; and of rough non-ferrous castings, 30 t/a.

Two shops will adjoin the casting shop. These will be a pattern shop and a department for machining rough castings with a capacity of 50% of the foundry output. This machine shop will

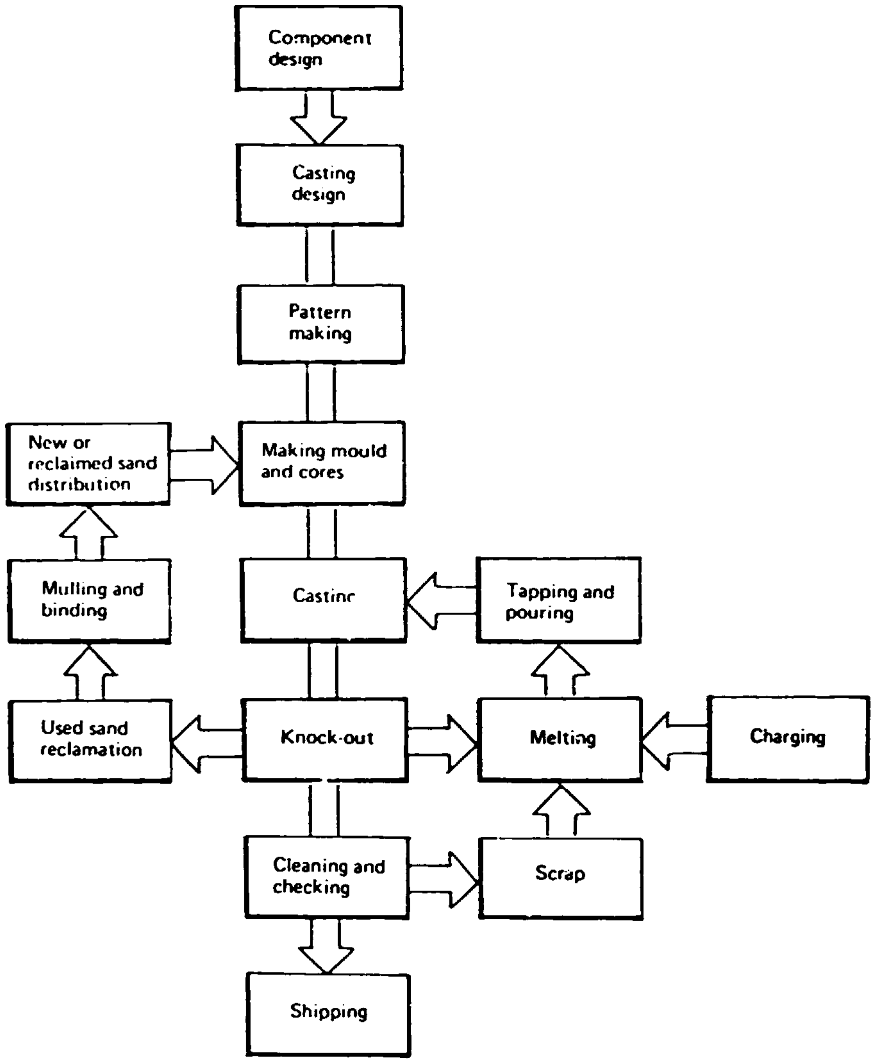


Figure 11. Process sequence of the main steps of the foundry processes

also produce for outside customers. These two shops will serve as producing and training centres that will train highly skilled people. The two shops are integral parts of the basic MPDU.

Plant and equipment

Figure 12 is a general floor plan of the foundry. The fenced area is 38,400 m²; the total covered area is approximately 6,000 m².

The rationale for equipment selection considers general characteristics of developing countries, existing equipment and processes, and the overall suitability of equipment and processes. These guidelines cover a wide range of possibilities. For the main processes, alternatives have been included. It is necessary to know in more detail the nature of the site where the unit is to be installed in order to propose specific equipment and materials.

Investment estimates

A detailed list of technological equipment and machinery, general installations, buildings and site development can be found in appendix I to this chapter. Table 34 summarizes the estimated cost of these items.

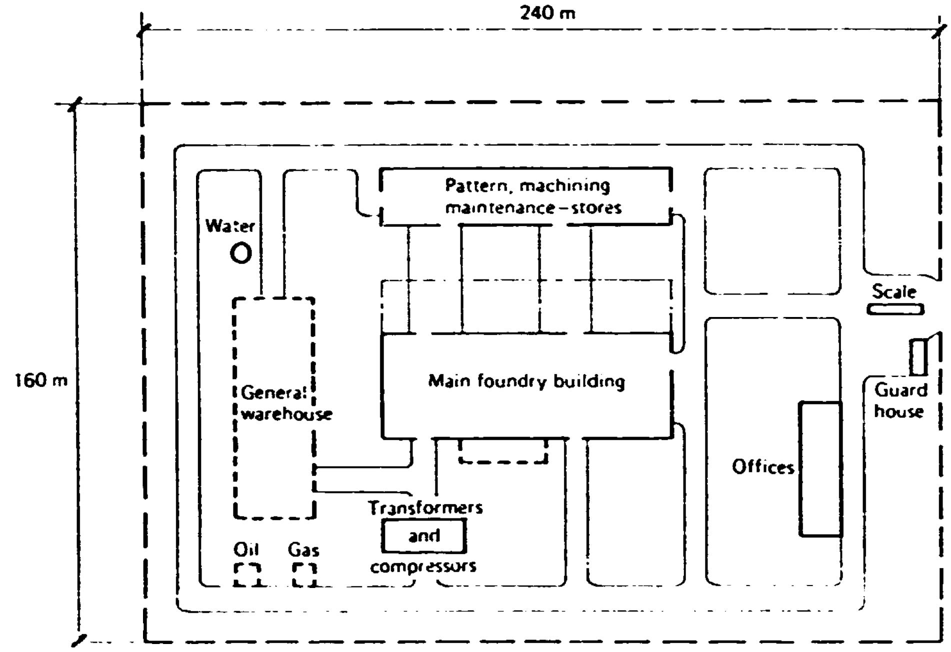


Figure 12. General floor plan of the foundry

TABLE 34. SUMMARY OF ESTIMATED CAPITAL COSTS FOR THE FOUNDRY

(Thousands of dollars)

Item	*Cost*[a]
Iron foundry facilities	1 235
Non-ferrous foundry facilities	138
Utilities and material handling	640
Inspection and laboratory testing	115
Pattern-shop	195
Machine and maintenance shop	780
Building and site development	1 000
Total	4 103

[a]Including freight, foundations, erection and installation

TABLE 35. SUMMARY OF ESTIMATED TRAINING COSTS FOR THE FOUNDRY

(Thousands of dollars)

Item	*Cost*
Non-local training costs	
Introductory in-plant group training for managers, engineers and counterpart trainers	182
Professional improvement for engineers and counterpart trainers	208
Technical assistance programme for five years, nine people (45 person-years)	3 765
Local training costs	600
Total	4 755

General training

One of the most important purposes of the unit is training. Training will make the unit independent of non-local expertise and know-how, as far as possible. Training needs are detailed in appendix II. Training may include non-local training, technical assistance programmes (experts will be integrated with counterpart trainers during the first stages of unit production) and in-plant training. Among different training programmes needed are those for managers, engineers and counterpart trainers, precision workers (machinists, mechanics), pattern makers, foundrymen, personnel staff, clerks, drivers and labourers.

Table 35 shows a summary of training costs. The costs are allocated over a period of one or more years according to the type of training. Training subsidies are expected to counterbalance training costs.

Overall operation

Tables giving details of production, personnel, wages and salaries will be found in appendix III. Production results from rough castings, pattern-shop services, workshop services and engineering services. Costs for castings have been estimated to be 20% above European levels. Local market prices have been estimated to be 30% higher than European prices for each type of casting. The estimated costs are $1.2 per t for grey iron casting; grey iron $1,200 per tonne; nodular iron $1,500; non-ferrous $3,500.

Production

Casting production will increase to a maximum in the fifth year. The first two years will be devoted to in-plant training. In the first year production work will be at a low level of efficiency with the percentage of rejects at about 50% of the output. This is to be expected due to the low level of skills and to the high failure rate of new machinery.

In the third year the same number of workers will produce twice as much and have a lower cost for materials.

Personnel and salaries

In the fifth year, there will be 130 personnel for the foundry, 16 for the pattern shop and 10 for the machine tool and fitting shop. Of the line personnel roughly 30% will be skilled workers, 35% semi-skilled and 35% unskilled. There will be 14 supervisors and foremen in the fifth year (12 for casting and 2 for the pattern and other workshops).

There will be 14 engineers after five years of plant operation. The work done by 12 of them will be service work for outside customers and will generate revenue (two engineers will be employed in production of castings and foundry design). The administrative staff will consist of 1 production manager, 2 other managers, 2 secretaries, 3 persons in financial services and 2 in sales.

Contingency reserve

Operating costs, revenues and depreciation are detailed in tables in appendix IV. For rough castings 10% of the manufacturing cost has been considered a "contingency" to be added to obtain operating cost. The contingency cost is 15% in the second year. Overheads for services (service sales and management) are included in machine costs.

Depreciation

Depreciation times for investments are assumed to be 25 years for site development and buildings (4% per year straight line), 20 years for general installations (5% per year straight line) and 10 years for technological facilities (10% per year straight line). The cost of auxiliary equipment ($150,000) is added to the investment for technological facilities. Patterns, tool fixtures and different types of materials to start production are considered as working capital.

Revenues from services

The pattern shop will devote roughly 40% of its time to pattern repair and 60% to the manufacture of new patterns for sale. The machine shop will devote 50% of its time to revenue producing activities. The revenue will be based on the wages, machine costs and overheads for sale and management.

Table 36 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.

TABLE 36. 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	583	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.

B. Adaptation of casting processes for developing countries

Production programme

The choice of the production technique depends on machine characteristics as well as other aspects of the foundry production programme. Table 37 shows the output of the foundry, assuming 225 eight-hour working days per year.

TABLE 37. OUTPUT OF THE FOUNDRY[a]

	Output	
Item	*t/a*	*Number of pieces*
Grey cast iron	1 360	76
Nodular cast iron	240	30
Total	1 600	106

[a]A 10% allowance must be made for rejects

Selection of pattern-making methods

Table 38 shows the characteristics of various pattern-making techniques. Special methods such as investment casting are not included.

The pattern-making department for the proposed MPDU foundry has been designed by adapting wood and plastic pattern-making machines. The immediate purchase of metal-pattern machines, requiring an investment in excess of $500,000, is not wise. The cost of the patterns for a run of only 1,000 castings is excessive. For these reasons, the construction of combined patterns has been considered only in the very infrequent cases of large runs.

Resin (usually epoxy) patterns can be produced from the wood pattern. Various other manufacturing methods are more suitable for certain types of production, infrastructure and labour skill.

For the jolt moulding machines, double match plates (top to bottom) have been chosen. These enable higher accuracy than opposed patterns, easier touch-up for half-mould finishing, and easier handling. Flaskless mouldings are suggested for larger castings using the mixer for production to prevent the use of heavy and expensive flasks. The unfinished patterns (and to a minor extent loose patterns) require highly skilled labour. Craftsmen from neighbouring villages may be trained for this hand moulding. Consequently, sweep or skeleton patterns can be produced in small numbers for spare parts. It is impossible at this stage to make a detailed study of resin types and their suitability because of differences in local climates and temperatures, and different end-uses. It is important to match materials and machining methods to the climatic conditions of the selected country.

Selection of sand-mould production equipment

Table 39 shows the general characteristics of the main moulding methods for cast-iron castings. Machinery for specialized use has not been included.

For castings less than 10 kg, the jolt-squeeze machine is an inexpensive and very versatile machine. It relieves the moulder from considerable physical fatigue and ensures satisfactory accuracy of the product. There is no requirement for metal patterns or for long professional experience. Productivity (though the process is not used in mechanized lines) is fairly good and can exceed 30 moulds per hour. Flasks 800 mm by 600 mm by 250 mm high seem to be the most suitable for castings up to 10 kg. A machine of this kind can produce an average of four castings per flask.

The most versatile machine for medium-weight castings (10 to 100 kg) is the continuous mixer, which may be used with a vibratory table. This machine allows hardening of mixes prepared by the mixer and does not require baking. Temperature, ambient humidity, and storage time are important considerations. These machines can produce (with minor mechanization) up to 10 moulds per hour. Accuracy, good surface finish, versatility, easy operation and start-up, low cost and no flasks, characterize this process. The patterns are usually made of wood.

An area is reserved for pit moulding where up to 2 t of castings can be produced using simple patterns. The cores and loose pieces may be assembled from products of a "no-bake" mix for the case of larger series. The pit moulding technique allows for special moulds and sizes and is essential in countries where individual items may be urgently required as spares. A projected small production run for marine and mining industries is incorporated in the MPDU planning.

Hand moulding requires experienced personnel. The MPDU includes provisions for workers to be carefully selected and trained in these techniques. Moulding methods and machines are shown in figures 13 through 20. Table 40 shows characteristics of core sand moulding methods.

Sand-core production methods

Hand core moulding requiring baking is limited to the special cases of large castings, very small series, or immediately required castings. This is due to the high skill usually required, and to the poor accuracy and low productivity.

TABLE 38. CHARACTERISTICS OF VARIOUS PATTERN-MAKING TECHNIQUES

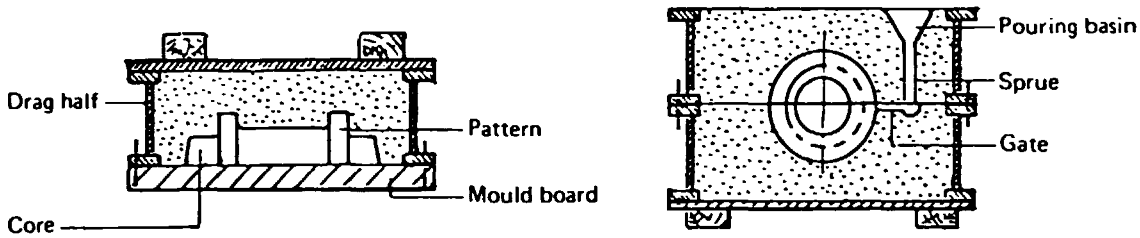
Pattern-making technique	*Materials used for pattern*	*Number of mouldings produced*	*Moulding method*	*Level of technical skill required*	*Relative cost*	*Relative casting size*	*Auxiliary tools used*	*Comments*	*Appropriateness for developing countries*
Full pattern									
Loose									
Single	Wood 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 200 (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		

TABLE 39. CHARACTERISTICS OF MOULDING METHODS

Moulding method	*Technique used*	*Run length and comments*	*Product quality*	*Manpower skills needed*	*Equipment*	*Relative productivity (number)*	*Equipment investment costs*	*Adaptability for developing countries*
Hand moulding								
In moulding box	Uses green or dry moulding sand in a unit or as facing and backing sands	Short run, generally large simple patterns	Low to very low	Medium	Loose pattern or wood splitted pattern	1 to 2	Low	Only for small foundries
In flaskless moulds	Generally uses baked sand unit	Short run and limited size castings	Low	Medium	Loose pattern or wood splitted pattern	1	Low	Only for small foundries
In pit		Short run, large castings	Very low	High	Loose pattern, even reduced (profile skeleton)	1	Low	
Machine moulding								
Squeeze	Uses compression plate, multiple rammers etc.	Simple shapes, limited size patterns	Medium	Low	Plastic or wood board pattern	15	Medium	Only for thin castings
Jolt	Uses different types of jolt	Patterns of limited size; complex profiles	Medium	Medium	Plastic or wood plate pattern	10	Medium	Long runs, with output of 20 moulds per h
Jolt-squeeze		Castings with sizes generally smaller than 1 500 mm	Medium	Medium	Plastic or wood board pattern	15	Medium to high	Medium run with output of 30 mould. per h
Pneumatic compression	Metal is blown or shot into mould	Long runs, for sizes smaller than 1 000 mm	High	Medium	In preference metal type	20	Medium to high	Good productivity but high pattern cost
Mechanized sequences		Very long runs, for sizes generally smaller than 2 000 mm	Very high	High	Metal type very precise and accurate	Greater than 100	Very high	Absolutely not suitable

TABLE 39 *(continued)*

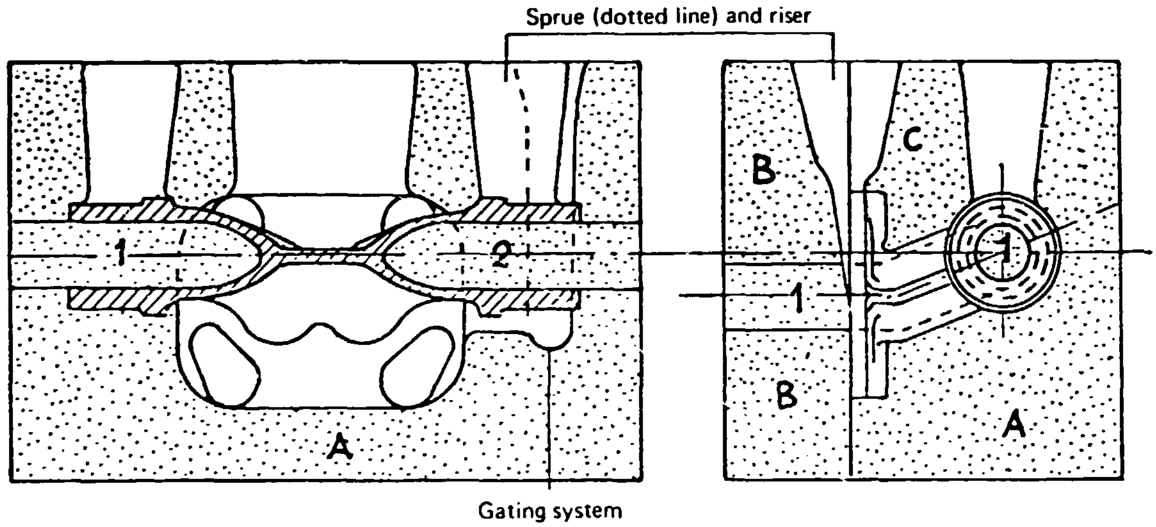
Moulding method	*Technique used*	*Run length and comments*	*Product quality*	*Manpower skills needed*	*Equipment*	*Relative productivity (number)*	*Equipment investment costs*	*Adaptability for developing countries*
Swing slinger	Metal is distributed by centrifugal force	Very flexible production of different types of castings	Medium to low	Medium	Plastic or metal type	10	High	Versatile but with high maintenance costs (patterns and impellers)
Continuous mixer	Concurrent addition of binders is possible, as is pre-mixing of sand with different binders	Flexible production for high surface quality and precision castings	Medium	Medium	Wood, plastic or metal type	8 to 10	Medium	Versatile, easy to employ, good quality results and simple patterns
Blowing with chemical hardening	May use several processes including CO_2 shell moulding and cold box	Long run	High	Low	Metal type	Greater than 100	Medium	Adaptability varies with bench life
Flaskless moulds mechanized line	Horizontal or vertical parting line	Simple, precise (possibly coreless), very long run castings	Very high	High	Very precise and accurate metal type	Greater than 100	High	Absolutely not recommended



A. Drag made by hand

B. Cope made by hand directly on the drag

Figure 13. Traditional hand moulding with split pattern



A. Front

B. Side

Figure 14. Flaskless hand moulding with internal cores

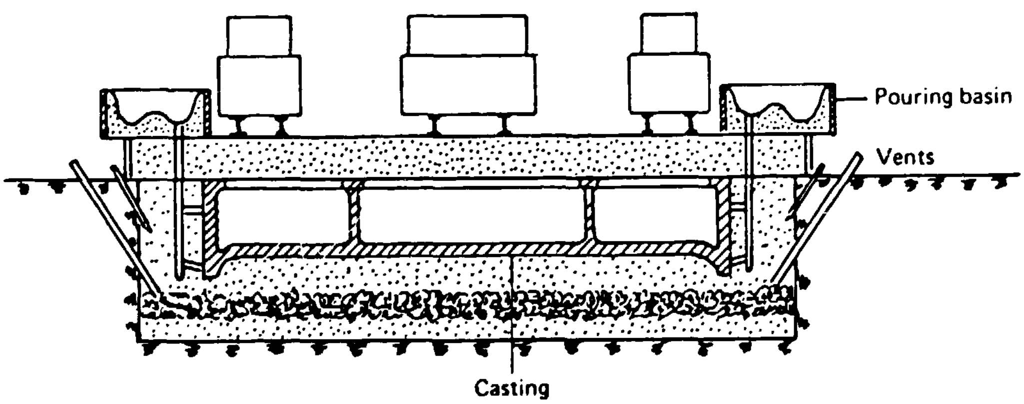
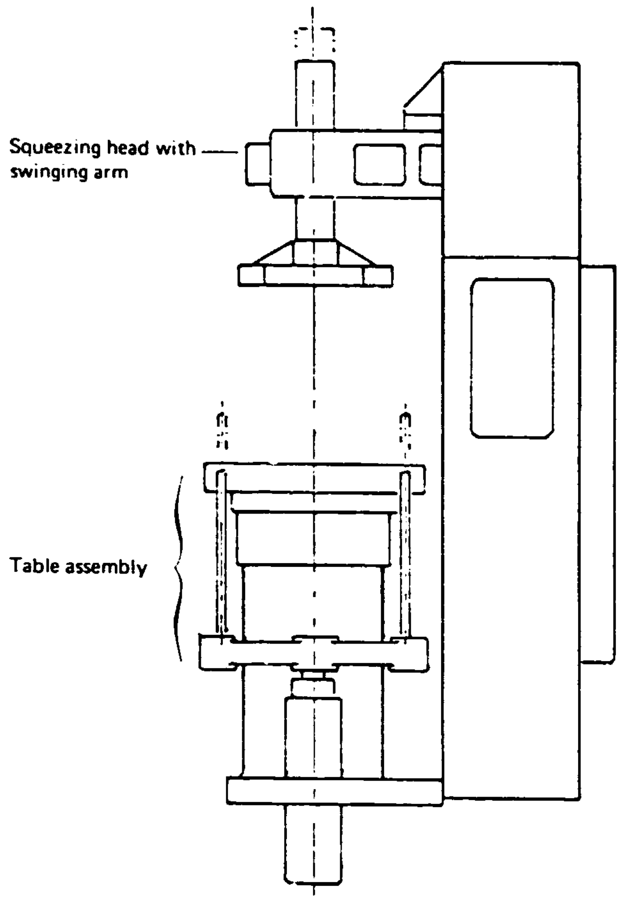
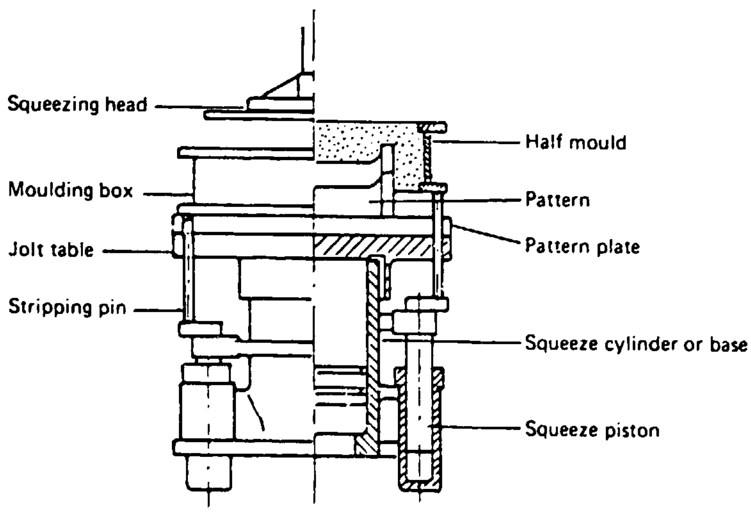


Figure 15. Pit moulding with cope

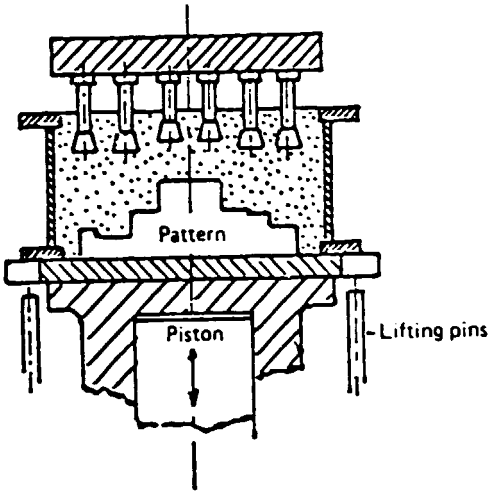


A. Schematic side view

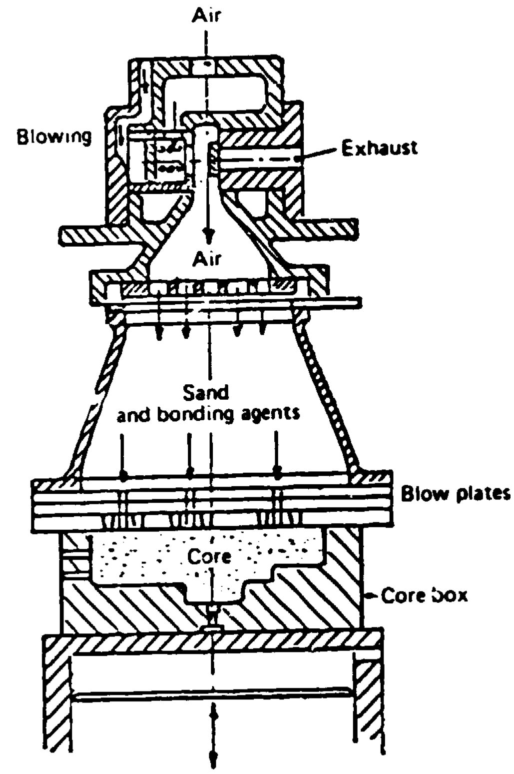


B. Enlarged view of table assembly

Figure 16. Jolt-squeeze machine



A. Multi-piston compensating head



B. Typical blowing set-up

Figure 17. Mechanized moulding machines

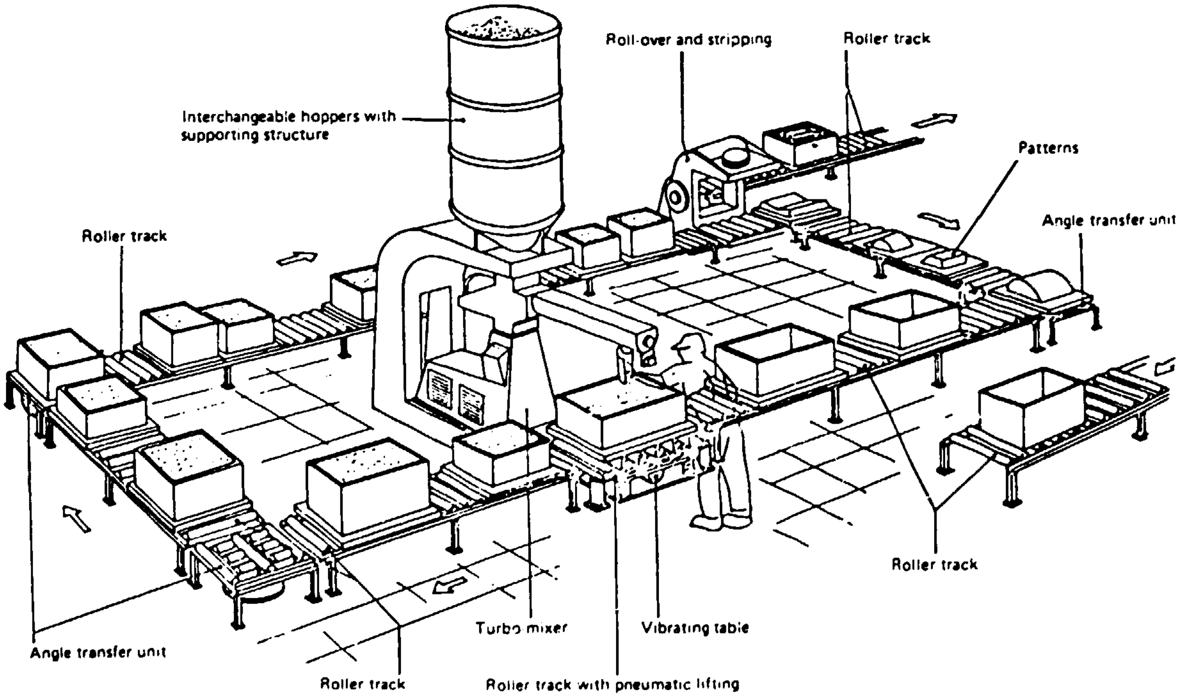


Figure 18. System for the no-bake moulding process

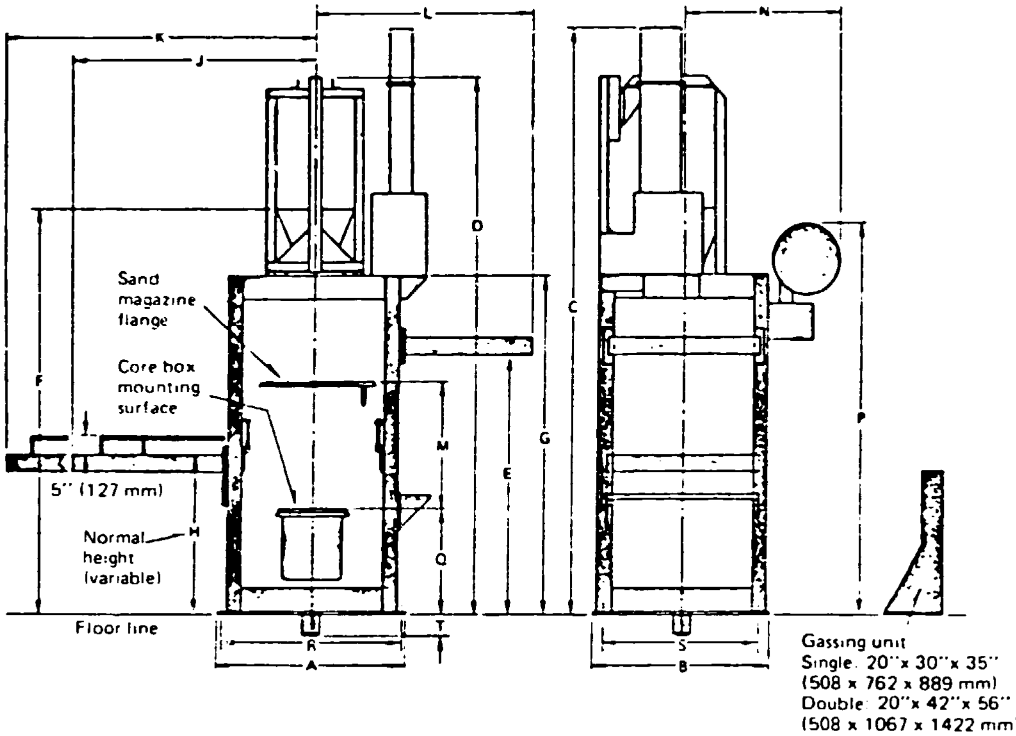
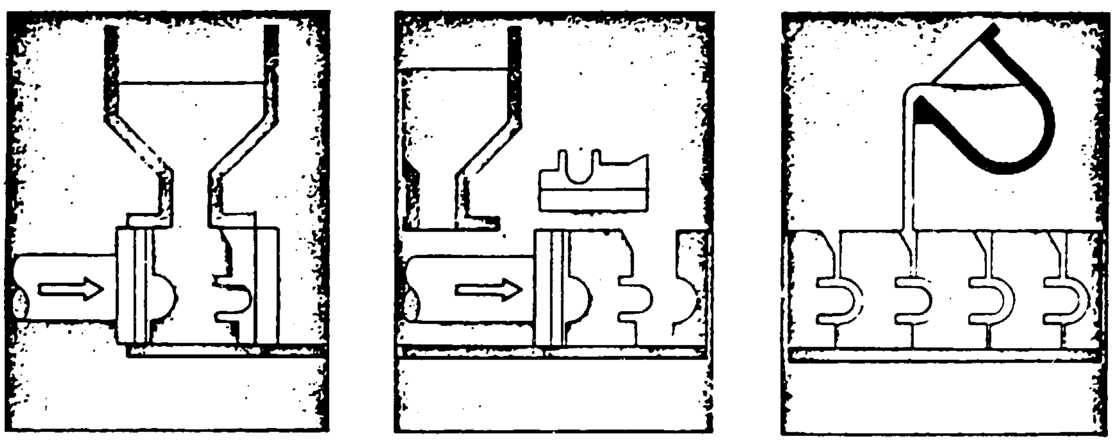


Figure 19. A shell-moulding machine



A. The moulds are flaskless. Using this moulding method, the sand is squeezed into a chamber, resulting in a completely homogeneous block of sand fully capable of withstanding the pressure of the liquid iron.

B. Moulds are positioned vertically. The advantage is evident. Whereas the horizontal arrangement calls for a drag and a cope to make up a mould ready for pouring, this method simply lines up the moulds, one after another.

C. Each mould carries two pattern impressions, front and back. This moulding method doubles the moulding capacity in comparison with conventional methods as the outside mould surfaces receive pattern impression.

Figure 20. Typical automated moulding by a flaskless method (capacity is 300 moulds per hour)

TABLE 40. 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 mixtures	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 cost	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

Oil-sand hand or machine moulding should be used in a limited way because of the core supports required before baking in order to prevent deformation.

For series cores (approximately 2,000 per d (day)), it is best to use two core-blowers (capacity 30 cores per hour ranging in size from a few grams up to approximately 10 kg) with a blowing station. The mix is hardened by a gas. Large cores can be produced with the continuous mixer, combined with flaskless mouldings or using special sand and additives. Figures 21 through 25 show sand core production equipment.

Table 41 shows the characteristics of principal materials used for sand moulds and cores.

For small to medium casting mouldings recoverable green sand (moisture 2.5%-4%) is undoubtedly the most convenient choice provided a good base sand and proper dust-exhaustion and cooling equipment are available.

In the foundry under consideration, green sand has been selected for the jolt-squeeze machines. By reducing the additives, it can also be used as backing sand where the methods of facing and backing sand in the same moulding box are employed. This method is obsolete in Europe for mass production (it is expensive, slow and non-uniform), but it is undoubtedly suitable for hand and pit moulding where highly refractory special sands are used as facing sand. For continuous mixer moulding suitable for production of flaskless mouldings as well as of cores, sand can be agglomerated with many types of binders requiring no-bake. In this case the set-up must be done with due consideration for the climatic conditions and their effect on bench life, stocking etc. The CO_2 method seems most suitable (see table 41).

Selection of smelting equipment

Table 42 shows the characteristics of fuel-fired melting furnaces. Table 43 shows characteristics of electric melting furnaces.

A smelting plant for a cast-iron foundry in emerging countries depends on many considerations:

- Metallurgy of the product
- Output rate of moulds
- Casting sizes and complexity
- Availability and rehability of energy
- Availabilty of materials (charge, refractories, spares)
- Availability and cost of skilled labour
- Investment and operating costs

In the following discussion the most favourable conditions for smelting in a non-industrialized country will be noted and specific application to the foundry under consideration will be studied.

A hot-air cupola is an expensive and delicate piece of equipment and must be operated with extreme care. Its operation may require special materials, alternate sources of combustion or fuels which are not available in countries where transportation is irregular, and imports restricted.

The natural gas or mixed-heat-source cupola is relatively new. Charcoal cupolas have limited application, low productivity and (at least at present) operate at low temperatures and produce low quality liquid cast iron unsuitable for this foundry programme.

Crucible furnaces are suitable for specific production of bonded cast iron. This method is, however, obsolete and not very versatile. Static reverberatory furnaces (which can be used as smelting or holding furnaces) are generally intended for large-size production (rolling mill rollers), for malleable cast iron and for non-ferrous metals. In general these are being replaced due to low thermal efficiency (where the air is not pre-heated) and restricted versatility.

Vertical channel furnaces are non-uniform in temperature and are beset by breakage of the bottom part of the refractory. Open channel furnaces have problems of heat exchange and side-channel erosion. Thus the horizontal tilt channel is best. For induction furnaces without a channel, low-frequency current is the most suitable for cast-iron casting for economical and metallurgical reasons. Generally, high tonnages of liquid cast iron can best be produced with low-frequency furnaces. Medium-frequency furnaces are suitable for small production working with a cupola.

The above considerations restrict the choice of furnaces possible for developing countries to the following:

- Reverberatory rotary furnace
- Electric-resistance rotary furnace
- Horizontal tilt closed-channel furnace
- Low and medium-frequency crucible induction furnace
- Electric-arc furnace

Considerations of suitability, cost, training needs etc. lead to the selection of a cold-air cupola plant with an unheated forefurnace (figure 26) for the MPDU foundry. This equipment can be combined with a medium-frequency induction furnace (for nodular cast-iron casting).

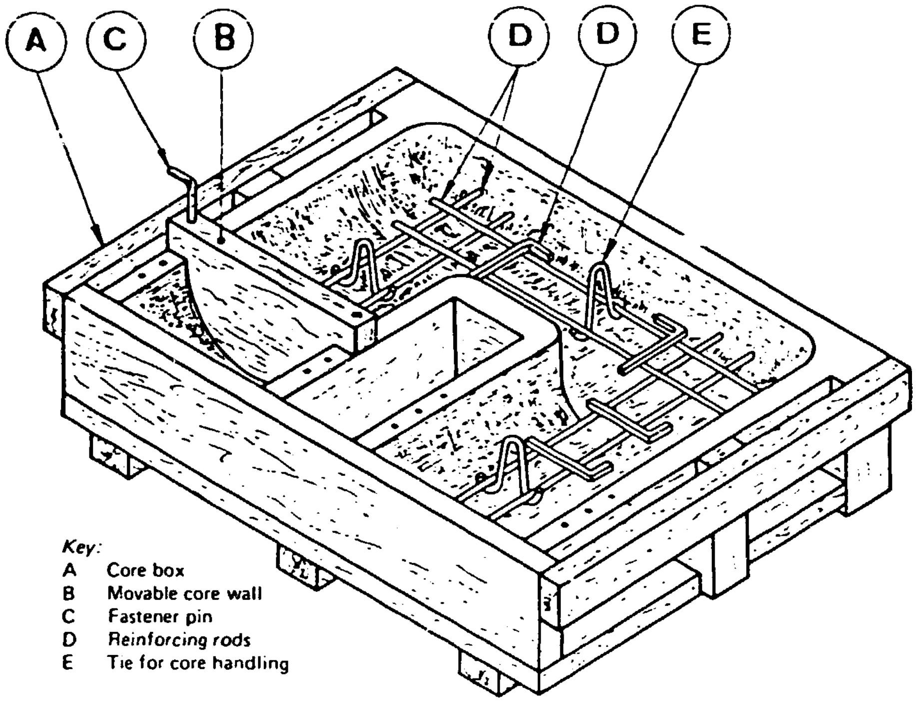


Figure 21. A core box

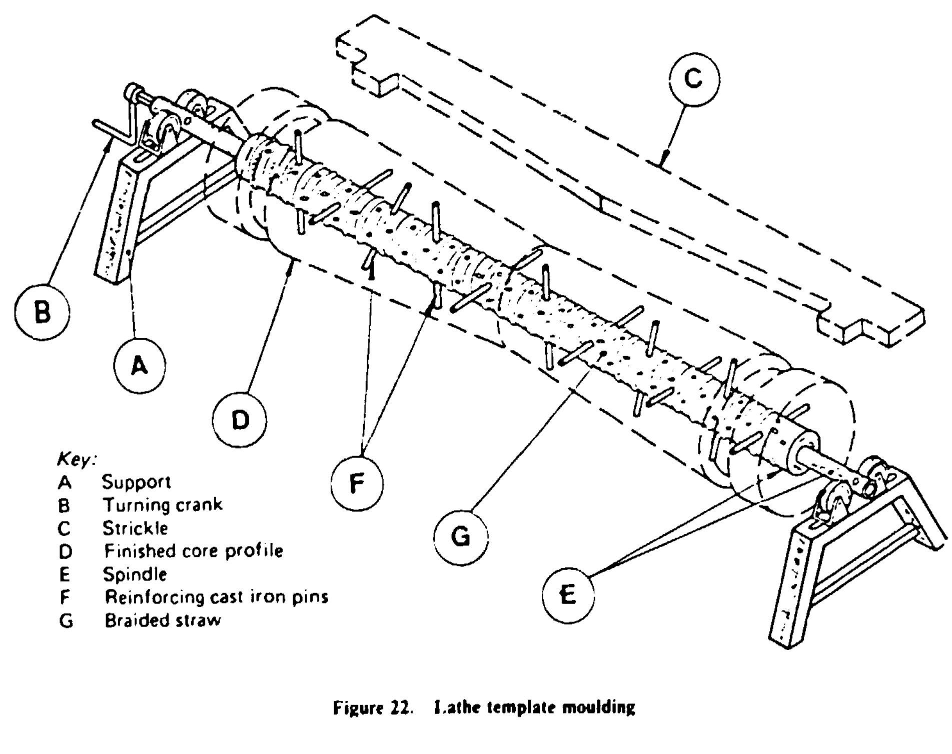
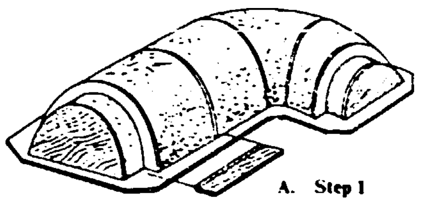
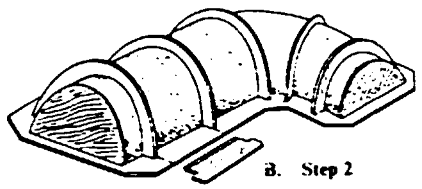


Figure 22. Lathe template moulding

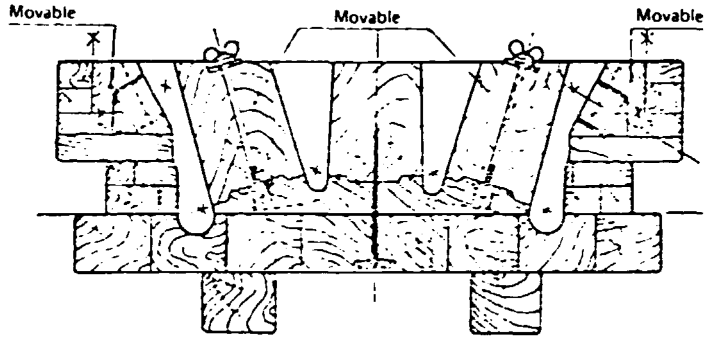


A. Step 1

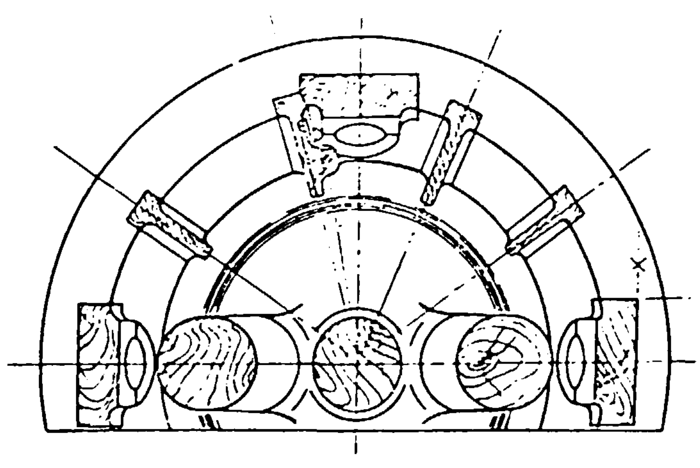


B. Step 2

Figure 23. Skeleton moulding of a core



A. Side view



B. Plan view

Figure 24. Core box for a marine diesel-engine cylinder head

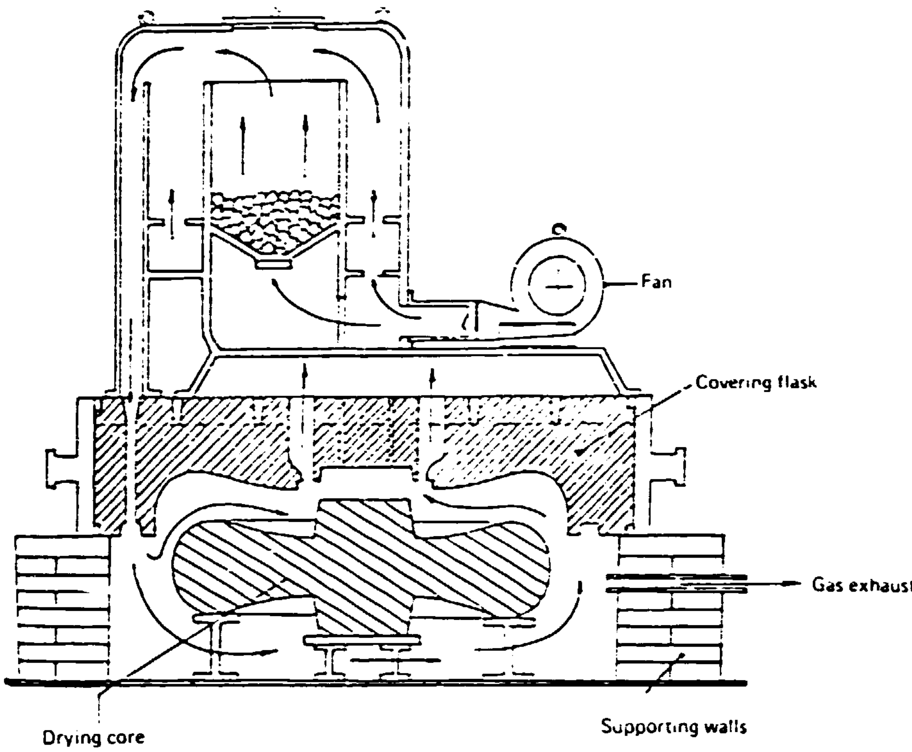


Figure 25. A portable core heater

Selection of sand recovery methods

The requirements for a green-sand recovery plant in developing countries are:

- Good selection of return sand
- Efficient cooling
- Excellent pulverization
- Easy withdrawal from storage bins
- Use of safe and simple equipment
- The ability to manually mix binders with the sand
- Good aeration of prepared sand

These requirements can be met by:

- Shake-out on fixed screen for large castings, and on vibratory screen for small to medium sized plants
- Double separation of metal parts (pulley and magnetic belt)
- A roller lump-crusher for easier maintenence
- Additional cooling with an elevator-cooler
- A properly exhausted disintegrating rotary sieve
- A fixed-tank discontinuous-cycle muller (10 t/h capacity)
- Pan metering of new sand and additives by manually controlled volumetric methods
- An aerator-pulverizer for prepared sand which can be adapted to a conveyor belt technique
- Small volume bins and hoppers, of proper shape, fitted with vibrators and extractors which must be designed for the specific project

Recovery of shaked-out sand during the process of moulding with a continuous mixer will not be considered due to the low volume and the assumed availability of raw material.

Figure 27 shows steps in the reclamation of moulding sand. Figure 28 shows a sand reclamation system for chemically bonded sands. Figure 29 shows sand recovery equipment. Figure 30 shows sand mullers. Figure 31 shows a conceptual view of recovery, mixing with new sand and mulling in a process sequence. Table 44 shows machinery for sand recovery operations.

Cleaning operations

Table 45 shows characteristics of cleaning operations. For developing countries knock-down

TABLE 41. CHARACTERISTICS OF MIXES USED FOR MOULDS AND CORES

Mix	*Use*	*Mould size*	*Patterns*	*Relative cost (number)*	*Relative productivity (number)*	*Compressive strength (kgf/cm2)*	*Average collapsibility (%)*	*Flowability*
Natural sand								
Sand, clay, water	Moulds	Unlimited	Wood	1	1	15 to 25	80 (average)	Poor
Cement sand								
Sand, cement, water	Cores and moulds	Large	Wood	1.5	1	10 to 20	50 (bad)	Excellent
Synthetic sand								
Sand, bentonite, seacoal, water	Moulds	Unlimited	Wood or metal	2	2	0.9 to 1.5	90 (good)	Poor
CO_2								
Sand, silicate	Cores	Small to medium	Wood, metal for long runs	2.5	2	15 to 70	50	Good
Sand resin								
Sand, resin catalyst	Cores and moulds	Unlimited	Wood, resin or metal	2.5	4	40 to 70	90	Good
Sand-furan								
Sand, furan resin, catalyst	Cores and moulds	Small to medium	Wood, resin or metal	3	5	50 to 80	90	Good
Hot box								
Sand, resin catalyst	Cores	Small to medium	Cast iron	2.5	4	50 to 60	90	Good
Cold box								
Sand, resin, hardener	Cores	Small to medium	Wood, resin or metal	3.5	5	50 to 80	90	Good
Fluid sand								
Sand, silicate surfactant, silicate	Cores	Medium to large	Wood, resin or metal	3	6		80	Excellent
Sand-oil								
Sand, oil and alkyd resins	Cores	Small to medium	Wood, resin or metal	2	1	9 to 12	90	Average
Shell moulding								
Sand, phenolic resins	Cores and moulds	Small to medium	Metal	8	5	40 to 70	85	Good

TABLE 42. 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 pro-cess 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)

TABLE 43. CHARACTERISTICS OF ELECTRIC MELTING FURNACES

Furnace type	*Heat source*	*Electrical characteristics*	*Capacity*	*pH*	*Lining*	*Energy consumption (kWh/t)*	*Utilization 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 80 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 650-760*	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 380 V. The ratio of power to capacity (kVA/t) 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

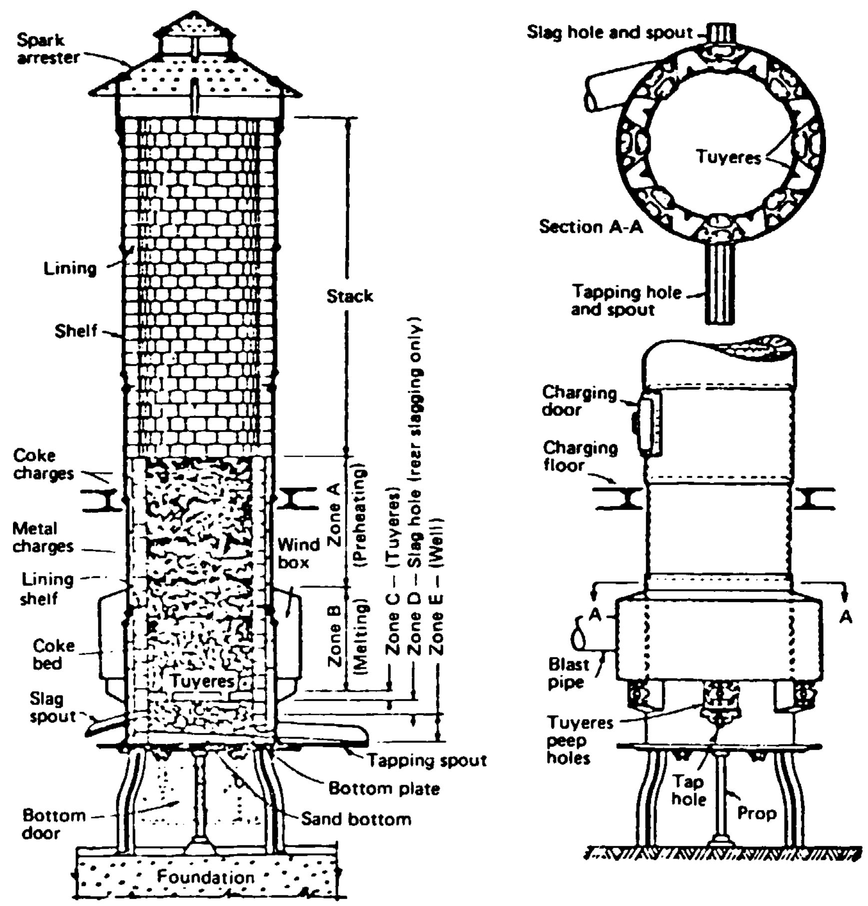


Figure 26. A conventional cold-air cupola

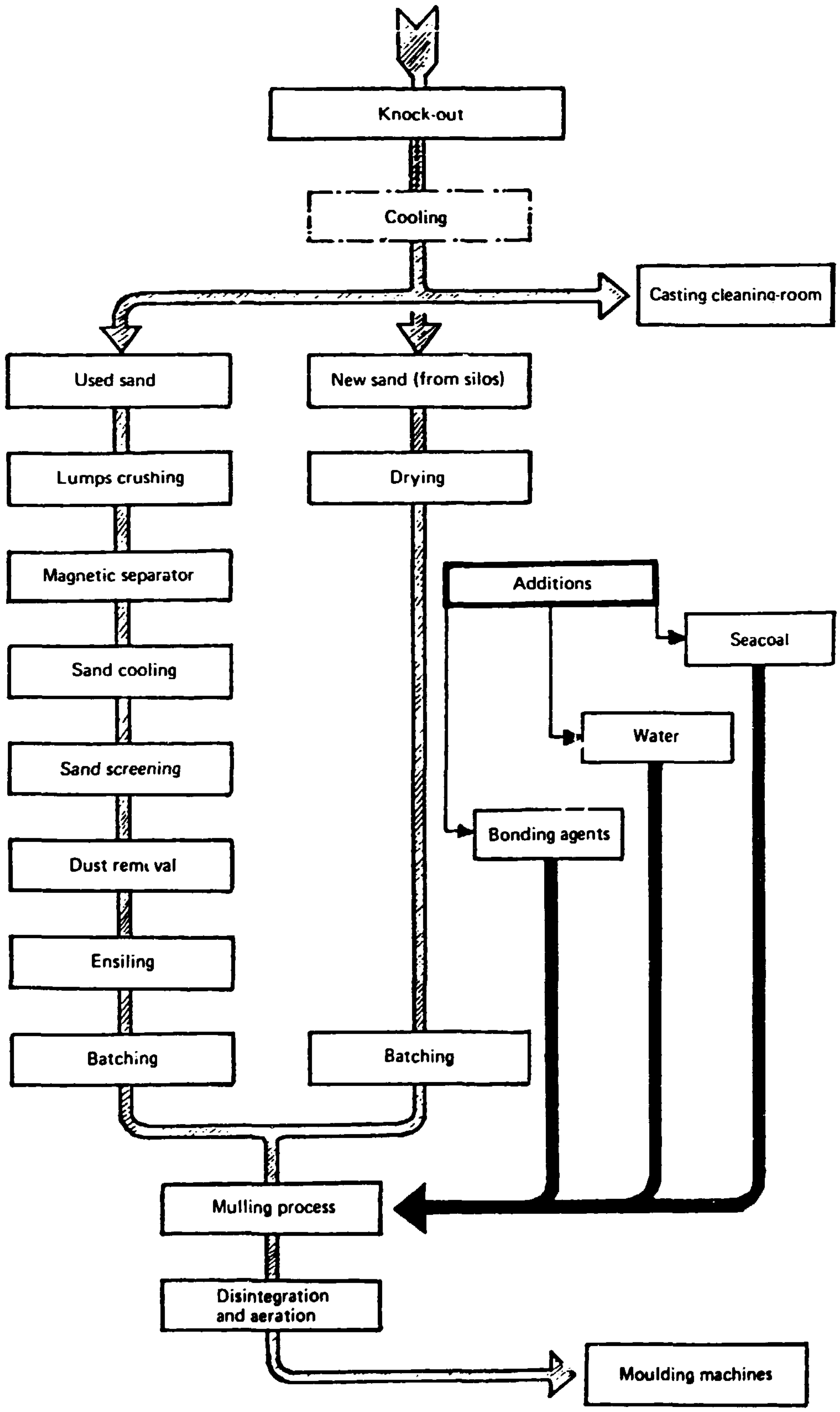


Figure 27. Steps in the reclamation of moulding sand

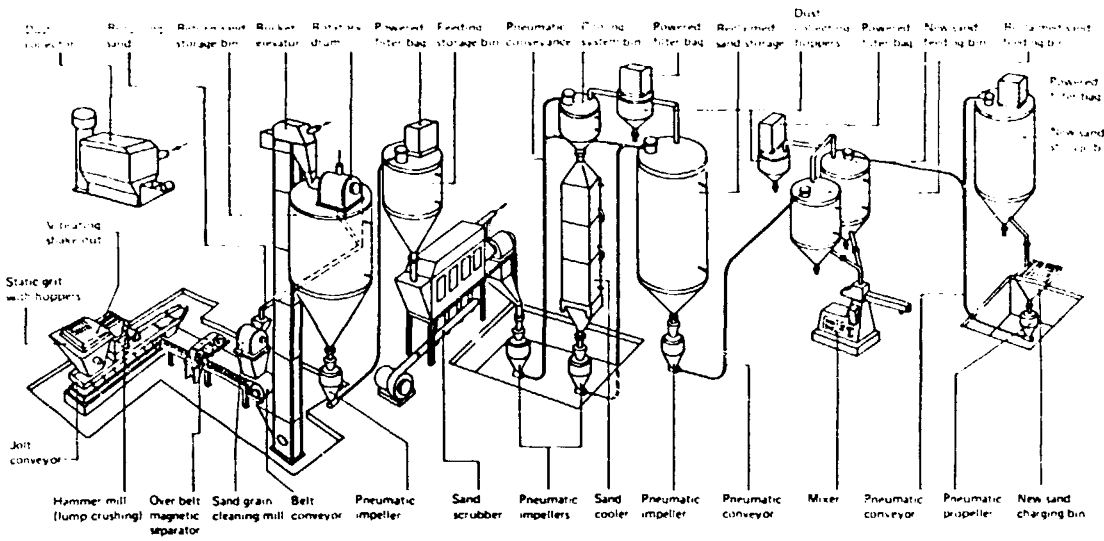
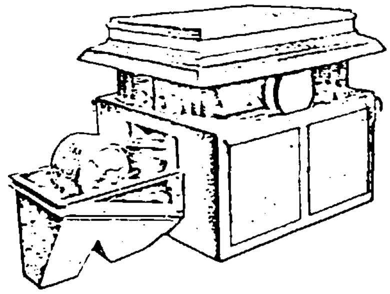
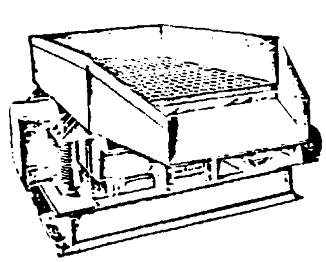


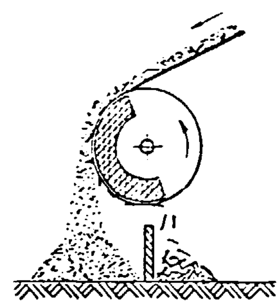
Figure 28. A sai ' reclamation system for chemically bonded sands



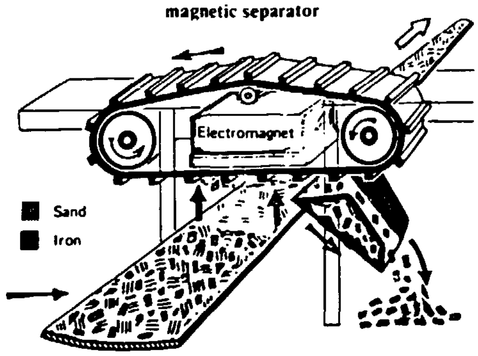
A. A vibrating screen shake-out with electro-magnetic separator



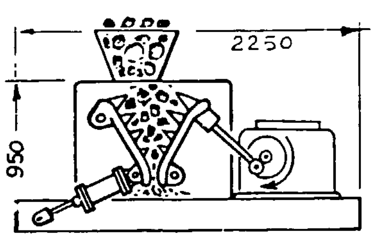
B. A vibrating mould shake-out



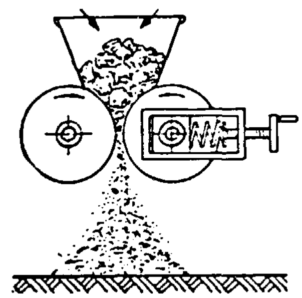
C. A magnetic pulley separator



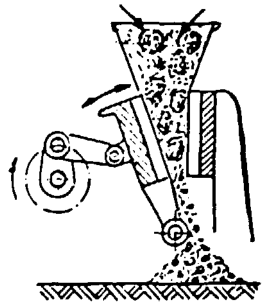
D. An over-belt magnetic separator



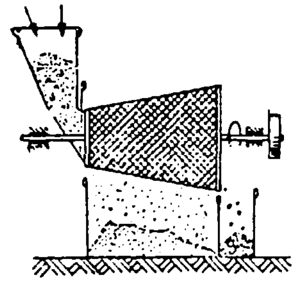
E. A lump crusher



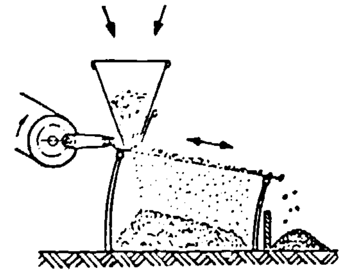
F. Another type of lump crusher



G. A hammer mill

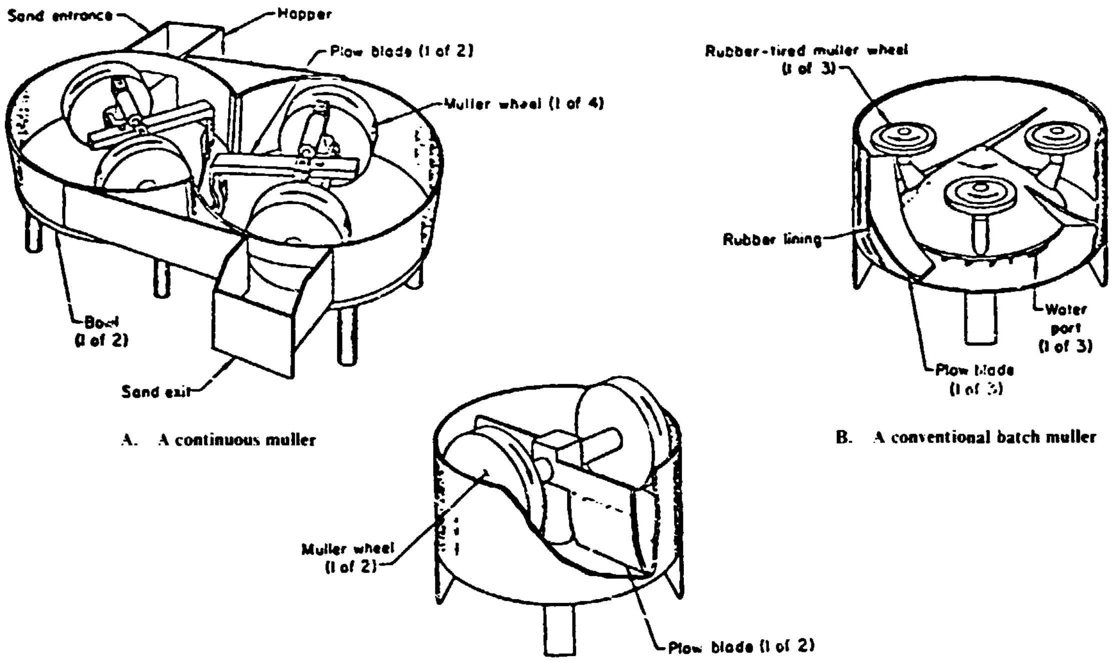


H. A rotary drum



I. A vibrating screen

Figure. 29. Sand recovery equipment



A. A continuous muller

B. A conventional batch muller

C. A high-speed batch muller

Figure 30. Sand mullers

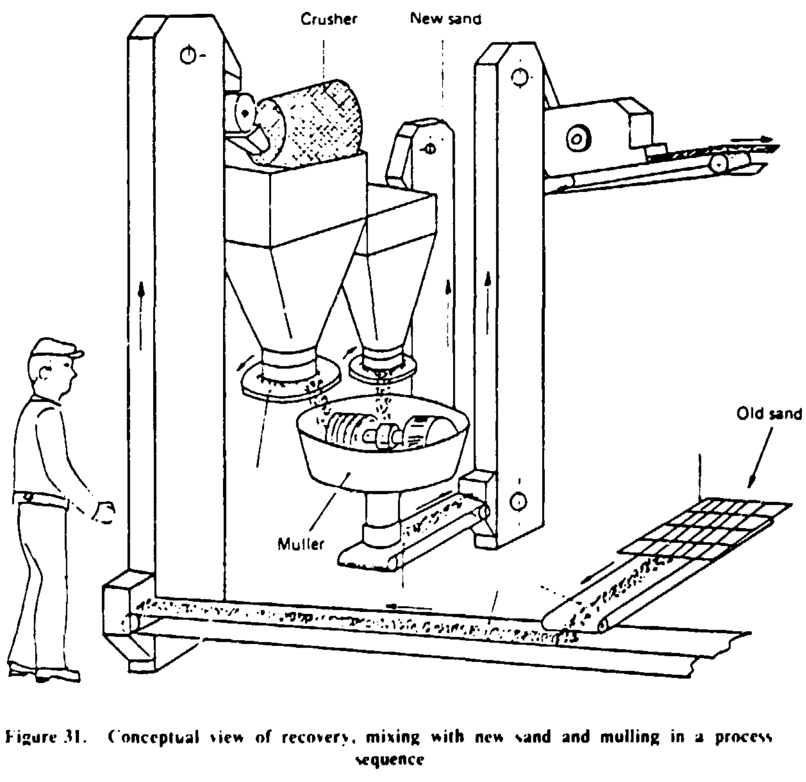


Figure 31. Conceptual view of recovery, mixing with new sand and mulling in a process sequence

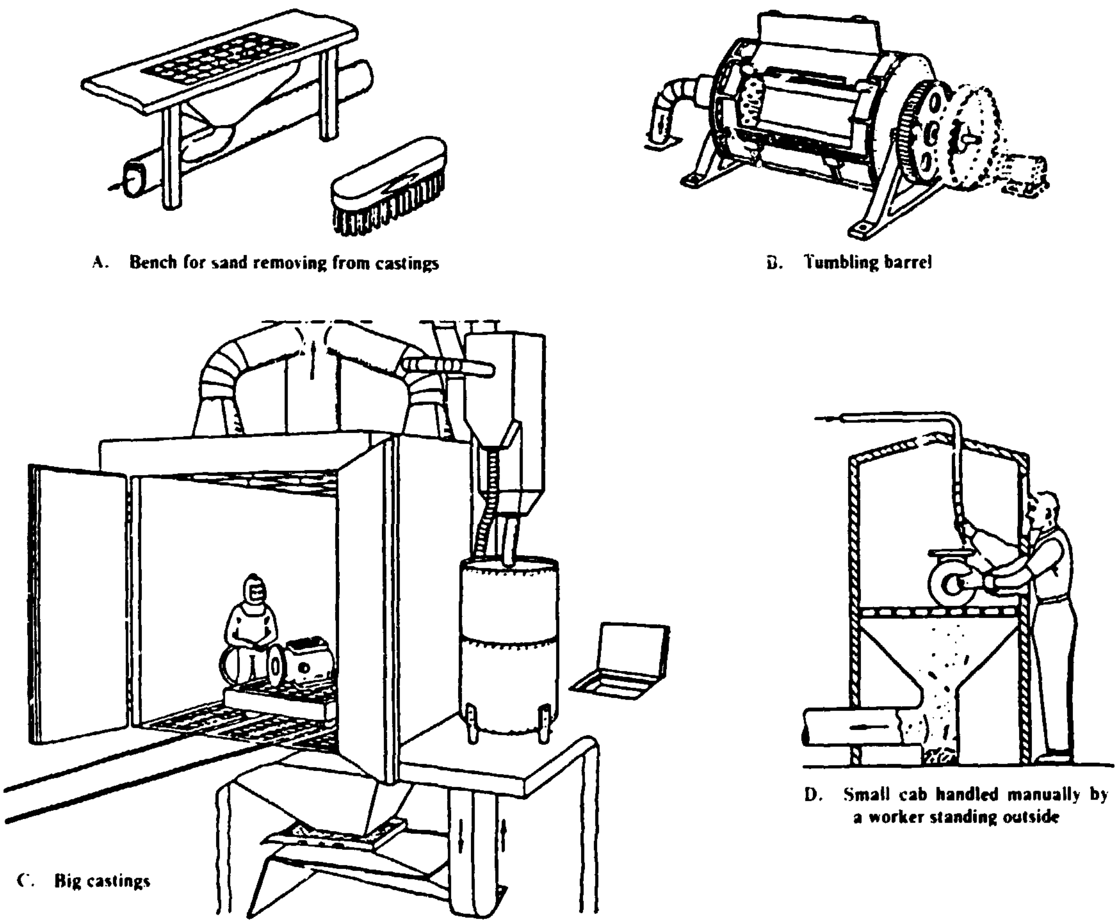
TABLE 44. MACHINERY FOR AND CHARACTERISTICS OF SAND RECOVERY OPERATIONS

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

TABLE 45. 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

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, spectography, 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	



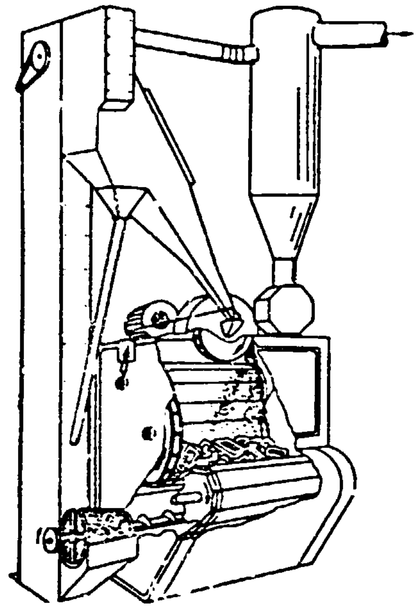
A. Bench for sand removing from castings

B. Tumbling barrel

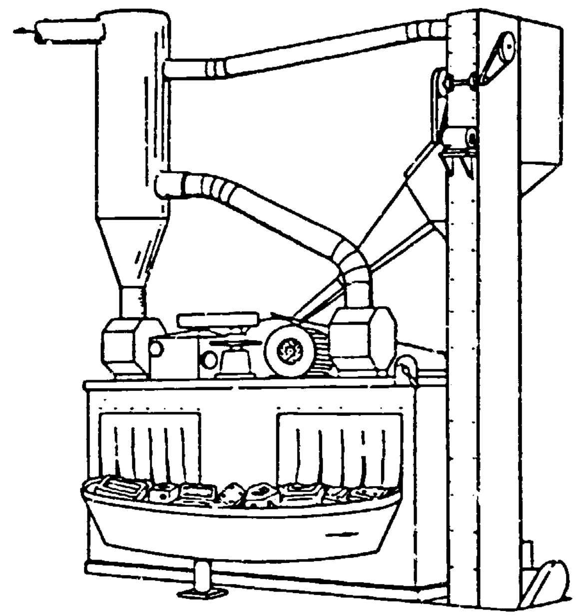
C. Big castings

D. Small cab handled manually by a worker standing outside

Figure 32. Manual cleaning of the castings

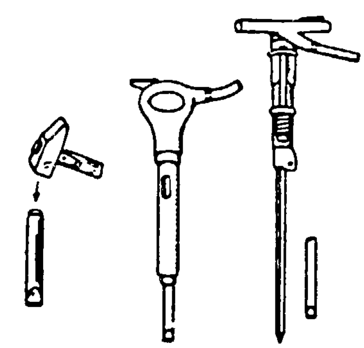


A. Sandblasting machine with abrasive throwing impellers and an endless apron conveyor

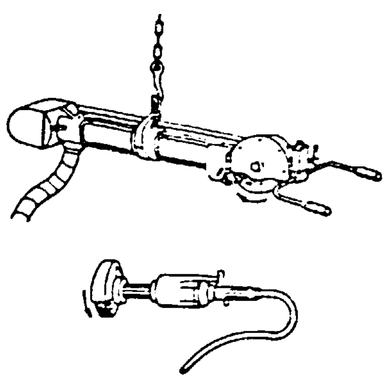


B. Turning table sandblasting with dust collector (continuous operation)

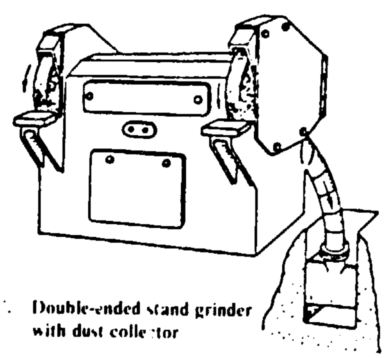
Figure 33. Mechanized cleaning of castings



A. Equipment for manual fettling



B. Hand operated grinders



C. Double-ended stand grinder with dust collector

Figure 34. Fettling equipment

should be manual and pouring techniques to aid the shake-out of sprues and risers. Figures 32 and 33 show cleaning machines.

Large castings should be sandblasted by means of compressed air. To prevent silicosis (or the need for heavy protection suits) the controls of the sandblasting tubes should be outside of the cabin where the part is located.

A manually charged continuous apron sand-blaster (or alternatively, a rotary table sand-blaster) seems to be the most suitable. Stand grinders for small castings and portable or hanging grinders for large castings are used with pneumatic hammers. Figure 34 shows fettling equipment.

Welding operations for small defects may be introduced at a later date when the needs of the operations are better defined.

Dimensional measuring devices, control equipment, devices to measure chemical composition, integrity of main components (magnetoscope), nodularity (metallographic microscope) and devices to measure sand humidity, cohesion, fineness, permeability and refractoriness are necessary.

The non-ferrous foundry

The purpose of introducing a small department for non-ferrous material is to produce small non-ferrous castings. This production will require:

(a) Manual moulding for light-weight castings done on a bench with divided patterns, on wood plates or on flasks by a single worker;

(b) Moulding of larger castings with flasks on a single-jolt machine. Ramming is done with a pneumatic rammer;

(c) For series mouldings (valves, pistons, domestic and trade tools) two small benches;

(d) For cores, a 5 litre core-blower and manual moulding. For large cores, the cast-iron foundry continuous mixer can be of aid;

(e) A 135 litre diesel-oil furnace with double crucible can supply enough metal of adequate quality;

(f) The most important machine in fettling is a belt saw.

Appendix I

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 (65 m³), 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	

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)	
Side shed (sand plant)	
Pattern making, machining maintenance and general store	140

Item	Cost (Thousands of dollars)
Office buildings (at $300 per m²)	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

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.

The above-listed costs are brought together in table 46 with the corresponding freight and installation costs.

TABLE 46. 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	89	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

Appendix II

TRAINING AND TECHNICAL ASSISTANCE COSTS FOR THE FOUNDRY

Non-local training costs for the foundry include introductory in-plant group training for 1 general manager designate, 1 deputy general manager designate, 6 engineers, and 6 counterpart trainers, i.e., a total of 14 people, for 4 months. The breakdown is as follows:

Item	*Cost per trainee ($)*	*Total cost ($)*
Travel	3 000	42 000
Per diem	4 000	56 000
Training	6 000	84 000
Total		182 000

Non-local in-plant training for 8 trainers and 8 engineers (total 16) for 4 months each over a 5-year period will cost $208,000.

The costs of a technical assistance training programme are shown in table 47, those of the local programme in table 48. The distribution of all these costs over five years is summarized in table 49.

TABLE 47. TECHNICAL ASSISTANCE PROGRAMME FOR THE FOUNDRY[a]

Function	*Personnel requirement (person-years)*	*Cost by year (thousands of dollars)*					*Total cost (thousands of dollars)*
		Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	
Project manager (first three years acting general manager)	5	80	90	90	100	100	460
Foundry shop manager-trainer	4	40	80	80	90	45	335
Moulding trainer	3	35	70	80	40		225
Melt and casting trainer	3	35	70	80	40		225
Machine-tool operator trainer	3	35	70	80	40		225
Machine-tool mechanic trainer	4		70	80	80	80	310
Pattern-maker trainer	5	70	80	80	80	80	390
Foundry plant engineer	3	70	80	80			230
Cast-iron design engineer	4		80	80	90	90	340
Industrial engineer-economist	3	35	80	80	40		235
Metallurgist	2		80	80			160
Marketing engineer	2	70	80				150
Short-term (4-6 months each)							
Specialist engineering experts (for brassware, special product design and plant design etc.)	4		20	80	80	150	330
Preparatory project in first year (equipment purchasing, local building activity, recruitment etc.)							150
Total technical assistance	45	470	950	970	680	545	3 765

[a]Another 8 person-years of workshop experts and 8 person-years of engineering experts are required to develop a tool-making shop.

TABLE 48. LOCAL TRAINING PROGRAMME FOR THE FOUNDRY

Function	*Year 0*		*Year 1*		*Year 2*		*Year 3*		*Year 4*		*Year 5*		*Beginning salary ($ per year)*
	Personnel requirement	*Cost (thousands of dollars)*	*Personnel requirement*	*Cost (thousands of dollars)*	*Personnel requirement*	*Cost (thousands of dollars)*	*Personnel requirement*	*Cost (thousands of dollars)*	*Personnel requirement*	*Cost (thousands of dollars)*	*Personnel requirement*	*Cost (thousands of dollars)*	
General manager designate-deputy	2	16											8 000
Secretary-accountant	1	6											
Counterpart trainers/ supervisors (moulding, pattern, machine tools)	8 for ½ year, 2 for 1 year	18	12	40	12	42	14	56	14	62	14	68	3 000
Counterpart engineers and technicians (one engineer and one technician for each expert)	6 for ½ year	15	6	30	2	10	2	10	2	10	2	10	5 000
Trainees, pattern-makers	10	10	18	20	15	20							
Trainees and foundry workers	18 × ½ year	9	20	22	20	30							1 000
Trainees and machine-tool mechanics and other skilled workers	20 × ½ year	10	20	22	30	45							
Assistant accountants and other secretaries	2	5											2 500
Clerks, drivers and labourers	4	4											1 000
Total		93		134		147		66		72		78	

TABLE 49. TOTAL FOUNDRY TRAINING COSTS BY YEAR
(Thousands of dollars)

Item	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Total*
Non-local introductory in-plant group training		—	—	—	—	
Non-local professional improvement of engineers and counterpart trainers	182	52	52	52	52	390
Technical assistance programme	150	950	970	680	545	3 765
	470					
Local training	225	149	66	72	88	600
Total	1 027	1 151	1 088	804	685	4 755

Appendix III

PRODUCTION AND PERSONNEL FOR THE FOUNDRY

TABLE 50. ROUGH CASTING PRODUCTION BY YEAR[a]

	Year 2		*Year 3*		*Year 4*		*Year 5*	
Item	*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	

[a]Year 1 has no production.

TABLE 51. 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 52. NUMBER AND KINDS OF PERSONNEL IN THE FOUNDRY AT FULL PRODUCTION

		Job category		
Department	*Total*	*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	—	—

Department	*Total*	*Job category*		
		Skilled	*Semi-skilled*	*Unskilled*
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 53. 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 54. 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 55. 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.

Appendix IV

COSTS AND REVENUE FOR THE FOUNDRY

TABLE 56. 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 57. 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 58. 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 59 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

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