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APPRAISAL

OF

PROPOSED FOUNDRY PROJECT

FOR

ANDHRA PRADESH CORE CASTINGS LIMITED

PD 692
MAY 1987

FOUNDRY MANAGEMENT & DESIGN CO. LTD.
REIGATE, SURREY, ENGLAND.

FINAL REPORT

APPRAISAL
OF THE
FOUNDRY PROJECT
FOR
ANDHRA PRADESH CORE CASTINGS LTD

SI/IND86/801
PD692

MAY 1987

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ADDENDUM TO REPORT

1. INTRODUCTION

1.1 Andhra Pradesh Core Castings Ltd (APCCL) of, 12-13-195 Tarnaka, Secunderabad 500 017, India, is a recently established company, which proposes to build a new foundry to produce high quality castings in flake graphite irons and SG irons, primarily for the automotive industry.

1.2 APCCL commissioned Metallurgical and Engineering Consultants (India) Limited, (MECON) to prepare a techno-economic report, on the feasibility of the project. Upon receiving the report and after studying it, APCCL prepared a supplementary report containing certain of their own concepts and modifications to the MECON study.

1.3 UNIDO were then approached for technical assistance by APCCL, to review both reports. As a consequence of the approach to UNIDO, Foundry Management and Design Co Ltd (FMD) were commissioned to carry out an appraisal of the two reports and to suggest any modifications to processes and/or equipment thought to be advantageous. FMD were further asked to prepare outline specifications for certain items of plant/equipment.

1.4 Mr S Pugh of FMD made a visit to APCCL from 26th October to 1st November to discuss the project and a summary of the discussions can be found in Appendix 1. The most significant developments which arose out of this visit were the presentation of a modified concept for the design of the foundry and the selection of a new site. The new site was not shown to Mr Pugh.

1.5 This report consists of an appraisal of the MECON and APCCL reports with suggested modification for improvements. The latest concept for the foundry presented by APCCL is also considered. The report is in 4 sections with 5 appendices. Following this introduction, Section 2 is concerned with the design criteria while section 3 is a detailed appraisal of the two reports. Section 4 summarises the conclusions drawn by FMD. Appendix 1 is a report on the visit to India and of the discussion held with APCCL both in India and subsequently in the U.K. Appendix 2 sets out some of the criteria affecting the choice of production technology and Appendix 3 relates to considerations in the execution of the project. Appendix 4 is concerned with the information required in order to prepare equipment specifications. The application of computers in the foundry industry can be found in Appendix 5.

A new layout drawing (PD 692/1) has been prepared by FMD to illustrate its proposed modifications.

1.6 FMD would like to express its thanks to Mr Venkatesh of APCCL for his kindness and hospitality shown to FMD staff during the visit to India.

2. DESIGN CRITERIA

2.1 One of the main criticisms of both the MECON and APCCL reports is the lack of data relating to the anticipated product mix. In the case of the MECON report, there is a single table (Table No 04.01) which sets out some very broad criteria leading to the conclusion that the design capacity of the foundry should be 6000 tonne per year. The APCCL report suggests an increase in capacity to 9000 tonne per year on a 2/3 shift basis but does not substantiate this figure.

2.2 FMD sought to obtain more information relating to the proposed product mix but was not successful. Furthermore, a section of the MECON report entitled "Market Review" was missing from the version given to FMD. It is not possible, therefore, to comment on the conclusions drawn by MECON and APCCL in respect of either the proposed design capacity of the foundry, or the choice of products.

2.3 There are numerous references in the report to the production of high integrity, thin walled castings to be produced to very close tolerances. As a basic manufacturing philosophy, FMD believes that this is the right approach in that the emerging automotive industry in India will have need for an increasing quantity of castings produced to close dimensional accuracy and international standards of quality. If successful, the proposed new foundry should meet little competition in India and could compete in international markets. Furthermore, the installed capacity in India for SG iron castings at the present time is understood to be only 18 000 tonne per year so the ability of the foundry to supply SG iron castings (in an expanding market) will be particularly advantageous.

3.0 APPRAISAL OF THE PROJECT AS PROPOSED BY MECON AND APCCL

For the production of high quality, thin walled castings such as cylinder blocks and heads, it is essential that the selected equipment is able to produce very precise moulds and cores consistently at the production rates required. Additionally, the choice of melting equipment must permit very close control to be exercised over metal composition and pouring temperature. These considerations are of paramount importance in the production of automotive castings and cannot be compromised. Both MECON and APCCL have recognised those factors which have been fully taken into consideration in each of their reports.

3.1 MELTING, HOLDING AND POURING

3.1.1 General Proposals of MECON and APCCL

MECON have recommended line (mains) frequency and APCCL, medium frequency coreless induction furnaces for primary melting. Either can be used and MECON is correct in stating that in iron foundries where electric melting is used, line frequency coreless induction furnaces are at present used more than any other type of electric melting furnace.

3.1.2 Line Frequency Coreless Induction Furnaces

3.1.2.1 This type of furnace is available with crucible capacities ranging from about 1 tonne up to 70 tonne.

3.1.2.2 Modern line frequency furnace equipment is compact and modularised with the consequent advantage that installation is comparatively simple and speedy.

3.1.2.3 Within the limits imposed by crucible size, it is possible under normal operating conditions, to melt most types and sizes of charge materials, without any pre-preparation except for drying. Very good control over the chemical composition and temperature of the metal is possible.

3.1.2.4 The induced current, at line frequency, creates turbulence in the metal bath and the resultant stirring action is beneficial in the melting of iron to ensure rapid absorption of carburisers and alloy additions, with minimum losses of these expensive materials.

3.1.2.5 The capital investment requirement for environmental control equipment is usually low.

3.1.2.6 There are, however, a number of disadvantages in using line frequency coreless induction furnaces and these are outlined below.

3.1.2.7 This type of furnace is not a true batch melting unit, since its ability to melt a cold charge in a comparatively finely divided state, is strictly limited and slow. The furnace operates most efficiently with a retained liquid heel (bath of metal) of between 55% and 70% of the total crucible capacity. The actual size of the heel is dependent upon the furnace design and operating technique.

3.1.2.8 Since the start of the melting process requires a 'solid starting block', cast from foundry iron and the first melt from a cold furnace is slow, it is normal practice to retain the liquid heel, even during none operating hours and weekends. This requires that a certain amount of power is constantly used and that personnel are necessary to keep watch over the furnace at all times. This inevitably adds to the operating costs.

3.1.2.9 It is essential that the charge materials used in this type of furnace (which operates with a retained heel of liquid metal) be absolutely dry. This is to ensure the safety of the personnel and to prevent damage occurring to the furnace and other equipment as damp materials can create serious explosions when charged into liquid metal. Thus the capital investment cost and operating costs of scrap drying equipment must be included in any financial evaluation of melting systems.

3.1.3 Medium Frequency Coreless Induction Furnaces

These furnaces are similar in design to the line frequency coreless induction furnaces but operate at higher frequencies and some of the advantages and disadvantages in comparison with other primary melting units, apply to both types. There are also some significant differences between the two types and recent research has further enhanced some of the advantages that this furnace has over the line frequency type. These advantages may be summed up as follows:-

3.1.3.1 The power to charge weight ratio is better on this type of furnace than on the line frequency type. Therefore, for a given melting rate, the crucible capacity can be smaller.

3.1.3.2 It is a true batch type melting furnace. The medium frequency power supply gives a fast melt down from a cold charge and a 'solid starter block' is not required. Normal charge materials can be used and a liquid heel is not required; the furnace operating more efficiently without a liquid heel.

3.1.3.3 With the latest generation of furnaces, higher power can be applied per unit of crucible capacity than was formerly the case. This gives turbulence in the bath of liquid metal which is equivalent to that achieved in the line frequency type.

3.1.3.4 From the safety point of view, it is not necessary to use dry charge materials, although in some cases it may be technically desirable to do so.

3.1.3.5 With the correct operating procedures, the power consumed per tonne of metal melted is lower than that used by a line frequency type of the same melting capacity.

3.1.3.6 It is quicker and more straightforward to change from melting one type of alloy to another, than is the case with the line frequency furnace.

3.1.3.7 With the latest generation of this type of furnace, there is little, if any, difference in investment cost per kW of installed power, when compared to the line frequency type.

3.1.3.8 The main disadvantage of medium frequency coreless induction furnaces is that they are not made in very large capacities and crucible sizes rarely exceed ten tonne. Thus, in some instances, where one line frequency furnace may be sufficient, two medium frequency furnaces may be necessary. This point is not particularly relevant to the proposed foundry for APCCL.

3.1.3.9 If the power supply to the furnace is not carefully selected, the turbulence in the liquid metal bath may be much reduced or lost, leading to poor recovery of carburisers and lack of homogeneity.

3.1.3.10 In the light of the above considerations, FMD is in agreement with the proposal of APCCL to use medium frequency coreless induction furnaces as the primary melting units.

3.1.4 Holding Furnace

Where the product mix encompasses a wide range of piece weights it is necessary to provide an intermediate reservoir of molten metal between the melting furnaces and the moulding line. This serves as a "buffer" to balance out the varying molten metal demands from the moulding line with the constant output from the melting furnaces.

3.1.4.1 It is standard practice in automotive foundries to use a channel induction furnace (usually of the vertical as opposed to the horizontal drum type) and FMD consider that MECON is correct in its selection of this type of holding furnace. Although channel induction furnaces cannot be emptied and switched off over the weekend, the amount of power consumed when operating in the holding mode is minimal. The main consumption of power takes place when the furnace is operating in the superheating mode.

3.1.4.2 Other types of electric furnaces have been and are being used as holding furnaces including both line and medium frequency coreless induction furnaces but only in cases where unusual circumstances prevail. The disadvantage with both of the coreless induction types is that as the metal level falls, the power input from the coil reduces and the superheating efficiency decreases. Below about one third of the crucible capacity, the metal will actually lose temperature, even with full power on the coil, because the metal line will be at the bottom of, or below the level of the coil.

Since the metal level in a holding furnace will fluctuate constantly during moulding operation hours, it is inefficient both with regard to power consumption and in respect of providing consistent metal temperatures. Generally speaking, the refractory cost per tonne of throughput will be higher in the case of coreless induction furnaces (when used as holding furnaces) than it will be with channel induction furnaces.

3.1.4.3 In the opinion of FMD, the useful capacity of the holding furnace requires further consideration. It is not known how the proposed 10 tonne capacity for the holding furnace was arrived at since details were not made available to FMD during the visit to APCCL, but it is recommended that the calculations are checked prior to a final decision being taken on sizing the holding furnace.

3.1.5 Mould Pouring Unit

There are a number of mould pouring units available. They range from tilting, electromagnetic, weighing/stopper and "Pressure Pour" types and they can be automatic, semi automatic or manual in operation. The main advantages over pouring from conventional manually operated suspended ladles can be summarised as follows:-

3.1.5.1 The pouring speed is constant and the amount of metal is metered, so that wastage is minimised.

3.1.5.2 The metal temperature can be adjusted to suit individual casting requirements and once set, will remain constant. The pouring units normally incorporate a channel inductor so that metal can be maintained at the required temperature. The type suggested by APCCL is the pressure pour type which has been proved over a number of years and is well suited to the proposed application. However, too many changes of castings types on the moulding line during each operating shift are to be avoided, as the pouring unit has to be adjusted each time a change takes place.

3.1.5.3 Since FMD has not had access to the data from which the capacity requirement for the mould pouring unit was calculated, it is not possible to comment, except to say that a 2 tonne useful capacity unit is likely to be the minimum size.

3.1.5.4 With regard to the gas used to presurise the pouring unit when SG iron is being poured, the general view is that nitrogen gas has only a marginal advantage over compressed air which is normally used in Europe. However, some companies in the USA do use nitrogen or sometimes Argon, although the latter is an expensive gas.

3.1.5.5 The use of a mould pouring device does introduce a problem in connection with the production of SG iron. The nodularising process "fades" when metal is held for any length of time and after approximately half an hour, metal which was initially SG iron reverts back to grey iron. SG iron cannot, therefore, be retained in a holding/pouring device. If such a device is used, then the nodularising process must take place in the mould cavity which virtually dictates the use of a single process; namely, the "In-Mold" process.

3.2 MOULDING

3.2.1 General Proposals of MECON and APCCL

There are a number of different methods in use for producing high pressure greensand moulds and these are well described in the MECON Report although a specific method has not been recommended. APCCL have selected the shoot-squeeze type of machine, which is perfectly suitable for the production of moulds for automotive castings. FMD is, therefore, fully in agreement with the choice of the "shoot-squeeze" machine.

3.2.2 Moulding Flask Size

3.2.2.1 The mould flask size is given as 900mm x 700mm x 300mm/300mm in the MECON Report and 900mm x 700mm x 250mm/250mm in the APCCL Report. Leaving aside the difference in the depth of the flask, the main dimensions, 900mm long and 700mm wide are not substantiated in either report and in the absence of any definitive data on the product mix, it is difficult to comment on the dimensions of the moulding flask. As a general observation, however, FMD would have expected the moulding flask to be slightly larger, possibly 1 000mm x 850mm x 300mm/300mm which would be in line with many other automotive foundries. The selection of the mould flask size is probably the single most important consideration in the design of any automated foundry and once the size is chosen, it cannot subsequently be changed.

3.2.3 Moulding Production and Mould Handling Equipment

3.2.3.1 For the rate of mould production required, a single machine should be adequate to make cope and drag half moulds alternately. A multiple foot squeeze head is not required in this case, nor is it normally provided with a shoot-squeeze type machine.

3.2.3.2 The moulding machine should have adjustable squeeze pressure with overhead sand feed incorporating a metering device. It should be operable in manual, single cycle or continuous cycle modes. It should be complete with an hydraulics system, including cooler. Hydraulic fluid should be compatible with hydraulic fluids available in India. The machine should have guards, safety devices and interlocks fitted in accordance with recognised international safety standards.

3.2.3.3 The moulding machine should incorporate a pattern changing device so that new patterns can be introduced; ideally within the cycle time of the machine. There are several ways in which this can be done and it is not appropriate to describe the various methods at this stage.

3.2.3.4 The depth of pattern draw should be specified in line with the types of castings to be produced. This is especially important in the case of brake drums (which are included in the product mix) where the sand "cod" which forms the inside profile of the castings, is particularly deep.

3.2.3.5 The acceptance specifications for moulds, as proposed by APCCI have little significance when related to cylinder blocks and heads. With both of these castings, most of the critical dimensions are created by the relationship between cores and/or between cores and the mould. With regard to the surface finish of the castings, the type of moulding machine selected plays a relatively small part in determining this feature. Other factors such as the coarseness or fineness of the sand; the grain size and purity of the sand; the pouring temperature of the metal, the type of alloy etc, all influence the surface finish of the casting to a greater or lesser degree.

3.2.3.6 Coring moulds for cylinder blocks and heads involves assembling cores in a transfer fixture outside of the moulding cycle and then transporting the fixture and locating it above the drag half mould.

The assembled cores are then lowered into the mould. This is the method proposed by MECON with which FMD fully agree.

3.2.3.7 Both MECON and APCCL have proposed mould accumulation tracks with transfer cars and FMD considers this to be more suitable than the continuous type of pallet conveyor which is often specified, as the cooling times in the mould can be varied more easily. FMD therefore agrees with both the MECON and APCCL layouts with respect to this point.

3.2.3.8 Provision for pouring moulds from a normal ladle should be included, to prevent a stoppage to production in the event of a fault occuring on the automatic pouring unit and to give scope for a choice of methods in the production of SG iron castings. This is not included by either MECON or APCCL.

3.2.3.9 Punching out sand "parcels" complete with castings, from the mould flask and transferring the "parcels" to another conveyor for further cooling is a design feature that has been applied to moulding lines for many years. For high production moulding lines, depending upon the "in mould" cooling time required, there can be a saving in the number of mould flasks required and also in the area requirements. However, it must be pointed out that it is not possible to generalise with regard to possible economic advantages and each project should be considered on its merits.

3.2.3.10 It is quite normal practice, on high production moulding lines, to use a remote controlled manipulator, (operated by a man located in an air conditioned cab) which removes the hot castings from the shakeout and places them in tote bins. It is this type of manipulator that FMD would recommend for use by APCCL.

3.2.4 Points to Consider in the Selection of a Moulding Plant

3.2.4.1 The mould flask size is critical if future, as well as present requirements are to be met. It is suggested that the proposed size be rechecked to ensure that potential markets for automotive castings will not be lost because the flask size is too small for certain castings.

3.2.4.2 The depth of pattern draw requested on the moulding machine should be specified, and the supplier should be clearly informed, if it is anticipated that brake drums are to be manufactured at present, or in the future. The required mould production rates should be clearly stated for Phase 1 and for Phase 2, and whether they are the actual rates required or the machine/mould handling capacity.

3.2.4.3 The "in-mould" cooling time is an important factor with regard to design and layout of the mould handling line. This requirement is difficult to assess without drawings and specifications of the castings contained in the product mix. However, if SG iron castings are to be produced in the 'as cast' state, that is without heat treatment, then it is likely that a provision should be made for $1^3/4$-2 hours "in-mould" cooling, for a product mix as given in the MECON Report.

3.2.4.4 The MECON and APCCL Reports cover the individual mould handling/processing units adequately, but for a moulding line rated at 100 moulds per hour or less, FMD would recommend a single line of moulds from the moulding machine through mould closing. The number of positions for core placement in the half mould should be equivalent in length to eight half moulds, this should be adequate even when the moulding rate is upgraded in Phase 2. Provision should also be made for pouring moulds from a manually operated ladle(s) in the event of a breakdown on the automatic pouring unit. The system should cover a length equivalent to six or seven moulds and be located alongside the automatic pouring unit.

3.2.4.5 FMD is not convinced that the automatic temperature profile controlled cooling furnace is either necessary or advisable.

3.2.4.6 It is recommended that a remote controlled castings manipulator be used to lift hot castings from the shakeout/conveyor and place them into containers or onto pallets. The operator should work in an air conditioned cabin. The use of a castings manipulator will reduce manpower requirements around the shakeout unit and prevent men from having to work in an unpleasant environment. The manipulator would handle all castings, not just selected ones.

3.2.4.7 FMD Drawing No PD692/1 shows a suggested layout for the moulding line and its relationship with other departments. This moulding line can be expanded up to 15 000 net tonnes per year by the addition of two further mould cooling lines, as shown on the drawing.

3.3 NEW SAND HANDLING, SAND RECONDITIONING AND SAND PREPARATION

Before appraising the specific proposals of MECON and APCCL, it is appropriate to consider the overall requirements for providing new sand, sand reconditioning and preparation systems.

3.3.1 Silica Sand

3.3.1.1 Silica sand, in one form or another, has for many years been the main material used for making moulds and cores in foundries. Other materials such as Olivine, Chromite and Zircon are used for special applications but form only a very small proportion of the total usage when compared to the amount of silica sand used. Modern moulding and coremaking techniques have resulted in fairly strict specifications being imposed on silica sand that is supplied to foundries.

3.3.1.2 In general terms, silica sand used in modern foundries should be of high purity (95% + SiO_2), be low in alkalis, have rounded or sub-angular shaped grains (this precludes the use of crushed quartz rock), and be of suitable grain size distribution.

3.3.1.3 In most western countries, silica sand suppliers will deliver the sand to foundries by tanker, in the washed, dried and classified condition to individual foundries specifications. It is not unusual for a particular foundry to specify at least two grades of sand; one for moulding and one for coremaking.

3.3.1.4 It is sometimes necessary in a new foundry project involving modern production techniques, to include sand washing, drying and classifying equipment in the capital investment estimate. Even so, care still has to be exercised in selection of the raw sand source, if minimum waste is to be achieved from the classifying unit.

3.3.2 Bonding Agents and Additives

3.3.2.1 The type of bonding agent used in sands for high pressure moulding systems is bentonite, of which there are two types, sodium and calcium. Generally speaking, sodium bentonite is better for high pressure moulding sand than is the calcium variety, as less binder and less water is required to develop the required sand properties. However, it is not unusual to use a blend of both types of bentonite in iron foundries, but it must be emphasised that the bentonite must be of good and consistent quality.

3.3.2.2 The second additive used in moulding sands for most iron castings, is coaldust, which should be prepared from coal having a low ash and low sulphur content, it should also be classified to a suitable fineness number and the quality must be consistent. Water, of course, has to be added to develop the bond, the amount being critical.

3.3.2.3 Occasionally, dextrin or wood floor may be used as a third additive principally to increase the deformation characteristics of the sand. The use of these additives should, however, be very carefully controlled as potentially serious side-effects can occur.

3.3.3 Moulding Sand Reconditioning

3.3.3.1 As the mixture of moulding sand and core sand falls through the grid of the shakeout, it is normally transported by an underground conveyor system to the reconditioning plant. Generally, an overband magnetic separator is mounted over the head pulley of the last belt conveyor, prior to a bucket elevator to remove tramp metal from the sand. The bucket elevator will then transport the sand to the inlet point of the screen. On travelling the length of the screen (rotary type) the moulding sand will break down and fall through the screen mesh to be collected in a surge hopper, while the oversize lumps (usually unburned pieces of core) will be discharged to a waste chute/hopper. The surge hopper for the screened sand can be fitted with temperature measuring devices at a number of levels which feed information to a microprocessor. A drag out belt conveyor will then transport the sand from the surge hopper to a fluidised bed cooler/dryer where the temperature and moisture content of the sand is monitored and the information fed to the microprocessor. This will automatically adjust air flow and control the metering of water onto the sand according to the information received from the monitors. The whole reconditioning system generally comprises a vertical tower and requires a comparatively small floor area. There remains the requirement for a bucket elevator and/or conveyor belts to transport the reconditioned sand to the storage hopper(s).

3.3.3.2 A dust and fume extraction/collection system should be installed on the sand reconditioning plant from the shakeout, downstream on all conveyor transfer points, elevators and reconditioning units, and the dust is normally collected into one unit. Traditionally, "wet" type dust collectors have been used for moulding sand reconditioning plants but in more modern plant "dry" type collectors fitted with diaphragms as opposed to bag filters are also being used.

3.3.3.3 FMD Drawing No PD692/1 shows the layout of a typical moulding sand reconditioning plant, incorporating a rotary drum sand cooler.

3.3.4 Moulding Sand Reconditioning. APCCLs Concept

3.3.4.1 The rotary breaker screen referred to is intended for moulds/cores made by the resin bonded air setting sand process, which is a dry sand process. This equipment is not suitable for the "greensand process" and would not operate efficiently or achieve the desired aims.

3.3.4.2 Sand drying cannot be avoided for several reasons:-

a) Sand must be dry for use in core sands.

b) Wet silica sand cannot be put through classifying screens.

c) The moisture content of stored silica sand can vary within wide limits.

d) The amount of new silica sand required to be added to the moulding sand will vary.

3.3.4.3 Sand cooling takes place continuously from the time the poured mould is shaken out, even on the belt conveyors. FMD is not aware of any iron foundry that currently uses a premixing process for moulding sand. Modified mixers have been used for cooling sand but these are not particularly efficient.

3.3.4.4 Where wet dust collectors are used, some foundries may use some of the water from the collector as an addition to the sand mixer. This water will contain some unburned coal dust and bentonite as well as burned coaldust, dead clay and unwanted fines. Provided that the amount of water used is carefully controlled, this procedure can reduce the wastage of useful materials. If dry collectors are used (diaphragm type) the dust can be transported to a hopper/silo above the mixer and added to the sand in the same way as new bentonite and coal dust. FMD is, therefore, in agreement with this proposal.

3.3.4.5 Load cells for weighing sand/additives and electronic moisture controllers are standard items on modern sand plants and FMD would, therefore, agree with these proposals.

3.3.4.6 FMD agrees in principle, with the proposal to install a high intensity mixer/aerator but depending upon the selection of mixer and moulding machine and the characteristics of the specified mixed sand, it may be necessary to provide a separate unit to aerate the sand after mixing.

3.3.4.7 Generally, sand reconditioning plants are designed to meet the worst conditions likely to be encountered, which is normally taken as the hottest sand. The criterion usually specified is that the sand, after reconditioning, shall not exceed a given temperature above ambient (normally in the range 10°C-15°C), and that moisture content shall not exceed a given percentage (normally 1,0%).

3.3.4.8 Four tests which are carried out on a regular basis and should be included are:-

a) Granulometric analysis of reconditioned and new sand.
b) Determination of volatile matter.
c) Shatter index.
d) Mould hardness.

3.3.4.9 FMD agree with the proposal to install equipment of a capacity to meet the Phase 2 capacity generally, but considers that it may be wise to install the full mixer capacity in Phase 1 also. The final decision will be influenced to a large extent on the capacity of the sand plant that is finally decided upon. However, it should be noted that to install two mixers at different times will mean duplication of the metering (weighing and delivery) systems. These items will have to be added to the capital cost and it should be borne in mind that there will also be some disruption to production during the installation period of the second mixer.

3.3.5 New Sand Storage and Conditioning

3.3.5.1 Table No 07.02 of the MECON Report states that 8 500 tonnes of new sand will be required per year for 6 000 net good tonnes of castings. It should be noted that the report does not provide supporting information to justify the figure of 8 500 tonnes. However, at the Phase 2 capacity of 15 000 tonnes of net good castings, the new sand requirement is likely to be in the order of 21 250 tonnes per year. If it is not possible to obtain silica sand ready dried and classified, then equipment will have to be installed to dry and classify the sand and possibly to wash it.

3.3.5.2 Generally speaking, FMD would specify a fluidised bed type sand dryer, with the sand being dried to a moisture content not exceeding 0,1%. It is understood that the older type rotary dryers as shown by MECON, are more easily available in India. This type can be used, but requires more floor area and is not as efficient as the fluidised bed type.

3.3.5.3 Normally, the hot, dried sand is fed directly from the dryer into a fluidised bed cooler which will cool the sand to a temperature not exceeding 15°C above ambient. In some cases it may be appropriate to specify a temperature not exceeding 10°C above ambient.

3.3.5.4 Classifiers used in foundries are usually of the dry, multi-deck vibrating type. The number of screens and mesh sizes will depend upon the granulometric analysis of the new sand and the AFS Fineness Number required of the classified sand. It is likely that two classified sands will be required, one for moulding sand and one for coresand. The two sands will be collected in hoppers from where they will be transported (generally by pneumatic means) to daily use hoppers located above the moulding sand mixer and the coresand mixer(s).

3.3.5.5 The MECON Report states that an allowance has been made for the storage of 3 months supply of moulding materials. The number of storage bunkers shown in both the MECON and the APCCL layout drawings are inadequate to store the quantity of new sand (moulding and cores) for Phase 1, if 3 months storage capacity is the accepted criterion. Emergency requirements generally call for storage facilities sufficient to accommodate 5-20 working days usage. It is suggested that the figure of 3 months storage requirement be checked to see if it has been overestimated.

3.3.5.6 A possible layout and location for the new sand conditioning plant is shown in FMD Drawing No 692/1.

3.3.5.7 Normally, FMD would recommend that raw sand be tipped into a comparatively small surge storage hopper, from where can be fed directly into the drying, cooling, classifying system, and then stored in suitably sized silos, to meet the emergency requirement.

3.4 CORE MAKING

3.4.1 Design Considerations

The main points to consider in the selection of the core making process(es) for the proposed foundry can be summarised as follows. These points must be studied and evaluated before a particular process can be selected and in many foundries some compromise is made. It is also usual to find more than one process in use.

3.4.1.1 The foundry will be of the repetition/semi-repetition type.

3.4.1.2 The type of castings to be produced are, in the main, intricate and heavily cored.

3.4.1.3 Individual cores are required in medium/large quantities.

3.4.1.4 What coremaking processes/binder systems are available indigenously.

3.4.1.5 What are the climatic conditions (ambient temperatures and humidity) at the foundry site.

3.4.1.6 What type of base sand is available.

3.4.2 Principal Coremaking Processes

The main processes used in modern foundries fall into 3 main categories. These are the hot box, cold box and airset processes.

3.4.2.1 As the name implies, with the hot box process, the corebox is heated. The mixed sand is then introduced into the corebox, usually by blowing and is cured by the heat of the box. This process has been in use for a considerable number of years and is particularly well established in automotive foundries. There are three main types of hot box process, namely the Shell (Croning) process, the "wet" process and the warm box process.

With the Shell (Croning) process, the grains of sand are individually and thinly coated with a phenolic resin. The sand is dry and flows as a dry silica sand would flow. The sand is introduced into the corebox by blowing or dumping, depending upon the intricacy and/or the size of the core. The binder first softens and then commences to cure; the time required for curing depending upon the thickness of the core and the temperature of the corebox, but is normally not more than 30-40 seconds. In the case of larger cores of suitable configuration, after the core has partly cured, the closed corebox is inverted allowing uncured sand to flow out. The final core is, therefore, hollow which gives rise to the term 'shell core'. This process produces very good cores with good breakdown characteristics and is used for intricate cores such as water passageway cores in cylinder blocks and heads. It is one of the more expensive processes and is, therefore, used selectively.

The "wet" process uses a sand mixed with a liquid resin and catalyst, hence 'wet mix'. The mixed sand is blown into the heated corebox and allowed to remain for a period of time to cure. This process produces good cores and is somewhat less costly than the Shell process, however, it is not suitable for some of the more intricate cores.

The Warm Box Process is a recent modification of the 'wet process'. It is based on the use of furan resins with additives and is more energy efficient as the coreboxes only require heating to about 150°C-180°C.

3.4.2.2 There are four well established cold box processes. They are, Silicate/CO_2, Amine, SO_2, and Gaseous Ester.

With the Silicate/CO_2 process, Sodium Silicate is first mixed with the sand and the mixture then introduced into the corebox where it is cured by the passage of carbon dioxide gas. Environmentally and from an ecomonic standpoint, this process is good although it does have a number of disadvantages. Specifically, cores which are stored in a damp or humid atmosphere will absorb moisture and lose strength. Also the surface finish on castings is sometimes poor. The most serious disadvantage, however, is that the breakdown characteristics of the sand are poor and this can create serious problems in the cleaning/finishing departments.

The amine process is based upon mixing a two part binder of Phenol Formaldehyde and an isocyanate with the sand. After the sand has been introduced into the corebox, amine gas is passed through the core to cure the sand. The gas is toxic and after purging, must be scrubbed before exhausting to atmosphere. The cores are good but in some castings, "finning" can occur.

With the SO_2 process, the sand is mixed with a Phenolic Urethane, a Furfuryl/Alcohol Polymer or a Furan Resin. The mixed sand is then introduced into the corebox and sulphur dioxide gas passed through it to effect the cure. The cores are good and the castings are not prone to finning problems.

The gaseous Ester Process is a more recent cold box process which is finding favour in an increasing number of European foundries. An alkali phenolic resin is mixed with the sand, following which, the mixed sand is then introduced into the corebox and cured by the passage of a vapourised ester. This is more acceptable environmentally than either the amine or SO_2 processes and the fumes can be released to atmosphere without scrubbing. The cores are good, sulphur content is low and the casting surface finish is good.

3.4.2.3 The Airset process is based on mixing a binder (furfural alcohol) and a catalyst with the sand. Curing commences immediately, thus the 'bench' life of the sand is limited. The speed of curing is partly dependent upon the amount of catalyst added to the sand. The process is widely used to make moulds on the so called 'boxless' moulding systems and has almost replaced the traditional 'drysand' method for making large moulds. It is also used for the production of large cores, and cores required in very small quantities. It is not widely used for the production of repetition type cores since the production speeds are not as fast as those achieved by some of the other processes.

3.4.2.4 The IQU process is not in widespread use and FMD, whilst appreciating the technical advantages when compared to the standard hot box process, would want more evidence of its successful application specifically in automotive foundries, before making a firm recommendation. The following general points can, however, be made:-

The comparisons are with the hot box and Shell processes only, which have been proved over many years in large automotive foundries.

Warm box, with or without Vacuum, requires metal coreboxes; preferably cast iron.

While some energy will be saved on heating the corebox, energy will be expended on creating the vacuum.

The claimed cost advantage is not substantiated and it is not clear with which binders/processes the comparison was made. Neither is it clear what type of castings/cores were made.

It is recommended that further evaluation of this process should be made in the light of the specific circumstances prevailing at APCCL. Modern automotive foundry installations tend to use the shell and cold box processes for production of cores, but the final choice for the APCCL project cannot be made until it is known what binder systems are available in India.

3.4.3 Coremaking Equipment

3.4.3.1 Sand mixing equipment can be divided into two main types, continuous and batch. Continuous mixers can be supplied in rated capacities from about 2 tonne per hour up to 30 tonne per hour. They are normally based on a screw conveyor type of mixing system and may be of the single or twin screw design. Binder and catalyst are mixed into the sand by metering pumps for liquids and/or powder feeders for dry additives. Continuous mixers have the advantage that any quantity of sand can be prepared at any one time; thus minimising wastage.

Batch mixers are more traditional and as the name implies, they mix a pre-determined quantity of sand per cycle. This type of mixer has to a large extent been superceeded by continuous mixers although for some processes, small batch capacity mixers can be located on the core machines to deliver precisely measured amounts of mixed, fast curing sand into the blowing chamber of the machine.

3.4.3.2 There are many types of core machines available, ranging from simple core blowers/shooters which may be manually operated, to multi station machines that are fully automatic. In many cases, the core machines for hot box core processes have a basic design similar to that used for the cold box process. However, for 'shell' cores, (which may be hollow), the machines are designed to be inverted and to oscillate the corebox to assist in the removal of excess sand. Corebox heating may be carried out by the use of either gas or electricity. Normally, gas is preferred as to use electricity requires heating elements to be incorporated into the corebox and these can sometimes be difficult to maintain. However, electrical heating is often preferred for 'warm box' applications. FMD is unable to comment on the machines recommended by MECON or APCCL, since the reports do not contain any information regarding the types of cores to be manufactured or the number of impressions per corebox.

3.4.4 Core Coating, Finishing and Storage

3.4.4.1 Some cores will require coating with a refractory material. FMD recommends a graphite based material suspended in water. This may be brushed on, sprayed on, or the cores may be dipped into a tank containing the coating material. After the coating has been applied, the core must then be placed in an oven to evaporate the water. Because of the diversity of the cores to be produced, it is probable that two types of coating equipment will be necessary in the proposed foundry; namely, the spray (airless) type, and the dipping tank. Drying can be carried out in a radiant panel oven of the batch or continuous type, or in a vertical, continuous, warm air oven, but a bogie type oven as shown in the MECON layout, is not recommended.

3.4.4.2 For the glueing of cores into assemblies and sub-assemblies, FMD recommends that electrically heated, hot guns should be used.

3.4.4.3 Ideally, cores should be stored on multi-shelved racks which are fitted with castors so that they are mobile. Static core racks as shown in the MECON and APCCL layouts are not recommended as they must be moved by fork lift truck, with an attendant risk of damage to the cores.

3.4.4.4 A mobile hoisting unit of 2,5t-3,0t capacity will be required in the coreshop for changing corebox rigs on at least some of the core machines. Some of the corebox rigs are quite large and can weigh up to 2,0 tonnes or more.

3.4.5 Coresand Reclamation

3.4.5.1 Chemically bonded sands have been reclaimed for many years, but usually this is incorporated into moulding systems which use airsetting chemically bonded sands for producing moulds, not cores. Whilst the idea of core reclamation is good, in most cases the economics are not favourable for the following reasons:-

The coresand is inevitably mixed with the moulding sand (greensand) at the shakeout and in the moulding sand reconditioning units, this coresand cannot be separated for reclamation.

A decoring unit before shotblasting will not remove all of the coresand, and again, moulding sand will contaminate the coresand.

In the opinion of FMD, the reclamation of coresand will prove to be both impractical and uneconomic.

3.5 CASTING COOLING CLEANING AND FINISHING

After shakeout, castings are collected and cooled to ambient temperature or to a temperature at which they can be handled comfortably. They are then cleaned by shotblasting, which can be carried out either before or after the runner systems are removed.

3.5.1 Casting Cooling

3.5.1.1 It is not normal procedure on medium/high production moulding lines to allow castings to remain in the moulds until they have cooled to ambient temperature as this practice would tie-up a large number of moulding flasks and demand a large cooling area. Normally, castings are shaken out when they have cooled to a temperature of about 550°C or less. The exception may be SG iron castings where a ferritic structure, as cast, is called for and for safety, castings may be shaken out at a lower temperature.

3.5.1.2 The simplest method for casting cooling is to place thg castings from the shakeout into containers or onto trays or skids, and move them outside the building until they have cooled. However, they should be protected from inclement weather and the cooling area should be roofed over.

3.5.1.3 Castings from self discharging shakeouts may be transported on vibrating or slat conveyors which serve to both cool and convey the castings to the next operation.

3.5.1.4 Overhead monorail continuous or "power and free" conveyors are sometimes used in high production moulding systems. These can be routed around the outside of the buildings at high level and serve to provide cooling time, storage and transport to the next process, without imposing on floor space.

3.5.1.5 FMD Drawing No 692/1 shows the casting cooling area outside of the Finishing Building.

3.5.2 Casting Cleaning and Removal of Runner Systems

Casting cleaning is invariably carried out by means of airless shotblasting methods, using steel shot or chilled iron grit as the abrasive medium. There are many types of shotblast units available and the selection of a particular type is to a large extent dependent upon the castings contained in the product mix. It is possible to have shot blast units designed purely to handle cylinder blocks or heads, but in this case, FMD consider that MECON and APCCL are correct in opting for a more general purpose machine, since the product mix is somewhat varied. However, there are some points that should be considered before the final selection is made.

3.5.2.1 A continuous monorail type shot blast unit is not normally specified in terms of its throughput in tonnes per hour as its capacity is dependent upon the maximum hook load in kgs, the volume of a hook load and the number of hooks per hour.

3.5.2.2 The number of shot throwing impellors must be specified together with the kW/HP rating of each impellor motor. For this type of application, low kW ratings for motors give inefficient cleaning, and FMD would suggest 35kW as a minimum rating for each impellor motor.

3.5.2.3 Once inside the cabinet with the doors closed, the monorail hook, from which the castings are suspended, should rotate to ensure that all parts of the castings are exposed to the streams of shot.

3.5.2.4 Cycle times should be adjustable and the machine should have manual, single cycle and automatic modes. Full safety interlocks must be provided.

3.5.2.5 The length and configuration of the monorail system outside of the cabinet should be specified. For this type of unit the monorail usually has a powered section and a free section to facilitate loading and unloading.

3.5.2.6 It is good practice to shotblast the casting running systems before returning them to the stockyard for remelting as otherwise sand adhering to the runners can generate excessive amounts of slag in the melting furnaces. In some foundries, running systems are removed after the castings have been shotblasted, in others they are removed before the castings are shotblasted and then subsequently cleaned.

3.5.2.7 MECON and APCCL have proposed that coresand be reclaimed. As stated earlier, FMD has reservations about the practicalities of this procedure but if it can be done, then the decoring operation must precede shotblasting. Decoring will be easier if the running systems are removed first, in which case, provision will have to be made for cleaning the running systems separately.

3.5.2.8 For many of the grey iron castings contained in the product mix, a simple blow with a hammer will break off the running systems.

3.5.2.9 For "as cast" SG iron castings, however, and possibly some of the grey iron castings, removal of the running systems by a hammer blow may prove to be difficult and will be impossible in the case of ferritic SG iron castings. In many foundries, running systems are removed by high speed, abrasive disc-cutting machines; in others, an hydraulically operated wedge device has found application. FMD are of the opinion that both manual methods and abrasive discs should be specified in the APCCL foundry.

3.5.2.10 FMD Drawing No 692/1 shows the layout of the shotblast machine for primary cleaning and roller conveyor lines for storage, visual inspection of castings and transport to the finishing booths/ benches. This layout does not show equipment for decoring, as FMD is not convinced of its viability.

3.5.3 Casting Finishing

In general terms, 'Finishing' with regard to grey iron and SG iron castings, means grinding operations of one type or another and possibly chipping to remove "flash" and excess metal.

3.5.3.1 Most iron foundries are equipped with abrasive disc cut off machines, swing frame grinders, hand grinders of various types, pedestal grinders, and chipping tools. Chipping tools are usually pneumatically operated and hand grinders can be operated pneumatically or electrically.

3.5.3.2 Swing frame grinding is normally used to remove metal stock from medium/large castings and should be regarded as a rough grinding operation.

3.5.3.3 Hand grinding is carried out in areas of castings that are inaccessible to the swing frame grinder, or where more precise grinding is required. Some hand grinding may also be performed on the internal surfaces of cored holes in the castings.

3.5.3.4 Pedestal grinding, using floor standing grinders is carried out on the outside surfaces of castings light enough to be handled manually. Ten kilogrammes would be considered as the maximum weight of a casting suitable for a pedestal grinding operation.

3.5.3.5 Chipping may be used to remove heavy flash and/or fused sand, often from cored holes. Abrasive disc cut-off machines may also be used and these are referred to in section 3.5.2.9 earlier.

3.5.3.6 For maximum efficiency, all grinding machines should be of the high speed type and hand grinders of the high frequency type are preferred. It is not possible to comment upon the numbers or types of grinders proposed without having more details of the castings to be produced.

3.5.3.7 Provision for the rectification of improperly finished castings should be made.

3.5.3.8 Both MECON and APCCL reports and layouts lack details of the finishing operations. Handling and transport facilities for the castings are inadequate as are surge storage areas. Each grinding station (except pedestal grinding) should be equipped with lifting equipment such as jib cranes or preferably monorail electric hoists of 200kg-250kg capacity. Insufficient use is made of gravity roller conveyor for transportation of castings through the finishing stations. All grinding booths/benches should be fitted with an effective dust extraction/collection system.

3.5.4 Heat Treatment Procedures

The automatic temperature profile controlled cooling furnace is an idea which, as far as FMD can ascertain, is not in use in automotive foundries in the Western Hemisphere. There are probably a number of reasons for this:-

3.5.4.1 Castings are produced to specifications supplied by the customer and in the case of blocks and heads, some customers will specify a stress relieving heat treatment and some will not.

3.5.4.2 Generally speaking, automotive castings foundries, with their accumulated experience, can meet a customers specification without resorting to heat treatment and only heat treat if the specification calls for it.

3.5.4.3 Foundries are reluctant to add a process cost to a casting if it is not specifically called for, since it may be very difficult, if not impossible, to recover that cost from the customer.

3.5.4.4 The investment and operating costs of providing a continuous heat treatment furnace can be greater than the investment cost involved in increasing the length of the "in-mould" cooling lines and of providing a batch type heat treatment furnace.

3.5.4.5 Given that a stress relieving treatment is required for the blocks and heads produced by APCCL, then it wowld require a continuous heat treatment furnace having a minimum length of 48m. This assumes a cooling rate of 100°C per hour from 600°C down to 200°C and a loading capacity of four castings per tray.

3.5.4.6 To remove certain castings (according to design and varying section thicknesses) from the mould, can in itself create stresses if the temperature is too high. Distortion can also take place, which would not be corrected by subsequent stress relieving treatment.

3.5.4.7 Running systems should be removed from the castings prior to placement in a heat treatment furnace if the volume of the furnace and energy consumption is to be minimised. In this connection, removing the running systems from castings which have just been extracted from the mould and are still red hot, is a difficult and unpleasant task. The castings would of course still be coated with sand and some cores would probably not have fully broken down.

3.5.4.8 Batch type furnaces would not be suitable for the controlled cooling of castings from the shakeout as the time taken to collect a furnace load of castings, would result in a loss of residual heat.

3.5.4.9 There may be some advantages in controlled cooling of the castings if all, or most potential clients of APCCL specify heat treatment for the castings they order. This however, can only be evaluated when the specifications for the castings are made available.

3.5.5 Inspection, Testing and Painting

3.5.5.1 In the case of automotive castings, it is standard practice for the customer to specify tests on grey iron castings for hardness, dimensional accuracy (checked by jigs against cast-on datum points) and pressure testing of cylinder blocks and heads. They may also ask for a percentage of the castings to be marked out and/or sectioned, with test bars to be pulled, microstructures to be checked and the chemical analysis of the metal to be determined and recorded. The metal analysis, metallography and tensile testing will, of course, be carried out in the laboratories. The remainder of the tests will be carried out in the final inspection area of the finishing department.

3.5.5.2 A marking out table will be required together with a set of precision measuring instruments.

3.5.5.3 Brinell hardness testing equipment will be necessary. This may be portable.

3.5.5.4 Jigs will be required to check datum points. It should be noted that these are usually supplied as part of the pattern tooling.

3.5.5.5 Sonic testing devices can be used for checking the nodularity of SG iron castings and ultrasonic testing equipment may be useful for flaw detection. Radiography, however is not normally carried out on automotive castings and it is unlikely that a press, 'for straightening castings' will be particularly useful bearing in mind the type of castings which APCCL intend to produce.

3.5.5.6 Many customers specify that a protective coating be applied to the castings. Therefore, FMD agree with the proposal by MECON and APCCL to install a spray booth. The booth must, of course, be well ventilated and it should also be borne in mind when selecting the exact location, that protective paint/fume is invariably flammable.

3.5.6 Despatch

This department will collect the castings into the appropriate batch/order quantities, pack and/or palletise them, weigh them and load them onto the truck(s) for delivery. The practice is fairly standard and should not present any problems provided that sufficient area is made available.

3.6 ANCILLARY DEPARTMENTS

The ancillary departments are very important if the foundry is to operate efficiently. The impression gained from reading the reports is that insufficient attention has been given to some of these departments, which could have an adverse effect on the successful operation of the foundry.

3.6.1 Pattern Shop/Pattern Stores

This is a vital department for any foundry producing complicated castings and should not be combined with the general works maintenance department as has been proposed.

3.6.1.1 The area of the building allocated for pattern maintenance and pattern stores is considered to be too small and FMD would suggest a floor area in the region of 600m^2 with a height to the crane rail of approximately 7m.

3.6.1.2 The MECON/APCCL reports do not show any lifting equipment in this department. FMD would recommend that an EOT crane of at least 3 tonnes capacity be installed in the pattern shop/stores building.

3.6.1.3 The pattern shop will be concerned primarily with checking, maintaining, modifying and carrying out repairs to pattern and corebox tooling. It is unlikely that pattern tooling (in metal) for complicated castings will be designed and manufactured "in-house", at least not for some years.

3.6.1.4 FMD would normally propose that machinery be installed in a patternshop, comprising a lathe, band saw, circular saw, planer, sanders, universal milling machine, bench grinder, drill and both electrically and compressed air operated tools. This equipment is necessary for the manufacture of master negatives from which resin/plastic pattern tooling can be produced. Minor repairs/

modifications to the metal pattern tooling can be carried out using the metal working machinery which is installed in the works maintenance department under the supervision of a qualified patternmaker.

3.6.1.5 A marking out table and full set of precision measuring equipment is essential for checking pattern tooling.

3.6.2 Works Maintenance

When modern, sophisticated equipment is installed in a foundry, it is essential that scheduled maintenance be carried out, as opposed to repair or breakdown maintenance. The scope required of maintenance staff has also increased, with hydraulics and electronics now being widely used in the industry, thus the maintenance facilities have increased as have the numbers of skills that are required.

3.6.2.1 A separate facility should be provided for the general maintenance department. It should comprise areas for machining operations, fabricating/welding, hydraulics, pneumatics, electrics and a clean room for electronics. As a guide, FMD believe that the works maintenance department should occupy an area of approximately 600m^2 and should be served by an EOT crane of 5 tonne capacity. The maintenance department as proposed by MECON/APCCL is not considered adequate.

3.6.3 General Stores

The building area designated for general stores is also considered to be too small for a foundry of this type, particularly when the requirements for stocking a wide variety of spare parts are included with the day to day maintenance consumables. FMD suggest that the building area for the general stores should be in the order of 700m^2 which is approximately twice that shown on the MECON and APCCL General Layout.

3.6.3.1 MECON is correct in providing a separate and isolated store for flammable materials, irrespective of whether local and/or national regulations require this to be done. In this way, only the flammable materials would be lost in the event of an accidental fire. FMD would never recommend storing flammable materials in a general store.

3.6.4 Laboratories

These are well covered in both the MECON and APCCL Reports and in general terms FMD agree with the proposals. Nevertheles some modifications to the equipment/apparatus listed would be advantageous.

3.6.4.1 Mechanical/Physical Laboratory

The Durometer should be deleted and a Brinell hardness testing machine should be substituted. A mechanical saw, bench grinder, bench drill and Lathe should be included in the list of equipment and an area should be left for the future installation of an Impact Testing Machine.

3.6.4.2 Metallographic Laboratory

Add: Abrasive Wheel Cut-off Machine.
Sample mounting press.
Sample etching apparatus.
Sample drying oven.

3.6.4.3 Wet Analysis Laboratory

Add: Fume cupboard.

3.6.4.4 Moulding Materials Laboratory

Although useful, FMD do not consider the following items to be necessary for routine materials testing.

Hot shell tensile tester.
Hot distortion tester.
Gas evolution equipment.
Peel back tester.

A shatter index tester should be added to the equipment specified for this department.

3.6.4.5 Rapid Test Laboratory

FMD suggest that a vacuum emission spectrometer be installed together with sample preparation equipment, as this could also be used to analyse incoming furnace charge materials, particularly steel scrap. In this case, the LECO system could be deleted. A thermal type carbon/silicon determinator should be installed and there should be provision for wedge tests. Portable immersion (not optical) pyrometers should be provided for temperature measurement of liquid metal.

3.6.4.6 NDT Equipment

FMD do not see any necessity, at least during the initial operations, for Radio fluoroscopy equipment. It should be noted that pressure testing equipment for cylinder blocks and heads is normally operated pneumatically not hydraulically. A portable hardness tester should be added to the list of equipment for this department.

3.6.4.7 The pneumatic sample delivery system should not be necessary, if the rapid test laboratory is located near to the melting/holding furnaces.

3.7 SERVICES

3.7.1 Compressed Air

3.7.1.1 According to the MECON Report, the amount of compressed air required, at a net good annual production of 6 000 tonnes castings, is 21,7m^3/minute. This does not appear to allow for any usage of compressed air for pressure testing of blocks and heads or, as far as can be ascertained, in the general maintenance shop, the patternshop or the melting shop.

3.7.1.2 The APCCL Report proposes to uprate the Phase 1 capacity to 9 000 tonnes per year, this implies that the moulding machine production rate will be increased and more core machines will be installed to meet the increased requirements. Although it is likely that 3 x 12m^3/minute compressors operating simultaneously will meet the demand, the requirements should nevertheless be reassessed.

3.7.1.3 FMD would normally recommend the installation of a ring main with a minimum diameter of 150mm to supply compressed air to the principal production departments. If not supplied with the moulding machine, an air receiver should be installed adjacent to it with other receivers in the core shop and close to each pneumatic transporter.

3.7.1.4 It is normal practice to install compressors in a large well ventilated building, outside of the main buildings. It is unusual to see compressors installed in a building within a building as proposed by MECON/APCCL.

3.7.1.5 FMD prefer screw type compressors instead of the reciprocating type but this is not a major point of difference.

3.7.2 Water

If the losses quoted in the MECON report are correct then a consumption rate of $10m^3$/hour of water would seem to be accurate. However, a figure of 3,3% loss of the circulating water in the evaporative cooler would appear to be slightly optimistic, given the prevailing climatic conditions. If wet type dust collectors are to be used then water losses from this source will need to be taken into account.

3.7.2.2 The emergency water supply requirement for the coreless induction furnaces should be checked once a final decision has been taken on the type, number and capacities of the furnaces. This applies also to the channel induction holding furnace and the automatic pouring furnace. It is normal practice to run cooling water through the coils of a coreless induction furnace for a minimum period of four hours after the furnace has been emptied, to prevent damage to the coils and/or the refractory. The water pumps of the channel induction holding furnace and the automatic pouring furnace will be supplied with power from the emergency power generator.

3.7.2.3 Consideration should also be given to sizing the emergency water tank to meet the final capacity of the foundry, otherwise a second emergency water tank and associated pipework system will have to be installed when the capacity is expanded beyond Phase 1.

3.7.2.4 The height of the emergency water tank above the water inlet to the furnaces should be checked, to ensure that the delivery pressure is correct.

3.7.3 Fuel Oil

If fuel oil is used in a modern foundry as a source of energy, then it is usually of the diesel or light gas oil type. Heavy fuel oils are not normally used. Fuel oil should be stored away from the main buildings.

3.7.3.1 A scrap dryer is not required if medium frequency coreless induction furnaces are to be installed and operated on the charge/melt/empty system. However, MECON, in their report have referred to a scrap preheater and it must be pointed out that this equipment serves a different purpose to that of a scrap dryer. Since there appears to be no further reference to a scrap preheater in either the MECON or APCCL Reports, it is assumed that this type of equipment is not under consideration.

3.7.3.2 There are now available, a range of very efficient electric ladle dryers/preheaters. These are environmentally more acceptable than either the gas or oil fueled types and are comparatively easy to install when compared with the alternative equipment. It is suggested that the different systems are evaluated in the light of the comparative energy cost in India before a final decision is taken.

3.7.3.3 If the scrap dryer is deleted and/or an electric ladle dryer/ preheater is installed, then the oil fuel storage and distribution system will need to be redesigned.

3.7.4 Electrical Power and Distribution

3.7.4.1 It is normal practice and is considered advisable to site any 33kV electrical supply and transformer station in a remote area just inside the perimeter fence. The main transformer station should not be sited adjacent to the production buildings.

3.7.4.2 In view of the proposal to install medium frequency electric melting furnaces, alternative designs for the installation of the electrical supply system are possible. Transformers may be installed to convert from 33kV to 415V directly and supply power to all equipment at this voltage. Alternatively, transformers may first convert from 33kV to 6,6kV and supply at this voltage to transformer sub-stations near to the foundry buildings. These transformers would then convert from 6,6kV to 415V and supply power to all equipment at this voltage.

3.7.4.3 It is normal practice to lay longer runs of HT cables with LT cables to be kept as short as possible.

3.7.4.4 Even though savings in electrical equipment could be made by installing the first option, the longer cables of high current low voltage supply would result in power losses through the cables, which would ultimately be less economic in terms of operating costs.

3.7.4.5 FMD would, therefore, strongly recommend that the electric supply scheme as submitted by MECON should be adopted.

3.8 TOOLING

3.8.1 Estimated Tooling Costs

3.8.1.1 Table No 16.05 of the MECON Report, Item 16 shows one set of patterns and coreboxes costing 950 000 Rupees which is equivalent to about 74 200 US Dollars. It does not state which casting the pattern equipment is intended to produce, but if it is for a cylinder head then FMD consider that this allowance is very low by a factor of about 5. In this connection, a set of tooling for a 3 cylinder diesel engine block purchased in neighbouring Pakistan in 1984 cost US 375 0000.

3.8.1.2 It is common practice, in the case of automotive castings, for the customer to supply (or pay for) the pattern tooling which is to be used by the foundry. In this case the pattern tooling then remains the property of the customer.

3.8.1.3 The supply of pattern and corebox tooling is a major consideration in the design of any foundry and particularly so in the case of an automotive foundry. This aspect of the project does not appear to have been adequately covered in either the MECON or APCCL reports.

3.9 SITE PLAN AND BUILDINGS LAYOUT

It is understood that the site referred to in the MECON and APCCL Reports is no longer available and that a new site has been approved and obtained. This information was given to FMD during the visit to India and although a request to visit the new site was made, the visit did not take place. Furthermore, no information was given as to the exact location, size or configuration of the site. Thus, the following comments are only of a general nature and apply specifically to the site plans/buildings shown in the MECON and APCCL Reports.

3.9.1 Future Expansion

The strategy behind the future expansion is not clearly explained and the individual department layouts do not appear to allow for easy unobstructed expansion from Phase 1 to Phase 2. For example, there is no indication as to where dust collectors or fume exhausts/scrubbers are to be located and as these are invariably situated on the outside of buildings, their location is important as the siting of the ductwork could affect future expansion plans.

3.9.2 Relative locations of buildings (MECON Layout)

3.9.2.1 The juxtaposition of the main production building with the fettling and finishing building is good.

3.9.2.2 The fuel oil storage should be remote from the points of usage, as shown by MECON but it could more conveniently be located to the east of the main building and closer to the stockyard and melting department where the heaviest consumption is likely to occur.

3.9.2.3 The location of the pattern shop and pattern store is satisfactory but as indicated earlier, the building is too small.

3.9.2.4 The ideal location for the general stores should be near to the Maintenance Department which is not provided for in the proposal but this is not a major criticism. The general store building is, however, too small.

3.9.2.5 The location of the laboratory is good and FMD suggest that the Quality Controller and Chief Metallurgist should also be accommodated in this building.

3.9.2.6 The position of the administration building and works offices is satisfactory from the standpoint of the administration personnel. Offices for works management/technical staff should be located within the various departments.

3.9.2.7 The main water supply is near to the points of maximum usage and is entirely satisfactory.

3.9.2.8 The location of the main electrical substation is largely dependent upon where the incoming power line enters the site. With this in mind, FMD would prefer to see these facilities situated to the north of the road and not to the south as shown. It is accepted, however, that this may not be practical.

3.9.2.9 FMD would favour locating the Compressor House between the two main production buildings where most of the compressed air will be used.

3.9.2.10 The location chosen for the flammable store is satisfactory.

3.9.3 Relative locations of buildings (APCCL Layout)

3.9.3.1 The juxtaposition of the main production building with the fettling and finishing building is good.

2.9.3.2 The fuel oil storage should be remote from the points of usage, as shown by MECON but it could more conveniently be located to the east of the main building and closer to the stockyard and melting department where the heaviest consumption is likely to occur.

2.9.3.3 The location of the pattern shop and pattern store is satisfactory but as indicated earlier, the building is too small.

2.9.3.4 The ideal location for the general stores should be near to the Maintenance Department which is not provided for in the proposal but this is not a major criticism. The general store building is, however, too small.

2.9.3.5 The location of the laboratory is good and FMD suggest that the Quality Controller and Chief Metallurgist should also be accommodated in this building.

2.9.3.6 The position of the administration building and works offices is satisfactory from the standpoint of the administration personnel. Offices for works management/technical staff should be located within the various departments.

3.9.3.7 As mentioned earlier, the MECON location for the water facilities is convenient and FMD is in agreement with the proposal. APCCL, however, have chosen a different location without giving a reason.

3.9.3.8 The location shown for the diesel generators is unsatisfactory in that they have been sited inside the main building. It is inevitable that a problem will be encountered with the extraction of exhaust fumes. FMD prefer the location for the Transformer, Substation and Diesel Generators to be as referred to in 3.9.2.8.

3.9.3.9 FMD would not locate the Compressors in this area, but as suggested in 3.9.2.9.

3.9.3.10 APCCL have deleted the Flammable Store. FMD strongly disagrees with this decision particularly as some types of corebinders and catalysts are flammable, as is calcium carbide.

3.9.4 Buildings

3.9.4.1 FMD do not agree with APCCL's proposal to reduce the crane girder heights or the truss heights in the charge make-up and melting departments. They should remain as specified by MECON. Column spacings in the vicinity of the melting furnaces will need to be reviewed when definitive furnace dimensions are available. Five tonnes capacity, heavy duty EOT cranes are required as suggested by MECON and two electro magnets will be required for the stockyard EOT crane. The equipment contained in the melting shop is too congested and will cause operating inefficiencies, and blocking of accessways. FMD do not consider that 12m is wide enough for this type of melting bay. If a single control room is used for multiple furnaces it should be mounted at furnace platform level or higher, not at foundry floor level. This layout could present difficulties when additional equipment has to be installed in Phase 2. The APCCL layout does, however, offer a better system for transfer of metal to the automotive pouring furnace than does the MECON one. To be able to pour from ordinary ladles in the event of a failure of the pouring furnace, or when SG iron castings are being produced, will necessitate some modifications to the molten metal transfer and pouring system.

3.9.4.2 If mobile core racks are used there should not be any necessity to provide an EOT crane in the Core Storage/Assembly bay, and the height of this bay could be reduced. However, the total height of some core machines is such, that FMD would recommend a minimum of 8m to truss level in the coremaking bay, or higher if the coresand mixers and sand hoppers are to be mounted on a mezzanine floor. The core machine dimensions will, in fact, be larger than shown in the APCCL layout, and it will not be possible to arrange them as shown. The bay is both too narrow and too short. The core drying oven should be relocated into the next bay, as should the core coating operation which is not shown on either the MECON or APCCL layout drawings. Some space can be gained by deleting the Core Box Storage (which is too small to serve any useful purpose) and by deleting the Pattern Storage area and relocating the Moulding Line Control Room.

3.9.4.3 The area allocated for the moulding sand reconditioning and preparation plant is large enough, given modern equipment and processes. However, APCCL have deleted the facility to dry new sand and neither APCCL or MECON have considered that new sand may require classification and possibly washing. If new sand cannot be purchased in the dried state, then it cannot be obtained in the classified state since sand classification is a dry process. Furthermore, if washing is necessary, then further equipment will be required. Until information is available regarding the quality of the incoming silica sand, it is difficult to propose a layout for the sand plant. FMD do not accept the APCCL concept of premixing sand to 'temper' it prior to final mixing as this is neither necessary or desirable, given modern sand practices and reconditioning equipment.

3.9.4.4 A moulding line having an ultimate capacity in Phase 2 of close to 100 moulds per hour and a mould size as specified for this project, should not be housed in a building which is only 15m wide. FMD would recommend a minimum bay width of 20m and a crane rail height of approximately 9,0m. Modern moulding machines, with sand hopper, metering system and sand delivery conveyor will reach a height of about 7,5m-8,0m above floor level, therefore, to enable an EOT crane to clear the machine, the crane rails must be a minimum of 9,0m high. Assuming that a single moulding machine has sufficient capacity to meet the Phase 2 requirement, then the easiest way to increase production from, say 50 moulds per hour to 100 moulds per hour would be by adding further parallel mould cooling lines. It is wrong to build area constraints into a new project where the future expansion of a department(s) is ultimately envisaged.

3.9.4.5 Insofar as the fettling and finishing of castings is concerned FMD do not consider that the building areas shown on either the MECON or APCCL drawings will be large enough and, based on an output of 9 000 net good tonnes per year, insufficient work stations have been allowed for in both layouts. Little surge storage area has been provided and the casting handling facilities are inadequate. The height of the building, suggested by APCCL as 6,5m to the crane rail, is too low and it is likely that the shot blast equipment and exhaust trunking will be close to that height. APCCL have located the heat treatment furnace in the shortened bay but have not included an EOT crane for handling castings. Depending upon the properties required in the austempered SG iron castings then a warm water quench tank will be required and the oil or salt quench tank will also have to be heated.

3.9.4.6 Ventilation Plant

Much of the equipment will need to incorporate fume and/or dust extraction equipment such as the shakeout, sand conveyors, moulding sand reconditioning and mixing plant, new sand drying/classifying plant, core sand reclamation plant (if installed), core machines (for certain processes), shot blasting equipment, melting furnaces, painting booths and fettling/finishing stations. Given reasonable louvered buildings and a height of 10m or more, then the amount of air extracted will ensure a good working environment. APCCL have proposed that the ventilation/exhaust equipments should be concentrated together in a single location inside the building. This is not normal practice as it will entail very long runs of ductwork with associated higher capital and operating costs. Irrespective of the decision to accomodate all of the ventilation/exhaust equipment together, it should be outside of the building.

3.10 FINANCIAL EVALUATION OF THE PROJECT

3.10.1 Estimated Costs for Equipment

FMD has reservations about the estimated costs for plant and equipment which are shown in the reports and feel that they may be low in several areas.

3.10.1.1 Some of the items are not correctly specified and have almost certainly been underestimated. These items include the Sand Plant, core shooters, Item 4 of the melting department, coresand mixing, shotblast machine, pattern tooling, Item 17 of the fettling and finishing department, the heat treatment furnace and the laboratory facilities.

3.10.1.2 Certain items are missing from the capital cost estimate. These are the sand classification and associated equipment, core sand reclamation equipment (if required), heated oil/salt quench tank, heated water quench tank, non destructive testing and certain other items of inspection equipment.

3.10.1.3 FMD also considers that there is insufficient lifting equipment included in the studies.

3.10.1.4 MECON has obviously not taken account of certain items of equipment such as the "temperature profile controlled cooling furnace" and "automatic casting extractor" which have been included in the APCCL Report.

3.10.2 Operating Costs

FMD can only make general comments with regard to the projected operating costs since the costs of raw materials and manpower etc are assumed to be correct as printed in the MECON Report and based on 6 000 net good tonnes castings per year.

3.10.2.1 The amount of bentonite used will depend upon the required moulding sand characteristics and on the type and quality of the bentonite available. If the bentonite is of good quality, then the 640 tonnes per year shown in the report should be sufficient.

3.10.2.2 The allowance for the coal dust additive appears to be low at 320 tonnes per year and should be recalculated.

3.10.2.3 From the information given in the report, FMD do not anticipate any requirement for a dextrin addition and would question whether such an addition is necessary.

3.10.2.4 The requirement for corebinder and catalyst will depend upon the process selected and upon the final product mix. If the hot box (wet mix) process is selected and the product mix is as stated by MECON, then the figures given in the report are correct.

3.10.2.5 FMD do not see any use for coldset (airset binders) and suggest that these be deleted.

3.10.2.6 The quantity of purchased charge metallics required will depend upon the quality of the steel scrap available and upon the types of cast iron to be produced. The more SG iron of ferritic grade is produced, then the more special pig iron will be required. The product mix simply calls for SG iron without specifying the types to be produced so it is not possible to comment further on this point.

3.10.3 Total Investment Cost for the Project

3.10.3.1 FMD cannot comment on the cost of Buildings or of Land and Site Development as detailed knowledge of Local costs is not available. However, it is felt that the amount of pitwork foundations and tunnels required for conveyors may have been underestimated.

3.10.3.2 Based upon plant/equipment prices obtained on previous projects, FMD considers it likely that the cost for plant/equipment has been underestimated. Furthermore, it is also considered likely that the costs for equipment foundations and installation is low.

3.10.3.3 The cost of employing foreign technicians will largely de d upon how much equipment is to be imported, the type of equipme the requirement for different disciplines. At current charg r technicians, it is estimated that 800 000 Rupees is equivalent to about 180-200 man days, which is low in FMDs experience of implementing projects in Asian countries.

3.10.4 Economic Appraisal

The appraisal is correct as the figures stand, however, FMD would make two points:

3.10.4.1 As indicated in the previous section, when full specifications for all items of plant and equipment have been prepared and issued to suppliers, it is almost certain that the quoted prices will be higher than the budgetary prices shown in the MECON Report. Other things being equal, this will, of course, adversely affect the economics of the project.

3.10.4.2 Potential investors will almost certainly want to see some evidence that Automotive Manufacturers will be prepared to pay a premium of 7,1% for grey iron castings and 6,25% for SG iro castings above standard prices for higher quality castings from APCCL. General experience shows that automotive manufacturers are reluctant to pay premium prices for castings. They provide comprehensive specifications for the castings they require, covering metallurgical quality, dimensional tolerances, machining allowances, etc. If more than one supplier can meet these requirements then they invariably accept the lowest price. The assumed price increase shown in the reports is very important to the profitability of the project and should be verified if possible. FMD would always use current market prices in a financial evaluation unless there was firm evidence to support the use of prices which are higher than the market "norm".

3.11 PERSONNEL REQUIREMENTS, TRAINING AND TRANSFER OF TECHNOLOGY

3.11.1 Manning Figures

3.11.1.1 The total number of personnel proposed by MECON is lower than that proposed for many similar sized projects in developing countries but without seeing a job by job breakdown, it is difficult to comment on the accuracy of the figures. However, for the layout and type of equipment shown, the total does appear to be optimistic for a two shift operation. Furthermore, APCCL apparently propose the same manpower for 9 000 tonne per year as MECON propose for 6 000 tonne per year.

3.11.1.2 The organisation chart provided by MECON is, in the opinion of FMD, over simplified. It does not for instance, take account of the fact that some of the departments will be operating for two or three shifts per day.

3.11.1.3 The organisation chart provided by APCCL (handed to FMD during the visit to India) is both more appropriate and more detailed and covers the shift requirements. As it is a draft organisation chart, it is likely to undergo some modifications as the strengths of the individuals appointed to key positions become known. However the APCCL chart does indicate an increase in the number of managerial/technical/supervisory staff requirements. All the functions are covered and whilst FMD may question some of the groupings, the differences are not so great as to warrant a serious objection.

3.11.2 Training

3.11.2.1 The training requirements for personnel vary from project to project, according to the qualifications and experience of the individuals appointed to the various positions, the type of foundry installed and technologies adopted. It is not possible to lay down a precise training programme in a feasibility study and, therefore, the normal practice is to give outline job specifications and preferred qualifications/experience for all the key positions. A suggested training programme is also given; this programme being adjustable according to the qualifications/experience of the individuals recruited for each key position.

3.11.2.2 However, there are certain points in establishing training programmes for new foundry projects which are common to most projects.

3.11.2.3 Key personnel should be recruited early enough to allow for a period of training in a foundry which is using similar processes and/or equipment as well as in the suppliers works, before installation of equipment commences.

3.11.2.4 Key personnel should be involved in the installation of equipment in their particular department to enable them to become absolutely familiar with the equipment and processes which they will ultimately control.

3.11.2.5 On-the-job training will take place during the period of time when commissioning of the equipment will be undertaken by the Suppliers' commissioning engineers on site.

3.11.2.6 If there is a Transfer of Technology Agreement, then the engineers seconded to the foundry as part of the agreemment, will provide further training, for the period of time that they are on site.

3.11.2.7 FMD have, for some projects, arranged special intensive courses for key management/technical staff at a college specialising in advanced foundry technology. These courses have concentrated on the processes/technology applicable to that particular project and have proved a valuable adjunct to other forms of training. The courses are normally of 10-12 weeks in duration and are designed for a maximum of 10 people so that individual tuition can be given.

3.11.3 Transfer of Technology

The production of thin wall, high integrity automotive castings involves the use of sophisticated equipment and advanced manufacturing techniques. FMD would strongly recommend that APCCL should establish a long term association with a recognised supplier of such castings. Such an association would undoubtedly reduce the "learning curve" and would provide APCCL with an on-going source of expertise to assist them in the production of these very difficult castings.

4.0 CONCLUSIONS

4.1 In general, the technical proposals given in the MECON and APCCL reports are well considered and provide a sound basis for the design of a foundry using advanced technology to produce high quality castings. However, foundries which produce high integrity thin walled castings for automotive applications cannot be considered as jobbing foundries and the types of castings which can be produced on a single high pressure moulding line are limited. In the short term, therefore, although it may be expedient to produce a range of products as diverse as cylinder blocks and bearing caps on the same moulding line, in the longer term this strategy cannot be sustained and a second, smaller, moulding line will need to be installed. Close study of the two reports reveals that although there are gaps in information and a shortage of data in some areas, as a starting point for detailed engineering, the reports are soundly based technically.

It is felt, however,that the capital investment cost for equipment has been underestimated and the viability calculations are predicated on the assumption that customers will be prepared to pay up to 7,0% over the market price for higher quality castings of the types contained in the product mix. FMD would wish to see to some evidence to support this assumption.

In commenting upon the MECON and APCCL Reports, it should be noted that where figures contained in the two reports have been queried, it is invariably because of a lack of supporting information and not necessarily because the figures themselves are thought tc be inaccurate.

4.2 One of the main criticisms of both the MECON and APCCL reports is the lack of data relating to the proposed product mix. FMD sought to obtain more information but was not successful. Furthermore, a section of the MECON report entitled "Market Review" was missing from the version given to FMD. It is not possible, therefore, to comment on the conclusions drawn by MECON and APCCL in respect of either the proposed design capacity of the foundry or the choice of products.

4.3 The selection of technologies/processes are entirely applicable to the type of foundry considered in the reports. The foundry appears to be designed for a final tonnage of 6 000 (MECON) or 9 000 (APCCL) net good tonnes per year and although there is a reference to a second phase expansion up to 15 000 or 18 000 tonnes per year, no positive proposals have been made to explain how this level of expansion could be achieved. With this in mind, the plant layout in the No 1 building is satisfactory if further expansion is not envisaged.

4.4 In so far as the choice of melting furnaces is concerned, FMD would recommend the use of medium frequency coreless induction furnaces as prime melting units as proposed by APCCL instead of the mains frequency furnaces advocated by MECON.

4.5 The capacity of the holding furnace should be checked and thought should be given as to how the installation of a sufficient holding furnace capacity to meet the Phase 2 requirements, can be achieved. The vertical channel type of holding furnace, as recommended by MECON is the standard for this operation and is fully supported by FMD.

4.6 FMD believes that consideration should be given to using a porous plug type ladle as a means of desulphurising small quantities of liquid metal.

4.7 The"Press-pour" type of automotive pouring furnace,is well tried and proven for this type of application. and FMD fully agrees with this Proposal. Nevertheless, an alternative system for pouring moulds from manually operated ladles should be incorporated in the overall layout. This will provide a back-up system in case of a breakdown of the auto pour unit but more importantly, it will widen the choice of the nodularisation process. Due to the phenomenon of "fading", the use of automatic pouring units for SG iron production virtually dictates the use of the "In-Mold" process.

4.8 The shoot-squeeze type high pressure moulding machine as proposed is a suitable choice for the production of greensand moulds and FMD has experienced very good results from this machine. FMD do not have adequate information regarding the proposed product mix, but even so, have some reservations about the mould size, which is considered to be rather small for full advantage to be taken of the potential markets. A mould size, of 1000mm x 850mm x 300mm/300mm would be more in line with the size adopted by many automotive foundries.

4.9 The mould handling equipment is well covered and for the mould size and output quoted a single moulding machine producing copes and drags alternately will be satisfactory. A single line of moulds through the pouring area will be adequate, with parallel 'in mould' cooling lines. This concept will permit the casting cooling times to be varied.

4.10 If SG iron castings are to be produced in the 'as cast' condition, then 'in mould' cooling time will need to be in the range $1^3/4$-2 hours. Casting cooling can be carried out entirely within the mould flasks or, after an initial cooling period in the mould flasks, the sand parcels can be punched out and transferred to a secondary conveyor system for final cooling. Although this dual cooling system saves on both space requirements and investment costs for mould flasks, the additional cost of the secondary cooling system often counter balances the saving on flasks. It is suggested that a final decision is deferred until quotations have been received from suppliers of both systems and the relative merits have been evaluated both technically and financially.

4.11 At this stage, there does not appear to be any justification for the use of a 'Temperature Profile Controlled Cooling' furnace, as proposed by APCCL.

4.12 FMD agree with the use of a 'castings extractor' but in a somewhat different form and for a slightly different purpose than that proposed by MECON/APCCL. It is recommended that a remote controlled manipulator be used to remove hot castings from the shakeout deck and to place them in containers for transport to a cooling area. The operator would be located in an air conditioned cabin which would eliminate completely the need to employ any operators at the shakeout to undertake this particularly arduous and unpleasant task.

4.13 FMD do not agree with the idea of pre-mixing sand. This concept was used some years ago as a method of cooling return sand, but was discarded as more modern and efficient sand cooling equipment became available.

4.14 If it is not possible to obtain dried, classified silica sand, then sand drying and classifying equipment will have to be installed. It may also be necessary to install sand washing equipment, depending upon the quality of the available silica sand.

4.15 The necessity for a storage requirement equivalent to three months usage of materials is not explained and in the opinion of FMD, such an amount is excessive except possibly for imported materials.
For indigenous materials, a maximum of one months supply should be adequate.

4.16 FMD is not convinced of the viability of reclaiming coresand. Much of the coresand will be mixed with moulding sand at the shakeout and coresand removed from the castings by means of a specific de-coring operation will also be contaminated with moulding sand. It is suggested that once the foundry is established, trials should be carried out to ascertain how much coresand can be collected and to what degree it will be contaminated with moulding sand. A final decision can then be taken as to whether or not reclamation equipment should be installed. In any event, core sand reclamation plant should not be installed initially.

4.17 The processes finally selected for the production of cores will be influenced to large extent by the types of corebinders which are available in India. The 'Croning/Shell' process, using precoated sand, is commonly used (for certain cores) in cylinder block and head castings and is particularly stable in hot, humid environments. For the other cores, various processes can be used, some of which have been discussed in the MECON/APCCL reports. Of particular relevence are the following:-

4.17.1 The Hot Box (Wet Mix) and Warm Box processes use energy to heat the coreboxes. The favoured method of heating corboxes for the hot box process is by gas whereas electricity is generally used for the warm box process. The corebox tooling for the Hot Box process is usually more expensive than for most other processes.

4.17.2 The Cold Box processes use less energy than the Hot Box processes and generally the core box tooling is less costly. However, because Amine or Sulphur Dioxide gases are used in two of the processes, the exhaust fumes have to be scrubbed before they can be released to atmosphere. A third process, using gaseous Ester, does not have this constraint.

4.17.3 The coldset (Airset) system suggested by MECON is not considered to be appropriate for this project; at least not in the way that its use has be proposed.

4.17.4 After the process has been selected, care still needs to be taken in specifying the binders and catalyst for this project, as binders/catalysts should be Nitrogen and Sulphur free. This applies also to the pre-coated sand for the Croning/Shell process.

4.18 Since details of the product mix are not available to FMD, it is not possible to comment on the selection of the core machines. Nevertheless, 25 litre capacity for the larger machines and 6 litre capacity for the small machines would seem to be adequate. The number and types of machines required can only be ascertained by detailed study of the drawings for those items which are contained in the product mix. Continuous mixers are recommended for the preparation of coresand.

4.19 In general, the layout of equipment in the Finishing Department requires revision, as do the facilities for transporting and handling the castings. In this connection, FMD has prepared a new layout drawing to illustrate the suggested revisions. A heat treatment furnace will be required for rectification of those SG iron castings which do not meet the required standards in the 'as cast' condition. This furnace can also be used, initially at least, for the stress relief of grey iron castings where this is specified by customers. If a specific demand is confirmed for austempered SG iron castings and worldwide the demand is increasing, then a separate and smaller heat treatment furnace will be required together with a heated oil or salt bath and possibly a warm water quench tank.

4.20 Some items of equipment specified for NDT inspection can be deleted as FMD would not normally anticipate any use for them. It is further suggested that some changes should be made in the selection of equipment for the laboratories. Both of these points are further explained in section 3 of this report.

4.21 Certain of the ancillary buildings appear to be inadequate in size and it is suggested that facilities for the mechanical, electrical and electronic maintenance of equipment should be housed in a separate building. It is also strongly recommended that the flammable store, as proposed by MECON, should be retained. Generally speaking, the site plan and buildings layouts proposed by MECON are preferred to those proposed by APCCL.

4.22 The proposals relating to the consumptions of water, compressed air and power should be adequate for operations at 6 000 net tonnes per year but since APCCL have proposed a 50% increase in capacity, then the requirements should be reassessed; particularly for power and compressed air.

4.23 The requirement for fuel oil will be reduced if the charge drying equipment is deleted (this is possible if medium frequency coreless induction furnaces are installed) and/or the ladle dryers/heaters use electric energy.

4.24 FMD is in general agreement with APCCL's proposals to make extensive use of computers for both Foundry Operations and Management Information purposes. A note on the application of computers in the foundry industry, can be found in Appendix 5.

4.25 FMD recommend that the electrical system as proposed by MECON be adopted.

4.26 FMD considers that 21 months is optimistic as a schedule for the project implementation programme. If the purchase of foreign equipment is through international competitive bidding, then the total implementation time (from the date of approval to proceed) is likely to be closer to 30 months.

4.27 Because of the high level of technology to be incorporated into this project APCCL should establish a long term association with a recognised producer of high integrity, thin wall castings.

APPENDIX 1 : VISIT TO INDIA AND DISCUSSIONS HELD WITH APCCL

The visit was made to clarify points arising out of a study of the MECON and APCCL Reports. However, no additional supporting information was made available and despite a request by FMD to visit the site, this could not be arranged. Discussions centred largely around the latest APCCL concept for the proposed foundry, the main points of which are set out below.

1. THE REVISED PROPOSAL OF APCCL

1.1 APCCL has decided to restrict the types of castings to be produced to thin wall castings for the automotive industry; specifically cylinders blocks, cylinder heads and other high integrity, thin wall components. Figures relating to the quantities of castings and the number of different types of block and head to be made, were not available to FMD but the initial capacity of the foundry was projected at 9 000 net good tonne per year.

1.2 The introduction of SG iron castings is to be delayed to some future date; probably one to two years after commencement of commercial operations was given as the likely time scale.

1.3 APCCL propose to install a second mould production department based on the Cold Set (Airset) Sand process, for production of jobbing castings as yet undefined.

1.4 APCCL have proposed that the main production departments (including melting), will operate on 270 days per year, 2 shifts per day, 8 or 8 $^{1}/2$ working hours per shift.

1.5 The main moulding line will be initially rated at 60 moulds per hour, then uprated to 90 with a further uprating at sometime in the future to 140 moulds per hour. The mould flasks will retain the same dimensions for length and width as given in the report but two sets will be obtained having different heights; namely 250mm/250mm and 375mm/375mm.

1.6 Consideration is being given to the use of Zircon sand instead of Silica sand for the production of both moulds and cores.

1.7 The removal of running systems from castings as well as the primary shot blasting operation is to be carried out in an intermediate department, situated between the moulding and finishing departments

1.8 The introduction of automatic flash grinding machines is now being considered.

1.9 It is understood that the site discussed in the MECON and APCCL Reports is not now applicable and that an alternative site has been procured. FMD were not taken to see the site during the visit.

2. COMMENTS ON THE REVISED PROPOSALS

2.1 The decision to reduce the product mix to a few specific and similar types of castings can only be regarded as advantageous from the standpoint of improved operating efficiency and quality control. This, of course, assumes that there is a market for these types of castings. Information indicating the size of the markets was not made available to FMD.

2.2 Based on the average figures given in the MECON Report for the product mix and assuming one cylinder block per mould, and two cylinder heads per mould, then the annual requirement for moulds including a 10% allowance for scrap castings, and 9000 net good tonne per year would be 166 665 or 39 moulds per hour. Assuming an operating efficiency of 70%, then the moulding line will need to be rated at 55 moulds per hour. It must be pointed out that the use of average figures can be misleading.

2.3 Bearing in mind the planned ultimate capacity of the line, it should be noted that a moulding line rated at 140 moulds per hour, operating at 70% efficiency and assuming the same average figures as used previously, will be capable of producing 22 860 net good tonne of castings per year.

2.4 To produce 9 000 net good tonne per year when melting on two shifts will require a net melting capacity of 3,63 tonne per hour and a rated furnace capacity of 4,84 tonne per hour. At 22 860 net good tonnes per year, the net melting capacity increases to 9,22 tonne per hour and the rated furnace capacity to 12,29 tonne per hour.

2.5 To begin operations in a new foundry always presents difficulties and starting production with a new team of staff and operators attempting to make two of the most intricate grey iron castings can only exacerbate the difficulties. FMD, therefore, fully support APCCL's decision to delay the introduction of SG iron until the foundry has established its credibility.

2.6 FMD is not aware of the circumstances which led APCCL to the decision to incorporate a second moulding system based on the "Cold-Set" process into the foundry. Nevertheless, provided that sufficient space can be made available, it is not difficult or costly to set up a boxless moulding unit based on the "Cold Set" Process. Using the "Pattern-Flow" principle, this type of moulding unit is suitable for the production of one off or short series work in a range of mould and casting sizes/weights. The introduction of this unit would add some flexibility to the foundry in terms of the type of work it could undertake.

2.7 The concept of operating production departments over two shifts per day is noteworthy. In highly mechanised and/or automated units it is normal practice to operate on two shifts and carry out programmed maintenance during the none operating shift. The high capital cost of the equipment dictates that it should not be allowed to stand idle for 16 hours per day. Melting/holding furnaces can be operated on three shifts and in many countries there is an economic advantage in using "Off-Peak" electricity.

2.8 The final capacity of the moulding line will require careful consideration, since the specification for the initial line and layout will influence the final capacity. For a mould size as stated in the reports, a single moulding machine should be suitable for moulding rates up to 90-100 moulds per hour. For moulding rates in excess of 100 moulds per hour, it is almost certain that two moulding machines will be required, together with the associated extra mould handling equipment. This would have to be taken into consideration when preparing layouts for the initial installation.

2.9 Zircon sand is used to some extent in the production of moulds and cores although FMD do not know of any ferrous foundry where it is in use for the production of all types of cores and as far as can be ascertained, no foundry uses it as a base material for unit greensand to produce moulds on a high production moulding line. It is expensive when compared to silica sand and its value as a replacement for silica sand is not proved for the production of castings of the types contained in the product mix. It is suggested that the use of Zircon sand could be the subject of trials and development by APCCL but should not be used in the initial operation of the foundry.

2.10 Automatic flash grinding machines could prove economic if the product mix is comprised mainly of cylinder blocks and heads. Based on 15 000 net tonnes per year, there would be a requirement to process about 40 blocks and 40 heads per hour and at this rate flash grinding machines could possibly be justified. Nevertheless until the actual composition of the product mix has been established, no decision can be taken as to whether flash grinding machines would be economically viable.

APPENDIX 2 : SOME FACTORS AFFECTING THE CHOICE OF PRODUCTION TECHNOLOGY

1. INTRODUCTION

1.0.1 This section of the report is intended to give some general background information on the production techniques that are available to modern foundries and the important points to be considered in planning a successful foundry operation. It should help to substantiate the choice of technology adopted for the Andhra Pradesh project.

1.0.2 Historically, all sand-mould foundry practices have developed from the use of silica sand bonded with clay (generally bentonite) and sufficient moisture to impart good mouldability to the mix, i.e the ability to reproduce and retain an accurate impression of the pattern in the "green" (i.e undried) mould. Originally, of course, all castings were made by skilled manual moulding techniques and the only differences between moulds for the lighter, simpler castings and those for the larger and/or more complex castings were that the latter contained mild steel reinforcing rods and were subjected to a stove-drying process. The dried sand had a much higher physical strength and a dry-sand mould was therefore able to resist the very heavy erosion and deformation effects associated with the pouring of castings weighing many tonnes.

1.0.3 Today, in most foundries of the industrialised world, greensand moulding remains the most economical process for the quantity-production of small to medium-sized cast components in iron. This is true for foundries supplying castings to the more sophisticated mechanical engineering concerns, such as the world's major motor vehicle manufacturers. Throughout the twentieth century considerable advances have been made in the technology applied to the greensand moulding process. The most important advances that have been made are concerned with the development of equipment for the production of the moulds, i.e. the production of moulds by machine, with moulding sand from an automatic sand preparation plant, fully automatic mould handling through closing, pouring, cooling and shake-out operations, etc. Thus the process no longer relies on the skills and heavy manual effort of a large work force, but relies instead on the expertise of a relatively small group of highly-trained production operators and maintenance technicians. A most important factor in the development of modern moulding machines relates to the discovery that the rigidity of the greensand mould has a marked influence on the quality of the resulting castings. The use of hydraulic pressure (rather than pneumatic pressure) as a key factor in the mould compaction process, together with other innovations, has had a major influence on the development of the modern gereration of moulding machines.

1.0.4 In connection with the quantity-production of small to medium sized iron castings it is appropriate to mention the Croning or shell process, which was developed in the 1940's and which employs a heat-curing phenolic resin as the sand binder. The sand is applied to a heated pattern-plate and according to the time the sand dwells on the pattern, a thickness of cured sand is built-up. Un-cured sand is tipped off for use in a subsequent moulding cycle, and the mould is stripped from the pattern as a "shell" or "biscuit" of cured sand. Prior to the adoption of higher pressures in greensand moulding, it was considered that the shell process could offer the advantages of improved castings accuracy and surface finish compared with castings produced in greensand. In comparison with the latest greensand technology, however these advantages are barely significant and shell moulding would not be regarded as economic for the defined product mix, due to the following factors:-

1.0.4.1 Low rate of production compared with greensand moulding.
1.0.4.2 High material costs compared with greensand moulding.
1.0.4.3 Cost of energy for pattern plate heating.

This process is not considered to be appropriate in the context of the foundry's product mix for the initial development period.

1.0.5 For the production of the larger castings, for which greensand moulds are unsuitable, the foundry industry has developed a range of chemical binders, to avoid the mould-stoving process which was an expensive, time-consuming element in the drysand technique. A range of binder systems are now available and a number of different, and very complex, chemical reactions are used for the hardening of the sand. Some of these binder systems are listed in the next section of the report, but they all operate in a manner which allows similar principles to be adopted in the practical aspects of the moulding process. The largest castings of all, of course, must still be made on the foundry floor or in moulding pits, but using chemically-bonded sand which hardens in situ. Those items which are considered to be best suited to production in chemically-bonded moulds can be manufactured by semi-mechanised techniques in a pattern-flow moulding system.

1.0.6 In recent years, Japanese foundry researchers have developed a process to avoid any form of chemical bond in the production of a sand mould. The principle of their process, named the V-Process, is to enclose the top and bottom surfaces of each half-mould in a thin film of plastic and exhaust the air from the sand contained between the plastic films in the moulding box by applying vacuum suction. The process offers the advantages of very rigid moulds, absence of metal-mould reaction, absence of shake-out problems (the sand "pours" away, after release of the vacuum), and re-use of sand to which no binders are added. Since the process employs very expensive moulding boxes, fitted out with vacuum pipes (which must be connected to pumping equipment throughout the various phases of the process), it is clear that the throughput of moulds could not compete with that achieved in modern automatic greensand moulding. The process has found a practical (and economic) application in certain very specialised areas, generally based on a standard, long-running product mix involving relatively large moulds, say 1,25m square or larger, produced at rates of 15 per hour or more. For example, the process is being applied successfully in the UK by Crown Foundry Ltd for the production of piano frame castings. There are no castings which lend themselves specifically to this process in the product mix for the proposed APCCL foundry.

1.0.7 The latest developments include the use of expendable patterns and dry, unbonded silica sand, for some types of smaller castings. This process shows promise but has not been pr ved commercially up to the present time.

1.0.8 Sand cores, placed in moulds to form the inside shape of hollow castings, were traditionally based on greensand or dried oil sand. These methods are still practised in some of the small foundries currently operating in some parts of the world though they have been largely superceded in the modern foundries of the industrialised countries. Chemical binders similar to those used in the "Air-set" moulding practice are now used to produce cores by machine, at a high rate, the binder and catalyst often being introduced in such a way as to give very fast curing times. Two types of hot box process are also available, one based on blowing furan-bonded sand into a heated metal corebox, and the Croning or shell process, based on blowing a sand precoated with a phenolic resin into a similar heated corebox. The choice of binder system, and whether a hot-box or cold-box process is adopted, is dependent on the availability of the necessary chemicals and the economics of the various systems in relation to the particular types of core required.

2. CHOICE OF TECHNOLOGY

2.0.1 Even if the specifications for the castings could be met using traditional or semi-mechanised methods, the skilled, labour-intensive nature of such production methods would result in recruitment difficulties in the establishment of a new foundry in Andhra Pradesh.

2.0.2 To meet the requirements of the product mix for the proposed foundry and to enable the foundry to compete with other producers, only one process is necessary for the range of items to be manufactured; namely high pressure greensand moulding.

2.1 High Pressure Greensand Moulding

Greensand moulding is one of the oldest methods in use for the manufacture of iron castings and accounts for the highest tonnage of castings produced. Modern greensand moulding equipment has been developed to incorporate a high degree of automation, where appropriate and demonstrates the following features:-

2.1.1 Modern moulding machines often use hydraulic pressure to compact the sand, with or without a jolt action and give a mould with a high and consistent level of hardness throughout the contours of the compacted sand mass. Thus, the castings produced conform closely to the configuration and dimensions of the pattern, and do not suffer significantly from defects caused by loose sand or inadequate mould compaction.

2.1.2 The machine cycles are automatic and each element of the cycle can be preset according to optimum values determined during trial production with each different pattern. Therefore, moulds can be produced which are consistent in quality and speed of production. The quality and tempo of production is not, therefore, dependent on the degree of motivation of the machine operator.

2.1.3 Modern automatic moulding machines can cycle at a very rapid rate, with the result that mould handling equipment has been developed to match the potentially high mould production. The use of heavy manual effort in the moulding process has thus been eliminated.

2.1.4 Where high mould production rates are used and the handling equipment is automated, manning requirements are minimal and the risk of human error is reduced. Furthermore, it is not necessary for operators to be trained in traditional moulding skills. This radically reduces the time necessary for training, and allows a wide choice of people suitable to become operators.

2.1.5 Automatic handling of moulds removes the necessity for manual operations in some of the less desirable areas of the foundry, such as the area around the mould shake-out unit. This enables such areas to be enclosed, so that dust and fume extraction and noise suppression can be applied, thus improving the working environment in the foundry as a whole.

Within the range of automatic greensand moulding systems that are available, there are three categories of plant:-

2.1.6 Horizontally-parted moulds, in moulding boxes. This is the most conventional category of moulding systems, simplest in terms of core-placing and mould inspection, with the flexibility to accommodate a very wide-ranging product mix. In view of the extensive content of cored work in the product mix, and the need for very accurate core placement, this is the system recommended for the production of high integrity automotive castings.

2.1.7 Horizontally-parted flaskless moulds (i.e without moulding boxes). Flaskless moulding was originally developed as a simplification of the moulding process, in which the uni-directional work-flow principle was adopted, i.e the need to re-circulate mould boxes was avoided. Since the moulds must be closed in the machine, the process of core placing is extremely difficult. Recent developments by BMD in their Formatic machine and George Fischer in their Turnstile machine have eased this core placing problem, but in general terms the principle is not ideal for heavily cored castings.

2.1.8 Vertically-parted flaskless moulds. The Disamatic and Wallwork machines were developed on this principle in order to achieve very high mould production rates, e.g 200 to 300 moulds per hour, for components required in mass-production quantities. This type of moulding is widely adopted for small bore (malleable) pipe fittings and the very high mould production rates sometimes specified is most suitably achieved from the adoption of this type of plant.

2.2 Chemically Bonded Moulding and Coremaking Systems

In the industrially-develped countries of Western Europe and North America, the drysand moulding process has, to a very large extent, been replaced by processes based on chemical-bonding of the sand, which offers many significant advantages compared with drysand practice. These advantages can be summarised as follows:-

2.2.1 The hardening of the mould partially (or fully) in contact with the pattern, provides rigid moulds of accurate and consistent dimensions.

2.2.2 The process demands the pre-forming of running systems, etc, which must be built into the pattern equipment. The method for each successive mould is entirely consistent, therefore, and a consistent casting quality is achieved. The skill in the manufacture of the casting is thus designed into the pattern equipment by the Methods Engineer and Patternmaker, and the production of the mould on the shop floor can be undertaken by less skilled and experienced personnel than those required for the production of drysand moulds.

2.2.3 The rigid, high quality moulds permit castings to be produced consistently at the optimum casting yield, which is therefore improved compared with that achieved with drysand moulding.

2.2.4 The consistency of the production technique ensures minimum scrap rate on series production of the castings.

2.2.5 The hardening of the mould in situ, on the foundry floor, minimises the requirement for handling of mould parts and cores, and therefore reduces the labour requirement to a minimum.

2.2.6 Energy requirements for chemical-bond sand moulding are much lower than those of the drysand process, by virtue of the elimination of the mould-stoving operation of the latter process.

2.2.7 The elimination of the majority of the core and mould irons which were a characteristic of the drysand process considerably simplifies cleaning and fettling procedures for castings produced by the chemical-bond process.

2.2.8 The working environment associated with the chemical-bond sand moulding process is generally better than that associated with the operations involved in the drysand process.

2.2.9 The capital investment necessary to establish chemical-bond moulding is generally less than that necessary for drysand processing plant.

Although the binders used for the chemical-bond sand moulding process are numerous and considerably more expensive than the bentonite for the drysand process, the advantages for the process listed above generally result in an overall reduction in costs when the chemical-bond and drysand processes are financially evaluated in detail.

2.2.10 Acid Catalysed Furan Binders. The first true no-bake moulding binders became available in the late 1950s and were known by the generic name "furan". The resins used in the foundry are usually derived from urea formaldehyde-furfuryl alcohol, or phenol formaldehyde-furfuryl alcohol. These resins are thermal setting and extremely reactive at room temperature in the presence of any one of a number of strong acids. Initially phosphoric acid was employed as catalyst, but later binder systems have used more expensive catalysts such as toluene sulphonic, benzene sulphonic, xylene sulphonic acids, or blends thereof, which have been employed to achieve faster strip times compared with the original phosphoric acid system. The properties and performance of furan resins vary considerably according to their nitrogen, water and furfuryl alcohol contents. Strip times are varied with the catalyst type and concentration.

2.2.11 Urethanes. Air-setting binders based on urethane-forming chemicals (e.g the Pepset system) have been offered as an alternative to the acid-cured furan resins. The binder system comprises low-nitrogen content materials consisting of a phenolic resin, an isocyanate and amine catalyst, and the proportions of these three components can be varied to suit the desired curing rate and bench life. This system differs from the acid-curing furan resins, in that bench life can be as high as 75% of the strip time, which is itself variable from 30 seconds to 15 minutes. The acid-cured furan resins start to harden immediately on mixing.

2.2.12 Ester-Hardened Silicate Binders. The use of sodium silicate-bonded sand hardened by the passage of CO_2 gas through the sand, provided the foundryman with one of the earliest rapid-hardening core and mold production systems. For the production of large moulds the control of the gassing operation tends to be unsatisfactory and inefficiencies in the use of labour and the consumption of carbon dioxide are difficult to avoid. The silicate binder can, however, be hardened with the use of an inorganic ester in a two part reaction, in which, firstly the ester is hydrolized by the alkaline nature of the silicate and, secondly, the acid formed causes a chemical jelling. The reaction speed is dependent on the silica to sodium oxide ratio of the silicate and on the type of ester used as hardener.

2.2.13 Aluminium Phosphate Binders. This type of binder was developed in an attempt to avoid problems of breakdown and reclaimability which proved to be disadvantages of the silicate binders. A typical system (e.g the Inoset process) comprises a clear aluminium phosphate polymer resin and a magnesium oxide powdered hardner with the speed of reaction varying according to the level of hardener employed and the temperature of the sand.

2.2.14 Cold Setting Alkaline Resins. Among the most recent developments in cold setting binder technology one supplier has introduced an alkaline phenolic resin binder system hardened by means of an ester, i.e the Alphaset process. Like the silicate process the alkaline resin system avoids the presence of nitrogen and sulphur in the sand practice and avoids the production of fume in mixing of the sand and pouring of the moulds. The process is also useable with sands of high acid demand.

2.2.15 The above summary of some different systems available for the binding of foundry moulds and cores is by no means complete and, throughout the world, suppliers of foundry materials can offer a very wide selection of chemicals for sand binder applications. To a very large extent the choice of binder system adopted will depend on the relative costs quoted by the different suppliers, since the arrangement of the binder systems in order of ascending cost is likely to vary in different countries, depending on the scale of the various suppliers' organisation and trade in those countries. Although there are marked differences between the characteristics of the silicate binders and those of the other types described above, there are nevertheless many binder systems which are interchangeable. The adoption of an acid-catalysed furan binder system initially, for example, does not prevent a foundry changing to a urethane binder system, or some other system, that may subsequently be proved to be more economical.

2.2.16 As a general rule silicate bonding of moulds and cores represents the cheapest of the chemical-binder systems. However, silicate bonded sand suffers from three serious disadvantages. The silicate bond is relatively weak and brittle compared with organic resin systems. Secondly, the most serious drawback of the system is the lack of collapsibility after pouring, such that the removal of cores from enclosed, inaccessible cavities in the castings can prove very difficult. Thirdly the extent to which sand reclamation can be practised is limited to about 50%, since with higher usage of reclaimed sand, the build-up of sodium oxide results in progressive shortening of the bench life and lowering of the refractoriness of mixed sand.

2.2.17 <u>Furan Gassing Cold Set Resins</u>. In principle any of the furan binders used in air-setting, acid-catalysed binder systems can also be readily hardened by the passage of SO_2 gas. The procedure depends on the addition of a peroxide to the sand (instead of an acid catalyst), so that when SO_2 is passed through the coresand it reacts with the peroxide to form the SO_3, which dissolves in the water present in the binder to form sulphuric acid, which induces rapid exothermic polymerisation of the resin. The method can be applied to resins of the phenol formaldehyde, urea formaldehyde/furfuryl alcohol, phenol formaldehyde/furfuryl alcohol and furfuryl alcohol/formaldehyde types. Two types of peroxide may be used, methyl ethyl ketone (MEK) for bench life of up to 8 hours, or hydrogen peroxide, where shorter bench life of around 3 hours is adequate. The SO_2 gas may be provided direct from a cylinder, but for long running production a vapouriser is preferable, using liquid SO_2 from a pressure container. The SO_2 fume must be prevented from escaping into the foundry atmosphere, so the coreboxes must be gassed in an exhausted enclosure, from which the fumes are ducted to a scrubbing tower containing a 10% caustic soda solution. The SO_2 gas is passed through the core for between 0,5 secs and 5 secs depending on the core size and configuration. The core is then purged with compressed air for 5 to 10 secs to remove all residual SO_2 gas. The total coremaking cycle time is therefore generally in the range 7 to 15 secs.

2.2.18 Urethane "Cold-Box" Gassing Process. This process is operated with a three part binder system, a liquid phenolic formaldehyde polymer resin, a liquid resin containing methylene bis phenyl isocyanate and a vapourised amine such as triethylamine (TEA) or dimethylethylamine (DMEA). The amine can be injected into a stream of air en route to the corebox or air can be bubbled through the amine solution, maintained at a constant temperature of around 25°C. As a third alternative, cylinders containing a mixture of liquid amine and liquid CO_2 are available. The amine gas is toxic and, again, the coreboxes must be totally enclosed when gassing takes place, and the fume must be conveyed to a suitable fume treatment unit, such as an afterburner or an acid scrubbing tower. After passage of the amine, the core must be purged with compressed air. The total gassing and purging time can be as short as 5 secs for cores of medium size and simple shape.

2.2.19 "Fascold" System. This binder system operates with highly reactive phenol formaldehyde/furfuryl alcohol or urea formaldehyde/furfuryl alcohol resins catalysed with strong acid catalysts to give setting or strip times from around 40 seconds. Production rate from a correctly formulated Fascold installation can exceed 60 cores per hour. The process demands a high speed mixer if the shortest strip time is to be achieved. The mixer consists basically of two primary screw mixers in parallel, one mixing sand and resin and the other mixing sand and catalyst. These premixed components are then discharged together into a high speed mixer in pre-determined amounts, mixed for about 5 to 10 seconds and discharged into the corebox. The mixer is then automatically purged with air. Total sand mixing time is about one minute. The quantity of sand for any given corebox is metered by means of a variable time switch. The very rapid curing time demands very consistent measurement of sand and additions and standard operating conditions. For example, the sand should be maintained at 20oC to 25°C to achieve maximum throughput and strength, with minimum binder consumption. The Gisag system developed in East Germany is similar to the Fascold process which is described above.

2.2.20 The furan resin binder systems hardened by gassing with SO_2 or amine, or rapidly catalysed with acid in a Fascold-type mixer will all allow the rapid production of small cores that will be compatible with moulds and large cores made with an air-setting furan resin binder system. The choice of systems for the manufacture of small cores can, of course, be enlarged to include furan resin-bonded cores hardened in a hot corebox, though it would be considered preferable if a cold process could be employed, to avoid unnecessary energy consumption in core production, and to avoid operator discomfort from the handling of hot cores and the servicing of the machine. Cold processes also simplify core box changes and thus minimise both the lead time for the production of cores and the volume of core storage.

2.3 Sand Preparation

2.3.1 The installation of medium to high pressure moulding machines, having high production rates, leads to a requirement for the preparation of moulding sand with very closely controlled properties to suit very high rates of usage. The demand for sand, in terms of both quantity and quality, imposes a requirement for high speed mixers and automation of the sand mixing, delivery and return systems.

2.3.2 Modern sand preparation plants can be designed with very sophisticated monitoring equipment that allows the plant to operate in a fully automatic fashion. The sand mixer will operate automatically, as will the sand and additive feeders to the batch weigher. The amounts of each additive and the mill cycle can be preset as required. High and low level sensors will monitor the amount of sand in hoppers supplying the moulding machines and batches of sand discharged from the mill can be automatically routed according to which of the machines represents the most urgent demand. The sand plant logic is designed to prevent damage to the plant by preventing sand being discharged into hoppers that are full or conveyors that are stationary. The electrical interlocking of all items of equipment and the use of cascade and zero speed switching ensures that all conveyor belts and other items of equipment can only be started and stopped in the correct sequence. In the event of one conveyor stopping, due to a fault, all other units feeding the faulty one will also stop.

2.3.3 The control equipment at the sand mill will accurately control the components of the sand mix and the milling cycle. This control is only effective in maintaining consistent batches of high quality moulding sand if the re-used greensand from the previously poured and shaken-out moulds is also returned in a consistent condition, particularly in terms of temperature and moisture content. For this reason, the installation of cooling facilities in the return sand system is essential, ideally operating on the evaporative cooling principle, so that moisture is reduced to less than 1% and temperature to no more than 15°C above ambient.

2.4 Control of the Melting Process

2.4.1 The alloys to be produced initially by APCCL, include flake graphite (grey) iron, and grades of ductile or SG iron. The irons conform to conventional, well established specifications, but will require conscientious control to meet the requirements laid down in the specifications and thus ensure that consistent quality standards are maintained.

2.4.2 Strict control with regard to incoming furnace charge materials, charge preparation, melting and innoculating procedure etc, will be necessary if the quality and the cost of the liquid metal is to be maintained at acceptable levels.

2.4.3 Depending upon the choice of furnace type and the method of operation, furnace charges can be made up using a variety of materials, to enable given specifications to be met. However, the following criteria should normally be observed:-

2.4.3.1 As far as possible, charges should be calculated to use foundry returns at a consistent rate equivalent to the rate at which they arise. These are a reliable source of materials of known analysis.

2.4.3.2 The components of the furnace charge should be standardised, thus reducing the risk of error by the charge make-up operators. Furnace operating procedures can thus be standardised with beneficial effect on the consistency of the output of molten metal in terms of composition and temperature.

..4.3.3 Furnace charges should be selected to give the most economical cost per tonne of liquid metal at the pouring station. It should be noted that this does not necessarily mean using the lowest priced charge materials.

2.4.4 Strict control must be exercised over all incoming charge materials, whether they are returns from the foundry, or purchased from outside sources.

2.4.5 An area is required for classification and preparation of charge metallics, prior to their transfer to the ready-use charge make-up bunkers. Classification requires that an analysis of the incoming materials is carried out and that it is also segregated according to type, e.g. heavy, medium, light. At this stage all non-ferrous materials should be removed. For the preparation of charge materials in the proposed foundry, mechanical shears may be found advantageous to make use of the most economic forms of scrap steel available which, as delivered, may be unsuitable for charging into the furnaces.

2.4.6 It is essential that the returns from the ductile iron and flake graphite irons should be kept separate from each other to prevent contamination.

2.4.7 To achieve adequate control over identification of materials, all castings and returns will need to be clearly marked with an alloy identification code or colour. Ultimately, however, segregation of returns and control over materials will depend upon the vigilance of supervisors and the care taken by operators in the exercise of quality control procedures.

2.5 Casting Cooling Prior tc Shake-Out

2.5.1 Two alternative methods of cooling the castings after the pouring of the moulds can be considered, in one method the sand and casting remain undisturbed in the moulding box for the entire cooling period, i.e until the casting is recovered for routing into the finishing department. This is referred to as "in-mould" cooling. In the second method, a very short period of "in-mould" cooling takes place and then the sand and casting are punched out of the moulding box on to a suitable conveyor where "secondary" cooling of the casting occurs while it lies within the mass of moulding sand. In this way it is protected from the excessive thermal gradients which might develop if the red hot casting was exposed to the atmosphere. The case for the application of "in-mould" versus "secondary" cooling for a given foundry cannot usually be made until the engineering of the project is in underway. This is because the difference in capital cost between the application of the two methods is likely to be smaller than the variation in capital cost which will be found between the bids of different moulding plant manufacturers for a suitable moulding plant. The variation in operating costs between the two mould cooling principles will be small in the context of the financial evaluation carried out to test the viability of a proposed foundry project. The considerations behind the choice of cooling method are, however, discussed in the following paragraphs.

2.5.2 After the sand mould has been poured, a certain minimum period of time must elapse before the casting can be shaken out, i.e the removal of the sand and the recovery of the casting. This period of time is necessary to allow for the complete solidification of the casting, including that critical period after the external surfaces have solidified. The minimum period of time necessary to complete the solidification process depends on the composition of the metal and the configuration and dimensions of the casting. In practice, of course, the castings are generally left embedded in the moulding sand for a much longer period than is necessary to complete the solidification process, for reasons which may include one or more of the following factors:-

2.5.2.1 It may be necessary to control the cooling rate of the casting to achieve the correct microstructure in the casting, which, in turn, ensures that specified mechanical properties are achieved.

2.5.2.2 It may be necessary to control the cooling rate to avoid distortion of the casting. High thermal gradients (or thermal shock) can occur due to the premature removal of the casting from the insulating effect of the hot moulding sand. The thermal gradients may be sufficient, in some cases, to create stresses which may crack a casting. The tendency for thermal stresses to produce cracks, varies from alloy to alloy.

2.5.2.3 Cooling of the castings in the moulding sand is essential to maintain a good working environment in the foundry. No finishing operations should be carried out until the casting has reached a temperature at which it can be conveniently handled. In modern moulding plants it is customary for the shake-out operation to be automatic. The castings may then be transferred to a casting cooling conveyor, in which they are stored/transported for a period of time which ensures that they have cooled to a satisfactory temperature before reaching the subsequent cleaning/finishing operations.

2.5.3 The conventional or traditional method of cooling castings after pouring is the "in-mould" method. The punching-out of a sand package, containing the casting, on to a "secondary" cooling conveyor is a relatively recent innovation, designed for automatic, high production moulding plants. The advantages between the "secondary" cooling system and conventional "in-mould" cooling vary from application to application, and the factors to be considered are as follows:-

2.5.3.1 The precision-machined moulding boxes for an automatic, high production moulding plant are expensive and in certain applications a "secondary" cooling conveyor may by installed at a lower capital cost than that necessary to purchase the additional moulding boxes and handling equipment which would be necessary for conventional "in-mould" cooling.

2.5.3.2 For a given moulding rate, mould packages which are closespaced on a "secondary" cooling conveyor, take up less space than that necessary for an "in-mould" conveying system. Where area is restricted, therefore, the "secondary" cooling conveyor can offer a space-saving advantage.

2.5.3.3 Variable cooling from mould to mould is not easy to achieve with "secondary" cooling. The "in-mould" cooling system, however, can be arranged with a number of parallel mould conveyors, and can therefore be arranged to provide varying cooling times to suit a varied product mix.

2.5.3.4 Where the product mix contains a number of different alloys, moulds may be batched on storage conveyors to accumulate sufficient moulds to take the metal from a complete furnace heat. Under these circumstances the number of moulding boxes in the system is that which is necessary to operate the mould accumulation and pouring system and the "secondary" cooling principle offers no significant advantages.

2.5.4 The choice between the adoption of "in-mould" versus "secondary" cooling would not be expected to have any significant influence on the result of a feasibility study of a proposed foundry. This choice, like the choice between the moulding machines offered by the various equipment suppliers, can only be made when a detailed technical specification has been drawn up and discussed with the appropriate suppliers. Typical moulding plant layouts shown on drawings which accompany tender documents serve to establish the area requirements and the levels of capital cost which will be appropriate for the production of the projected castings output. The layouts would be, however, typical and not definitive. After the feasibility of a project has been established, a great deal of detailed engineering study would be necessary to establish the definitive design of plant from the chosen supplier but the final area, capital cost and operating cost parameters would be expected to conform to the estimates contained in a feasibility report.

2.6 Casting Finishing

2.6.1 After a period of "in-mould" cooling, the castings are shaken out from the moulds. This process is generally accompanied by a release of a considerable quantity of dust and fume, but can be accomplished automatically with modern equipment and can therefore be totally enclosed. This prevents the escape of dust and fume into the working environment as well as suppressing the noise generated in the process.

2.6.2 After shake out, the castings will require a further period of cooling prior to cleaning. For this purpose, a free area outside the main production building can be reserved to store containers of castings for cooling. These containers would then be handled by fork lift truck to the finishing department.

2.6.3 Following the initial shotblasting operation, the running and feeding systems have to be removed from the castings and in the case of flake graphite iron, it is customary to remove these systems manually, by hammer-blow. Mechanical removal methods are increasing, however, and is essential with some alloy and spheroidal graphite irons. For castings manufactured in sufficient quantities, the use of a cut-off machine with tailor-made jigs to accept the casting concerned can automate the process. For castings manufactured in smaller quantities it is customary to use an abrasive disc in a hand-held tool or in a standard pivotting-head unit.

2.6.4 The principal finishing process is grinding, to remove feeder and runner stubs, excess metal and mould-joint "flash", etc. For many types of small casting, particularly those manufactured in only small batch quantities, manual grinding using a pedestal grinding machine is the only economically-acceptable process. The work is not attractive, however, and great care has to be taken to ensure that satisfactory environmental conditions are provided for those who undertake this work. Much attention has been paid in recent years to the removal, as far as possible, of the manual content of this work.

2.6.4.1 Where quantities are sufficient, automatic grinding machines have been developed. Typical applications include the grinding of the periphery of brake drums, and the flash grinding of cylinder blocks and heads. Such machines are not flexible, however, since they are designed for specific purposes and cannot be adapted to a wide-ranging product mix.

2.6.4.2 More recently robots have been developed which can manipulate the castings, thus allowing more flexibility in the types of grinding operations that can be carried out. In future years it is considered likely that increasing use will be made of robots in the finishing departments of foundries.

2.7 Commercial Viability

The success of any new foundry venture is dependent to a large extent on the length of the learning curve and the rate at which the efficiency of the new facility can be increased as measured by the output of saleable castings relative to the installed capacity. Of course, the role of the production personnel and the maintenance team are crucial and the key members of these departments must be recruited early in the development of the project. They should receive training on the type of plant to be installed and should be intimately involved in the construction of the foundry from the earliest possible date. The other key departments which will have a significant influence on the rate at which the foundry attains commercial viability are referred to briefly in the following paragraphs.

2.7.1 Quality Control

Quality control must not be construed as the inspection of castings at the end of the production line. To ensure that castings pass final inspection and meet specification requirements it is essential that each stage of the foundry process should be subject for rigorous quality control procedures, applied to both materials and to methods. Although certain items of equipment are essential to effective quality control, the key to the successful application of quality control procedures lies in the skill of experienced technologists in both material and process control. Skilled supervisors are essential to ensure that correct operating methods and procedures are followed. It cannot be over emphasised that quality controls should be imposed at the earliest possible moment, normally at the time of equipment commissioning and running in trials.

2.7.2 Methods

Methods engineering as applied to foundries, involves the design of the pattern layout and running systems and thus represents a key function in the efficient operation of the plant. The Methods Engineer will define the number of castings that should be produced in each mould and the associated running and feeding system. His expertise can maximise the production of good saleable castings with the least possible requirement for liquid metal and also define the amount of work that will be necessary to remove runners and feeders in the finishing department. The Methods Engineer also has a major responsibility for the selection of the most appropriate processes for the production of moulds and cores.
He, therefore, represents a key member of staff whose recruitment at an early stage in the development of the project will be essential to its successful outcome.

2.7.3 Cost Control

It is essential that departmental cost standards should be established quickly and continuously monitored. Cost standards require to be checked against actual departmental direct and indirect costs and any necessary action taken to establish the reason for variances. Constant efforts should be made, not merely to maintain costs at given levels, but to ensure that advantage is taken of any opportunity to reduce operating costs.

2.7.4 Programming and Production Control

The application of skilled programming and production control procedures are essential, if delivery schedules are to be met, and if the foundry is to be operated economically, with the optimum utilisation of the plant and facilities. Once the average melting rate necessary to achieve the annual requirement for liquid metal has been defined and the furnaces are installed, there is little opportunity to vary the melting rate and the maximum amount of liquid metal available in a given period of time becomes fixed. This, therefore, is the base from which a production programme is designed. Ideally, the production of moulds should be such that the demand for liquid metal matches the rated melting capacity of the furnaces. Unfortunately, however, the weight of individual items in the product mix and the need to maintain a constant moulding cycle rate, generally means that this balance cannot be achieved consistently. To allow for some flexibility in the programming of variable-weight castings to the moulding lines, it is standard practice to install a holding furnace to act as a reservoir of liquid metal, to compensate for the high and low levels of demand from the mould pouring lines. It is inefficient to change patterns on moulding machines at intervals of less than 2 or 3 hours and in some automated foundries, the minimum acceptable interval is considered to be at the end of the shift. The essence of good programming, therefore, is to prepare departmental production schedules which meet acceptable criteria for the utilisation of the plant and avoid excessive periods of down-time due to tooling changes. In foundries producing intricately and highly cored castings, programming is not just to match the moulds availability to the melting capacity, consideration also has to be given to any constraints generated by the core production facility.

3. AVAILABILITY OF RAW MATERIALS

3.i Historically the production of iron castings was based on furnace charges composed primarily of a mixture of purchased pig iron and the foundry's own circulating return material. Today, however, the economy of the world's production of iron castings has been significantly influenced by the gradual replacement of pig iron in the furnace charges with cheap steel scrap. This process has been greatly encouraged by the greater control which electric melting equipment and modern direct-reading spectrometers now give compared with historical procedures based on cupola melting and chemical analysis. Techniques with electric melting equipment and the direct reading spectrometer allow the foundryman to analyse the composition of the melt while it is "held" at temperature (the analysis only takes a few minutes) and thus allow him to correct or modify the composition before the melt is poured. Naturally, this technique can accommodate a much wider range of raw materials, including steel scrap of uncertain origin, compared with the traditional melting procedures in which the control of the composition and quality of any given heat was based entirely on melting materials of known composition and the interpretation of historical analysis data from previous heats.

3.2 Clearly it is of particular advantage in the development of a foundry, if local supplies of steel scrap can be used for the production of iron castings. This avoids the expenditure of money on the purchase of expensive pig iron and ensures that raw material costs are maintained at the lowest possible levels.

4. SUPPORTING FACILITIES

4.1 Pattern Shop Facilities

4.1.1 No foundry can operate efficiently without the services of skilled patternmakers to carry out essential maintenance work on patterns and to make such adjustments to running and feeding methods as may be deemed necessary by the Quality Control and Methods Staff. In the established foundries of the industrialised nations, the pattern shop would also be expected to undertake the production of new patterns, though it is very rare for a foundry to be totally self-sufficient as far as the production of new tooling is concerned.

4.1.2 The reason why foundries with established pattern shops find it difficult to make all their own new tooling arises from the fact that the volume of patternmaking work represented by the acquisition of new orders is never likely to be planned into a consistent workload throughout the year for a fixed number of pattern-makers. The volume of this work for a foundry in any given year and the relatively short pattern delivery dates necessary to allow the foundry to produce samples well in advance of the castings delivery date, means that the patternmaking man hours demanded month by month will be very variable. No foundry can therefore afford to employ sufficient patternmakers to deal promptly with all their new tooling requirements, since during the intervals between the acquisition of new work there would undoubtedly be periods when the pattern makers would be under-employed.

4.1.3 In Europe, therefore, most foundry patternshops are staffed to deal primarily with pattern maintenance and with the manufacture of only a proportion of the requirement for new tooling. When new orders are acquired and new patterns and coreboxes are to be produced, the foundries send out enquiries to a selection of the specialised master patternmaking companies which now exist and in which a large part of Europe's skilled patternmaking manpower are now "pooled". The foundry can thus select the tender which combines the optimum delivery date with an acceptable estimate of cost. A very large order for new tooling can be divided between a number of master patternshops to achieve a suitably short tooling delivery date, particularly when sample castings are to be despatched to, and approved by, the foundry's customer in advance of the mass-production of the castings.

4.1.4 In the case of a new foundry which is to be established with little likelihood that experienced patternmakers can be recruited, it would be impossible to envisage that the patterns required during the initial development of the project could be manufactured in-house. In studying the feasibility of such a project, it is necessary to assume that all the patterns to suit the proposed initial product mix will be obtained from clients or from existing master patternshops. Nevertheless, the recruitment and training of skilled personnel to undertake the maintenance and adjustment of the pattern and corebox equipment represents one of the key "personnel considerations" in the development of the project.

4.1.5 Insofar as the initial equipping of the patternshop in a proposed foundry project is concerned, it must be assumed that it will be necessary for the work undertaken to include the adjustment and modification of metal patterns (but not the manufacture of new metal patterns), the manufacture of new pattern impressions (part patterns) in epoxy resin, and the manufacture of patterns for small batch and jobbing work, in epoxy resin and wood. Throughout the life of a proposed foundry it is expected that the amount of new patternmaking which will be undertaken will increase, and eventually could include the manufacture of sophisticated metal patterns and coreboxes. However, it is essential that the programme for the staffing of the patternshop and the training of that staff proceeds in advance of the purchase of sophisticated metal working machine tools.

4.2 Maintenance Department

4.2.1 For foundries having modern equipment, the importance of scheduled mechanical/electrical maintenance cannot be overemphasised. It is the practice in virtually all modern, high production foundries, to restrict operating shifts to two per day, with the third (non operating) shift reserved for scheduled maintenance of plant/equipment.

4.2.2 Equipment suppliers must provide a detailed maintenance manual with the equipment. From the maintenance manuals a scheduled maintenance programme for all plant/equipment can be developed.

4.2.3 A well equipped maintenance workshop should be provided, with a clean room for checking/maintaining electronic equipment/instruments. The maintenance workshop should be a priority in the implementation programme, as its facilities will prove very useful and time saving during the plant/equipment installation phase.

4.2.3 Adequate spare parts should be ordered with imported equipment and in developing countries, this may cover a period of two years or more.

4.2.5 Maintenance Engineers and Technicians should be recruited in time to assist with the installation of equipment as this will enable them to become familiar with the equipment. Key Engineers and Technicians should be sent to the Suppliers works for training before the equipment is installed.

APPENDIX 3 : SOME NOTES ON THE EXECUTION OF THE PROJECT

The efficient execution of any project depends upon the expertise of the team who are selected to carry out the implementation.

1.0 A schedule of events must be prepared and agreed.

1.1 This schedule should be prepared after general arrangement drawings have been made for the foundry, based on an acceptable product mix and capacity.

2.0 A recruitment programme must be prepared.

2.1 This programme would ensure that key members of management/ technical staff are available at the correct time and to allow adequate time for off site training.

3.0 Detailed specifications must be written for the civil engineering work, mechanical and electrical services and for the procurement of process equipment.

3.1 It is noted that MECON have proposed for the moulding line, that part of the equipment should be imported and part should be manufactured locally. This is common practice and an acceptable approach, provided that the company which designs the equipment and provides the critical items of plant is made responsible for the whole. This is normally done by awarding the contract to one supplier who in turn usually sub contracts the items that are to be manufactured locally. If two separate contractors are appointed by the client, then problems can arise due to a division of responsibility at the interfaces of their equipment.

3.2 The contractual terms and conditions must be clear and a closing date stated for acceptance of bids.

3.3 Drawings showing equipment/plant layout and elevations must be included with the specifications. These would be typical and intended to indicate general operating principles and area requirements. Certain suppliers may produce alternative layouts, to suit their particular equipment. This is not important provided that areas are not increased, technical requirements are met and costs are in line with the budget.

4.0 Bids should be carefully evaluated.

4.1 Normally bids are evaluated for technical content first and those not meeting the specifications are rejected.

4.2 Only bids meeting the technical specifications should be processed through a financial evaluation.

5.0 Contract Negotiations

5.1 Care should be taken to ensure that all points are clarified during the contract negotiations.

5.1.1 Equipment suppliers sometimes consider certain items of steelwork as part of the supply of civils contractors. If this point is not clarified, each contractor may assume that the other is supplying the items in question and delays can be created.

5.1.2 Equipment suppliers normally commence design/manufacture on receipt of a downpayment by their bank and clarification of technical queries. It can sometimes be several weeks before a contract becomes "effective" and the delivery time will be extended by that amount.

6.0 Installation Procedures

6.1 FMD normally recommend the recruitment of the maintenance staff at an early date to form the nucleus of the installation team, using hired temporary workers as necessary. It is also recommended that the maintenance shop is constructed and equipped before the production departments are built as this can be useful in making minor modifications, fabrications etc to equipment during installation.

6.2 It is essential to ensure that equipment foundations, services etc are installed and checked, before requesting the supplier to send his supervising/commissioning engineers.

6.3 Erection/installation equipment to be provided by the client, such as mobile cranes, welding sets, drills, jacks etc, should be made available promptly so as not to delay the work of the suppliers supervising engineer(s) and risk incurring additional costs.

6.4 Regular meetings should be held with the suppliers supervising engineer to monitor progress and highlight potential problems at an early date.

6.5 In many projects with which FMD has been associated, the principal cause of delay has been in civil engineering, buildings and services. It is suggested that delivery dates given by contractors in these disciplines, be treated with circumspection.

7.0 Commissioning

There are essentially two commissioning procedure to be carried out, production/between services equipment and pattern tooling. The former has to be completed before commissioning of the pattern tooling can commence.

7.1 The services are comparatively straight forward to commission and test.

7.2 The production equipment is commissioned in stages. Taking an automatic moulding line for example:-

7.2.1 The individual items of equipment are tested one by one to ensure that they operate correctly and any adjustments and/or modifications made.

7.2.2 The whole line is then run, without sand, to e that the sequence of operations is correct and again any adju s and/or modifications made.

7.2.3 As for 7.2.2 but with sand.

7.2.4 The line is run for the acceptance test as specified in the contract.

7.2.5 Finally the line is run and metal poured into the moulds.

7.3 After the coreshop, sand plants, moulding line and melting departments have been commissioned and accepted individually and collectively, the pattern tooling can then be commissioned. The time necessary to commission pattern tooling varies widely according to the type of casting. Since the APCCL foundry is to be an automotive foundry, the case of a cylinder block is used as example.

7.3.1 Cores are produced from the coreboxes, checked for quality and dimensions, they are then coated (as necessary) and made up into sub assemblies as required. The coreboxes are adjusted/modified as necessary.

7.3.2 Moulds are produced from the pattern and checked for hardness, clean draw, position of vents etc. The pattern is adjusted/modified as necessary.

7.3.3 Further moulds are made and cores placed in the transfer jig and checked, if they are correct they are transferred into the mould and again checked. Again further adjustments/modifications are made to the pattern, corebox and transfer jig as required.

7.3.4 When everything appears to be correct, about 10 or 20 moulds are made, cored up, closed and poured.

7.3.5 The castings are then shotblasted complete with runners and inspected for obvious defects. Pattern tooling is modified as necessary. The castings are checked for hardness, microstructure and tensile strength and the metallurgy adjusted as required.

7.3.6 Apparently good castings are marked out and checked dimensionally, pressure tested, then sectioned as specified, to check internal metal thicknesses.

7.3.7 7.3.4, 7.3.5 and 7.3.6 are repeated until the castings appear to be satisfactory following which a small batch (15 or 20) will be sent to the client for their approval. The client will carry out his own tests including machining and may request further modifications. This will be repeated until the client is satisfied and approves the trial castings. Then and only then will it be possible to commence commercial production from that set of pattern tooling.

7.3.8 Even well established automotive foundries consider that a minimum of three months is necessary, from commencement of proving trials for new pattern tooling to approval by the client. FMD therefore consider that MECON are optimistic in their allowance of two months for commissioning.

APPENDIX 4 : PREPARATION OF EQUIPMENT SPECIFICATIONS

It is difficult to prepare equipment specifications without detailed information in respect of the anticipated product mix and as will be evident from Section 2 of the report, such information was not made available to FMD during the course of the study. Contained in the body of the report are points to be considered before specifications can be prepared and it may be helpful to highlight some additional points which are also relevant.

1.0 Design Criteria

1.1 MECON refers to 6 000 net good tonnes per year initially.

1.1.1 Moulding rate is given as 40 moulds per hour.

1.1.2 Operating time is given as 300 days per year, 2 shifts per day. Plus a third shift in some departments.

1.2 APCCL refers to 9 000 net good tonnes per year initially.

1.2.1 Moulding rate is given as 40 moulds per hour.

1.2.2 Operating time is given as:

1.2.2.1 Year 1 and 2, 300 days per year, 2 shifts per day.
1.2.2.2 Year 3 onward, 270 days per year, 3 shifts per day.

1.3 During Mr S Pugh's visit to Hyderabad, APCCL gave the operating time as 270 days per year, 2 shifts per day.

1.4 Comparison of 1.1, 1.2, 1.3.

1.4.1 If it is assumed that 1.1 is correct, at 40 moulds per hour to give 6 000 net good tonnes, then:

40 x 300 x 16 = moulds per year = 192 000

1.4.2 To achieve 9 000 net good tonnes on three shifts

192 000 x 1,5 = moulds per year = 288 000

At 270 days per year, 3 shifts per day

$\frac{288\ 000}{270 \times 24}$ = moulds per hour = 44,4

1.4.3 To achieve 9 000 net good tonnes on two shifts

192 000 x 1,5 = moulds per year = 288 000

At 270 days per year, 2 shifts per day

$\frac{288\ 000}{270 \times 16}$ = moulds per hour = 66,6

1.4.4 As can be seen from the above, the design criteria (and also the layout) will be different, depending upon whether the operating time is based on 1.4.2 or 1.4.3. It is not possible, therefore, to prepare a specification until these criteria have been defined.

2.0 Further points that need clarification are:

2.1 Is the quoted figure of 40 moulds per hour, the requirement for <u>poured</u> moulds to produce 6 000 net good tonnes per year or the moulding machine capacity, including the efficiency factor?

2.2 During the discussions with APCCL, it was stated that further thought had been given to the product mix and it had been decided to concentrate on cylinder blocks and heads. Since these are two of the heaviest castings in the MECON product mix, it could significantly affect the moulding rate required.

2.3 If SG iron castings are not to be produced in the initial phase, there is little point in making provision for extended 'in mould' cooling facilities.

2.4 Is the final capacity of the foundry in Phase 2 to be based on 15 000 or 18 000 net good tonnes?

3.0 The facilities required for core production will also change if only blocks and heads are included in the product mix. The changes will affect all or some of the following:

3.1 Number and types of machines.

3.2 Coresand requirements.

3.3 Capacity of coresand mixers.

3.4 Core coating.

3.5 Drying

3.6 Area requirements for coremaking, core storage, core assembly etc.

4.0 Changes will have to be made to the fettling and finishing department if only blocks and heads are to be considered.

4.1 Shotblast equipment will increase in capacity.

4.2 The use of flash grinding machines could be considered, which will reduce the swing frame and hand grinding operations, resulting in a different layout.

4.3 Greater mechanisation of painting and pressure testing will be necessary.

APPENDIX 5 : COMPUTER FACILITIES

Considerable use can be made of computers in the foundry and their application can be broadly divided into two parts. These are "Data Logging" which is concerned with the control and monitoring of the plant and "Management Information" which is concerned with the control of the company as a business.

1. DATA LOGGING

1.1 A telemetry system in its simplest form is used to transmit data from a remote location to a central monitoring station. These data will consist of plant information such as temperatures, pressures, flows, power consumptions, machinery condition etc. Where plant supervision is required over a wide area, telemetry (and remote control) may involve a network of distributed remote terminal units, each sending information back to one central control point.

1.2 The information and data sent back to the control room can be displayed and recorded using colour graphic VDUs, printers, mosaic panels, plotters etc. The network can be designed so that selected data is available for storage or display at any number of sub-stations as well as in the central control room. Thus, information on the operating characteristics of the melting furnaces can be displayed both on the furnace platform and in the control room.

1.3 The operator(s) in the central control room will monitor the data transmitted from the Remote Terminal Units (RTUs) and can react immediately to an alarm or change of state by sending the appropriate control command. The system could be fully automated such that no operator intervention will be necessary. The RTUs can be set up with high degree of intelligence so that complex levels of local control are possible. The advantage of this distributed intelligence throughout the network is that in the event of a communications failure, the RTUs continue to operate automatically, thereby increasing the operational security of the plant.

1.4 Data logging involves the collection, processing and storage of plant data. A data logging system can be a completely self contained unit operating in the "stand alone" mode or may form part of a larger distributed network of data logging systems reporting to a central location. The data can be stored on floppy disc, hard disc, magnetic tape or solid state memory. Standard software packages are available for different types of signal processing such as the detection of "pre-event status", maximum/minimum/average values and the statistical distribution of measurements. Data logging systems can be used in a wide variety of applications from environmental monitoring to process control and energy management.

1.5 It would be a matter of discussion with the plant suppliers to decide precisely which machines should be monitored in this way and the type of data which is to be recorded. Data logging could encompass the following activities:-

1.5.1 Charge make-up

1.5.2 Melting (primary furnaces and holding furnaces).

1.5.3 Pouring

1.5.4 Core making (including mixing and distribution of coresand)

1.5.5 Moulding line

1.5.6 Heat treatment (batch furnace).

1.5.7 Shot blasting

1.5.8 Sand drying, reclamation and distribution.

1.6 In addition to the main operations listed above, data logging should also cover the main services such as power distribution, compressor usage, fuel oil and water status. Vital information on the plant condition and equipment utilisation can be relayed to an RTU in the office of the General Manager or other Senior Management so that they will always be aware of the status of the plant.

1.7 Whilst data logging can be an extremely important feature of the plant design, it should not be the only monitoring function provided and the installation of closed circuit TV cameras may also be desirable in key areas.

2. MANAGEMENT INFORMATION SYSTEM

2.1 The process of operating a foundry involves the interaction of numerous management functions and a multitude of interconnection information flows. It is logical, therefore, to reflect these flows in the use of a fully integrated, multi-user, management information system, to cover the areas of:-

2.1.1 Financial Accounting
2.1.2 Management Accounting
2.1.3 Estimating
2.1.4 Sales Order Processing
2.1.5 Production Control
2.1.6 Quality Control
2.1.7 Despatch and Invoicing
2.1.8 Payroll
2.1.9 Stock Control
2.1.10 Purchasing
2.1.11 Credit Control

Such an information system should also incorporate a facility for generating reports as required. A schematic arrangement of one type of multi-user computer system is given in Figure 9 on the following page.

2.2 One essential attribute of this type of system, is that detailed information, covering all functions, is stored on a single data base which is accessible by all users of the system. Amongst the many benefits of having a central data base is that, as every piece of data is stored in only one place, there can be no duplication of data or confusion as to which data is being used. Immediately information is entered into any part of the system, it is available to all users. Furthermore, as all information is held centrally, management decisions are based on an agreed set of totally consistent data.

2.3 A further advantage of such a system is that the manual input of information is reduced to a minimum. As all information is stored on a common data base which is accessible by all users, the transfer of data between different computers in different departments is eliminated.

2.4 The way in which this type of computer system would operate can be illustrated by considering its effect on the various departments of the foundry.

2.4.1 Estimating Department : The role of the estimating department is to prepare accurate quotations which reflect the actual cost of production. To achieve this objective requires the input of technical data such as casting weights, operation times, scrap rates etc. On the financial side, accurate costs are required for labour, overheads, power, materials, plus subsidiary information on freight, duties and insurance. Once an estimate has been prepared, a sales price must be fixed to reflect the market conditions and also specific information relating to the customer must be taken into consideration in arriving at the sales price. Subsequently, it is critical to the estimating department to receive direct feedback from the production departments to allow them to verify the accuracy of the estimate. All this information, drawn from many different sources, would be made directly available by this system.

2.4.2 Sales Department : The sales department has three basic roles : to generate sales, to handle the processing of orders and to answer customer's progress enquiries. A major factor in a customer's purchasing decision is the ability of the foundry to meet consistently the delivery requirements. This system would allow the sales department to assess the forward load accurately and to test whether specific delivery dates are achievable.

A second function of the sales department is to handle the processing of orders, an activity which can have far reaching effects throughout the whole company. The integrated system can immediately validate that the correct customer details are entered, present a list of predefined addresses from which the delivery address may be selected and present full details of the casting including the selling price for validation. At the same time, the system can check whether there is a problem with the pattern, update the order log, provide advance notification to production control, ensure the customers current balance does not exceed his credit limit, check the stock files for a possible stock of unallocated finished castings and allocate raw materials for the production, or if necessary, initiate the purchase of materials.

Once an order is in production, the sales department must be able to handle customers queries immediately over the telephone. As this information is constantly being updated by the production control system it is always up to date and available to the sales department.

2.4.3 Production Control Department : The production control department has one of the most difficult jobs in the foundry, attempting at all times to provide the various load centres with co-ordinated and well balanced schedules which ensure that delivery requirements are satisfied. To enable this to be achieved requires immediate access to methods information, stock information, sales information, quality control requirements, labour and machine availability and the means to monitor the progress through the foundry.

2.4.4 Quality Control Department : The reporting of progress through the various departments of the foundry will provide immediate information on the quantities and causes of scrap at each operation so that the quality control department can take the necessary corrective action quickly. In addition, full traceability of a sales order can be provided to ensure complete control over all aspects of quality.

2.4.5 Despatch Department : Once castings reach the despatch department it is important that they are delivered to the customer as soon as possible. A further consideration is the efficient usage of available transport. By scheduling the despatch of the castings and by enabling the despatch department to see which castings are expected, will ensure that the availability of transport is considered in the production scheduling programme. A major factor in the cash flow of the company is the speed with which invoices can be sent out after the castings have been despatched. The system would ensure that the the invoice is prepared at the time of the castings are despatched so that it reaches the customer at the same time as the goods.

2.4.6 Accounts Department : Every activity within the production cycle of a casting has an effect on the accounting department. Whether it is the use of material or labour, the scrapping of a casting, the acceptance of an order or the despatch of the casting, every stage of the manufacturing process has a financial implication.

Therefore, the moment a movement is reported by any programme within the system, its effect is immediately reflected financially. The result of this is that all financial information is, at all times, up to date and available for use by all authorised users.

2.4.7 Credit Control Department : As all financial information is maintained in a current state, the credit control department can at any time enquire upon the details of a customer. In addition, the system can ensure that orders are not accepted from customers who have exceeded their credit limit and can, if necessary, cause a job to be suspended.

2.4.8 Stock Control Department : The stock system is at all times kept up to date which allows the controller to monitor the physical level of all raw material stocks and to generate automatic purchase requests dependent upon reorder levels or material requirements derived from customers orders. Naturally, the financial system will be updated automatically by the stock system which in turn is automatically updated by the production control system.

2.4.9 Purchasing Department : The system can, by co-ordinating the projected use of materials with their stock levels, anticipate the need to issue purchase orders, thereby ensuring that whilst materials are always available, the size of the stocks are never excessive. Once issued, the system maintains track of the order to provide warning of delays which may effect the production schedules.

2.4.10 Wages Department : The wages department will benefit from an integrated system by receiving directly from production control information, details of the hours worked and the operation completed by each worker or group. This will allow for the automatic calculation of bonuses if such an incentive system is considered appropriate.

2.4.11 Management : In a more general manner, an integrated management information system makes use of all of the information created throughout all of the departments of the foundry. Such information can then be presented in any manner via a report generator, to provide management with accurate, up to date and relevant information on the performance of the company.

2.5 The basic hardware required to allow integration of management information would be a multi-user mini-computer or a fully supported network of super-microcomputers or workstations.

A typical mini-computer configuration could consist of the following:-

2.5.1 Central processor with 5Mb of internal memory.

2.5.2 Disc storage capacity of 300Mb.

2.5.3 25 terminals.

2.5.4 12 printers.

2.5.5 Modem.

2.6 Multi-user systems can share both the processing unit and all associated peripherals between all users and have sophisticated operating systems designed to cope with numerous users simultaneously accessing the database.

2.7 Networked systems, whilst allowing numerous users to access shared resources of discs or printers, do not share the processing unit, as each computer on the network is separately equipped with its own memory and processor.

2.8 The choice between the two types of system is less clear than it used to be. With the introduction of the IBM Token Ring network, the network system should gain credibility. Both types of system have their advantages but on the grounds of cost, expandability, reliability and overall performance, the multi-user solution is currently more attractive.

ADDENDUM

TO

REPORT

INTRODUCTION

This Addendum has been prepared after discussions with the UNIDO expert Mr G.C.B. Lamb, the Managing Director of APCCL Mr. Venkatesh, and after a meeting Chaired by Mr. A. Buckle of UNIDO held at the UNIDO headquarters in Vienna on the 15th April 1987.

The importance of accurately identifying the available markets and their sizes, and from them establishing a definite product mix, item by item cannot be over emphasised. The MECON and APCCL Reports were lacking in both details of the markets and the proposed product mix.

It is recommended that a detailed Market Study be carried out, including visits to potential clients for automotive castings and discussions with them to establish their requirements, present and future, for these castings. It is further suggested that at least one member of the team should have detailed knowledge of grey and ductile iron automotive castings.

If the Market Study shows that adequate markets exist for automotive castings, then and only then, should a definitive product mix be prepared and a Technical Feasibility Study and Financial Evaluation be carried out to establish the capacity and viability for a proposed foundry to produce the castings.

Section 1.0 contains further information on core production and core machines, Section 2.0 gives general criteria and a budget price for a Temperature Profile Controlled Cooling Furnace. Section 3.0 gives an outline specification for a castings manipulator and a budget price. Section 4.0 outlines the main uses of a holding furnace. Section 5.0 gives an outline specification for a Greensand Plant. Section 6.0 gives a list of major items of equipment and Section 7.0 contains general comments.

1.0 Core Production and Core Machines

In foundries producing intricately cored castings such as cylinder blocks and heads, and certain other automotive castings, the core production facilities are just as important as the moulding facilities and at least as much time and thought requires to be spent on the design of these facilities.

As an example, for a recent project, FMD designed, built, commissioned and assisted in the commercial operation of a foundry to produce automotive castings in grey and ductile cast irons. The product mix was well defined and contained fourteen items, of which three were cylinder blocks and two were heads; the remainder included transmission housings, differential housings, hubs, axle housings etc., casting drawings were available for all items. The foundry is designed to produce 7 000 net good tonnes of castings per year on a two shift operation.

One of the cylinder blocks is a three cylinder diesel type commonly used in tractors and for other purposes, the requirement for this block being 10 000 per year.
To produce the cores for this block requires five multi impression corebox rigs and four different core machines.

The core machines are as follows:-

	Core box Size (mm)
a) Shell (solid) core machine (100 litre) Horizontal, multi loose pieces	950 x 650 x 250
b) Shell (solid/hollow) core machine (20 litre) Vertical, double corebox	500 x 400 x 100 +100
c) Coldbox core machine (36 litre) Horizontal, multi loose pieces	900 x 600 x 255
d) Coldbox core machine (20 litre) Horizontal, multi loose pieces	600 x 500 x 340

To produce 10 000 good cylinder block castings per year requires approximately 25% of the operating hours available on the four core machines even with multi impression corebox rigs in use.

Depending on the types and sizes of the installed coremachines, changing corebox rigs can take up to 1,5 hours, and longer in the case of shell/hot box machines taking into account the time needed to bring the rigs up to operating temperature.

In the foundry referred to eight core machines are provided 1 of type a), 2 of type b), 2 of type c), 1 of type d) and 2 of type e) which is a Coldbox coremachine (7 litre), vertical, with mandrel, corebox size 400 mm x 360 mm x 260 mm. These machines do not give excessive capacity.

The cores have to be trimmed, checked and as necessary, rubbed in rubbing jigs, coated and dried, glued into sub assemblies (in jigs) before being placed into storage on mobile racks. The core requirements for this particular block need approximately 8,5 manhours per tonne of castings.

Neither the MECON or APCCL reports contain any details of the cores, (except one reference in the MECON report to 3 000 cores per day) even so it is considered optimistic to allow only four core machines for the items and quantities contained in the product mix. The quantities of cores to be produced only form part of the criteria in the selection of the number, type and capacities of the core machines to be installed.

It is difficult to generalise with regard to core production facilities required for automotive foundries, but FMD do not know of any foundry producing 6 000 tonnes of intricately cored automotive castings per year, which only has four core machines installed.

In very general terms FMD would consider it likely that an automotive foundry producing 6 000 good tonnes of castings per year with a fair proportion of cylinder blocks and heads in the product mix will require seven or eight core machines. The selection would probably be three shell core machines and four or five cold box machines. Machine capacities would probably be 5 litre, 12 litre, 20 litre and 25 or 30 litre. The corebox size capacity would depend on the number of impressions per corebox and sizes of individual cores, but in the case of APCCL it is anticipated that the would be less than for the foundry refered to above. It is likely that the smaller machines would be designed for use with vertical joint corebox, whilst the larger machines would be for horizontal joint coreboxes, at least some of the machines will require multiple loose piece facilities. All the machines would be designed for automatic core ejection, and operate on manual, single cycle automatic and continuous automatic modes. However, it is essential that a detailed analysis of the core requirement for each item contained in this product mix, is carried out before the design and specifications for the core making facility are prepared. The following tables indicate the calculations that are necessary to establish the requirements for core machines.

Table No. 1
Sheet 1 of 5

ESTIMATED CORE AND CORESAND REQUIREMENTS

Item No	Sets per Year	Core Type and Process*	Cores per Year Net	Scrap %	Cores per Year Gross	Weight per Core kg	Weight per Year t	Corebox Size mm	Cores per Box	Machine Cycles per Year	Equivalent Machine hrs @ 21 cycles/hr
1	7 317	Jacket H	7 317	10	8 130	8,0	65,04	860x660x240	2	4 065	193,57
		Bore C	43 902	7	47 207	12,0	566,48	860x660x240	2	23 604	1 124,00
		Head C	7 317	7	7 868	15,0	118,02	960x760x240	2	3 934	187,33
		Bearing H	7 317	7	7 868	1,5	11,80	300x300x200	1	7 868	374,67
		Oil Gauge H	7 317	7	7 868	0,2	1,57	300x300x200	6	1 312	62,44
2	7 500	Jacket H	7 500	12	8 523	4,5	38,35	960x760x240	1	8 523	405,86
		Rod H	30 000	7	32 258	0,8	25,81	300x300x200	2	16 129	768,05
		Nozzle H	45 000	6	47 872	0,1	4,79	300x300x200	6	7 979	379,94
		Exhaust H	22 500	7	24 194	0,9	21,77	400x400x230	2	12 097	576,05
		Air Inlet H	30 000	6	31 915	1,0	31,92	400x400x230	2	15 958	759,88
		Draw Back H	7 500	7	8 065	2,0	16,13	960x760x240	9	896	42,67
3	13 483	Main C	13 483	6	14 343	3,5	50,20	400x400x230	2	7 172	341,53
		Sub-Totals H C	164 451 64 702	-	176 693 69 418	-	217,18 734,70	-	-	74 827 39 710	3 563,13 1 652,86

*H = Hot, e.g. Shell Process C = Cold, e.g. CO_2 Process

Table No. 1
Sheet 2 of 5

ESTIMATED CORE AND CORESAND REQUIREMENTS

Item No	Sets per Year	Core Type and Process*		Cores per Year Net	Scrap %	Cores per Year Gross	Weight per Core kg	Weight per Year t	Corebox Size mm	Cores per Box	Machine Cycles per Year	Equivalent Machine hrs @ 21 cycles/hr
4	6 742	Main	C	6 742	6	7 172	1,5	10,76	400x400x230	2	3 586	170,76
5	6 522	Main	C	6 522	6	6 938	1,5	10,41	400x400x230	2	3 469	165,19
6	6 742	Main	C	6 742	6	7 172	10,0	71,72	860x660x240	1	7 172	341,52
		Sub A	C	6 742	6	7 172	0,7	5,02	300x300x200	1	7 172	341,52
		Sub B	C	6 742	6	7 172	0,4	2,87	400x400x230	2	3 586	170,76
		Sub C	C	6 742	6	7 172	0,2	1,43	300x300x200	4	1 793	85,38
7	12 195	Jacket	H	12 195	10	13 550	6,0	81,30	640x540x180	2	6 775	322,62
		Bore	C	36 585	7	39 339	7,0	275,37	860x660x240	2	19 670	936,64
		Cam.	C	12 195	7	13 113	2,0	26,23	640x540x180	4	3 278	156,11
		Cam. Sub	C	12 195	7	13 113	1,0	13,11	640x540x180	4	3 278	156,11
		Water Rail	H	12 195	7	13 113	1,0	13,11	640x540x180	5	2 623	124,89
		Head	C	12 195	7	13 113	7,0	91,79	640x540x180	2	6 557	312,21
		Sub-Totals	H C	24 390 113 402	-	26 663 121 476	-	94,41 508,71	-	-	9 398 59 561	447,51 2 836,20

*H = Hot, e.g. Shell Process C = Cold, e.g. CO_2 Process

Table No. 1
Sheet 3 of 5

ESTIMATED CORE AND CORESAND REQUIREMENTS

Item No	Sets per Year	Core Type and Process*	Cores per Year Net	Scrap %	Cores per Year Gross	Weight per Core kg	Weight per Year t	Corebox Size mm	Cores per Box	Machine Cycles per Year	Equivalent Machine hrs @ 21 cycles/hr
8	12 500	Jacket H	12 500	12	14 205	2,5	35,51	640x540x180	1	14 205	676,43
		Air Inlet H	25 000	6	26 596	0,8	21,28	400x400x230	3	8 866	422,16
		Exhaust H	25 000	7	26 882	0,6	16,13	300x300x200	2	13 441	640,05
		Support H	12 500	7	13 441	8,0	107,53	860x660x240	2	6 721	320,02
9	11 111	Main C	11 111	7	11 948	45,0	537,66	860x660x240	1	11 948	568,95
		Side C	11 111	7	11 948	30,0	358,44	860x660x240	1	11 948	568,95
		Aux. C	11 111	7	11 948	5,0	59,74	400x400x230	1	11 948	568,95
10	11 236	Main C	11 236	6	11 954	9,0	107,59	400x400x230	2	5 977	284,62
11	10 870	Main C	10 870	6	11 564	2,8	32,38	300x300x200	2	5 782	275,33
		Sub-Totals H C	75 000 55 439	-	81 124 59 362	-	180,45 1 095,81	-	-	43 233 47 603	2 058,66 2 266,80

*H = Hot, e.g. Shell Process C = Cold, e.g. CO_2 Process

Table No. 1
Sheet 4 of 5

ESTIMATED CORE AND CORESAND REQUIREMENTS

Item No	Sets per Year	Core Type and Process*		Cores per Year Net	Scrap %	Cores per Year Gross	Weight per Core kg	Weight per Year t	Corebox Size mm	Cores per Box	Machine Cycles per Year	Equivalent Machine hrs @ 21 cycles/hr
12	11 236	Main	C	11 236	7	12 082	14,0	169,15	960x760x240	2	6 041	287,67
		Drawback	C	11 236	7	12 082	12,0	144,98	750x300x200	2	6 041	287,67
		Small	C	22 472	6	23 906	0,5	11,95	300x300x200	4	5 977	284,60
13	11 236	Main	C	11 236	7	12 082	14,0	169,15	960x760x240	2	6 041	287,67
		Drawback	C	11 236	7	12 082	12,0	144,98	750x300x200	2	6 041	287,67
		Small	C	22 472	6	23 906	0,5	11,95	300x300x200	4	5 977	284,60
14	30 488	Jacket	H	30 488	10	33 876	2,0	67,75	640x540x180	3	11 292	537,71
		Bore	C	121 952	7	131 131	3,0	393,39	750x300x200	2	65 566	3 122,17
		Head	C	30 488	7	32 783	4,5	147,52	860x660x240	4	8 196	390,28
		Cam	H	30 488	7	32 783	1,0	32,78	400x400x230	2	16 392	780,55
		Wheel	H	30 488	7	32 783	2,0	65,57	400x400x230	1	32 783	1 561,10
		Small	H	91 464	7	98 348	1,0	98,35	300x300x200	3	32 783	1 561,10
		Sub-Totals	H C	182 928 242 328	-	197 790 260 054	-	264,45 1 193,07	-	-	93 250 109 880	4 440,46 5 232,33

*H = Hot, e.g. Shell Process C = Cold, e.g. CO_2 Process

Table No. 1
Sheet 5 of 5

SUMMARY OF ESTIMATED CORE AND CORESAND REQUIREMENTS

		Cores per Year Net	Cores per Year Gross	Weight per Year t	Machine Cycles per Year	Machine * Hours @ 21 Cycles per Hour	Average Cores	
							Per Day +	Per Hour •
Sub-Totals	H	446 769	482 270	756,49	220 708	10 510	2 010	155
	C	475 871	510 310	3 532,29	251 754	11 988	2 126	164
TOTAL		922 640	992 580	4 288,78	472 462	22 498	4 136	319

EQUIVALENT CORE MACHINES

Corebox Size mm	Cycles per Year		Machine Hours per Year		Number of Machines Req'd	
	H	C	H	C	H	C
860 x 660 x 240	10 786	82 538	514	3 930	0,17	1,26
960 x 760 x 240	9 419	16 016	449	763	0,14	0,25
750 x 300 x 200	-	77 648	-	3 698	-	1,19
640 x 540 x 180	34 895	13 113	1 662	624	0,53	0,20
400 x 400 x 230	86 096	35 738	4 100	1 702	1,31	0,55
300 x 300 x 200	79 512	26 701	3 786	1 272	1,21	0,41
					3,36	3,86

SAND

		t
H. Shell Process.	Usage	756,49
With 5% Waste.	Req'd	794,31
C. CO_2 Process.	Usage	3 532,29
With 5% Waste.	Req'd	3 708,91

NOTES

* Includes allowance for 70% efficiency

\+ Assumes 240 working days per year

• Assumes 13 working hours per day
(2 shifts of 6,5 hours)

H Hot (Shell) Process

C Cold (CO_2) Process

2.0 Temperature Profile Controlled Cooling Furnace

If heat treatment is carried out at all on grey cast iron cylinder blocks and heads, it is normally a stress relieving treatment. Depending on the Automotive Manufacturer and the design of the block or head, the treatment specified is normally heat to a given temperature (usually in the range 450°C - 600°C), hold for a period of time, (one to two hours), slow cool in the furnace down to about 2oo°C, withdraw from furnace and allow to cool to ambient temperature. This treatment is normally carried out in a batch type heat treatment furnace.

To carry out this treatment in a continuous heat treatment furnace, on castings extracted from greensand moulds, is likely to present some problems; operating, area and cost. The furnace would be of the pusher or walking beam type, moving trays of castings through the treatment tunnel with a roller conveyor system to return the trays for reloading. The furnace would probably comprise a temperature equalising zone, where all incoming castings are brought to the treatment temperature, a soaking zone where all castings are held at the treatment temperature for the specified time, a cooling zone where castings are cooled at the specified rate down to approximately 200°C, and possibly a fast cooling zone to quickly cool castings from 200°C down to near ambient, alternatively the castings could be withdrawn at 200°C and allowed to cool in the trays on the roller conveyor. The area requirement for furnace, tray return conveyor and ancillaries is estimated to be minimum of 55 m x 7 m.

It is not known whether such a furnace can be designed and manufactured in India, but based on European prices the installed cost is likely to be about 450 000 US Dollars.

Operating problems would arise with the removal of runner systems from the castings, sand adhering to the castings, or internal cores and programming if the different castings require varying treatments or some do not require any treatment.

A batch type heat treatment furnace would still be required to rectify any 'as cast' SG iron castings not meeting the requirements. FMD still considers that the Temperature Profile Controlled Cooling Furnace is not necessary or justified on the basis of the product mix given in the MECON report.

Preliminary Calculations

40 Moulds/hour (6 000 t/year)
1 Block/Mould
Block say 600 mml x 200 mm
Blocks loaded 4 side by side on a tray
Tray approx 1 000 mm x 700 mm
Cycle 1 hour equalising temp.
2 hours soaking
4 hours cooling (600°C - 200°C @ 100°/hour)
40 Blocks per hour = 10 x 0,7 m = length of furnace per hour.
7,0 m x 7,0 hours = 49,0 m

Plus allowance for tray entrance/exit and pusher mechanism, total approximately 55,0 m long.

Width Calculation:-

Tunnel	1,2 m
Structure, refractories, burners etc. each side 2 x	0,7 m
Gap between furnace and return conveyor	2,0 m
Return conveyor, overall width	1,5 m
Access on side	1,0 m
TOTAL	7,1 m

This does not take account of access/working area around return conveyor.

For pro rata production to 9 000t/year the furnace would have to be longer.

3.0 Castings Manipulator

The castings manipulator which FMD would recommend for the proposed APCCL foundry is the comparatively simple type, comprising an articulated arm with opening/closing jaws on the end and operated hydraulically. All movements to be controlled by a man who would be located in an air conditioned cab. The function of the manipulator would be to remove hot castings from the deck of the shake-out or a vibrating trough conveyor following the shake-out, and place them into containers for transport by fork lift truck to the castings cooling area.

It is not known whether such manipulators are manufactured in India, but a manipulator of this type would have an FOB price (Europe) of approximately 65 000 US Dollars depending on size and capacity, which cannot be specified until a final layout is prepared for the area around the shake-out.

4.0 Holding Furnace

A holding furnace may have a variety of uses, but it's main function is to enable the moulding line(s) and the melting furnaces to operate efficiently. If you have a product mix which gives varying mould poured weights, then the hourly demand for liquid metal will also vary. As an example, if a foundry has a moulding line rated at 50 moulds per hour, and a product mix with items ranging from 40 kg up to 100 kg mould pour weights, then the hourly liquid metal requirement will range from 2,0 tonnes up to 5,0 tonnes. Without a holding furnace the melting furnaces would have to be rated at 5,0 t/hr, if the moulding rate is not to be reduced when the heavy item is being produced, but if the furnaces are rated at 5,0 t/hr they would have to operate (inefficiently) at 2,0 t/hr when the light item is being produced. A suitably sized holding furnace installation allows both the moulding line and melting furnaces to operate at rated capacity.

A second use of a holding furnace is to allow melting to take place outside of the normal operating hours of the moulding line, eg. the moulding line may operate for 2 shifts (16 hrs) per day and the melting furnaces for 3 shifts (24 hrs) per day. If the daily requirement for liquid metal is 48 tonnes and the moulding line and melting furnaces operate 16 hours per day, then the minimum melting rate that can be specified for the melting furnaces is 3,0 t/hr. If a 16,0 tonnes useful capacity holding furnace is installed and the furnaces operated over 24 hrs, then the specified capacity of the furnaces can be reduced to 2,0 tonnes per hour. It should be noted that it not always advantageous economically, and an economic evaluation of two shift and three shift melting should be carried out, if this is the sole reason for the installation of a holding furnace.

Other uses for the holding furnace are to adjust metal temperature and chemical composition, but the primary function is to balance out the varying demands for molten metal from the moulding line with the constant output from the melting furnaces.

A holding furnace is not a substitute for a production programme, it is an assistance to the efficient operation of plant and equipment if the production programme is designed correctly.

In some cases holding furnaces and mould pouring units can be combined and become a single unit, however, there are a number of points to consider;-

a) A mould pouring unit usually has a storage capacity of about one hours supply of liquid metal (or less). If melting is to take place on three shifts, then the holding capacity will need to be equivalent to eight hours, (which is quite large).

b) If expansion is envisaged in the future, do you specify the holding/pouring unit to meet Phase I or Phase II requirements?

c) If liquid metal is required elsewhere you have to take it direct from the melting furnaces.

d) If there is a breakdown on a unit that is for pouring only, you can still take metal from an independent holding furnace and pour moulds. If a combined holding/pouring unit breaks down you cannot pour moulds with the metal contained in it.

5.0 Greensand Reconditioning and Preparation Plant

Preparing specifications for sand plants is largely a matter of preparing drawings, layouts showing individual items of equipment and interfaces with other equipment and elevations and sections; these serve to indicate to Suppliers any constraints imposed on them. These drawings are prepared after the layout for the moulding line(s) are finalised.

5.1 Sand Reconditioning

FMD often specify a vibratory steel trough conveyor directly beneath the shake-out surge hopper since pieces of red hot sand and/or tramp metal will not affect this and they could burn the cover of a belt conveyor.

Belt Conveyors

Inclination on belt conveyors is usually not more than 20°-25°.

Idlers on the load side should not be pitched more than 1,0 m, the return idlers can be pitched at a greater distance.

Skid plates used where sand from one belt is discharged onto another.

Tail (tension) pulley either spiral or slatted form.

Belt; Endless, 3 fabric plies, Rubber cover 3 mm + 1 mm, 650 mm wide (for 50,0 t - 70,0 t/hr), speed 60 m - 65 m/min. Belt conveyors should be fitted with cleaners; rotary brushes or scrapers. Drive; in modern plants belt conveyors are often driven by drum motors as an alternative to motors through gearboxes. In either case all the drives for belt conveyors should be standardised as far as is possible. Belt conveyors for use on the return sand side of the system should be heat resistant up to 120°C - 130°C.

In the return sand side of the system FMD would normally use two magnetic seperators, one of the overband type, installed in line with the belt conveyor (not across the belt), and a head drum type Bucket elevators should be specified at double the nominal capacity of the sand plant, be of the type without boot, supported above floor level and have drop bottom door(s) for easy clearance of any accumulated sand.

Return sand drying/cooling equipment may be of the rotary drum type or the fluidised bed type, in either case it should be specified to cool sand to a temperature not exceeding 10°C above ambient and a moisture content not exceeding 1,0%.

Rotary screen with waste chute and hopper will be incorporated.

All items of equipment contained in the return sand/reconditioning systems should be interlocked, with cascade switching (sequencial starting/stopping).

5.2 Sand Preparation

The requirements are storage facilities for the components of the prepared sand, metering devices for proportioning the components, mixing facilities, water supply, and aerating equipment if necessary. Return sand hoppers should have a capacity equivalent to 1,3 to 1,5 times the sand contained in all the moulding boxes on the moulding line.

At least two additives hoppers will be required, one for bentonite and one for coal dust (or substitute), a third hopper is often provided in case a third additive such as pregelatinised starch or woodflour is to be used. If a dry, diaphragm type dust collector is used then a fourth hopper will be required if the fines (or some of them) are to be used in the prepared sand. FMD normally give the capacity of the additives hoppers as equivalent to one days usage of the materials. A bag splitting unit and pneumatic transport system (dense phase) will be required to deliver the additives materials to the hoppers. A hopper will also be required for new sand, the capacity would also be equivalent to approximately one days usage. All hoppers should be fitted with high and low level sensors which transmit visual/audible signals to the control panel of the sand plant.

The return sand storage hopper(s) can be fitted with a drag out belt conveyor or a vibratory feeder, which will discharge sand into a batch weigh hopper located above the mixer. Other hoppers may be fitted with rotary valves and screw type or vibratory tubular/feeders, which discharge into an additives weigh hopper.

The batch weigh hoppers should be of the load cell type.

A water metering system is required.

FMD would recommend that a high intensity sand mixer be installed, and that it should be of sufficient capacity to meet the requirements of phase II, this will prevent disruptions caused by the installation of a second mixer and arranging feeds from the sand and additives hoppers.

5.3 Prepared Sand Delivery

A surge hopper should be located below the outlet of the mixer, the capacity equivalent to two mixer batches. Sand from the surge hopper should be fed by drag out belt conveyor onto belt conveyors and bucket elevators (if necessary) for delivery to a hopper located above the moulding machine(s).

A separate sand aerator may be necessary, in which case an overband type could be installed above one of the belt conveyors.

A sand discard system should be included, to enable batches of prepared sand not meeting specified requirements to be diverted away from the moulding machine hopper and onto the return sand conveyor system.

5.4 Dust/Fume Extraction

The shake-out should be adequately equipped with dust/fume extraction enclosure/hood, and at all sand transfer points on the return sand conveyor system. These points should be connected by trunking to a suitable exhaust/collector unit, which may be of the wet or dry type.

5.5 Control

A control room is required, dust proof and air-conditioned containing control panels for all items of equipment, signal lights and audible alarms, mimic diagram etc.

The system can be automatic, semi automatic or manually operated.

5.6 Safety

All conveyors should have adequate guards for the protection of personnel.

A system of emergency stop buttons should be installed throughout the plant.

6.0 Plant List Major Items of Equipment

6.1 Metallics Stockyard

1 E.O.T Crane, class 3, 5 tonne capacity, cab operated, suitable and equipped for use with an electro magnet.

1 Electro-magnet, 900 mm diameter.

1 Mechanical Shears, if unclassified steel scrap is to be used for charge metallics.

6.2 Furnace Charge Make-up

1 Weighscale with tare capability.

4 Charging buckets with drop bottoms (clamshell gates).

1 Transfer car or monorail system for transporting charges to furnace(s).

6.3 Melting Furnaces. (Coreless Induction Type)

3 Furnace bodies complete with coils.

2 Medium frequency power packs complete, with change over switch so that any furnace coil can be connected to either power pack.

Transformers

Hydraulic tilting system, and emergency tilting system.

Closed circuit cooling system and water cooling system. Valves and drainage system for emergency water supply. Electric and Hydraulic (tilting) control panels.

Refractory linings and formers.

1 Weighscale for alloy additions etc.

Note (1) Crucible capacities and melting rates can only be specified when foundry capacity and operating hours are defined. This applies to production equipment in general.

6.4 Holding Furnace (Channel Induction, Vertical Type)

1 Furnace body

2 Inductors (one spare)

1 Set electric equipment including transformer.

Inductor cooling system

Hydraulic tilting system and emergency tilting system.

Electric and Hydraulic (tilting) control panels.

Refractory lining.

Note (2) Capacity can only be specified, when moulding line metal demands and operating hours are defined.

6.5 Melting Shop Ancillaries

Ladles, various capacities and types depending on melting furnace capacities, metal treatment, metal demand from the moulding line and nodularising process used.

1 E.O.T Crane, Class 3, 5,0 tonne capacity (minimum), cab or pendant operated, fitted with heat shields.

2 Ladle heaters/dryers, with fume exhaust.

1 Fume exhaust system for desulphurising process.

6.6 Mould Pouring Unit

1 Pressure operated mould pouring unit, channel induction heated. Complete with electric equipment and controls, quick exchangeable launders, stopper mechanism (if deemed necessary) and pour quantity controls.

Refractory lining.

1 Spare Inductor.

Capacity equivalent to approximately one hours production from the melting furnaces, unless the moulding line is going to operate on two shifts and the melting furnaces on three shifts. A manually operated pouring system should be provided so that in the event of a breakdown of the pouring unit, moulds can still be poured.

1 Transport system to deliver ladles of liquid iron from the holding furnace to the mould pouring unit and the manual pouring system. This could be an E.O.T Crane, or monorail hoist system depending on the final layout of euipment.

6.7 Moulding Line

1 High pressure moulding machine, shoot squeeze type (or similar), suitable for production of horizontal parted moulds in tight flasks and rated at 90-100 complete moulds per hour. Complete with pattern shuttle or turntable device to produce drag and cope half moulds alternately. Provision to be made for changing patterns within the time cycle of the machine.

Machine is to be suitable for moulding flasks .. mm x .. mm .. x .. mm/ .. mm.

Maximum pattern draws .. mm.

Squeeze pressure to be adjustable in the range ... kg/cm^2 - ... kg/cm^2. (Actual dimensions and pressures subject to final specification).

1 Sand cutter unit to level back of mould

1 Mould turnover unit

1 Sprue cutting unit, adjustable

1 Venting unit, adjustable

1 Transfer unit for core transfer jig. (Note. If it is a bridge monorail system it can be included or excluded from the moulding line scope of work).

1 Cope mould turnover unit) These may be combined
1 Mould closing unit)

1 Set indexing edge roller conveyors

2 Mould transfer cars

1 Mould punch-out

1 Mould flask splitter and cleaner

1 Set hydraulic equipment and controls

1 Set pneumatic equipment and controls

1 Set electrical equipment and controls

<u>Note</u> State equivalent mould spaces for coring moulds
State equivalent mould spaces for pouring moulds
State equivalent time for in mould cooling.

1 Complete set pallets

1 Complete set mould flask to fill moulding line and spares.

6.8 Sand Plant (Greensand)

Return Sand System

1	Sand spill belt conveyor
1	Discharging shake-out
1	Steel trough vibrating conveyor
	Return sand belt conveyors and bucket elevators according to layout requirements.
1	Overband type magnetic separator
1	Drum type magnetic separator
1	Rotary Screen
1	Fluidised bed sand cooler/dryer, alternatively, rotary cooler/dryer.

Sand Preparation

	Sand/additives storage hoppers fitted with high and low level sensors, and fitted with drag-out belt, or rotary valve/vibratory/screw feeders as appropriate.
1	Load cell type batch weigh hopper for return sand and new sand.
1	Load cell type batch weigh hopper for additives.
1	Water metering device for supply of water to sand mixer.
1	Mouldability controller if deemed necessary.
1	Intensive sand mixer, capacity ..... tonnes unit greensand per hour, for high pressure moulding machine, producing moulds for iron castings.

Prepared Sand Delivery

1	Surge storage hopper with drag-out belt conveyor, capacity equivalent to two batches from the sand mixer.
	Belt conveyors and bucket elevators as required.
1	Overband sand aerator.
1	Sand discard system.
1	Sand storage hopper located above moulding machine, and fitted with high and low level sensors, capacity equivalent to approximately 10 moulds.

Pneumatically operated ploughs as required, on return sand and prepared sand delivery systems.

All supporting steelwork, platforms, access gangways stairways/ladders, and guardrails.

Safety Systems

All tail pulleys, drives and idlers to be adequately guarded.

Emergency Stop push button system to be installed. Lockable isolators to be provided for safety of maintenance personnel.

Additives, Delivery to Silo's/Hoppers

1 Bag splitting unit compete with dust hood.
1 Pneumatic Transporter, complete, 500 litre capacity.
3 Horizontal Receivers to be fitted to silos/hoppers.
3 Filter units to be fitted to silos/hoppers.
1 Complete set of wear resisting pipework with replaceable bends.
Boosters as required.
Pipe switches as required.
1 Control Panel Complete

Sand Plant Controls

1 Complete Control Panel(s) comprising but not restricted to the following:-

Cascade (Sequential) switching.
Manual/Automatic Mode Selector Switches.
Audible/Visual Warning lights.
Variable setting controls for additives, new sand, water and return sand weights.
Mimic Diagram.
Timer for Dust/Fume exhaust system.
Cycle timer for sand mixer.
Plough controls.
Main Isolator for Power.
Main Valves for water and compressed air.

Please note that this list is not comprehensive and much depends on the final design/layout of the sand plant.

Dust/Fume Exhaust and Collection Equipment

1	Wet or Dry Dust Collector.
1	Exhaust fan with motor.
1	Chimney Stack.
	Exhaust hoods at all points where return sand is discharged from one conveyor/unit onto another.
	Exhaust hood/cover over mould shake-out.
	Exhaust cover over rotary screen.
	All interconnecting trunking and dampers.
1	Isolator and starter, installed in sand plant control panel.

6.9 Purchased Sand Treatment Plant.

1	Surge storage hopper and grid, capacity 15 t-20 t.
1	Drag out feeder belt conveyor, adjustable speed.
1	Belt conveyor.
1	Chain and bucket elevator.
1	Fluidised bed dryer.
1	Fluidised bed cooler.
1	Chain and bucket elevator.
1	Dry sand classifier with horizontal vibratory screen decks.
1	Surge hopper for classified sand.
1	Rejects chute.
1	Pneumatic Transporter, complete, 500 litre capacity.
2	Horizontal receivers to be fitted on top of storage silos.
2	Filter units to be fitted on top of storage silos.
1	Complete set of wear resisting pipework with replaceable bends.
1	Pipe switch.
	Boosters as required.
2	Classified sand storage silos, one for moulding sand and one for core sand, each fitted with high, middle and low level sensors. Capacity equivalent to required emergency supply of sand. Silos should be fitted with anti segregation devices.
1	Control Panel complete.

Please note, the system can be designed for manual, semi automatic or fully automatic operation.

Sand washing plant will be required if the purchased sand is not of sufficiently high quality.

The plant should be specified to dry sand to 0,1% moisture and cool it to a maximum of 15°C above ambient temperature.

6.10 Classified Sand Delivery Equipment

1 Pneumatic Transporter, complete, 500 litre capacity (located beneath classified sand storage silos).

2/3 Horizontal receivers, located on tops of new sand hopper/silo in greensand plant, and new sand hopper/silo core shop.

2/3 Filter units, located on tops of new sand hopper/silo in greensand plant, and new sand hopper(s)/silo(s) in core shop.

Complete set of wear resisting pipework with replaceable bends.

1/2 Pipe switches.

Boosters as required.

1 Control Panel, complete.

6.11 Coremaking Equipment

Section 1,0 of this Addendum describes in some detail the design criteria for core machines, but these are for outline specifications only. Table No 1, sheets 1 to 5, pages 5 to 9 show the data developed before core machines are specified, Items 1, 7 and 14 are cylinder blocks, and Items 2 and 8 are cylinder heads in this Table.

6.12 Casting Cleaning

1 Continuous monorail type shotblast unit, minimum of three (3) impellors, hook capacity 2,0 t, complete with shot cleaning/recovery system and dust extraction/collection system.

1 Decoring unit, if deemed necessary.

6.13 Casting Finishing

The number of work stations will depend on the product mix and the type of equipment installed.

FMD consider that APCCL will require cut-off machines for ductile iron castings, swing frame grinding facilities and hand grinding equipment. The use of flash grinding machine is a question for economic evaluation, according to the product mix.

A hand grinding/chipping station would comprise a finishing bench, with side and back guard plates, downdraught and rear dust exhaust, push-pull monorail with 250 kg capacity electric hoist, high frequency hand grinders suspended on balancers, and incoming/outgoing gravity roller conveyors. Dust exhaust collector, one to one station, or one to two station, located behind the booth, may be of the dry or wet type (there are some good wet collectors available now).

1 Heat Treatment Furnace, top hat type, LTM refractory lining, twin hearth including refractories.

Clear internal dimensions, these depend on the anticipated load requirements, but suggest 3,5 m in long x 2,0 m wide x 1,0 m high. If gas or oil (light oil) used, then each burner should be fitted with spark ignition and flame failure system. All necessary blower, motorised control valves, governers, pressure switches, shut-off valves and pipework should be provided.

A forced air cooling system can be provided if required. A Controller and Programmer will be required, together with thermocouples and compensating cables.

If an E.O.T shop crane is not installed, then a lifting gantry of suitable capacity will have to be provided. It will be necessary to specify the heat treatments that will be carried out in the furnace.

Note This furnace is not to be considered as suitable for austempering treatment of ductile iron castings.

6.14 Secondary Casting Cleaning Equipment

Primarily intended for cleaning castings after heat treatment.

1 Shotblast unit, in-out monorail type, minimum of two (2) impellors, hook capacity 2,0 t, complete with shot cleaning/recovery systems and dust extraction/colletion system.

Note A table type shotblast unit could be installed as an alternative but much depends on the product mix with regard to final selection.

7.0 General Comments

7.1 The plant list is not intended to be comprehensive, indeed it is impossible to prepare such a plant list without an agreed final layout of equipment.

7.2 The specifications given are outline only, a definitive product mix is required before design criteria and then detailed equipment specifications can be prepared.

7.3 If E.O.T shop cranes are not to be used generally, then care will need to be taken to provide adequate local lifting facilities to ensure efficient operations at the various work centres.

INFORMATION FOR THE USER:

SOME MAPS ARE NOT PHOTOGRAPHED DUE ITS BIG SIZE