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REPORT
SP.1623

FINAL REPORT

UNIDO PROJECT NO
SI/IND/86/801

PROJECT TO PROVIDE TECHNICAL ASSISTANCE IN ESTABLISHING MODERN FOUNDRY PLANT IN ANDHRA PRADESH - CONTRACT NO. 86/62.

REPORT TO:- UNITED NATIONS INDUSTRIAL DEVELOPMENT
ORGANISATION - VIENNA, AUSTRIA

JANUARY 1987

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January 1987

SP.1623

PROJECT TO PROVIDE TECHNICAL ASSISTANCE IN ESTABLISHING A MODERN FOUNDRY PLANT IN ANDHRA PRADESH - CONTRACT NO.86/62

for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VIENNA, AUSTRIA

NOTE:- This report is issued in accordance with the requirements of Contract No. 86/62 between UNIDO and BCIRA signed 22nd September and 1st October 1986.

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TERMS OF REFERENCE

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To review the plant capacity and sizing of equipment.

To review the product mix proposed and make suggestions, if appropriate, for value added items.

To comment on the selection of production processes.

To advise on selection of production processes, performance/procurement specifications of major equipment (moulding, coremaking, sand plant etc).

TERM 2 - MELTING, METAL CONTROL AND POURING

To consider and comment upon the melting, holding and pouring equipment.

To prepare technical specifications for the automatic pouring unit.

To recommend the make and type of pouring machine.

TERM 3 - MOULDING

To review APCCL's technical specifications for moulding machinery.

To review the mould acceptance specification.

To assess the moulding machine layout and propose general arrangement drawing, to enable production of cast SG iron.

TERM 4 - CASTINGS EXTRACTION AND COOLING

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To make any appropriate suggestions for effective management control and development.

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To carry out a detailed review of the following:-

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b) the use of metal stream inoculation with the automatic pouring unit;

c) the application of IQU Vacuum Warm Box process technology for the coreshop; (See Term 6)

d) the sand plant system proposed by APCCL;

e) the application of hot distortion sand testing;

f) the use of semi-automatic ultrasonic testing equipment for cylinder heads;

g) the possible production of austempered bainitic nodular irons in the foundry;

h) to formulate other comments and recommendations as to the modalities of execution of such a large project, investment requirements, training programmes, commissioning of the plant etc.

1. INTRODUCTION

Andhra Pradesh Core Castings Limited (APCCL) is planning to build a modern automotive foundry primarily for the production of cylinder blocks, cylinder heads and other castings demanding the highest quality. Metallurgical and Engineering Consultants (India) Limited (MECON) has prepared a techno-economic feasibility report, and APCCL has produced a number of conceptual reports.

APCCL sought the assistance of the United Nations Industrial Development Organisation (UNIDO) for the evaluation of the concept, and UNIDO invited BCIRA to carry out an assignment involving the review, not only of the MECON report, but also of the APCCL conceptual reports.

Having studied the relevant documents, a senior member of BCIRA staff visited India for discussions and up-dating on the project, and has led the team which has carried out this assignment. This Report reviews the original MECON report and the latest conceptual reports prepared by APCCL.

Starting from the envisaged product mix, the consultants involved studied the process technology and plant proposed for each production department, the plant layouts and services, the energy conservation and quality control procedures to be adopted, and material and personnel proposals. Also reviewed were the practicalities of using certain special equipment and processes. Comments on all these matters, and where necessary BCIRA recommendations on alternative plant or procedures, make up the body of this Report.

2. GENERAL

Both MECON and APCCL envisage a speciality foundry based on automatic greensand moulding, electric melting, and modern coremaking processes capable of providing cured cores directly from the coreboxes. BCIRA endorses this general approach.

There are, however, a number of differencies in detail between the MECON concept and APCCL's latest views. The most far-reaching and important of these is the net good tonnage of castings to be produced at the initial stage of the development. MECON's report is based upon a 6000 tonnes per year output, whereas APCCL is planning for 9000 tonnes initially, rising to 18000 tonnes eventually. This has considerable implications insofar as the rated outputs of the individual production facilities are concerned, and these matters are dealt with in detail in subsequent sections of this BCIRA Report.

With regard to melting, MECON has proposed mains frequency coreless induction furnaces and a channel-type holding furnace. BCIRA prefers the more modern system of small high-powered medium frequency coreless induction melters, with a mains frequency coreless furnace for holding molten metal. The reasons for this, and the necessary plant details, are given in Section 5 of this report.

For moulding, MECON's Report outlines the advantages and limitations of various types of automatic greensand moulding lines, without stating a specific preference. In Section 6 of this Report, BCIRA recommends a shoot-squeeze machine for the series production of greensand moulds. However, there will be a need for a means of making prototype and very short series castings whose production on the automatic line would be either technically or financially impractical. For these BCIRA recommends a small air-set moulding section.

For coremaking, MECON would rely on hot box, shell and cold set processes, whereas APCCL has shown a preference for warm box coremaking. For reasons given in Section 9 of this Report, BCIRA believes a coreshop should be built to use hot box, shell and cold box (gas-hardened) processes, with the cores for one-off and short series production being made in the air-set moulding section.

Wherever practicable, BCIRA would prefer automatic fettling, primarily to ensure the quality of castings delivered to the customer. However, this is likely to be restricted to certain cylinder blocks, cylinder heads, and a number of castings of circular section, hence provision will need to be made for the use of swing-frame, pedestal and hand-held grinders, as noted in Section 11 of this Report.

3. PRODUCT MIX AND ANNUAL PRODUCTION REQUIREMENTS

3.1 Annual Production Requirements

In the MECON report a table is given (Table 04.01) which indicates a proposed product mix for the foundry as follows:-

Grey Iron	Average Wt. Kg.	Pieces/Yr	Tonnes/Yr
Blocks	60	20 000	1 200
Heads	30	20 000	600
Gearbox Housing	50	10 000	500
Flywheel Housing	30	10 000	300
Clutch Housing	20	5 000	100
Brake Drum	20	55 000	1 100
Exhaust Manifold	6	16 500	100
Misc. Small Items	5	20 000	100
		156 500	4 000
SG Iron			
Diff. Housings & Crankshafts	10	30 000	300
Front & Rear Hubs	8	75 000	600
Brake Drums	20	5 000	100
		110 000	1 000
SG Iron for Other Industries			
Brg. Shells & Pandrols	10	40 000	400
Compressor Parts	30	20 000	600
		60 000	1 000

TOTAL - 6 000 Tonnes/Year

In the absence of specific market and design data, BCIRA accepts these as being indicative of the numbers of pieces per year and likely weights involved, for an output of 6000 tonnes per year. All appear suitable for the proposed foundry.

APCCL has shown that its initial development programme is aimed at a net good castings output of 9000 tonnes per year. This figure has therefore been taken into account by BCIRA in assessing facility requirements e.g. in melting, moulding etc., and comprises 6000 tonnes of grey iron and 3000 tonnes of SG iron.

3.2 Additional Possibilities

BCIRA would recommend that the following additional possible applications should be explored by APCCL.

Grey Iron	SG Iron
Brake Discs	Suspension Arms
Clutch Plates	Turbocharger Housings
Hydraulic Valve Blocks	Steering Knuckles
Pump Housings	Axle Housings
Electric Motor Housings	
Textile Machining Parts	

These items are suggested on the basis of quality, value and general suitability for the proposed development, but BCIRA has not carried out any form of market research.

The initial concept of plant capacity is for a total of 9000 tonnes per year but an ultimate capacity of 18000 tonnes per year is foreseen and the possibilities for the expansion must be taken into account.

4. THE POSSIBLE PRODUCTION OF AUSTEMPERED BAINITIC NODULAR IRONS IN THE FOUNDRY.

The development of nodular, spheroidal graphite or SG iron in the late 1940's was a major contribution to the foundry industry. These irons are now very important worldwide and are used for a diverse range of applications including automobile parts, pipes and fittings, municipal castings, valve and pump bodies and gearbox components. Usually they have a ferritic or pearlitic matrix. Ferritic materials normally have a tensile strength of about 400 N/mm² and a ductility of 18% elongation at failure, whereas those with a pearlitic matrix typically have tensile strengths of up to 800 N/mm² and a minimum elongation of 2%. SG irons can also be quenched and tempered to give tempered martensitic materials with similar tensile strengths and ductilities to the pearlitic irons, but with a higher impact value and a higher proof stress: tensile strength ratio.

A comparatively recent development is the application of an austempering heat treatment to SG iron castings to obtain a variety of bainitic matrix structures. The heat treatment consists essentially of austenitisation, typically for one hour at 900°C, rapid quenching to a lower predetermined temperature within the range 235 - 450°C and holding at this temperature to allow the austenite to transform isothermally to bainite. The holding time would typically be one to two hours. Components are then cooled to room temperature . The resulting austempered SG irons have a combination of tensile strength and ductility which makes them superior to existing grades of SG iron.

In practice the essential steps in the production of a finished austempered bainitic nodular iron component are -

i) To cast the components.

ii) To carry out any major machining operations.

iii) To austemper the components to develop a bainitic matrix structure.

iv) To carry out any finishing operations such as final machining and shot peening.

A major feature of this flow is the requirement for the austempering heat treatment. Specialised equipment is necessary and a very high degree of control must be exercised. Clearly, austempered bainitic nodular irons will be more expensive than the ferritic or pearlitic materials. The first applications announced were in the USA where this type of iron was chosen to replace a case carburised forged steel for the manufacture of rear axle hypoid pinion and ring gears of certain Pontiac vehicles.
The use of the material for gears has since increased and there are known applications in Europe as well as America. There are also development programmes being undertaken in Japan and China. Quite a wide range of general engineering components could benefit from production in this type of material.

There are therefore considerable potential applications for bainitic nodular irons or austempered ductile irons as they are often known. However, at this stage of their development it is unlikely that there would be a sizeable market developed in India in the near future and it is BCIRA's opinion that APCCL would be wise not to include these materials in the forecast product mix. Should a market ultimately develop, then APCCL should evaluate its possibility. The following clearly defined factors will need to be taken into account:-

a) The foundry must be able to produce high quality SG iron castings at a competitive cost.

b) It must be able to guarantee the integrity and properties of its products.

c) Austempering heat treatments will have to be carried out under strict control and at a competitive cost. This may necessitate either using sub-contract heat treatment facilities or setting up a dedicated plant.

APCCL will have the ability not only to produce the quality castings required, but also to demonstrate its capability in this direction. However, with regard to the heat treatment plant required, it is unlikely that suitable sub-contract heat treatment will be available. In order to enter into this market therefore, APCCL would almost certainly have to set up an expensive heat treatment facility. At this time, the size of the market which can be foreseen for these highly specialised materials would not justify such a high capital expenditure.

5. THE MELTING FACILITY

5.1 Molten Metal Requirements

Assuming a 60% overall yield for grey iron and a 40% overall yield for SG iron, the total metal requirements for the MECON scheme and the APCCL scheme are as follows:-

	Molten Metal Requirements MECON T/Y	 APCCL T/Y
Grey Iron	6667	10000
SG Iron	5000	7500
TOTAL	11667	17500

On the basis of 300 working days per year, the AVERAGE daily molten metal requirement would be 40 tonnes to meet the MECON report and 60 tonnes to meet the APCCL requirements.

5.2 Metal Melting Proposals

BCIRA endorses the proposal to use coreless induction furnaces for metal melting. The MECON report suggests that mains frequency furnaces be used to provide the molten metal requirements. Three 3 tonnes capacity furnaces are proposed which would provide a melting rate of about 2 tonnes per hour total. Over a three shift operating period, these furnaces would produce 48 tonnes of molten metal per day, and as the moulding plant is only operating for two shifts it would be necessary to provide a holding facility to store the additional metal melted due to three shift operation. To meet the requirements of 40 tonnes per day, approximately 20 hours working would be involved on the melting furnaces and, assuming that the moulding shift is 8 hours, it can be seen that a holding facility would be required for four hours melting, i.e. about 8 tonnes. The MECON report suggests the use of a 10 tonne channel type holding furnace for this purpose.

APCCL prefers medium frequency coreless furnaces for melting as these furnaces have many advantages, including the ability to be emptied between melts, thus facilitating changes in metal grades. BCIRA would agree with such a choice.

Originally APCCL stated that three 2 tonne furnaces would be provided together with two power packs which would allow melting on two furnaces at the same time, the third furnace being held for maintenance and breakdown occasions. This proposal would allow a production of about 3 tonnes of molten metal per hour and to meet the daily requirement of 60 tonnes, a melting period of 20 hours would be involved. As indicated above, a holding facility would be required to cover four hours melting i.e. about 12 tonnes. The APCCL report indicates that they have included a 10 tonne channel type holding furnace, which, on the basis of the above figures, would not be large enough.

Channel type holding furnaces require power 24 hours every day for 365 days every year. They also operate with a substantial retained molten heel, e.g. of 2 or 3 tonnes on a furnace of 10 tonnes useful capacity, which makes metal grade changes difficult due to the need to dilute this molten heel.

An alternative, which BCIRA has suggested to APCCL, and which has been accepted, would be to install a large, mains frequency, coreless holding furnace. This unit could be emptied to facilitate metal grade changes and could also be switched off when empty and not required.

APCCL, in discussions during the site visit, proposed that a two furnace melting installation should be provided, of the medium frequency type, with only one power pack. The unit would need to be sized to provide the requirement of 3 tonnes of metal per hour and would therefore require furnaces of 4 tonnes capacity, which, when supplied with power of about 2000kW would melt at the appropriate rate. BCIRA recommends that, in addition to the power supply for melting, a further power supply should be provided to allow molten metal to be held at temperature in the furnace body, and a changeover switch should be provided to allow the melting and holding facilities to be switched to either furnace.

5.3 Summary of BCIRA Recommendations

BCIRA recommendation, therefore, is that molten metal be supplied from a facility which consists essentially of:-

2-Four tonnes capacity coreless induction melting furnaces.

1-2000kW, 250Hz thyristor-controlled power supply for melting.

1-200kW power supply for holding.

1-Changeover switch for the above.

1-12 tonnes capacity mains frequency coreless induction holding furnace.

1-425kW power supply for this furnace.

In BCIRA's opinion, the charging of the melting furnaces should be carried out directly by means of a magnet suspended from an overhead crane rather than via a charge bucket and transfer system, which would be more expensive and no more effective. Control of charge weighing should be carried out either by mounting the melting furnaces on load cells or via a suitable crane mounted weighing system.

5.4 Pouring

BCIRA agrees with the proposals made to provide an automatic pouring system. It is recommended that such a system should consist of:-

One automatic pouring furnace to pour both grey and treated SG iron through a stopper rod and nozzle arrangement. The furnace should have a useful capacity of 2.5 tonnes and should be supplied with equipment to allow complete emptying at any time. To allow tilting of the furnace in the event of power failure a hand pump would need to be provided. The furnace body needs to be mounted on to a movable carriage to allow the body to be adjusted 300mm parallel to or 1m at right-angles to the moulding line.

A suitable preheating system utilising a gas supply, complete with all valving and control equipment, should be provided to allow pre-heating of the furnace after re-lining to achieve the required lining temperature, and also to maintain the lining temperature during periods when the unit is not operating.

The pouring unit would be used to fill moulds at the rate of up to 140 per hour. The pouring rate must be infinitely variable up to a maximum of 20kg per second.

The furnace body should be supplied fully lined and complete with all the necessary electrical control and operating equipment. Provision needs to be made in the electrical control system to connect an auxiliary power supply to the furnace should this be found necessary.

Water cooling equipment, preferably of the sealed closed circuit air blast type, needs to be provided and this equipment must be complete with all valves and tanks etc., and should also incorporate a water treatment system, if this is considered necessary. Samples of the normal water supply at the works would be provided for the tenderer to obtain analysis and determine the water treatment which may be necessary. In addition to the water cooling system, the tenderer should supply all the necessary fittings for an emergency water supply which would be filled from an existing mains water system. Alternative cooling systems may need to be examined due to high ambient temperatures.

When pouring grey iron the pressure medium will be compressed air, but when pouring treated SG iron, nitrogen will be the pressure medium. Provision for both systems needs to be made including all valves, piping and controls.

The tenderer should incorporate into his offer the costs for full installation, the supply of maintenance manuals and operating procedure manuals as requested by the customer. Copies of all drawings must also be provided to the customer.

The above specification should be used in due course for the calling in of quotations for the pouring unit, before a final decision is reached. Subject to a satisfactory offer being received, however, BCIRA believes that a 2.5 tonne, 60kW, ASEA unit, of the gas-pressurised type, equipped with stopper rod control, would meet the foundry's requirements. Initially, a smaller 1.25 tonne, 60kW unit would probably be satisfactory, but at a later stage in the foundry's development, e.g. when mould outputs of up to 140 per hour are achieved, the larger unit suggested would be better, requiring less frequent metal transfers.

5.5 Metal Stream Inoculation

Certain materials added in small amounts to the metal just before pouring reduce the tendency to form eutectic carbide or white iron structures, commonly referred to as 'chill'. The practice of adding these materials, which include graphite, ferro-silicon and calcium silicide, is known as 'inoculation'. The amounts added are small, but the effect is much greater than would be expected from the change in composition.

Flake graphite irons of high carbon and silicon contents are unlikely to require, or benefit from, inoculation. SG irons, however, require inoculation even when carbon and silicon contents are high, since the magnesium and/or cerium added to produce the spheroidal graphite structure has a strong carbide-promoting effect. Inoculation also increases the number of graphite spheroids in the structure and improves the properties.

The effect of an inoculant is at a maximum almost immediately after it is dissolved in the iron. The effect fades at a rate depending on the operating conditions and the inoculant used: more than half the effect can be lost within the first five minutes. Control of the inoculation practice is therefore very important, as is the pouring of iron quickly after addition of the inoculant.

Traditionally, inoculants have been added to the tapping stream from the furnace or during transfer from ladle to ladle. It is, however, much more effective to add the inoculant to the stream of metal as it enters the mould - this practice is referred to as late metal stream inoculation.

This technique gives the maximum effect obtainable from an inoculating addition, leading to economy in the use of inoculants - amounts may be as little as one-fifth to one-third of the quantities required for ladle inoculation - and greater consistency of castings.

Metal stream inoculation is especially suitable for automatic moulding lines, particularly where an automatic pouring unit is employed.

In the latter instance, the dispensing unit for the inoculant can be fixed to the pouring head, and the signal to the control unit initiated by the automatic pouring unit. An alternative method, more widely used when conventional ladle pouring is practised, is to use a suitable sensor as a metal-stream detector to activate the dispenser automatically as pouring commences.

Equipment for this purpose is available which can be programmed to ensure that a given rate of inoculant is dispensed and that even the first metal to enter the mould is fully inoculated.

The use of this technique is recommended as a positive aid to control of casting quality, as well as a means of effecting economy in the use of material.

6. MOULDING

6.1 Moulding Machine

The MECON report discusses the various types of moulding machines available which are capable of producing high density moulds. In this report no final selection of the type of machine is made. APCCL has selected from the range discussed two possible alternatives, shoot/squeeze or air impact/squeeze.

Of the above two methods BCIRA has a preference for the shoot/squeeze system which will produce a mould of high density and has been shown, in other installations, to be a reliable robust machine.

The machine needs to be provided with pattern shuttle facilities and pattern changing also needs to be considered. The machine manufacturer generally incorporates such facilities in his supply.

The MECON report indicates that for the production levels stated, i.e. 6000 tonnes of saleable castings per year, an average output from a suitable moulding machine, would be about 40 complete moulds per hour. BCIRA has calculated that about 600 moulds per day, 300 per shift, which is approximately 38 moulds per hour, would be necessary, confirming the MECON findings.

Originally, APCCL envisaged a production level of 9000 tonnes per year and a mould requirement of 40 per hour. BCIRA considers that a more realistic mould output rate of 60 per hour is necessary to achieve the initial production level required. This matter has been raised in discussions during the site visit and APCCL has revised its mould output rate requirements, as follows:-

Phase I	60 moulds per hour.
Phase II	90 moulds per hour.
Phase III	140 moulds per hour.

6.2 Moulding Box Size

The plan profile selected for the moulding box of 900mm x 700mm appears suitable for the range of castings identified in the MECON report. The depth of box quoted in the MECON report of 300mm appears a little high and in the original APCCL report this has been reduced to 250mm. However, APCCL qualifies this by stating that the machine and handling equipment supplied should be designed to allow one of the pair of boxes to be 300mm deep.

BCIRA does not recommend the use of two different box depths on automatic moulding systems, preferring to maintain both halves of the mould at the same depth. This simplifies the design of the mould handling system.

During the site visit, APCCL again suggested that two box depths be provided, 250mm and 375mm. BCIRA strongly recommends that if the deeper size is required then only this depth of box should be provided for the reasons stated above and also because this would require the purchase of only one set of moulding boxes and removes the problem of changing a full set of boxes on the plant.

6.3 Mould Handling

BCIRA agrees with the recommendation given in both the MECON and APCCL reports that an indexing pallet moulding line be installed. The alternative, a continuously moving conveyor, would complicate corelaying and metal pouring.

6.3.1 Corelaying The spaces shown on the layout drawings prepared by MECON and APCCL for corelaying appear adequate. The layout prepared by MECON indicates that top half (cope) moulds, and bottom half (drag) moulds should be carried on two separate lines, to the mould closing area, where the cope is located and placed on the drag. Whilst this has the advantage that drag moulds index more slowly through the corelaying area and are stationary for a longer period than as indicated in the APCCL report, where only one line for both cope and drag moulds is provided, it has the disadvantage that extra equipment is required and provides additional areas where maintenance problems can occur.

BCIRA would suggest that the system proposed by APCCL would be more reliable but it should be remembered that with such a system the time during which the mould is stationary in the corelaying section is halved.

6.3.2 Mould Clamping No mention is made in the MECON report concerning clamping of the cope mould to the drag mould, whilst APCCL suggests that weights should be placed on top of the mould after closing. BCIRA recommends that a fully automatic box clamping system be provided and not weights, as the latter restrict the available area for pouring molten metal into the closed mould, and weight transfer systems are prone to mechanical breakdown.

6.3.3 Venting Both the MECON report and the APCCL report indicate equipment for venting the cope mould and BCIRA agrees with this provision.

6 .3.4 Pouring As stated previously, BCIRA agrees with the provision of an automatic pouring unit to dispense molten iron into the moulds, but also believes that a back up system needs to be provided to cover those periods of time when the pouring unit is inoperative. Such a system, comprising a monorail and a number of manually controlled ladles, needs to be incorporated in the layout.

6 .3.5 Mould Cooling For the production rate envisaged in the MECON report of 40 moulds per hour, the layout drawing indicates a cooling time of about 1½ hours. This cooling time is adequate for the range of castings to be produced.

Similar comments apply to the APCCL proposed mould cooling facilities when applied to a production rate of 40 moulds per hour. However, as stated in Section .1, BCIRA believes that this figure needs increasing to 60 moulds per hour and in this case only one hour cooling can be achieved with the layout as drawn. BCIRA considers this cooling time to be adequate for the range of castings presently envisaged.

6 .4 Sand Storage Over Machine

Sand storage over the moulding machine has to be provided and whilst MECON do not recommend a capacity the APCCL report indicates 5m^3. BCIRA agrees with the figure quoted by APCCL.

BCIRA also agrees with the APCCL approach to feeding of the stored sand to the moulding machine using controlled feeding and measuring equipment.

However, in discussion during the site visit, APCCL expressed a wish to use a facing sand and backing sand system to fill the moulds. With the moulding machine envisaged for APCCL, i.e. of the blow/squeeze type, it will not be possible to cater for such a system unless two mould filling stations are provided at the machine. Such systems are available but BCIRA considers that the use of two sands of different properties is unnecessary as the sand plant will be capable of providing a good quality unit sand which would meet all the requirements for the production of the range of castings envisaged.

BCIRA therefore recommends the use of a single unit sand which can still be fed to the box at two positions. At the first position sand can be metered directly into the half moulding box, then at the second position further sand can be added by blowing. The whole assembly would then be compacted by squeezing.

6.5 Moulding Machine Specification

The APCCL report gives details of the moulding machine requirements in relation to -

a) final casting accuracy and tolerance,

b) noise,

c) sand hardness of compacted mould both on vertical and horizontal faces,

d) pattern draw.

We agree with the APCCL specification and believe that all the major moulding machine manufacturers can provide equipment which meets these requirements.

6.6 Plant Control

The method of controlling the operations of the proposed plant is not specified by MECON, whilst APCCL indicates the use of solid state control using relays and proximity switches, whilst stating that a Programmable Logic Control (PLC) would be considered.

BCIRA strongly recommends the use of a PLC control system which should also incorporate a diagnostic capability for fast, easy determination of plant stoppages.

6.7 Compressed Air Supply

A supply of compressed air at a pressure of $7 kg/cm^2$ is recommended by MECON and BCIRA agrees with this.

6.8 Lubrication

A centralised automatic lubrication system for the moulding machine complex is considered essential by BCIRA. The indexing pallet wheels should also be provided with an automatic lubrication system, separate from the machine complex.

7. SAND PLANT

The two schemes are based on automatic greensand moulding machines and a unit sand is to be prepared in adjacent automatic sand plants.

7.1 MECON Sand Plant

The MECON sand plant is designed to provide 40 tonnes per hour of prepared unit greensand to meet an anticipated requirement of 30 tonnes per hour for the moulding unit. New sand is to be dried in an oil fired rotary sand drier. This sand will be transferred to two bunkers installed above the sand mills by means of vibroscreen, belt conveyors and a bucket elevator. Separate bunkers will be erected at the sand mills to contain clay and coaldust.

Sand which is returned from the knockout at the moulding plant will be transferred to a surge bunker via a belt conveyor, magnetic separator and polygonal screen. This return sand will then be passed through a fluidised bed cooler and carried to bunkers at the sand mills by means of belt conveyors and bucket elevator. The sand will be mixed in two intensive turborotor mullers of 20 tonnes per hour capacity. Belt and screw feeders will be used to feed the mills by an automatic set programme.

The prepared sand will be delivered to the moulding machine by means of belt conveyors and bucket elevators. An aerator will be installed before the bunker above the machine to condition the sand.

The following sand plant equipment is specified in the MECON Report:-

1 Set -

Fully mechanised sand plant, capacity 40 tonnes per hour complete with two intensive turborotor type mix mullers capacity 20 tonnes per hour each, return sand cooler, magnetic separator, sand sieve, overhead bunkers, line aerator, belt conveyors, bucket elevators, feeders, grates with chutes, electrical equipment with control panel, dust extraction system, supporting structures, platforms, ladders and other auxiliaries.

1 Set -

Oil fired rotary sand drier capacity 2.5 tonnes per hour with auxiliaries.

7.2 APCCL Report

The estimated requirement for prepared sand is 22 tonnes per hour and 44 tonnes per hour when moulding rates are at respective levels of 40 and 80 boxes per hour. It is planned that two mixers of 22 tonnes per hour each will be installed at separate stages as the output increases.

New sand is to be fed into a floor grid and transferred into a 20 tonne capacity hopper via a surge hopper dragout belt and bucket elevator. This sand will not be treated in a sand drier.

Return sand will be transferred from the shakeout on the moulding machine by belt conveyor band to a 20 tonne surge hopper. An overband magnetic separator and a water spray device will be installed on this belt. The surge hopper will feed a rotary breaker screen and subsequently a sand cooling drum. Warm air from the knockout will be passed through the screen to provide evaporative cooling of the sand. Return sand from the cooling drum will be passed into a bucket elevator which discharges into a 6 tonne capacity surge hopper.

The preparation of the unit sand will then be carried out in two distinct stages. The necessary additions would be made to the sand in a pre-mixer and cooler unit and the mixture would be placed into storage in two large bunkers of 60 tonnes capacity. In the second stage the pre-mixed sand would be finally mixed in one, and later two high intensity mixers.

It is visualised that the pre-mixer/cooler will be provided with a batch weigh hopper to receive new and return sand. The new sand would be transferred to this unit from the 20 tonne silo via a vibrating tube conveyor. Day hoppers for coaldust, clay and dextrin would be installed above the pre-mixer/cooler and these materials would be delivered and metered by means of screw feeders and a weigh hopper. A bag emptier and hoist system would be provided for the replenishment of these additions hoppers.
It is proposed to pump and meter water slurry from the wet collector unit which serves the extraction on the sand plant, to make the necessary moisture additions to the prepared sand. This water will contain clay and coaldust fines which have been entrained in the air used for ventilation and thus these expensive materials can be reclaimed and conserved.
Prepared sand will be delivered to the moulding machine by means of a belt conveyor system.

APCCL has subsequently modified its views on the proposed sand plant and now envisage the following changes. The sand plant capacity will need to be revised to match the modified moulding machine requirements i.e. 40 moulds per hour and 80 moulds per hour originally proposed now becomes 60, 90 and 140 moulds per hour in three successive planned phases.

It is proposed to use an electrical capacitance instrument for metering the moisture requirements, this is to be installed at the final mixing stage.

The additions of return and new sand to the pre-mixer are to be made on the basis of volumetric timers rather than by a weighing system, to reduce the capital cost of the plant.

7.3 Comments and Recommendations on Sand Plant Proposals

The capacities proposed in both reports are clearly too small in relation to the revised level of mould output and modified box size which has been subsequently proposed by APCCL.

Since the ultimate moulding rate envisaged is 140 boxes per hour and flask size 900 x 700 x 375 x 375mm, it is recommended that the sand plant should be designed to prepare 110 to 120 tonnes per hour.

An output of 140 moulds per hour can typically be achieved by a modern automatic greensand moulding machine when it is operating at its normal cycling rate. It is prudent to provide sand preparation capacity to match this requirement even if the demand for average mould output is considerably under this figure in the initial phases of development. It is therefore recommended that the sand plant should be designed to prepare 110 to 120 tonnes of sand per hour from the outset so that an output rate of 140 moulds per hour can be sustained from time to time even in the early phases of foundry development. On this basis most of the itemised plant capacities specified in the two reports will need to be considerably increased.

In discussions during the site visit, APCCL expressed a wish to use facing and backing sands rather than a single unit sand. Whilst it is appreciated that there could be some merit in arranging for a layer of sand to be placed onto the pattern prior to the shoot/squeeze operation, it is recommended that only one type of sand should be used and that this should be prepared as a unit sand.

The MECON report proposed the installation of an automatic sand plant based on a pair of high intensity mixers. This is also proposed by APCCL but in this case the sand is to be pre-mixed in a mixer/cooler unit. The use of such a unit is considered to be advantageous in providing for additional cooling and in homogenising the sand so that greater consistency and control can be provided at the final mixing stage. It is recommended that this system be incorporated in the proposed sand plant.

The MECON scheme proposes to pass return sand through a fluidised bed cooler whereas the APCCL plan uses a cooler drum in conjunction with a forced ventilated screen and an air cooled pre-mixer. It is understood from the APCCL report that the cooling drum is available from Indian manufacturers. The fluidised bed cooler proposed by MECON is a well proven equipment and would be very satisfactory for this application. However, if the sand drum cooler is available locally, it could be worthwhile adopting the cooling system proposed by APCCL.

It would be prudent to install equipment for the use of liquid nitrogen to gain additional sand cooling in the event that the provisions made for conventional cooling techniques prove to be inadequate.

The installation of large bunkers for sand storage between the pre-mixer and the final mixers proposed in the APCCL scheme could lead to difficulties with damp moulding sand sticking and bridging. It is recommended that bulk storage of return sand should be provided prior to the pre-mixer unit.

It is suggested that this bulk storage of return sand should be in the region of 240 tonnes capacity.

Both the proposed sand plant layouts employ belt and bucket elevators at various stages in the systems. Bucket elevators have a tendency to suffer blockages particularly when handling moist prepared sand and should be specified considerably oversize for the intended duty. If possible they should be avoided altogether and the sand should be elevated on inclined conveyor belts. In this new foundry development an open site is available and the sand plant need not be placed adjacent to the moulding unit.
It is therefore recommended that a separate sand plant area should be provided at a sufficient distance from the moulding plant to enable sand to be transported by inclined belt conveyors throughout the process.

The two foundry schemes specify the use of one overband magnetic separator for the removal of tramp metal from the return sand conveyors. It is recommended that four magnetic separators should be incorporated in different sections of the return sand system. Small fragments of metal may be held down by the burden of sand on the belt conveyor and may not be extracted by a single pass under a magnetic overband separator.

It is recommended that provision should be made for a waste sand bunker; this is not mentioned in either of the proposed schemes.

The APCCL plan proposes to use warm air extracted from the knockout hood to pass through the rotary breaker screen. It is pointed out that the warm air would enhance the evaporative capacity of the air flow and hence improve the cooling of the sand. If a new sand plant layout is developed, based on inclined conveyor belts, this will mean that the sand screen will be too far from the knockout to make this arrangement practicable.

Both the schemes propose to use a pair of high intensity mixers for the preparation of the moulding sand. This proposal is endorsed. This type of mixer develops the high quality sand required for automatic plants both rapidly and economically.

The MECON scheme proposed the installation of a sand aerator on the belt conveyor delivering prepared sand to the moulding machine. The APCCL scheme does not include an aerator at this point. It is recommended that a belt aerator should be fitted to the prepared sand conveyor to improve the texture of the sand prior to its arrival at the moulding unit.

The use of the electrical capacitance technique for assessing moisture content of sand at the mills is endorsed.

7.4 Summary of Recommendations for the Development of the Sand Plant

The sand plant should be designed to prepare 110 to 120 tonnes of unit sand per hour. A new layout should be developed using inclined belts for gaining elevation in the sand system. The return sand should be passed under four overband magnetic separators at various points in the layout. This sand should be passed under a water spray and should then be passed through a ventilated cooler drum. (Provision should be made for the possible use of liquid nitrogen for further cooling should that prove necessary, this should be added at an aerator unit prior to the moulding machine). The cooled sand should be directed into a series of return sand storage hoppers with a capacity of 240 tonnes total. An additional hopper should be provided to contain waste sand for subsequent disposal. Sand from the return sand hopper should be transported to a batch weigh hopper above a pre-mixer/cooler. This unit would pre-mix the sand in batches. Water additions would be made by means of a slurry pumped from the sludge tanks of the wet collector units to economise in the use of clay and coaldust. The pre-mixed sand would be fed into a batch hopper set above intensive mixers. Final water additions would be made at this point and suitable proportions of clay and coaldust and if necessary dextrin would be added via screwfeeders from day hoppers. The prepared sand would be delivered to the hopper over the moulding machine by means of belt conveyors. An aerator would be installed on this line of conveyors just prior to the moulding machine.

The return sand conveyors and other equipment should be sized to accommodate sand surges which may be several times the 120 tonnes per hour of prepared sand.

New dry sand should be added to the return sand from a hopper which will be replenished by a front loader, and should be added to a return sand conveyor.

The coaldust clay and dextrin additions should be stored in day bunkers above the final mixing station. These bunkers should be replenished by means of a pneumatic conveyor which is fed from a ventilated bag splitter unit.

The sand plant should be provided with a control cabin which is amply instrumented.

A dust extraction system must be installed to provide ventilation at all sand plant items and at all points where dry sand is being transferred or otherwise disturbed so that airborne dust will arise.

8. RECOMMENDATIONS FOR THE PREPARATION OF SPECIFICATIONS FOR THE SAND PLANT

It is recommended that the automatic sand plant be installed in an area outside the main building containing the moulding plant. This proposal, which is illustrated in the layout drawing, Fig.2, has the following advantages:-

i) The operation of a separate sand plant offers greater cleanliness in the foundry.

ii) The use of bucket elevators, which may be troublesome, can be eliminated by employing inclined belt conveyors.

iii) The weather-proofing of the sand plant can be provided by purpose-built individual housings for the principal items of equipment. The construction of very high bay buildings within the main foundry building can thus be avoided.

It is recommended that when specifications are prepared for the sand plant tenders, the supplier should be given the functional requirements of the plant items, statements of the throughputs and spacial dimensions for principal entry and exit points for materials.

It is generally better to avoid stating mandatory design details such as thickness of materials, diameters of pulleys, shafts, motor horsepowers and speeds etc. This gives the manufacturers the opportunity to design their equipment for satisfactory all round performance at competitive costs.

However, there will be a number of areas in which it will be desirable to specify some minimum detailed requirement for the guidance of the manufacturers.

It will, of course, be essential that the suppliers provide APCCL with detailed specifications and drawings for their proposals. This information will be vital when comparing quotations and the detailed specifications should be requested when placing the enquiries.

The specifications for tenders must embody a number of general requirements. All equipment must meet the local mandatory standards and codes of practice for mechanical and electrical safety. Adequate provision must be made for the control of airborne dust.

All plant which is above floor level must be provided with access and inspection walkways, platforms, staircases or ladders complete with safety hand railing. The suppliers should be asked to provide inplant wiring, operating switch gear, emergency stop buttons and isolators to suit mains power supply specified by APCCL.

It is worthwhile specifying that all equipment should be suitable for operation in a foundry environment.

All parts which are normally painted should be properly prepared and given at least one coat of primer and one top coat by the manufacturer. Sufficient paint to be supplied to allow patch painting after erection.

The supporting structure for most items of plant should be extended by the manufacturer to carry weather protection including side walls sufficient to prevent the wind from blowing loose sand from conveyors etc.

The quotation should include insurance, delivery, recommended spares and erection costs on prepared foundations and the supplier should be asked to provide drawings in addition to operating and maintenance literature.

8 .1 Belt Conveyors

These should be specified individually, giving the intended duty and purpose, the required carrying capacity (i.e. surge loading) and the approximate distance between centres. The belt conveyors and ancillary fittings should be designed to minimise sand spillage.

8.1.1 Support Structure Robust construction must be specified with safe access platforms, walkways and stairs. Under belt guards must be specified for areas covering normal walking access.

8.1.2 Drives It should be specified that all drive motors shall be provided with reduction gearboxes and flexible drive couplings which are fully guarded. Motor sizes should be of adequate horsepower for intended duty and where possible should be standardised. Arrangements must be incorporated to prevent inclined belts from running back after switching off the motors.

8.1.3 Belting Belt lengths (centres), minimum widths, troughed or flat, material, grades, number of plys and cover thicknesses will need to be specified for each conveyor. The belt joint should be vulcanised. The return sand conveyors should be generally capable of withstanding temperatures of 100°C except in the ca of the belt conveyor immediately following the knockout which should be specified to have a heat resistance to 160°C.

8.1.4 Pulleys The specifications should provide for heavy duty crowned face head and tail pulleys. The drag out belts should be provided with lagged head and tail pulleys to improve grip.

8.1.5 Idlers The minimum diameter, type and pitch will need to be specified for the appropriate duty on the various belt conveyors. 'Sealed for life' bearings are preferable.

8.1.6 Belt Tension It will be necessary to specify heavy duty take up bearing units to be supplied on the tail pulleys, and be mounted on sliding carriages with screw tensioning adjustment.

8.1.7 Belt Scrapers Efficient self adjusting belt scrapers should be specified for all conveyors and should be so arranged at the head pulley that any sand which they remove is directed into the main discharge chute.

8.1.8 Sand Transfer Chutes These must be specified where applicable.

8.2 Overband Magnetic Separators

The overband type of magnetic separator should be specified to be fitted at right-angles to the belt conveyors on the return sand section and designed to operate with a working gap of 150 to 230mm. The discharge chutes should have a stainless steel lining for the top portion and should terminate at a suitable bin.
Some means of adjustment must be provided in the mounting arrangement. Four of these units should be installed.

8.3 Water Spray Unit for Return Sand Conveyor

An automatic water spray unit must be specified with sensors for sand temperature and bulk presence which control the addition of water. Tines should be provided to disturb the sand on the belt conveyor.

8.4 Rotary Sand Cooler Drum

Sufficient capacity should be specified for this unit to cater for surge loading on return sand system. The unit should include the necessary support structure. Provision should be made for oversize lumps to be directed via a tailings chute into a bin placed at ground level. The unit should be capable of reducing the temperature of the sand to 10°C above ambient temperature and water spray facilities should be fitted at the inlet end of the drum for this purpose.

8 .5 Sand Storage Hoppers

The various hoppers or sets of hoppers should be specified separately. They will contain return sand or prepared sand, and their useful capacities in tonnes should be given. (It may be assumed that this return sand has a bulk density of 1100 to 1200kg/m^3 and that prepared sand has a bulk density of 900kg/m^3).

High and low level probes should be installed in each hopper.

The prepared type of discharge should be indicated (bin activators or drag out belts), and the hoppers should be provided with the necessary supporting structure. The hoppers must be designed to promote the free flow of the sand to be stored.

8 .6 Sand Ploughs

Automatic, remotely controlled ploughs should be specified for the return sand storage hoppers, at the sand mixer and on the prepared sand belt conveyor.

The ploughs should be Vee type with pneumatic actuation, double unit being provided at the return sand storage hoppers. The equipment should be fully adjustable and fitted with scraper blades which can be readily replaced. Limit switches should be provided to indicate the plough positions to the sand plant operator.

8.7 New Sand Additions Equipment

It is necessary to specify equipment for the addition of new silica sand to the return sand system.

A sand hopper should be fitted with a drag out belt discharge unit to feed sand onto the return sand belt conveyor at a preset rate. The operation of this sand feed should be initiated by the sand plant operator when new sand is required.

The new sand hopper should be of a simple open top design replenished by means of a front loader vehicle. (The bulk density of silica sand is approximately 1600kg/m^3).

8.8 Clay, Coaldust and Dextrin Addition Equipment

Day hoppers and supporting structures should be specified for containing coaldust, bentonite and dextrin. Measures should also be specified for the coaldust hopper to minimise the consequences of internal fires and explosions. A replenishment system must be provided, such as by means of ventilated bag splitters and pneumatic conveyors. The hoppers should be provided with high and low level probes and discharge should be by means of screw feeders. It is anticipated that the dextrin additions will be less than 0.25%.

8.9 Batch Weigh Hopper

A batch weigh hopper and supporting structure should be specified in terms of its capacity (weight) and a description of the intended method of filling and discharging the hopper should be given, i.e. sand to be delivered by belt conveyor which is switched on and off by the load cell weighing equipment. A bottom gravity discharge is to be arranged and this is to be initiated automatically.

8 .10 Sand Pre-mixer/Cooler Unit

Specifications must be supplied for the pre-mixer/cooler unit giving the required batch weight and the quantity of sand to be processed per hour. The method of filling and discharging the unit should be specified, i.e. overhead filling from batch weigh hopper, discharge into a surge hopper of 1½ times mixer capacity with rotary table under. The unit must incorporate a fan and distribution ductwork for injecting cooling air into the body of the mixer. The unit should be capable of cooling the sand to a temperature 10°C above ambient.

8 .11 Reclamation of Slurry from Wet Collector

Specifications should be provided for a system for reclaiming clay and coaldust fines which have been carried into the dust extraction system and have become suspended in the sludge tanks of the wet collector units.

Water from these tanks enriched with clay and coaldust is to be pumped to the pre-mixer machine and added to the charges of return sand in the batch weigh hopper. The water should be continually circulated in a ring main by means of a pneumatically operated double diaphragm pump. A remotely controlled valve will be needed at the pre-mixer to release the water as required by the sand plant control system. The ring main should also incorporate valves for isolating, draining and flushing operations.

8 .12 Final Sand Mixers

It is necessary to specify that the final mixers shall be of high intensity type with a certain batch capacity and hourly sand throughput. The machines shall be capable of producing the required sand quantities having properties developed to suit the moulding machine which is to be installed. The properties required should be specified in the light of the recommendations of the moulding plant manufacturer. As a guide required properties are likely to generally conform to the following:-

Moisture	2½ to 3½%
Green Strength	110 to 165 kN/m²
Shatter Index	70 to 80
Compactibility	38 to 42%

The intended method of filling and discharge should be described and these facilities should be supplied with the mixers (e.g. batch hopper above mill [not a weighing unit] and a surge hopper 1½ times mixer capacity under the mixer, this hopper being fitted with a rotary table discharge).

Supporting structures and operators' platforms must be provided with the mixers.

8 .13 Moisture Control Equipment

It will be necessary to specify an automatic moisture control system to be installed at the final sand mixer. This should be operated on the electrical capacitance principle and will also measure the sand temperature before automatically operating the water valve to admit the required amount of water to the mixers.

8.14 Aerator

A sand aerator should be specified for installation over the belt conveyor which transports prepared sand to the moulding machine. The unit should be of the overband type and should be fully enclosed to prevent sand spillage. The blades should be adjustable for height above the belt conveyor.

It is considered to be prudent to provide for additional sand cooling by the use of liquid nitrogen. This should be applied to the sand whilst it is being conditioned in this aerator unit. This is intended as a standby cooling method which will only be brought into operation if the sand temperatures rise to excessive levels. The equipment should include temperature sensors which trigger the nitrogen spray at a pre-set temperature (designed to give a maximum temperature of 45° to 50°C at the moulding machine). The liquid nitrogen will be stored in a vacuum insulated vessel and this will be connected to the spray via an insulated pipe and suitable valving.

8 .15 Dust Extraction Equipment

A dust extraction system should be specified for the sand plant to provide ventilation at all points where dry return sand is being transferred or is being disturbed such that airborne dust may be generated e.g. at conveyor belt discharges, the cooling drum, mixers, shakeouts etc. The minimum rates of extraction applied at each point must be sufficient to comply with local factory regulations and codes of practice. In the case of the cooler drum the ventilation is serving a dual role of controlling airborne dust and of inducing evaporative cooling of the sand. The extraction rate will be governed by the design of the drum to be installed.

A wet collector system should be used to clean the extracted air and an induced spray design should be specified. If eliminator plates are to be used these should be readily accessible for cleaning purposes. Alternatively, a wet collector could be installed which is designed to operate without eliminator plates. The exhaust from the fan unit should preferably be fitted with a silencer.

Ductwork is necessary to connect the extraction points with the dust collector which is to be placed outside the foundry buildings. It should be specified that the entire extraction system should be of robust construction and capable of withstanding conditions associated with a sand plant environment. The ductwork material should conform to the following minimum specification:-

Up to 200mm diameter	-	1.2mm mild steel
200mm to 450mm diameter	-	1.6mm mild steel
450mm to 750mm diameter	-	2mm mild steel

All ductwork should be galvanised. Connections between plant and pipework should be by means of bolted flanges except for ducting less than 200mm diameter which may be slip jointed. All ductwork must be provided with access doors at regular intervals not exceeding 4m and so placed to allow the interior of all ducts to be reached for cleaning purposes. Blast gates should be provided in the ductwork to enable the whole system to be balanced.

8 .16 Sand Plant Control Unit

A control unit should be specified for the sand plant based on a programmable micro-computer. This unit will automatically control the operations of all sections of the sand plant including the proportional weighing, moisture additions, ventilation and sequencing of the various items. A mimic diagram should be provided to indicate the state of the sand plant operation and a VDU should be incorporated to indicate the control data, the prevailing temperatures, fault diagnosis etc. The unit can incorporate a print-out if desired to record the output details and materials in store throughout the shift.

9. CORESHOP

9.1 Coremaking Process

9.1.1 MECON Proposals The MECON Report refers to the use of hot box, shell and cold set processes, with coreshooters capable of making hot box and shell cores being provided. Cores are to be assembled on assembly jigs and an infra-red drying oven provided for drying of cores after application of wash.

Comment is made on the need for high quality cores, strong enough to withstand handling and resist erosion and deformation by metal during pouring. Reference is made to the need for the cores to be stable with a minimum of contraction and expansion, and sufficiently low in residual gas forming material to prevent excess gas from entering the metal. Provision must be made for venting of gases and the core must collapse after the metal solidifies, to minimise strains on the castings and to facilitate removal of the cores from the casting during knockout. Reference is made to the high degree of accuracy and very high production rates achieved by using hot box, shell and cold set processes. It is envisaged that shell cores will be used for thin delicate cores and some hollow cores. Solid cores are likely to be made by the hot box process, using mandrels to hollow out some of the cores. The cold set process envisaged by MECON is a phenolic urethane three part system containing a phenolic resin, an isocyanate component and a liquid catalyst.

9.1.2 APCCL Proposals APCCL originally proposed the use of the shell and the vacuum warm box processes. Subsequently, it has stated a preference for the alkyd resin (cold setting) process, as the best of the presently available systems in India. A phenolic alkali setting process and a phenolic gas-hardening process were considered as alternatives, in that order of preference.

9.1.3 BCIRA Comments For the major class of work to be made in this foundry, i.e. high-quality, intricately cored castings, processes and facilities must be selected to provide accurate, consistent cores. The optimum process for any given core, however, is dependent on many factors, including the size, shape and strength requirements, the ease of removal of gas, the support areas available, the accessibility for the removal of core sand from the casting, and so on. For that reason, it is desirable to provide this foundry, whose precise product mix is yet to be determined, with the capability of making cores by any of several different processes.

The hot box and shell processes are both well proven and are satisfactory for the production of cylinder blocks and heads, as well as for many less demanding applications. Equipment for their use should be provided.

The vacuum warm box process is much less used, and appears to offer little advantage to APCCL. It is based on a furan warm box binder catalysed by the cupric salt of paratoluene sulphonic acid. The polymerisation of the resin binder is accelerated by heat from the box and by the application of a vacuum. Whilst lower corebox temperatures are used than for hot box and shell, the process has the disadvantage of requiring a suitable vacuum pump, tank and filter. The maintenance of such equipment in a foundry environment can be problematic, and variations in vacuum can lead to undesirable changes in the strength of the cores produced.

The alkyd resin process would be totally unsuitable for the cores required in medium or large quantities, since strip times in the order of 60 minutes are involved. Thus, from one corebox, only about seven cores could be produced in one shift. Similarly, the phenolic alkali setting resin process is far too slow to be of use for other than very small quantity production.

There are, however, several modern processes based on gas-hardening of cores in unheated coreboxes. The amine-hardened polyurethane process (typified by Ashland's Isocure cold-box process) and the phenolic resin, volatile ester-hardened processes (e.g. Borden's Betaset process) are both satisfactory for many types of cores. Either could prove useful in this foundry, the former being already well established throughout the world, but the latter having the advantage in this instance of being less affected by moisture in the sand or air. This is believed to be APCCL's third choice process. So far as equipment is concerned, the main difference is in the type of gas generator required, hence it is unnecessary at this stage to decide between the two processes, although BCIRA would anticipate that the newer, phenolic resin volatile ester-hardened method would ultimately be chosen.

For cores required in very small quantities (e.g. for large castings and prototype work) some form of cold-setting process is required, as indicated by both MECON and APCCL. BCIRA would recommend that these cores be made, not in the coreshop but on the line provided for air-set moulding, where most of them are likely to be required. (If sand reclamation were to be successfully practised on this line, it would be necessary to make the cores in the same material as the air-set moulds). This could be the phenolic urethane system suggested by MECON, the phenolic alkali setting process mentioned by APCCL, or a furan resin system. In view of the rapid developments which are taking place in such processes, and the fact that very similar plant and equipment is required, a decision on which particular process should be used need not be made at this time.

9 .2 Core Production Machinery

BCIRA is proposing that the bulk of the cores required are produced on coreshooters situated on the ground floor of the coremaking area in the main foundry building. Sand will be supplied from mixing units placed at a higher level. It is likely that most of the cores, including the majority of those used for cylinder block and head production will be made by one of the gas-hardened cold processes. Water jacket cores and others virtually totally surrounded by metal would be better produced by the shell or hot box processes.

9 .2.1 General Specification for Core Production Machinery

.2.1.1 Coremaking Machines As stated previously the bulk of the core requirements should be produced by a gas-hardening process and it is suggested that the following specifications be used to obtain tenders for the necessary equipment:-

Four coreshooting machines capable of automatically producing cores up to 12 litres, together with gas generators, are required. Cores will be produced from vertically jointed coreboxes up to a maximum size of 350mm height x 650mm length x 300mm thickness (i.e. two halves each 150mm). Each machine shall be designed to eject cores onto a horizontal belt conveyor which will carry the cores to the machine operator and should be long enough to allow core inspection and dressing to be done along its length. The operating pressure on the machine should range between 6 and 8kg/cm^2 and the machine should be supplied with guarding to suit local and state regulations. Arrangements need to be incorporated to remove any fume produced and carry it to a suitable gas cleaning device before ejection to atmosphere. Ancillary equipment for blowing off, spraying etc., shall be provided on each machine.

Two coreshooting machines capable of semi-automatically producing cores up to 25 litres, together with gas generators are required. These machines shall be of the two station type which allows the operator to remove one set of cores from the corebox whilst the second corebox is being blown and gassed. The machines should be capable of working with either vertically or horizontally jointed coreboxes of the following maximum sizes: 900mm length x 700mm width x 500mm height. Corebox clamping facilities need to be provided for vertically jointed coreboxes which shall have the following maximum dimensions: 700mm length x 600mm width x 500mm height. The operating pressure on the machines should range between 6 and 8kg/cm^2 and the machines should be supplied with guarding to suit local and state regulations. Arrangements need to be made to remove any fume produced and to pass it through suitable gas cleaning equipment before ejection to atmosphere. Ancillary equipment for blowing off, spraying etc., shall be provided on each machine.

Some cores will need to be provided by hot process and the following general specification should be used to obtain tenders:-

Two coreshooting machines, 25 litres capacity, equipped to produce cores in either hot box or shell materials, and fitted with a facility to remove cores on forks. The machines should be designed to operate with horizontally jointed coreboxes with maximum sizes: 880mm length x 640mm width x 350mm height (175 + 175). The operating pressure on the machines should lie between 6 to 8 kg/cm^2 and the machine should be supplied with guarding to suit local and state regulations. Ancillary equipment for blowing off, spraying etc., shall be provided on each machine.

NOTE - All of the machines supplied must be fitted with air filters, lubricators and an air receiver sized to store sufficient compressed air for at least two cycles. On the machines supplied for use with cold box materials, air drying equipment must also be supplied.

9 .2.1.2 Coresand Mixing Equipment For mixing the coresand, to be used on the coreshooters, it is recommended that continuous feeder mixers be used and the following general specification should be used to obtain tenders:-

Two continuous feeder mixers rated at 4 tonnes per hour are required, one to prepare sand mixes for use with cold set gas-hardening materials and the other to prepare sand mixes using hot process material. The machines shall be equipped with pumps for binder additions each pump capable of variable delivery rates. The mixing troughs shall be supplied with easily removable mixing shafts, carrying a series of adjustable and interchangeable blades, and shall also be designed for easy access for cleaning. The mixer bases shall be of a substantial fabricated design and shall contain the switchgear, air filter and lubricator together with the pumping system. Easy access to the pumping system shall be provided.
The materials used in pump manufacture must be resistant to corrosive liquids.

10. CASTINGS EXTRACTION AND COOLING

10.1 Extraction

Originally, APCCL envisaged the use of a special castings extractor to remove hot castings from the moulds and transfer them to an automatic temperature profile controlled cooler. However, upon further consideration, the Company has decided that the development work and time involved in bringing the latter concept to a practical and satisfactory conclusion, for a foundry devoted to short series production, would be too great. It has therefore been concluded that castings extraction can best be achieved by means of a manually controlled, hydraulically powered manipulator. This is a tried and proven approach with which BCIRA concurs.

10.2 Automatic Temperature Profile Controlled Cooler

The MECON report proposed the installation of a bogie type heat treatment furnace of 1000°C capacity with a $2m^2$ hearth. This unit is to be installed in the fettling shop for the heat treatment of castings as required.

The original APCCL scheme involved the installation of a special purpose automatic temperature profile controlled cooler. It was intended that castings should be taken from the moulds by a robot whilst still very hot (say 900°C) and should be fed directly into the continuous furnace with the minimum loss of temperature. During progress through the furnace the castings would be subjected to a predetermined temperature/time cycle with the object of creating the necessary conditions for annealing or stress relief treatment.

The purpose of such a procedure would be to save the fuel required to re-heat the castings to high temperatures. It would also mean that the heat treatment of castings could be provided without the direct manual handling for loading and unloading such as would be required for the operation of conventional heat treatment furnaces installed in a fettling shop.

However, whilst the potential savings in fuel and handling are evident in theory, there appear to be substantial practical difficulties in the operation of this concept.

It is considered unnecessary to heat treat the cylinder blocks and heads and other grey iron castings provided that adequate 'in mould' cooling can be designed into the moulding plant. Furthermore, a large proportion of the SG iron production can be produced 'as cast' without heat treatment. Heat treatment may therefore only be required for say 20% of the output.

The continuous controlled profile cooling furnace would have to be provided with the full capacity to cater for the complete hour by hour output of the moulding machine.

The castings would be placed into the profile controlled cooler with core materials inside and with varying amounts of sand adhering to the outside. This would interfere with the control of the cooling profile. The loose sand would also have to be allowed for in the design of the furnace. The robot loader would have to transfer a variety of castings shapes and might sometimes be required to pick up several castings from the same mould.

The special cooling furnace would need to deal with castings with runner systems attached, whereas when operating a conventional furnace the load can be packed to offer a dense mass and to reduce casting distortions.

The controlled temperature cooler is rarely to be found in foundries and heat treatment is normally carried out at the fettling stage as suggested by MECON. The decision by APCCL not to pursue the controlled temperature cooler is therefore endorsed.

10.3 Heat Treatment

It is recommended that batch treatment furnaces should be installed and that these should take the form of two hearths with a single heated cover which is transferred from one to the other by crane. This 'top hat' type of furnace allows one hearth to be unloaded and repacked with castings whilst the castings on the other hearth are being heat treated. This offers a good furnace utilisation but the shop crane must be of sufficient capacity to carry out the transfer of the furnace top, and the building height must be such as to accommodate this transfer.

This furnace should be designed to heat treat 7 to 10 tonnes of castings per day.

10.4 Costs of Major Items of Equipment

Manipulator for castings extraction	£ 40,000.00
Heat treatment furnace: two hearths and single cover	£ 42,000.00

11. FETTLING AND FINISHING

11.1 MECON Proposals

This scheme is based on a fettling shop consisting of a single bay 18m wide x 66m long (1188m^2). This bay, which is detached from the main foundry building, is to be covered with a 3 tonne gantry crane (floor operated). The area is progressively allocated to core removal, shotblasting, fettling, heat treatment, inspection and despatch. The proposed facilities are designed to cater for 6000 tonnes per annum on a two shift basis.

The following equipment is to be installed:-

Cleaning & Fettling

One decoring shake out with rubbish disposal.

One hanger type airless shotblast 2 tonnes/hour, weight per hook 500kg.

Two lengths of roller conveyor.

Two 400mm dia swing frame grinders.

Four 400mm dia pedestal grinders.

Six pneumatic chipping hammers.

Six pneumatic hand grinders 100mm dia wheel.

Two manipulators for castings 200kg.

One bench grinder 150mm wheel dia.

The fettling work stations are to be installed within cabins for environmental control.

Inspection & Despatch

One DC arc welding machine 21 KVA.

One bogie hearth heat treatment furnace ($2m^2$ hearth area).

One C1 surface plate 1.6m x 1.0m.

Set of inspection tools.

One painting booth with handling facilities.

One hydraulic pressure testing unit.

One hydraulic press for straightening (50t).

11.2 APCCL Proposals

The fettling scheme put forward is based on the provision of a separate fettling building consisting of two parallel bays.

One bay is 15m wide and 66m long the other is 15m wide by 36m long (total area $1530m^2$). A 3 tonne cab operated gantry crane is proposed for the larger bay which is allocated to casting, cleaning, fettling and despatch. The other bay is to be devoted to inspection, heat treatment and despatch. The fettling layout is designed to process 9000 tonnes per year employing a two shift operation.

The equipment proposed for this fettling section is as follows:-

Cleaning & Fettling

One decoring shakeout, 3 tonne capacity with rubbish disposal.

One hanger type airless shotblast 2 tonnes/hour, minimum 30 hooks at 400kg capacity.

One table room shotblast 1tonne/hour, for heat treated work.

One roller conveyor or steel apron conveyor with rotating table and two manipulators to be installed at the discharge end of the hook shotblast machine.

One manipulator, vertical axis for cut-off.

One special purpose cut-off machine with carriage, jigs and horizontal table.

One GF wedge type runner breaker.

One right-angle cut-off grinder (electric, high frequency portable).

Two swingframe grinders with hydraulic pressure exerters 400mm dia.

Two sets of pneumatic chipping hammers and tools.

Two pedestal grinders with pressure exerters.

One pallet tilting device.

Two sets hand fettling tools.

Two sets pneumatic chipping hammers and tools.

One bench grinder (150mm dia wheel).

Heat Treatment

One bogie hearth type heat treatment furnace, hearth area 2m², (with 10 annealing boxes).

One austenitising salt or oil bath.

One set DC arc welder.

One set gas welding equipment.

One straightening press 50 tonnes capacity.

Inspection & Despatch

One set of inspection tools.

One CI surface plate 1.6m x 1m.

One weigh scale 2000kg capacity.

One hydraulic pressure test unit.

The fettling stations were to be installed in separate cabins to provide better environmental control.

APCCL has modified its views somewhat since the initial report and it is now proposed to provide a heat treatment facility adjacent to the moulding plant.

Cylinder blocks and heads would be transferred to this heat treatment furnace. These castings would then be loaded onto an overhead hook cooling conveyor by means of a manipulator. The conveyor would carry the castings to the decoring grid. The runner systems would be removed with the GF wedge unit and the castings passed to the hook shotblast by shaking conveyor.

Other castings would be placed into containers by a manipulator and allowed to cool. The cooled castings would be emptied into a shaking conveyor for runner removal and then passed directly to the proposed hook shotblast.

The hook shotblast would be located adjacent to the moulding bay and would be fitted with a manual spot shotblasting facility.

It is proposed to retain only the GF wedge runner breaker and a vertical axis manipulator from the special purpose fettling equipment which was planned earlier.

Air on air pressure testing is now proposed for cylinder heads and blocks, a small furnace is proposed to heat castings prior to reclamation by welding.

Facilities for dimensional checking are considered to be important but the proposed hydraulic straightening press is to be deleted.

The Company now proposes that the plant should be operated on two shifts rather than three shifts.

11.3 Comments on the Proposed Schemes

The MECON layout is intended for a throughput of 6000 tonnes per year on a two shift basis whereas the APCCL scheme is designed to process 9000 tonnes per year also on a double shift operation.

11.3.1 Cleaning Castings The MECON proposal for moving castings from the knockout to the cleaning station by fork truck in box pallets is considered to be more satisfactory than the APCCL scheme which involved heads and blocks being heat treated and then carried on an overhead chain conveyor to cool. However, it would be desirable to keep the shotblast cleaning separate from the main fettling activities as proposed by APCCL. This enables the dirtier operations to be kept away from fettling and inspection activities.

It is recommended that after the shake out castings should be discharged onto a vibrating conveyor. Runners should be detached at this unit by hand and the castings should be loaded into bins which are taken to a cooling area by fork lift truck. The cooled castings will then be taken to the shotblast units for cleaning.

A hanger type of shotblast has been selected for use in both schemes but in the case of APCCL a rotary table unit is to be installed in addition to a hook plant.

The hook type of shotblast is considered to be the most effective type of unit for the proposed block and head production. It is also considered that the manual spot-blasting facility proposed by APCCL could be useful for cleaning certain difficult castings.

It is recommended that the hook plant should have a decoring capability. A secondary shotblast could take the form of a tumble-blast type of unit rather than a rotary table. This should also have a decoring facility and be of sufficient size to accept a full bin of castings for each batch load. The tilting loader on these machines can be designed to receive a bin of castings which is directly placed into the tipping unit by a fork lift truck. Unlike the hook or rotary table plants, the tumble-blast unit requires no manual handling of individual castings. Certain shapes of castings including blocks and heads could sustain damage in the tumbling action in the shotblast chamber but it would be possible to safely clean a large proportion of the proposed output in such a unit.

On the basis of 9000 tonnes of castings per year it is considered necessary to provide shotblast capacity for the following quantities of castings:-

	Tonnes per Year
1st Blasting of output (castings and running system)	17500
2nd Blasting where necessary, e.g. cylinder blocks, heads, heat treated castings etc.	7500
	25000 tonnes

If the foundry is manned for 288 days per year on double shift operation this is equivalent to an average hourly throughput of 5.2 tonnes. If a utilisation of 75% is anticipated then an hourly capacity of about 7 tonnes must be provided.

A shaking device should be installed near to the discharge of the hook shot blast unit. This equipment will be used to dislodge core material and loose shot which is trapped within the water passageways of the cylinder head castings.

11.3.2 Runner Removal The bulk of the grey iron runner systems will become detached from the castings in the knockout unit and any that remain attached will be easily removed with a hammer.

A large proportion of the SG iron runners will be removable by hammer blows but the remainder will require some provision for a cut off process stage.

There appear to be no special facilities in the MECON scheme for cutting off SG iron runner systems. The original APCCL scheme made various provisions for this operation but it is now proposed to provide only a GF hydraulic wedge breaker and a simple vertical axis manipulator.

BCIRA considers that it will be necessary to install cut-off facilities and it would be an advantage to provide not only a GF wedge type breaker, but also an abrasive disc cutter. By employing breaker cores under some feeder heads their subsequent removal can be greatly simplified.

11.3.3 Fettling The fettling equipment to be installed in both schemes consists of swingframe grinders, pedestal grinders and portable grinders which are air operated in the case of MECON and high frequency electric in the case of APCCL. The MECON scheme has four pedestal grinders and six sets of portable grinders. Both schemes envisage the use of pneumatic chipping hammers. The MECON layout has eight fettling cabins whereas the APCCL layout has four severing cabins and six cabins for fettling operations.

For the face grinding of cylinder blocks and heads, an automatic grinding machine is highly desirable. Such equipment is expensive and is normally only justifiable where very large quantities of castings are to be processed. However, in this instance APCCL's objective is to produce castings of the highest possible quality and dimensional consistency for machining on machining centres.

Automatic fettling machines are also available for grinding the outside of circular castings and such a machine should be provided.

It is considered that pedestal grinders should be fitted with 600mm dia wheels rather than the 400mm dia wheels specified in the reports. The pressure exertion devices for the work pieces, mentioned in the APCCL report, are recommended.

Regarding portable grinders, the depressed centre disc angle grinder is a most versatile fettling tool and the foundry should be equipped with these grinders having a 230mm dia wheel. Small portable straight grinders should also be supplied for use with abrasive mounted points when internal areas of the castings need to be fettled.

Both schemes visualise two rows of fettling cabins with roller conveyors either running through the cabins or running past the doorways. This method of progressing castings through the various fettling stations can be unsatisfactory. There will be very little buffer storage of castings between operators' stations and there will consequently be a tendency for the slowest operation to dictate the rate at which the work flows. In the APCCL layout there would appear to be unnecessary work involved in carrying castings from the conveyor to the work stations within the cabins.

It is recommended that, initially, one swingframe grinder be provided, mounted within a ventilated booth, and three constant-speed single ended and three double ended pedestal grinders all with dust extraction at the grinding wheels. The hand fettling with power tools should be carried out at two ventilated benches and one ventilated booth. A roller track layout should be devised to give maximum flexibility for cylinder block and head fettling. Such a system allows work to be directed to the various work stations as it is required without causing delays at one position. Such a system is shown in Fig.3 of this report.

For other castings it is suggested that a bin system be used, the bins being moved from one work unit to the next by fork lift truck. The booths should be provided with lifting equipment to deal with heavy castings.

11.3.4 Heat Treatment The MECON layout provides for a bogie hearth furnace to be installed in the fettling shop. The original APCCL scheme included a heat treatment controlled cooling temperature profile furnace in the moulding area plus a bogie hearth unit in the fettling shop. The controlled profile furnace is no longer advocated for the initial development.

This aspect has been discussed in Section and it is recommended that a two hearth furnace should be installed in the fettling shop with a lift off top which is transferred by crane. It is estimated that a capacity of ten tonnes per day should be sufficient.

The austempering of SG iron castings will not be undertaken in the initial phases of the APCCL development and this decision is considered sensible in view of the foreseen slow growth of the market for austempered SG iron. APCCL has decided not to install the hydraulic straightening press and this is endorsed.

11.3.5 Inspection Both proposals incorporate a surface table for jigging castings at the inspection stage. This table is certainly required.

A hydraulic pressure test is advocated by MECON whereas an air in air test is proposed in the amended scheme put forward by APCCL. It is considered that an air in air pressure decay test should be employed for the cylinder blocks and heads. This type of test will segregate the sound castings from the leaking castings. The leakers must be transferred to a hydraulic test to identify the position of the leaks so that remedial action can be taken. The affected area must be ground prior to welding. A small furnace is needed to preheat the leaking castings before they are reclaimed with gas welding techniques.

Impregnation should also be considered for sealing some porous castings. Reclaimed castings should be marked as such.

The inspection department should be equipped to carry out hardness tests, crack tests and other non-destructive testing. APCCL is now considering using natural resonance frequency tests for nodularity and this is endorsed.

Qualifying fixtures should be provided for engine block and head castings with suitable tools for dressing location points.

11.3.6 Painting The two reports suggest the installation of a paint booth with handling facility. This is endorsed.

11.3.7 Despatch It is recommended that the blocks and heads should be stacked onto wooden pallets for despatch and these stacks should be made stable with wire or steel banding. The remaining castings should be despatched in bins or loose, depending on the customer concerned. The shop crane and the fork lift truck can be used for loading lorries. It is recommended that the shop crane should be floor controlled as in the MECON proposals, rather than be cab operated as in the APCCL report.

The area provided for despatch activities appears to be very small particularly for the MECON layout. The APCCL scheme advocated the installation of a weigh scale of 2000kg capacity. This view is endorsed because it is important to maintain a check on casting weights.

12. INSPECTION AND QUALITY CONTROL

12.1 Comparison of Recommendations for Control Laboratory Equipment

See Table 1.

12.2 Comments and Recommendations

12.2.1 Wet Chemical and Rapid Test Laboratories Both schemes propose to equip small laboratories for wet chemical analysis and in the case of APCCL a subsidiary laboratory for rapid tests with LECO carbon and sulphur apparatus is to be created. The carbon and sulphur apparatus for the MECON scheme is to be installed in the wet laboratory.

The equipment proposed for both schemes is quite conventional and rather more detail is supplied for the APCCL scheme. The rapid silicon determinator listed in the MECON equipment is now available from LECO. It is considered that the Electrolyser listed under the APCCL scheme is not necessary for grey and SG iron production control. The gas chromatograph apparatus in the same list would only be required for highly specialised investigations and is not appropriate for installation in a routine laboratory.

The metal analysis provided by a wet chemical laboratory tends to be largely for post-mortem information. Since close control of metal analysis is essential, consideration should be given to installing a spectrographic apparatus. An optical emission spectrometer or an x-ray fluorescence spectrometer could be considered. The latter provides a greater flexibility, but the former is less expensive.

In the interests of minimising the capital expenditure, it is recommended that an optical emission spectrometer be chosen, and this is indicated as a 'complementary' item in BCIRA's equipment list.

If the nature of the available raw material scrap dictates that lead is a critical element in the analysis, then it may be necessary to consider an Atomic Absorbtion Spectrometer. However, this situation is thought to be unlikely. It is necessary to provide permanent moulds for casting the samples.

If a spectrometer is installed it would still be advisable to maintain a small wet chemical analysis facility as a back-up. Apparatus for carbon determination, such as the Leco system, should be installed. It is also strongly recommended that carbon equivalent equipment be installed in the vicinity of the melting furnaces.

APCCL has decided against the installation of a pneumatic post installation for sample transport. BCIRA agrees with this decision.

12.2.2 Metallographic Laboratory Provision is made in both schemes for the preparation of samples for metallographic examination. The MECON scheme and the APCCL facilities provide for grinding, polishing, etching and viewing by a metallurgical microscope with photographic attachment. The APCCL equipment list specifies a more elaborate microscope. The latter is considered unnecessary, since a small bench metallurgical microscope would be quite adequate for normal control purposes and for the investigation of defects. The microhardness tester is not considered to be necessary for the type of work to be undertaken.

It is recommended that a facility for mounting micro samples in Bakelite should be purchased, since this is necessary if edges of castings are to be examined when investigating defects.

12.2.3 Mechanical/Physical Laboratory A mechanical testing laboratory is envisaged in both the reports and a number of items of standard equipment are specified. It is recommended that the impact tester mentioned in the MECON layout should be omitted and that hardness testing could be confined to Brinell hardness.

The sample preparation workshop proposed by APCCL will be necessary principally for machining test pieces, and will need to be equipped with a bandsaw for cutting large castings.

12.2.4 NDT Laboratories The two reports specify a number of items of equipment for non-destructive testing.

It is recommended that the ultrasonic flaw detector should have a frequency range of 0.5 to 5 MHz.

APCCL has proposed, subsequent to its initial report, that natural resonance frequency testing equipment should be installed for assessing the degree of nodularity etc. In principle, this decision is endorsed.

The apparatus which is proposed is manufactured by Novacast AB of Sweden. This Company has marketed a system called SON-A-TEST for some time. A more elaborate system called EXPERTEST is now available. It will be necessary to closely examine the claims made for this newer device before it can be offered as a firm recommendation.

The casting surface comparator listed in the APCCL scheme is a borderline item. The quality of the surface finish of an iron casting presents great difficulties in defining recognised standards. It is possible to purchase surface finish comparator samples (in plastic) for steel castings and it may be possible to make some use of a small number of the defined examples. Surface profile comparators are also sold by Elcometer Instruments Limited, these are intended for shotblast finishes.

It is recommended that the foundry should simply retain examples of some of the castings which it produces to use as a yardstick for the standards obtainable from the plant.

The radio fluoroscopy equipment for real time x-ray which was originally proposed by APCCL would be satisfactory for checking the simple castings but complex castings for cylinder blocks or heads would present considerable difficulties in interpretation. This equipment is extremely expensive and it should be deleted from the NDT lists.

Consideration is now being given by APCCL to pressure testing the engine castings using compressed air inside the casting which will be in air and not a liquid. A measurement of the rate of pressure decay of the charge of compressed air will reveal those castings which are leaking in some way. The suspect castings, only, will then be submitted to a pressure test under water to reveal the extent and location of the leaks for subsequent reclamation. This proposal is endorsed by BCIRA, as a means of speeding up the pressure testing procedure.

It is recommended that a Brinell hardness tester should be listed with the NDT equipment but it is appreciated that such equipment is specified for the mechanical/physical laboratory. A surface table for jigging and dimensioning castings is provided in the fettling equipment lists for both reports, and will be necessary. The remaining equipment which is listed in the NDT section of the APCCL report is considered to be fully appropriate to the proposed foundry.

12.2.5 Sands/Moulding Materials Laboratory The two reports make provision for laboratory facilities to control moulding and coremaking materials.

The list of equipment from the MECON proposals is duplicated in the more extensive list given in the APCCL report, an exception being the compactibility attachment to the sand rammer, which is not part of the APCCL list. It is recommended that a compactibility attachment should be provided. The items in the APCCL list are generally considered to be appropriate equipment for furnishing the sands laboratory. The flowability tester, mouldability tester and the sand fusion tester are not considered to be essential and are regarded as complementary equipment. It is recommended that, in addition to the listed items, a shatter index tester and glassware for clay determination should also be acquired. An apparatus for hot distortion testing for chemically bonded sands should be installed.

The hot distortion test is designed to assess the expansion, susceptibility to cracking, deformation and bending of chemically bonded sands at high temperatures. It would be used for routine control of coremaking materials and also for predicting the likely behaviour of new binders and sand mixtures.

The distortion tester requires a test piece of prescribed dimensions (typically 25 x 6 x 114mm). This can conveniently be produced on a small laboratory coreshooter and it is recommended that a standard test piece blower should be acquired. It is also possible, in some circumstances, to cut a test piece from a flat area of suitable size in a production core.

The test apparatus clamps one end of the test piece and holds it horizontally so that a cantilever load can be applied to the free end. The test piece is then strongly heated under controlled conditions at the centre of the underside. A displacement transducer connected to a chart recorder produces a record of the movement of the free end of the test piece with time.

The displacement curve thus plotted is then interpreted to assess the hot properties of the sand mixture. The characteristics of the curves produced on the graphs will indicate the rate of breakdown, the degree of thermoplasticity and tendencies to high thermal expansion and possible cracking.

12 .3 Suppliers of Foundry Laboratory Equipment

Wet Chemical Laboratory

a) Laboratory Equipment:
Baird & Tatlock, PO Box 1, Romford, Essex.

Gallenkamp, Belton Road West,
Loughborough, Leicestershire LE11 OTR.

b) Carbon & Sulphur Apparatus:

Leco, Hazlegrove, Stockport, Cheshire.

c) Carbon Equivalent Meters·

Leeds & Northrup Limited, Wharfdale Road,
Tyseley, Birmingham B11 2DJ.

d) Pyrometers:

Land Pyrometers Limited, Wreakes Lane,
Dronfield, Sheffield S18 6DJ.

Spectrographic Equipment

Applied Research Laboratories Limited,
Wingate House, Wingate Road,
Luton, Beds LU4 9PU.

Hilger Analytical Limited, Westwood,
Margate, Kent CT9 4JL.

Pye Unicam-Phillips, York Street,
Cambridge CB1 2PX.

Universal Testing Machine

Avery-Denison Limited, Moor Road, Leeds LS10 2DE.

Metallographic Laboratory

a) All Metallographic Materials and Equipment:

Buehler UK Limited, PO Box 150, Coventry CV4 9XJ.

b) Microscopes:

Olympus Optical Co. (UK) Limited,
2-8 Honduras Street, London EC1 YOT.

Olympus Metallurgical Binocular Microscope X.
Olympus Projection Microscope PME.

NDT Laboratory

a) Flaw Detection Equipment:

Ardrox Limited, Furlong Road,
Bourne End, Buckinghamshire SL8 5AX.

Magnaflux Limited, South Dorcan Industrial Estate,
Swindon, Wiltshire SN3 5HE.

b) Pressure Test Equipment:

A1 Industrial, London Road,
Pampisford, Cambridge CB2 4EF. (Pressure Decay)

Gibson Engineering, Brunswick Industrial Estate,
Brunswick Park Road,
Wednesbury WS10 9QR. (Hydraulic Test)

c) Surface Finish Comparators:

Steel Castings Research and Trade Association,
5 East Bank Road, Sheffield S2 3PT.

Elcometer Instruments Limited, Edge Lane,
Droylsden, Manchester M35 6BU.

Moulding Material Laboratory

Laboratory Equipment:

Ridsdale & Co. Limited, Newham Hall,
Newbury, Middlesbrough, Cleveland TS8 9EA.

TABLE 1 - CONTROL LABORATORY EQUIPMENT

MECON REPORT	APCCL PROPOSALS	BCIRA RECOMMENDATIONS
WET CHEMICAL LABORATORY	**WET CHEMICAL LABORATORY**	**WET CHEMICAL LABORATORY**
Carbon & Sulphur apparatus and accessories Electric muffle furnace Water distillation still Chemical balance Pan balance Bench drill 13mm capacity Rapid silicon determinator Laboratory racks and glassware	Carbon & Sulphur measuring devices Two laboratory hot plates Water distillation still Chemical balance Pan balance Titrimeter pH meter Electrolyser Gas chromatograph Viscosimeter Laboratory agitator Laboratory racks and glassware Mechanical bulk burette Spectrocolorimeter	Carbon & Sulphur measuring equipment Two laboratory hot plates Water distillation still Chemical balance Pan balance Titrimeter pH meter Viscosimeter Laboratory agitator Sinks and fume cupboards Laboratory racks and glassware Bench drill Mechanical bulb burette Spectrocolorimeter
PHYSICAL ANALYSIS	**PHYSICAL ANALYSIS**	**PHYSICAL ANALYSIS**
-	-	Optical emission spectrometer (C) Thermal analysis equipment
METALLOGRAPHIC LABORATORY	**METALLOGRAPHIC LABORATORY**	**METALLOGRAPHIC LABORATORY**
Microscope with photo attachment Specimen polisher and accessories Belt surfacer	Photographic microscope Microhardness tester for above Specimen polisher Wet grinder Developing equipment	Microscope with photo attachment Specimen polisher Wet grinder Mounting equipment for samples Sink, glassware, dryer for etching samples Developing and printing equipment
MECHANICAL TEST LABORATORY	**MECHANICAL TEST LABORATORY**	**MECHANICAL TEST LABORATORY**
Universal test machine, 40 tonnes Brinell hardness tester Impact testing machine	Universal test machine, 40 tonnes Test specimen marking machine Brinell and Vickers hardness tester Benches, cabinets, shelves, tables etc.	Universal test machine, 400KN Brinell hardness tester 300kg Small bench grinder Benches, cabinets, shelves, tables, etc.
SAMPLE PREPARATION AND WORKSHOP	**SAMPLE PREPARATION AND WORKSHOP**	**SAMPLE PREPARATION AND WORKSHOP**
-	Centre lathe Universal milling machine Vertical drill Shaping machine Mechanical hacksaw Pedestal grinder	Centre lathe Universal milling machine Vertical drill Shaping machine (C) Mechanical hacksaw Pedestal grinder Bandsaw

TABLE 1 - CONTROL LABORATORY EQUIPMENT - CONT'D

MECON REPORT	APCCL PROPOSALS	BCIRA RECOMMENDATIONS	
NON-DESTRUCTIVE TEST LABORATORY	**NON-DESTRUCTIVE TEST LABORATORY**	**NON-DESTRUCTIVE TEST LABORATORY**	
Ultrasonic flaw detector	Ultrasonic flaw detector	Ultrasonic flaw detector	
Dye penetrant testing equipment	Dye penetrant testing equipment	Dye penetrant testing equipment	
	Magnetic particle crack detector	Magnetic particle crack detector	
	Two casting surface comparators	Casting surface comparator	(D)
	Two endoscopes	Two endoscopes	
	BCIRA bloctector	Equipment for checking passageways	(C)
	Real time radiology equipment	Hydraulic test for cylinder blocks	*
	Hydraulic test for cylinder blocks	Pressure decay test	(C)
	Pressure decay test	Nodularity test for SG iron	(C)
MOULDING MATERIALS LABORATORY	**MOULDING MATERIALS LABORATORY**	**MOULDING MATERIALS LABORATORY**	
Sieve shaker and sieves	Sieve shaker and sieves	Sieve shaker and sieves	
Sand mixer	Sand mixer	Sand mixer	
Drying oven	Drying oven	Drying oven	
Universal strength tester	Universal strength tester	Universal strength tester	
Permeability meter	Permeability meter	Permeability meter	
Rapid moisture teller	Rapid moisture teller	Rapid moisture teller	
Sand rammer	Sand rammer	Sand rammer and compactibility attachment	
Flowability meter	Flowability meter	Flowability meter	(C)
Mouldability tester	Mouldability tester	Mouldability tester	(C)
Hot shell tensile tester	Hot shell tensile tester	Hot shell tensile tester	
Mould hardness tester	Mould hardness tester	Mould hardness tester	
Compactibility tester	Hot distortion tester	Hot distortion tester	
	Sand impact penetration tester	Sand impact penetration tester	
	Sand fusion point tester	Sand fusion point tester	(C)
	High temperature furnace	High temperature furnace	
	Methylene blue test for clay	Glassware for clay determination	
	Gas evolution tester	Gas evolution tester	
	Shell peel back tester	Shell peel back tester	
		Shatter index tester	
		Standard test piece blower	

KEY:

C - Complementary equipment
D - Additionally desirable equipment

All other equipment listed above is regarded as essential to establish satisfactory control.

* This item is likely to be installed in Inspection Department.

13. THE USE OF SEMI-AUTOMATIC ULTRASONIC TESTING EQUIPMENT FOR CYLINDER HEAD CASTINGS

The application of ultrasonic testing is a very valuable foundry technique for detecting hidden internal defects at critical locations in the castings. It can also provide a means of measuring the wall thickness of hollow castings in specific areas which might be difficult to reach with mechanical calipers.

Unfortunately, when an ultrasonic test is carried out manually, it requires considerable skill and operator time to obtain reliable results. The handling of the ultrasonic probes requires experience and skill by the inspector to obtain a proper coupling to transmit the ultrasonic energy. A great deal of experience is also necessary to correctly interpret the display given on the test screen. The operator must be assured that the discontinuity signal is due to an internal defect and not to some effect of surface roughness or the shape of casting.

In the case of cylinder head castings or other similar castings which are required in large batch quantities, it has been shown to be practicable to design a test rig which will enable a specific set of ultrasonic tests to be carried out quickly and accurately on a semi-automatic basis. The test apparatus can be arranged so that the degree of skill required by the operator is reduced to a minimum.

In order to 'deskill' the operation in this way, it is necessary to make it easy to obtain a satisfactory couple between the ultrasonic probe and the as-cast surface and also to automatically interpret the trace to provide information on the presence or otherwise of an internal defect.

The desired satisfactory couple can be obtained by partially immersing the casting in liquid, with the face from which inspection is to be carried out placed downwards below the level of the liquid. The cylinder head castings can thus be supported such that the liquid does not enter the passageways. When in this position, it is necessary to operate the probe within the liquid underneath the casting. Since the probe is thus hidden from view, it is necessary to provide a remote control system to enable the probe to be moved from one test area to another. A template or facsimile of the surface of the casting under test is provided for guiding the remote control linkages.

Many commercial ultrasonic sets have a 'gate' which causes an alarm to sound if an ultrasonic signal is detected outside an adjustable level at a chosen position in the display. In this way the operator's attention may be drawn to the presence of the defect. To apply this system to the semi-automatic test rig,it is modified by passing the signal from the 'gate' unit through a logic circuit so that the operation of the alarm is prevented unless the probe is positioned in an area in which inspection is required and in addition there is a reflection corresponding to a defect within this area. The logic unit is fed by a signal derived from a proximity detector sensing the presence of metal sheets in the facsimile at the critical test areas.

For maximum sensitivity, a specially designed waterproofed double probe is used in conjunction with an adjustable spacer to provide a water gap between the probehead and the casting surface.

The test rig should be provided with suitable mechanical handling equipment to feed the castings into and out of the test tank.

It is recommended that a semi-automatic ultrasonic test unit should be provided for testing cylinder head castings in the proposed foundry.

One Company known to be able to supply such equipment is:-

Wells Krautkramer Limited,
Castle Vale Industrial Estate,
Maybrook Road,
Minworth,
Sutton Coldfield,
England B76 8AY.

14 RAW MATERIAL CONSUMPTION AND STORAGE FACILITIES

14.1 Estimates of Raw Material Consumption Per Annum

	TONNES PER ANNUM		
	MECON[+]	APCCL	BCIRA
14.1.1 Moulding and Core Materials			
New Sand	8500	18300	14000
Resins & Catalysts	82	123	390
Bentonite	640	960	1150
Coaldust	320	263	1150
Pre-coated Shell Sand	1000	1200	600
14.1.2 Fettling Materials			
Shot	Nil	100	300
Grinding Wheels	Nil	15	20
14.1.3 Metal Materials			
Pig Iron	1080	1020	8750
Steel Scrap	5200	8400	1000
Calcium Carbide	30	45	75
Ferro Silicon 45	220	210	140 [*]
Ferro Chrome		120	70 [*]
Ferro Silicon Magnesium	80	120	70 [*]
Carburiser	260	390	175 [*]
14.1.4 Refractory Materials			
Furnace Lining Refractory	324	35	120
Ladle Lining Refractory	180	415	500
M/S/Asbestos/Mica Sheet	10	12	12

[+] Based on 6000 tonnes castings per annum; APCCL and BCIRA estimates based on 9000 tonnes of castings per annum.

[*] Dependent on pig iron analysis - 14 grades in Indian Specification 224/1979.

NOTE - With current relative prices of pig iron and steel scrap, it is assumed that a 50% pig iron charge will provide overall economy.

14.2 Storage Facilities of Raw Charge Materials

In the BCIRA layout suggested, shown in Fig.1, four pens each measuring approximately 6m x 4-1/4m x 4m in depth (2.5m below ground level, 1.5m above), have been provided for the storage of pig iron. It is estimated that these storage pens will store approximately 1500 tonnes of pig iron which is equivalent to two months storage on the basis of an annual usage of 8750 tonnes.

Two pens of a similar size have been provided for steel scrap, and these pens will hold approximately 275 tonnes which is equivalent to about three months storage assuming a usage of about 1000 tonnes per annum.

Two further pens have been provided, again of a similar size, for the storage of return scrap. These pens will hold approximately 360 tonnes of return scrap which is equivalent to about two weeks storage assuming a usage of about 7750 tonnes per year.

14.3 Sand Storage

It has been estimated that approximately 14000 tonnes of sand will be consumed each year, of which 13000 tonnes is to be used for coremaking, which is equivalent to approximately 44 tonnes per day. The intention is to buy moist sand, which will need drying before it is used in the coremaking or Air Set moulding processes. It is planned by APCCL to utilise the 'greenhouse' principle of drying but the amount of sand involved is rather high for such a process. Consequently it may well be necessary to install some facility for drying the sand in addition to that already proposed by APCCL, or to purchase pre-dried sand.

If it is assumed that storage is required for approximately one week, then 296 tonnes of sand need to be stored in localised hoppers/bunkers. Such a quantity of sand would occupy a volume of about 190 m^3 and bunker storage for such a quantity needs to be provided within the site. The site plan, Fig.4, indicates BCIRA's suggestion as to where this facility should be located.

15. HANDLING SYSTEMS AND EQUIPMENT

15.1 General

The new foundry will be established on a 'green field' site to the east of the main Hyderabad-Medak road. A minor road, traversable by motor traffic,presently passes the site and is scheduled for improvement to serve the foundry and adjacent industries on a shared cost basis as development progresses.

There is a railway line,about 1½km distance, close by the main road but all deliveries and despatches are expected to be by road transport.

It is understood that tipping trucks are relatively few in India, so all materials will be delivered on fixed bodied vehicles.

15.2 MECON Report

15.2.1 The MECON report envisages material receipts of 18100 tonnes per year and despatches of 16500 tonnes per year which will comprise mostly casting deliveries and waste disposal. The waste will be primarily used sand for which part of the site has been allocated as a dumping ground. These estimates are based on an output of 6000 tonnes/year and road transport.

15.2.2 The MECON recommendations with respect to material handling are generalised and restricted to the provision of:-

1 - Tractor.

2 - Trailers.

1 - 3 tonne hydraulic mobile crane.
1 - 2 tonne diesel fork lift truck.
4 - 2 tonne manual pallet trucks.

The handling of moulding sand is principally by means of belt conveyors and bucket elevators.

15.2.3 MECON has also proposed a number of overhead electric travelling cranes and monorail hoists as follows:-

1 No - Cabin controlled OET 5/2 tonne x 10.5m span crane with magnet (Metal stockyard).

1 No - Cabin controlled OET 5 tonne x 13.5m span crane (Melting Shop).

1 No - Pendant controlled single girder OET 5 tonne x 19.5m span crane (Moulding machine).

1 No - Pendant controlled single girder OET 3 tonne x 19.5m span crane (Core Shop).

1 No - Pendant controlled single girder OET 3 tonne x 16.5m span crane (Fettling Shop).

1 No - Pendant controlled single girder OET 1 tonne x 4m span crane (corelaying).

1 No - Monorail cabin controlled Telpher 1 tonne with grab. (Raw sand handling).

2 No - Monorail pendant controlled hoist block 2 tonne capacity.

The report contains no specific recommendations for handling of the various materials.

15.3 APCCL Review

15.3.1 APCCL has reviewed the MECON proposals and has proposed some alterations to their recommendations together with a more detailed examination of how the required materials movement is to be achieved. The following section is a resumé of APCCL's views for the main areas of technology.

15.3.2 Materials will be delivered to site by road vehicles, all deliveries will pass over a weigh-bridge on arrival. A good network of internal site roads will permit goods and materials to be delivered to the appropriate unloading points. Since tipping lorries are not common in this part of India, bulk materials will be unloaded by cranes or manually. All other materials will be delivered in packages, sacks or barrels, on pallets wherever possible, for unloading by fork lift trucks.

15.3.3 Metallic charge material will be unloaded by OET crane equipped with an electro-magnet and transferred to storage bunkers in the stockyard. This crane will also transport raw materials to a batch hopper which will load 1 tonne drop bottom charge buckets. These buckets may be transported to the furnaces by either of the stockyard or the melting bay cranes.

15.3.4 Molten metal is transported to the holding furnace and thence to the automatic pouring furnace by the OET melting bay crane.

15.3.5 Sand is delivered in open road trucks and unloaded manually or by grab crane into storage bunkers. It is then loaded onto the sand plant conveyor belt system by grab crane or manually for transportation to the greensand and coresand storage hoppers.

15.3.6 Prepared and used sand is circulated between the moulding machine and the sand preparation plant by a system of belt conveyors and bucket elevators.

15.3.7 A monorail loop is planned to transport patterns from the pattern store to the moulding machine.

15.3.8 Core sand is mixed on a high level platform and distributed manually to the various machine hoppers by means of a barrow.

15.3.9 Finished cores are stored on racks and transported by OET crane for core assembly.

15.3.10 Fettling will be done in a separate building and castings will be transported to the fettling shop in trolleys. Handling within the fettling shop is in tote boxes or stillages by means of overhead crane, fork lift trucks and roller conveyor.

15.3.11 APCCL envisages a number of overhead electrical travelling cranes and supporting equipment as follows:-

1 No - Cabin controlled OET 3/2 tonnes x 14m span crane with magnet (Metal Stockyard).

1 No - Cabin controlled OET 5 tonne x 11m span crane with crane weigher (Melt Shop).

1 No - Cabin controlled OET 2 tonne x 10.5m span crane (Core Storage and Assembly).

1 No - Cabin controlled OET 2 tonne x 11m span crane with grab (Sand Storage).

1 No - Cabin controlled OET 3 tonne x 14m span crane (Fettling Shop).

1 No - Pendant controlled OET 5 tonne x 13.5m span crane (Moulding Department).

15.3.12 In addition there shall be three fork lift trucks as follows:-

2 No - Diesel engined 3 tonne capacity fork lift trucks.

1 No - Battery, electric 1 tonne capacity fork lift truck.

also -

2 No - 2 tonne manual pallet trucks.

1 No - Diesel tractor.

2 No - Trailers for use with the tractor.

1 No - Diesel engined 'Jeep' type vehicle.

1 No - Passenger car.

15.4 BCIRA Observations

15.4.1 BCIRA observes that the MECON report gives only cursory consideration to materials handling. It is confined to listing the location and capacity of overhead electrical travelling cranes and auxiliary handling equipments such as fork truck, tractor and trailers etc. Specific duties in the various areas are not described, for example, systems for charge make up and metal handling are not developed.

15.4.2 A modern foundry is a complex materials handling problem and much of the economic success of the plant depends upon the selection of the most effective means for ordering the movement of raw materials and products through the plant. BCIRA finds the general approach of APCCL to be better defined than that of MECON and agrees with the bulk of changes suggested by APCCL.

15.4.3 However, BCIRA believes that further improvements can be made in some areas and would make the following proposals in line with the revised plant layout shown in Figs. 1,2 and 3.

15.4.4 The Melting Department would be in line with the metallics stockyard in a common bay served by two cranes each with electromagnets. The duty of the stockyard crane would be to off load incoming raw material and distribute it amongst the storage bunkers. In addition, it would re-stock the day bunkers adjacent to the melting furnaces. The charging crane would collect materials from the day bunkers and charge them directly into the melting furnaces. Charge weighing is best achieved by mounting the melting furnaces on load-cells or alternatively a weighing system can be built into the crane.

15.4.5 A monorail system with two hoists delivers hot metal from the melting furnaces to the holding furnace and from there to the automatic pouring unit. In addition, provision is made for manual pouring ladles to collect metal from the melting furnaces or the holding furnace as a back up for the auto-pour.

15.4.6 New sand for the moulding plant need not be dried and it is proposed that it should be added to the return sand belt after knock-out at a controlled rate as required from a hopper with a drag out belt and adjustable feed. This hopper would be charged using a front end loader on the diesel tractor. Coresand must be dried and screened before use. It is proposed that a solar drying shed is used and after passing through a vibrating screen the dried sand is transported pneumatically to a storage hopper above the coresand mixer. The same requirement exists for the chemically bonded sand used in the 'Air-set' moulding section and sand will be handled in the same way.

15.4.7 The use of bucket elevators in greensand systems is to be avoided wherever possible as these machines are notoriously unreliable. Inclined conveyor belts are preferred where space can be made available. The return sand belt system should be designed to have a capacity two to three times the delivery from the sand mills (ultimate output) to account for surges. Sand coolers and screens need a similar capacity.

15.4.8 A number of mobile racks with wheels and having 'flip-up' shelves is proposed for handling cores and core assemblies. Core machine operators will load cores onto these racks as the cores are made. Cores will then either remain on the racks in storage until put into moulds, or be taken for further processing or assembly. This will eliminate the need for fixed storage racks and the crane proposed for the core assembly area.

15.4.9 To facilitate the laying of complex core assemblies using mould assembly rigs, a light overhead crane must be provided over the moulding machine track.

15.4.10 BCIRA foresees increased use of fork lift trucks for handling castings and other materials within the plant. Diesel powered trucks are to be preferred as battery electric trucks tend to be abused and batteries are often left completely exhausted making rapid charging necessary to bring the truck back into service. A total of five fork lift trucks is recommended, three 3 tonne capacity and two 2 tonne units.

15.4.11 General transport around the site, the removal of waste sand, etc., can be accomplished with an agricultural type diesel tractor and trailers. The tractor should be fitted with a hydraulic pump, a front end loading bucket and the trailers with hydraulic tipping.

16. SHOP LAYOUT AND ANCILLARY BUILDINGS

As indicated in foregoing sections, BCIRA has reviewed the layouts of the foundry and fettling shop prepared by MECON and APCCL. Resulting from this examination it has been found necessary for BCIRA to prepare further layout drawings indicating preferred layouts and plant. These layout drawings are Figs. 1,2 and 3 of this report. Fig.4 of this report shows the proposed site layout incorporating the BCIRA proposals for plant and equipment layout and showing the areas which need to be provided for expansion as output rises from 9000 tonnes per annum to 18000 tonnes per annum.

The areas required for the foundry building and fettling shop are compared below:-

PROPOSED BY:	MECON	APCCL	BCIRA
Annual Tornage	6000	9000	9000
Foundry Building m^2	4500	3825	3500
Fettling Shop m^2	1188	1530	2015

As can be seen the BCIRA proposals occupy a smaller area for the foundry activity than either MECON or APCCL anticipate; however, the fettling shop is larger on the BCIRA proposal than either MECON or APCCL proposals. The smaller area of main foundry building proposed by BCIRA is due in large part to the removal of the sand plant from the foundry building. This has been found necessary because BCIRA prefers to use belt conveyors for transporting sand, as elevators are more prone to downtime due to damage and blockage under surge load conditions. It is proposed that the sand plant should only have localised weather protection rather than being installed within the foundry building.

The increase in the fettling shop area is necessary to accommodate the range of castings which may need to be produced by the foundry. As can be seen the BCIRA proposal separates the fettling shop into two main bays, one bay dealing specifically with cylinder blocks and cylinder heads, while the second bay deals with the remaining castings.

The general layout drawings, or site plans, prepared by both MECON and APCCL are very similar and BCIRA generally concurs with these. Fig.4 of this report confirms this.

17. UTILITIES

17.1 Introduction

BCIRA has reviewed the estimates for the provision of the various utilities reported by MECON. These are based upon a projected output from the foundry of 6000 tonnes per annum. Since it is now proposed by APCCL that the capacity of the foundry is to be 9000 tonnes, some of the estimates must be revised.

17.2 Water Supply Facilities

17.2.1 The foundry will require three categories of water - cooling water, process water and social water.

17.2.2 Cooling water will be continuously circulated through the various equipments and cooled in an evaporative cooling tower.

17.2.3 Process water will be consumed during the foundry operation, for instance, in the sand preparation and sand cooling or in providing make up water for the wet dust collectors and water cooling systems. This will also include emergency water for furnaces in the event of a power failure and fire hydrant water in case of fire. Additionally it will be used for gardens and vehicle washing.

17.2.4 Social water will be filtered and chlorinated so that it is fit for human consumption and can be used for drinking, food preparation and washing purposes. It is recommended that the laboratories also be connected to this supply.

17.2.5 Since there is no perennial source of water available near the site, a bore well will need to be sunk in the area of the plant. MECON have proposed a pump capacity of 10 cu. metres per hour. BCIRA estimates that the increased output will require 14 cu. metres per hour from the bore well continuously.

17.2.6 It is noted that a 200 cu. metre ground tank is provided for raw water storage and that the cooling water is circulated through it using centrifugal pumps of 65 cu. metres per hour capacity at 25m head. In the opinion of BCIRA a water tower of 300 cu. metres capacity should be provided with static head of approximately 20m. This will provide a reliable emergency supply and a constant pressure across the system.
The cooling water circuit should be a separate system circulated from the water cooling tower basin capable of cooling 150 cu. metres per hour.

17.2.7 With the increased personnel the demand for social water will increase and the usage is expected to be 2.5 cu. metres per hour and a chlorinator and filter capable of handling this demand will be needed. Storage will also need to be increased and it is suggested that 40 cu. metres is provided (16 hours supply).

17.2.8 The MECON scheme provides a 30 cu. metre emergency static cooling water tank for the furnaces in the event of a power failure. If a main water tower is provided the emergency tank will not be required.

17.3 Compressed Air Facilities

17.3.1 The total compressed air requirement for the foundry will be considerably above the 20 Nm^3 per hour suggested by MECON. The use of a shoot-squeeze moulding machine and the increased core demand for an output of 9000 tonnes per annum requires a total availability of about 40Nm^3/hr at a pressure of 7 bar and a receiver of 10 cu. metres capacity. Receivers will also be required at the moulding machine and in the coreshop.

17.3.2 MECON have proposed three reciprocating, two stage, air compressors each with a capacity of 12Nm^3 per min. Two on line and one on standby. BCIRA would suggest three 15 cu. metre/min rotary screw type. These compressors are very compact, comparatively quiet and vibration free and come as a packaged unit with all controls.

17.4 Fuel Oil

17.4.1 In the MECON report the use of fuel oil was foreseen to dry sand, pre-heat scrap and pre-heat ladles. Since sand drying and scrap pre-heating will not be required and APCCL have expressed a preference for gas heating of refractories and ladles, only light diesel oil (IS 1460) will be required to power the vehicles and fork lift trucks and to fuel the standby diesel electric generator.

17.4.2 Diesel oil will be delivered by road tanker and it is recommended that it will be discharged into a 25000 litre below ground level storage tank. The tank will have a lockable electric fuel delivery pump of conventional service station design with metering and recording of fuel dispensed to supply the various vehicles. In addition, there will be a connection to the tank of the standby diesel generator to keep it topped up.

17.5 Liquid Petroleum Gas Supply

As there is no piped supply of natural gas available LPG is recommended.

17.5.1 Owing to the high sulphur content of available fuel oil in India, APCCL have expressed a preference for LPG to pre-heat ladles and furnace refractories. The gas may also be used for hot box coremaking, drying of refractory washes and core assemblies, in association with oxygen for metal cutting and for heat treatment furnaces. Either butane or propane will be suitable depending on availability and cost.

17.5.2 A plant to store and convert liquified petroleum gas (Butane or Propane) will be needed. This should be sited at least 50 metres from the nearest building and securely fenced. It will comprise storage tanks of 35 cu. metres total capacity, a vaporiser, pressure regulator and fan. This would provide about 4 weeks supply of gas at rate of 10 cu. metres per hour at maximum production (1000 MJ/hr approx).

17.5.3 Butane/Propane gas will be distributed in the foundry by a ring main system.

17.6 Ventilation, Air Conditioning and Dust Extraction

17.6.1 Climatic conditions permit a very open construction system for the building and extensive use of natural ventilation. The design data expects about 20 air changes per hour which should be adequate.

17.6.2 Forced ventilation in the foundry will be concerned with four main aspects:-

a) Removal of atmospheric heat.

b) Fume extraction.

c) Dust suppression.

d) Pressurisation or Plenum ventilation.

17.6.3 The MECON report foresees six axial flow fans for the supply of clean air, with a total capacity of 102500 cu. metres per hour. In addition a high pressure (60mm wg) centrifugal fan of 40000 cu. metres per hour is proposed. The locations of these fans are not disclosed. APCCL repeats the above assumptions.

17.6.4 MECON proposes one centrifugal fan of 40000 cu. metres per hour at 80 mm wg, for fume extraction, APCCL foresees two such units.

17.6.5 MECON foresees 5000 cu. metres per hour of extraction at 150 mm wg, and four 500mm diameter cyclones for dust extraction. APCCL lists two 5000 cu. metre per hour fans and four cyclones for this purpose.

17.6.6 Filtered air, presumably 2500 cu. metres per hour (size of filter) is to be supplied to the electrical control rooms at slight positive pressure to prevent ingress of dust and to cool the equipment. The computer room will be air conditioned.

17.6.7 BCIRA is in general agreement with the APCCL approach. However, no mention is made of wet-type dust collectors which will be required for the sand plant, sand distribution system and shake out shotblast and sand cooling equipment. Obviously these units have been considered, as the MECON report deals with the disposal of sludge from wet scrubbers and APCCL provides for the re-use of slurry from the wet scrubbers in sand preparation. BCIRA's proposal to site the sand plant outside of the main foundry building will considerably ease the need for stringent dust control but nevertheless it is recommended that a 2000 cu. metre/min wet collector serves the sand plant (including sand cooling) and the shake-out area.

17.6.8 The principal sources of fume will be the melting furnaces, the pouring line and the coreshop. It is difficult to provide effective hoods for melting furnaces as these hamper charging and pouring, however the amount of fume generated is small and can generally be handled by effective natural ventilation or by assistance from roof fans.
Pouring and mould cooling fume requires the use of suitable extraction hooding and induced fan draught which can be discharged through a suitable chimney stack.

Core fume, particularly where toxic gases are used to cure the cores, must be dealt with either by incineration or chemical scrubbing. Containment of the gas within the machine guarding during operation is most important for operator protection.

17.7 Illumination

17.7.1 MECON state that interior lighting will comply with IS 3646 and relevant standards and power will be supplied from a separate feeder as per APSEB regulations. APCCL have expressed a preference for high pressure sodium vapour lamps with individual switching of single or small groups of lights for energy conservation.
APCCL further requests ample use of natural lighting with the use of perspex sheeting where suitable. BCIRA would counsel caution in this because of high levels of solar radiation in this location.

17.7.2 BCIRA would recommend high level, high pressure sodium vapour lamps to give a background illumination at ground level of 300 lux and twin tube fluorescent lighting at low level (3m approx) to give an illumination at the working area of 1000 lux. Proper reflectors and diffusers are required to put the maximum light on the work surface and eliminate glare.

17.8 Fire Precautions

17.8.1 MECON recommends portable fire extinguishers strategically placed in all important buildings, to include soda acid, CO_2, chemical foam and metallic powder, according to the demands of the particular location.
APCCL specifies a total of 34 such extinguishers supplemented by 20 sand buckets.

17.8.2 BCIRA recommends that fire hydrants and hose reels connected directly to the water tower should also be considered, along with a high pressure,engine driven trailer pump since the plant is a long way from any public fire fighting facilities.

17.9 Pollution Control

17.9.1 The control of water, air, solid waste and noise pollution is foreseen. The selection of modern machinery and processes with appropriate control systems should keep pollution within acceptable tolerances.

17.9.2 Water pollution in the discharged water must be within the limits specified by IS 2490 (Part 1) and IS 3307. A storm water drainage system and foul sewers must be provided. Chemicals used by the laboratory for wet analysis will be diluted and discharged to storm drains. Faecal sewage from the plant, offices, canteen, toilet blocks etc., will be treated in a septic tank and overflow discharged to the nearest natural water course.

BCIRA sees this as a reasonable system where no public sewage disposal facilities exist.

17.9.3 Air pollution at ground level is to be restricted to concentrations permitted by Indian Air (Prevention and Control of Pollution) Act 1981.

17.9.4 Solid wastes, other than sewage, which include waste sand, sludge from wet scrubbers, furnace slag and refractory wastes will be dumped on a disposal area adjacent to the foundry.

17.9.5 Noise pollution must be contained by proper selection of machinery, enclosure or appropriate siting to levels below 90dB (A). Where this is not possible workers should be provided with hearing protectors when in exposure areas.

17.10 Power Distribution

17.10.1 Estimated Power Requirements

The MECON report foresees a total connected load of 4.1MW and an anticipated maximum demand over 30 minutes of 3.0MW based on an annual output of 6000 tonnes. APCCL expects a total connected load of 4.4MW and a maximum demand of 3.5MW for the 9000 tonnes of annual output. BCIRA considers that the power requirements for melting, moulding and fettling are likely to be higher and estimates the total connected load at 5.1MW with an anticipated maximum demand over 30 minutes of 4.1MW.

TOTAL CONNECTED LOAD - KW			
PLANT ITEM	MECON ESTIMATE*	APCCL + ESTIMATE	BCIRA + ESTIMATE
Melting Furnaces	1900	2000	2215
Holding Furnace	500	300	435
Auto Pouring Unit	-	75	65
Core Shop	200	340	64
Air Compressors	270	325	360
Moulding Machine	310	110	248
Fettling Shop	270	400	515
Sand Plant	345	300	675
Heat Treatment	-	250	250
Lighting	100	100	150
Miscellaneous	200	200	123
TOTAL KW	4095	4400	5100

(* Based on 6000 tonnes annually).(+ Based on 9000 tonnes annually)

17.10.2 + Annual Power Consumption and Maximum Demand

AVERAGE POWER CONSUMPTION	APCCL		BCIRA	
PLANT ITEM	DEMAND FACTOR	AV CONSUMPTION KW	DEMAND FACTOR	AV CONSUMPTION KW
Melting Furnaces	70%	1400	70%	1550
Holding Furnace	55%	165	55%	239
Auto Pour Unit	60%	45	50%	33
Core Shop	75%	255	75%	48
Air Compressors	60%	195	60%	216
Moulding Machine	70%	77	70%	174
Fettling Shop	75%	300	75%	386
Sand Plant	65%	195	75%	506
Heat Treatment	45%	112	45%	112
Lighting & Misc.	50%	150	50%	131
TOTAL KW		2894		3395

17.10.3 Annual Energy Consumption

Assume 288 working days per year at 16 hours = 4608 hours.

Allow 15% for third shift working = 5300 hours/yr.

Total estimated power = 18×10^6 kWh (BCIRA)

16×10^6 kWh (MECON)

12×10^6 kWh (APCCL)

BCIRA concludes that for 9000 tonnes per annum APCCL's estimate is low.

17.10.4 Maximum 30 Minute Demand

$$\text{Estimated maximum demand} = \frac{\text{Total Demand} + \text{Average Demand}}{2}$$

$$= \frac{5100 + 3395}{2} = 4247\text{kW}$$

$$= 4.25\text{ MW.}$$

17.10.3 Site Network

Power is provided to the site through a single circuit 33kV line from the APSEB sub-station some 3km distant. MECON has recommended initial transformation from 33kV to 6.9kV with two further step down transformers from 6.6kV to 433kV. APCCL foresee transforming in one step from 33kV to 440V.

BCIRA is concerned about the APCCL proposal with respect to the very high levels of fault current possible at the 440V switchboard and has indicated on the power distribution diagram an intermediate step at 6.6kV as proposed by MECON.

Based on a 5.5MVA 33kV/415V transformer with 5% impedance then -

Fault MVA could be 20 x full load current = 120 MVA.

$$\text{Fault current (IF)} = \frac{\text{F.MVA}}{\sqrt{3V}} = \frac{120 \times 10^6}{1.732 \times 415} = 153\text{ kV.}$$

This is three times the acceptable level. The impedance of the land line will have a mitigating effect on the fault current but it is still considered undersirable as a suitable switchboard may need to be specially manufactured and would be costly. Furthermore, very heavy cables will be needed to supply the melting plant at 415V resulting in high line losses if the furnaces are far from the main transformer.

BCIRA recommends that three power transformers of 6.6kV/0.433kV be installed with facilities for manual or automatic tap changing to compensate for incoming voltage fluctuation. Consideration should also be given to vacuum switchgear in preference to oil as it is lighter in construction, easier to handle and requires considerably less maintenance. The switchgear would have sheet steel enclosure with transfer earthing and IDMT protection relays for earth and over current protection.

The melting equipment would be supplied from a 2500 KVA transformer and other production equipment from two 1500 KVA transformers connected to the 415V power distribution boards.

The power distribution boards would have air circuit breakers on the incoming feeders in preference to switch fuses to provide for intertripping between the HV and LV systems. In the event of a fault on the LV side, the HV circuit breaker will trip and vice versa. Switch fuses or circuit breakers would be suitable for outgoing LV lines.

Installation of a 300KVA diesel generator to power essential services on the furnaces is a prudent precaution and it will probably be necessary to divide the LV switchboards into essential and non-essential sections. Emergency lighting should not be overlooked when scheming this service.

BCIRA supports the use of XLPE cables throughout to reduce installation costs due to their increased current capacity compared to standard cables.

The accompanying single line power distribution diagram (Fig. 5) illustrates the BCIRA conception for the plant.

A 30 minute maximum demand indication and warning system should be installed in the furnace control room. Since the furnaces are the largest consumers of power, reducing the power in this section will have the most immediate effect if the maximum demand is approaching overrun. This would probably occur near the end of the 30 minute cycle and shutting down the furnaces for a few minutes will have only minimal effect on melting rate and metal temperature. Load shedding should be manual and not automatic as the decision must be made with reference to metallurgical and production requirements.

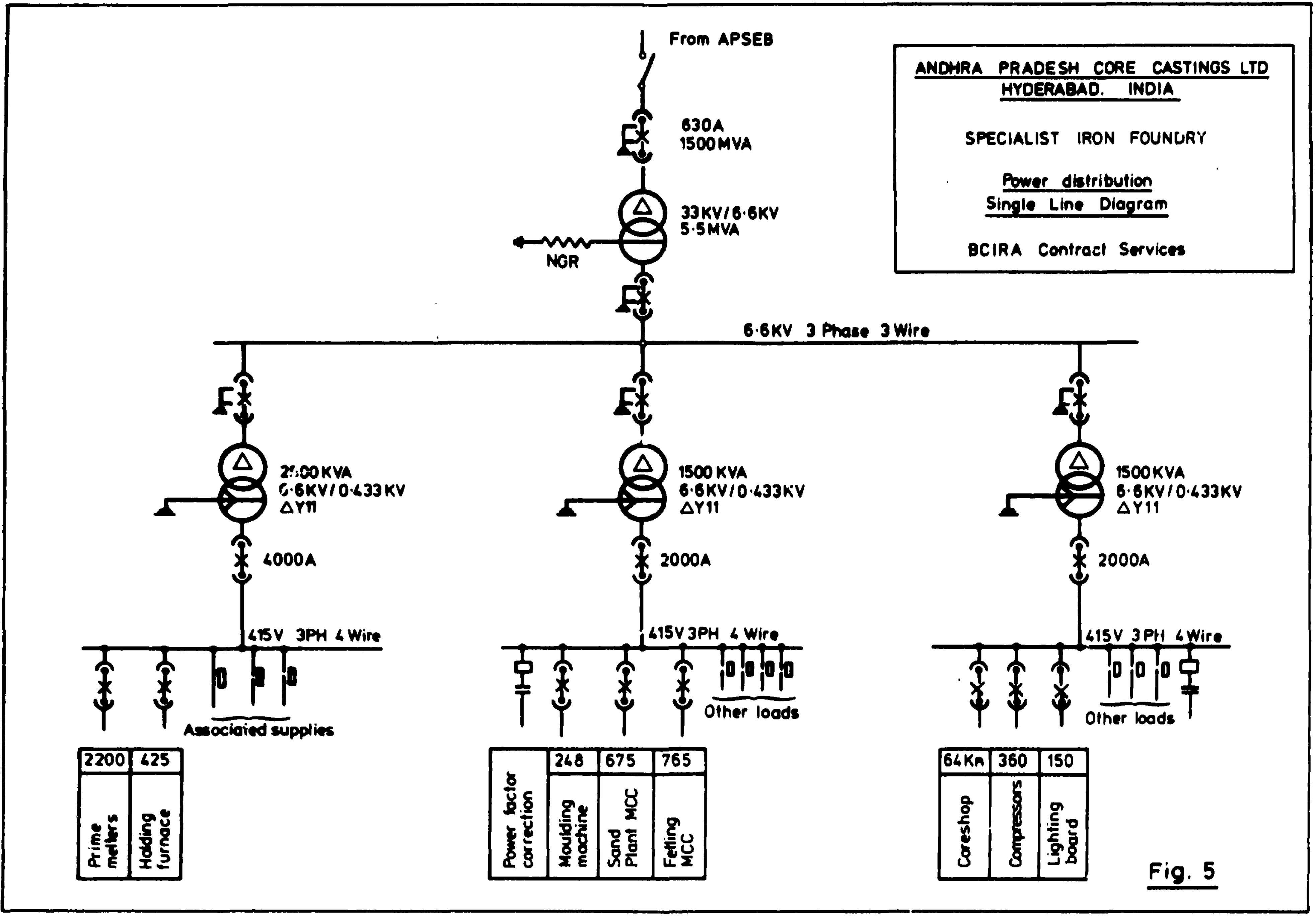

From APSEB
630A
1500MVA
33KV/6·6KV
5·5MVA
NGR
6·6KV 3 Phase 3 Wire
ANDHRA PRADESH CORE CASTINGS LTD
HYDERABAD. INDIA
SPECIALIST IRON FOUNDRY
Power distribution
Single Line Diagram
BCIRA Contract Services
2500 KVA
6·6KV/0·433KV
ΔY11
4000A
415V 3PH 4 Wire
Associated supplies
2200
Prime melters
425
Holding furnace
1500 KVA
6·6KV/0·433KV
ΔY11
2000A
415V 3PH 4 Wire
Other loads
Power factor correction
248
Moulding machine
675
Sand Plant MCC
765
Fetling MCC
1500 KVA
6·6KV/0·433KV
ΔY11
2000A
415V 3PH 4 Wire
Other loads
64Kn
Coreshop
360
Compressors
150
Lighting board

Fig. 5

18. MODIFICATIONS REQUIRED TO PLANT AND BUILDINGS WHEN PRODUCTION LEVELS RISE FROM 9000 TONNES PER ANNUM TO THE PROJECTED 18000 TONNES PER ANNUM

When forecast production levels exceed 9000 tonnes per annum, consideration needs to be given to possible plant and building modifications to achieve the higher level. At the time when production is anticipated to be at the 18000 tonnes per annum level then the following changes would be needed:-

18 .1 Melting

One additional medium frequency melting furnace of 4 tonnes capacity would need to be installed, this item being shown dotted on Fig.1, together with the necessary additional power supply for melting. The melting plant would then comprise three medium frequency melting furnaces with two power packs and one holding pack with the appropriate changeover switches and water cooling. This installation would then be capable of melting at a rate of 6 tonnes per hour.

18 .2 Moulding

On the moulding plant, the cooling time in the box at a production rate of 60 moulds per hour, to suit a good casting production of 9000 tonnes per annum, is approximately 1 hour. At the highest level of requirement, i.e. 18000 tonnes per annum, additional cooling will need to be provided to cater for the increased output of 120 moulds per hour from the machine line. This can be achieved by punching the mould compact from the moulding box into a container and circulating this container to achieve the desired cooling time. The moulding plant depicted in Fig.1 includes this additional facility.

18.3 Sand Plant

For production levels of 60 moulds per hour, i.e. to achieve the good casting output of 9000 tonnes per annum, only one sand mill is required together with the proposed cooler/pre-mixer. In addition it is only necessary to install two storage hoppers for return sand, but belt conveyors, sand cooling drum, screen and aerator all need to be sized to suit the final throughput of about 120 tonnes of sand per hour. The BCIRA drawing, Fig.2, indicates the plant required for the highest level of output.

18.4 Coremaking

The layout drawing, Fig.1, incorporates the coremaking facilities required to achieve a production level of 9000 tonnes per annum of good castings. At the highest level of 18000 tonnes per annum, a second coreshop building with core sand mixing and coremaking equipment would need to be provided. The additional building profile to house this facility is shown dotted in Fig.1.

18.5 Shotblast and Fettling

The shotblast facility for an output of 9000 tonnes per annum of good castings is shown on the layout drawings Fig.1 and 3. When output increases to 18000 tonnes per annum it will be necessary to provide a further shotblast installation to cater for this increase and this would need to be sited in the new fettling shop buildings which will be required. It will also be necessary to double the fettling facilities shown in Fig.3, and provision has been allowed for this as indicated by the dotted lines on the site layout Fig.4.

18.6 Heat Treatment

It has been assumed that 50% of the SG iron castings produced will need to be heat treated, the remainder being produced in the 'as-cast' state. The furnace provided in the initial plant has been sized to heat treat 3000 tonnes of SG iron castings per year, and it should not be necessary to provide any further capacity for the proposed higher output figures envisaged i.e. 6000 tonnes of SG iron castings, of which half will need heat treatment, out of a production of 18000 tonnes per annum.

18.7 Utilities

The supply of water and compressed air will need to be increased pro-rata with the increase in the envisaged castings output.

A further electrical supply together with sub-station facilities will also be necessary to cater for the increased demand arising from the increased production requirements. It has been estimated that the increased demand will be approximately 3000kW.

19. ENERGY CONSERVATION PROGRAMME

19.1 Metal Melting and Holding in Electric Furnaces

The proposal by APCCL to melt metal in medium frequency furnaces, and hold it for distribution in a mains frequency furnace is in line with the most modern practice. High power density medium frequency furnaces melt much more rapidly than their mains frequency counterparts, and hence are smaller and more energy-efficient than the mains frequency unit. Small furnaces, driven hard, are highly desirable. To utilise the third shift for melting, however, thereby reducing maximum demand when moulding is only on two shifts, requires capacity to hold molten metal not only in the melting furnaces but also in an additional large furnace. The 10/12 tonnes, 425kW holding furnace now proposed would be satisfactory. Since this furnace need not be capable of melting metal, there is no point in providing it with an expensive frequency convertor, hence a mains frequency furnace is suggested.

During operation, furnace covers should be kept closed whenever possible, and melting furnaces should be kept as full as possible to allow maximum power to be applied. Charge materials should be clean (e.g. return scrap and sprue metal should be shotblasted) to keep slag volumes low and reduce the time for which covers must be opened to remove slag from the bath. BCIRA fully endorses the APCCL view that metal temperatures should not be allowed to rise above those specified, and that metal should be transferred as soon as practicable from the prime melters to the holding furnace.

Each furnace should be equipped with a kWh meter to allow recording and monitoring of power consumption.

The bulk of the electrical power to be consumed by the proposed foundry will be absorbed by the melting units, hence the need for energy conservation will have to be recognised, not only at the plant design stage, but also during operation. The developer should be made aware that this is a particularly difficult problem in the early stages of bringing a foundry to its nominal capacity. During these first months, many difficulties arise with equipment, personnel, customer demands, etc., and much of the plant will operate at well below its designed capacity, with commensurate shortfall in energy efficiency.

19.2 Molten Metal Transfer, Distribution and Pouring

The intention to use covered ladles wherever practicable is sensible. In particular, ladles which are to be used for pouring metal into moulds on the conveyor system will need to be covered to reduce temperature losses. These ladles will normally only come into use when the automatic pouring machine is out of action.

The use of an automatic pouring unit, as indicated by APCCL, has many advantages, not least in the reduction of total energy used per tonne of good castings sold. The yield of good castings to metal melted should be kept as high as possible, and automatic pouring creates the possibility of employing small runner bushes and close control of poured weights. Since metal is held at controlled temperature within the pouring unit (rather than at falling temperatures when ladle pouring is practiced) it is not necessary to heat the metal to an unduly high temperature to compensate for temperature losses. Furthermore, with castings such as cylinder blocks and heads, very tight control on temperature is required to avoid scrapping castings for defects such as blowing and misrunning. The elimination of such causes of scrap is a major contribution to high yield of good castings. In the past, many foundries operating automatic moulding lines and using conventional pouring methods, have found that a considerable proportion of the downtime on the machine has resulted from the need to wait for metal to be delivered to the pouring line.

In this instance, a 2.5 tonne reservoir of molten metal, at constant temperature, is to be provided, hence overall plant efficiency will be enhanced. The waste of metal and energy which occurs when molten metal is spilled, or low temperature iron in ladles has to be returned for pigging or re-heating, is eliminated with automatic pouring.

BCIRA concurs with the view that the chosen layout should keep transport distances of molten metal to a minimum, to reduce heat losses, and this point has been taken into account in the suggested layout.

19.3 Energy Saving in Moulding and Coremaking

APCCL is clearly aware of the desirability of operating the moulding line at its rated speed. This has important ramifications in energy saving as in other facets of the business. The shorter the time for which the plant need be operated to achieve a given output, the shorter the time for which power has to be provided e.g. to drive compressors and conveyors, pressurise hydraulic systems, operate the sand plant and associated exhaust equipment etc.

One of the most effective ways of saving energy is to keep tight control of plant and equipment maintenance, and of sand quality, to ensure that scrap moulds are not produced. This is another good reason for operating plant at its nominal output rate: the problems of achieving quality at very low moulding rates are likely to be completely different from those encountered when the line operates at its design speed. Hence, it is not practicable to carry out quality enhancement programmes at low output rates and expect the solutions found to be effective when operating at the design rate.

It is doubtful whether 'Warm Box' rather than 'Hot Box' coremaking will prove satisfactory for the majority of cores required in the foundry, but the intention to insist on high core quality is sound. This casting facility will be designed to produce castings of the highest quality, and parts such as cylinder heads and complex cylinder blocks place extreme demands on coremaking technology. This will necessitate great vigilance and care in the design and operation of equipment. Many of the cores will be of a fragile nature, and unless processes, handling and transport arrangements are designed to cater for this, considerable core losses will t encountered. These are very expensive in terms of money, materials and energy.

The need for close control of corebox temperatures, and for production control to ensure that heating ovens are used efficiently, is clearly understood by APCCL.

As with moulding, so with coremaking, effective process control is the key to energy efficient operation.

19.4 Energy Saving in Heat Treatment

The heat treatment furnace proposed is likely to be used mainly for the annealing of those SG iron castings whose specified properties cannot be achieved economically in the as-cast condition. It might also be employed for certain cylinder blocks or cylinder heads for which the customer stipulates some form of heat treatment.

The proposal to use a low thermal mass lining is sensible and good modern practice. Also, APCCL recognises the need for efficient utilisation of the furnace volume. The density with which a furnace is packed with castings can significantly affect energy costs per tonne. Typically, a fully loaded furnace could heat treat SG iron castings at 250 kWh per tonne, whereas, if the furnace capacity is badly under-utilised, the figure might be 500 kWh per tonne for the same heat treatment cycle. (Naturally, the foundry should aim to avoid heat treatment wherever possible e.g. by providing high-quality as-cast SG iron castings, but there are designs and grades for which heat treatment is the practicable solution).

The intention to use flexible heat-retaining curtains on certain furnaces and ovens is endorsed and should be taken into account at the design stage. However, for the reasons given in Section of this Report, the use of an automatic temperature profile controlled cooling tunnel, whilst attractive in theory, is not regarded as desirable at present.

19.5 Energy Wastage in Casting Cleaning and Fettling

A major factor in keeping energy costs low in the finishing departments will be the quality of castings produced. APCCL has shown that it recognises the need for process control to minimise the shotblasting time. However, other energy demands in finishing are also influenced by casting quality. For example, inaccurate patternmaking or coresetting, or damage to cores and moulds, can lead to excessive flash on castings. This can not only give rise to cracking of castings, but also to prolonged chipping and grinding times and excessive use of power on tools.

As indicated in APCCL's Energy Programme. energy used per tonne of castings shotblasted is also considerably affected by loading of the machines. In both hook-type and tumble-blast shotblasting units it is highly desirable to fully load the machine to make best use of power consumed.

It is proposed to prevent repeat shotblasting wherever practicable. This will certainly be necessary, not only to keep energy costs low, but also to ensure rapid flow of parts through the finishing departments. Batches of castings awaiting re-shotblasting can cause immense hold-ups in production.

19.6 Ventilation

The decision to design buildings to take advantage of natural ventilation as far as possible is eminently sensible. Clearly, however, there will be a number of areas where forced exhaust ventilation will be required. Great care will be needed in the design of plant and equipment to keep such requirements to a minimum, whilst achieving necessary standards.

As suggested by APCCL, machine layouts in various workshops will have to take into account the need to keep ventilation demands under control. Wherever practical, automatic control systems should be incorporated.

19.7 Savings in Electricity for Lighting

Whilst the original design of the lighting system in the plant is very important, equally so is the management of the system. Attention is drawn by APCCL to the need for cleaning of lamps and reflectors. This will have to be part of a regular maintenance programme.

Experience shows that one of the most important aspects of energy conservation is the switching off of unnecessary equipment. This applies particularly to exhaust fans and lights. In each section of the plant, someone must be made responsible for ensuring that these are switched off when not required. This is easily overlooked, particularly when multi-shift working is practised, with breaks between shifts.

19.8 Compressed Air Energy Savings

The proposal to duct air to the compressors from outside the compressor house is sensible. For a given output a compressor uses approximately 1% more electricity for each 4°C increase in intake air temperature.

The desirability of checking for compressed air leakage is also agreed - a hole of only 1.5mm diameter leads to an air loss equivalent to 1kW power at the compressors.

Electrically driven hand tools are generally desirable for the reason mentioned, i.e. that the electricity consumed directly by these tools is less than that used indirectly, via the compressor installation, by air tools.

19.9 Correction of Power Factor and Control of Maximum Demand

A component of the current drawn from an AC supply by reactive loads such as motors, transformers, fluorescent lighting etc., is out of phase with the supply voltage. The product of the total current and the supply voltage is the apparent power. In reactive circuits the apparent power is always greater than the actual power delivered, and the ratio of useful to apparent power is known as the power factor.

Desirably the power factor should approach unity, and this is normally achieved by the application of capacitors to individual items of plant (e.g. motors) or at the point of supply. In the APCCL programme this point is taken care of. The major electrical loads on the foundry will be the electric furnaces, which will have their own capacitor banks and automatic switching as load conditions vary.

Since electricity costs are based, in part, on the Maximum Demand level in a given period, it is very important to control this parameter. Equipment is available which will monitor and display the demand level, provide digital and graphical records, and allow manual or automatic load shedding to ensure that a specific Demand level is not exceeded. Such a system should be installed in the proposed foundry.

20. APPLICATION OF MICRO COMPUTERS

20.1 General

The proposal by APCCL to make extensive use of micro computers, rather than a single main frame computer, is eminently sensible. At the inception of a plant such as that proposed, it would be most unwise for APCCL to get involved in the setting up of a major main frame computer fully integrated system. With the approach which APCCL favours, it will be possible to introduce the advantages of computerisation into individual sections without creating major problems of integration and without causing disruption to the whole of the manufacturing operation should difficulties be encountered in one section. The Company is wise to be very cautious in the application of computers.

The conceptual report points out that the greater emphasis is to be laid on the capture of data in order that computers may be introduced progressively. The design of appropriate forms for collecting and recording data is quite an involved process, since this documentation will have to cover each facet of the foundry operation. However, APCCL is certainly right in its proposal to design the collection of data, then develop an outline model of the system and finally to develop strategies for control. Only then is it proposed to introduce the control systems. It cannot be emphasised too strongly that, whilst this work may be going on in parallel with the commissioning and working up of the plant, there are likely to be many problems in bringing the plant into production and it is important that the introduction of micro computer control systems does not interfere with the major business.

20.2 Control of Manufacturing Costs

Cost analysis by work centre, job costing, budgetary control and calculation of piece work earnings have all been carried out by computers. Since much of this work is of a highly repetitive nature, it will be eminently suitable for computer control.

20.3 Controlling the Level of Utilisation of Capital Plant

APCCL indicates that it is anxious to achieve low work-in-progress, high machine utilisation, minimum change and maximum productivity per labour hour. The intention is to concentrate initially on highest capital cost area, i.e. melting, moulding and coremaking. Again, this is very much a case of simple data capture and manipulation and may well be one of the simplest areas to computerise. It should very quickly be possible to produce the rapid feed back and reporting system which will, in practice, allow the Managing Director to control all the major facets of his operation closely. For example, it should be possible for him to have, each morning, a statement of the utilisation of all the major items of plant, the work-in-progress levels, productivity achieved and trends in each of these parameters. As the foundry develops, the major constraints upon production and efficiency will become apparent and it should be practicable to have a simple reporting system indicating the utilisation of that item of plant or that process which is the major 'bottleneck'.

20.4 Production Planning

A number of different systems are available for the use of micro computers on production planning. It will be desirable to introduce this gradually, at different levels of detail.

In practice a major difficulty with production planning by means of computer is the need to know precisely the capacity of all items of plant and the utilisation of each item involved in the production of a particular casting. For example, it is not enough to know the number of castings per moulding box, since it will also be necessary to know the details of each core involved in the production of that casting, including the weight of the core and the time required for its production on particular coremaking machinery. A great deal of preliminary work will be required if an effective production planning system is to be designed. In this field, perhaps even more so than in most of the other aspects of computer control, the updating of information is absolutely essential. It is also necessary to recognise that knowledgeable production control staff will be needed to operate the computer and to produce alternative plans. The computer's main use in this case is to carry out the necessary arithmetic manipulations to show the effect of the plan which the production controller envisages.

20.5 Quality Control

APCCL proposes to use the computer in its quality control effort. It envisages determining the effects of production variables upon scrap levels and carrying out multiple regression analysis to relate dimensional tolerances to the production processes. The Company recognises the need for careful selection of the data. Once again BCIRA would counsel care in setting up the procedures for the use of the computer in the quality control role. Initially, it might be used simply to list and sort the scrap castings produced, in order that attention may be drawn to those which are causing most problems. Providing that data on the cost of each casting is included, it is possible to sort the defective castings not only by number but also by value.

Relating the production of scrap castings to changes in the manufacturing variables is more complex. It is unlikely to be practicable upon a continuing basis, although it can certainly be done during individual investigations.

The use of multiple regression analysis to relate dimensional tolerances to production process has been proved in practice. However, extreme care must be taken in carrying out such statistical procedures, since great skill is required not only in defining which parameters should be measured, but also in interpreting the results of the work. That being said, however, that type of activity is only practicable by the use of a suitable computer, in view of the very lengthy calculations involved.

It should be noted that customer industries are becoming much more interested in statistical production control, and whilst much of the arithmetic involved in this is fairly simple, the availability of a suitably programmed micro computer is most useful in carrying out the statistical control required.

20.6 Cost Control and Cost/Weight Estimation

APCCL anticipates introducing already available systems for cost and weight estimation. This is eminently sensible, since commercial systems are available for these purposes. It is important in choosing a system that it should be capable of carrying out a very rapid update of estimates whenever individual cost centre rates change. For example, if a moulder's wage rise is agreed, it should be possible to feed the figure into the data file and then immediately update every cost estimate within the foundry. Since this can be done for the various individual cost rates involved, it is possible to keep a very accurate record of changes in the cost of every item. Without this facility, it is normal for foundries merely to put blanket price increases upon their output, despite the fact that a change in one item of cost will have different effects on different castings. For instance, in the example mentioned above, the effect of a change in moulder's wage rate would vary from casting to casting depending upon the moulding time involved in each case.

20 .7 Process Control

At this stage it is planned by APCCL only to apply computers for the control of the sand plant and comments on this are made in the appropriate section of this report. However, many manufacturers are now incorporating either micro computers or other forms of micro processor control in the equipment they supply and it is probable that a number of items of plant in the foundry will be controlled in this manner.

20 .8 Plant Loading for Customer Service

APCCL is envisaging the use of a computer to hold the order file. It is proposing to use the computer to summarise the outstanding order load and, with knowledge of average weekly despatches, to calculate in which week any new business can be booked.

In practice, any such attempt will need to be closely linked with the production planning system which it is intended to introduce. This form of control will not be easy in view of the great deal of data required within the production planning system.

20.9 Control of Orders

APCCL is proposing to introduce and develop an order handling system, linked with a number of associated functions including invoices, sales statements, stock control and manufacturing instructions. The intention is to use this system to determine past trends, assess likely future trends and control delivery promises. Benefits foreseen are in the areas of accounting and better delivery performance.

All the functions required can be carried out by computer. In devising the system to carry out this work,however, it will be necessary to take very careful account of the quantity of information which must be handled as well as the arithmetical manipulation required. These factors will have a very important influence on the type and size of computer required and, in this respect, the Company's stated intention to take a cautious approach is to be commended. It will be essential to produce a full model of the system before both the hardware and the software required can be decided.

20.10 MECON Proposals Regarding Computer Facilities

Section 12 of MECON's Techno-Economic Feasibility Report refers to the requirement for a general purpose computer system. It recommends a unit with a main memory of 128/256 kiloBytes, two floppy disc drives, one Winchester disc drive, a line printer, a visual display unit and a keyboard. It refers to the need for the system to be capable of upgrading in terms of memory and peripherals and to have the capability to link up with other computer systems/terminals. It states that the system would need to be able to support languages like BASIC, COBOL, FORTRAN and assembly language. It also states that application software can be procured with the system.

Comment has already been made upon the fact that it will not be practicable to identify completely the hardware and software requirements for the various purposes envisaged by APCCL until far more detailed study has been carried out. However, the Company has wisely indicated its intention to proceed slowly into this area of computer control and for the purposes of evaluating the costs of setting up the first phase of this foundry development, it is recommended that the hardware indicated above be accepted as being a useful starting point.

21. ORGANISATION AND MANPOWER REQUIREMENTS

21 .1 MECON Recommendations - Manpower Requirement

MECON has proposed staffing for the foundry based upon an output of 6000 tonnes per year. It is now proposed that the output will be, in the first stage, 9000 tonnes per year. The working regime envisaged by MECON (04.03) foresees 300 working days per year with two full shifts and limited staffing in the areas of melting, coremaking, fettling and maintenance during the third shift. Numbers of employees in the various categories, including reserves for leave and absentees are as follows (MECON Table 14.01):-

Management and Executives		19
Highly Skilled Workers		30
Skilled Workers		163
Semi-Skilled and Unskilled		118
Ministerial Staff (Office)		30
Security and Miscellaneous		12
	TOTAL	372

MECON does not categorise working hours, breaktimes or distribution of workers across the shifts.

On the assumption that each worker is employed 8 hours per shift, 6 days per week with 1 hour for breaks in each shift, then number of working hours per week equal 42. If leave, absentees and staff turnover amount to 10% then total number of working hours is 703080 per year or 117 hours/tonne. MECON does not differentiate between direct and indirect labour and so it is not possible to get a direct measure of expected productivity.

MECON touches briefly on the need to recruit a nucleus of experienced executives and technicians during project implementation and to provide a comprehensive training programme.

21 .2 APCCL Reports and Revisions of MECON Proposals

APCCL has now set the required initial output of the foundry at 9000 tonnes per annum. In its reports it has indicated that the working regime will be twoshift operation for 300 days in the first and second year, and three shift operation for 270 days for the third year onward.

Subsequent discussions with APCCL during the site visit established the joint opinion that it was not feasible to run the plant efficiently for three shifts continuously due to maintenance needs and therefore the basis of the design should be two shifts for 300 working days per annum.

Fixed holidays are not customary in India but each worker is entitled to 30 days annual leave after 1 years service, sixteen days are national holidays and the remainder are optional by agreement with the Company. It was recommended, and accepted by APCCL, that the foundry should be closed for 12 working days every year as a mandatory annual holiday so that major maintenance programmes could be executed.

The APCCL report does not elaborate the manning schedule envisaged for the foundry [but in the discussions during the site visit possible management structures were examined in relation to the project progress and a series of organisational charts tabled].

BCIRA understands from the information provided that the available production time to produce 9000 tonnes of good castings is 4600 hours and each worker will contribute 2000 hours.

In the opinion of BCIRA this class of casting would be produced with similar equipment at about 31.5 man-hours per tonne, direct labour and first line supervision, in an equivalent plant in Western Europe. APCCL states that due to climatic conditions in India the work rate is recognised as being 70% of European standards, therefore a productivity rating of 45 man-hours per tonne can be expected for grey iron. SG will require about 15% additional labour, say 51.5 man-hours per tonne, giving an overall average of 47 man-hours/tonne. Therefore BCIRA expect a direct labour force of 212 and since indirect labour is normally about 25% of the direct labour (excluding maintenance) a shopfloor workforce of 284 is foreseen plus 46 maintenance personnel (14% of total workforce).

This provides a total workforce of 330 persons, excluding management, sales and office staff. BCIRA would expect to find in this type of operation management and office staff of approximately 20% of the total employees, say 88 persons, giving a total workforce of 418 persons for 9000 tonnes per annum. MECON has estimated a total of 372 for 6000 tonnes output.

The objective of APCCL is to produce specialist high quality castings and to this end it intends to use sophisticated, largely automatic, equipment. The purpose is to eliminate intervention in the processes by skilled and semi-skilled operatives, therefore it is envisaged that the plant will be operated principally by unskilled personnel controlled and directed by highly skilled technicians.

The balance of the workforce over two shifts is likely to be:-

Unskilled Workers	200
Highly Skilled	50
Technicians	16
1st Line Supervision	18
Maintenance	46
Office and Auxiliary Staff	45
Management and Administration	43
TOTAL	418

Allowance has been made for leave and absentees in this schedule. Office staff and management will work one shift and maintenance will be on a three shift rota.

21 .3 Management Structure

The MECON report proposes a structure based on two General Managers reporting to the Managing Director, one being responsible for administration, finance and marketing, the other for the manufacturing, quality functions and plant maintenance.

BCIRA is of the opinion that this organisational approach is deficient in the following respects:-

i) There is no Technical Manager or supporting Department indicated.

ii) The Company Secretary is subordinate to the General Manager, Admin/Finance /Marketing.

iii) The Quality Control Manager is subordinate to the General Works Manager.

Since the Company is seeking to establish specialist status in the production of high quality castings technical expertise is of prime importance and merits the appointment of a Senior Manager.

The Company Secretary is the only executive, other than the Managing Director, who will attend board meetings and therefore warrants senior manager status.

There is always a conflict between the objectives of Production Management and Quality Control therefore the Quality Manager should be responsible only to the Managing Director. Some major castings consumers consider this as mandatory to their supplier quality approval procedures.

21 .4 Training

MECON correctly identifies the need to recruit and train key technicians and executives during project implementation without specifying the functions for which they are needed or at what stage they should be acquired. It will not be easy to obtain training in India as it is believed that very few foundries will be using comparable technology and in the case of overseas foundries, those who are able to provide training may be reluctant to supply it to a potential competitor. A training programme must be developed using classroom techniques allied to the commissioning programme of the new foundry as it progresses.

Arrangements should be made for selected maintenance engineers to spend time in the works of suppliers of major items of equipment, particularly during the final stages of assembly.

It must be acknowledged that organisation structures are seldom perfect and never sacrosanct. The evolution of an organisation depends upon many interacting forces and priorities, not the least being the abilities and personalities of the people involved. The organisation proposed should be regarded therefore as a foundation upon which to build the Company, to be amended or restructured as conditions dictate.

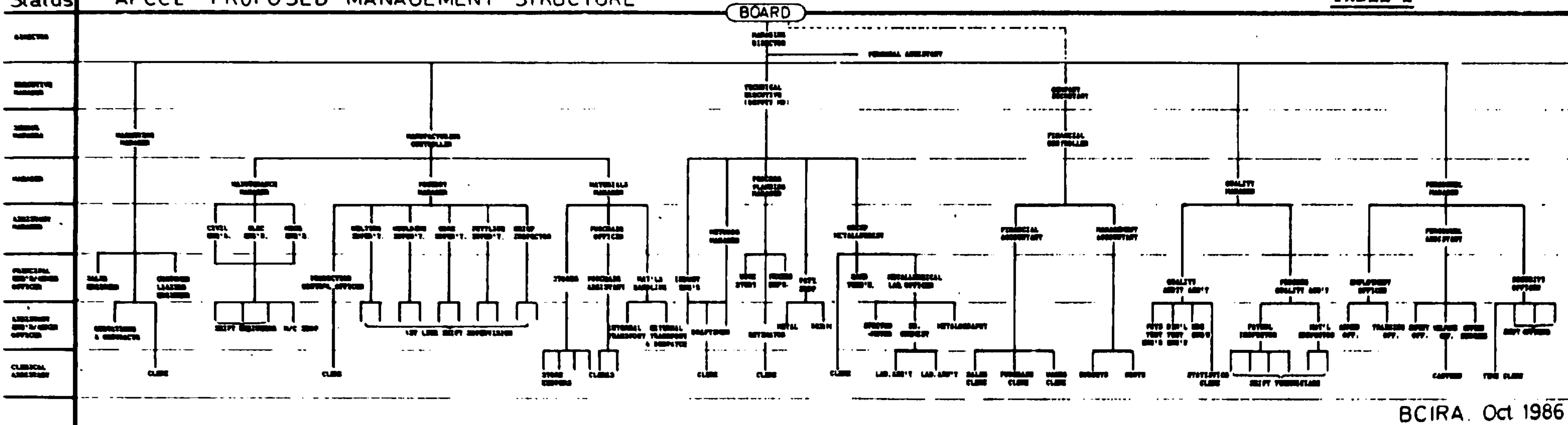
A series of organisation charts was developed byAPCCL indicating the progressive build up of staff during project implementation.

APCCL considers it important that the titles and positions in the organisation should reflect status and give a clear indication of the promotional ladder, and this view is endorsed by BCIRA.

Table 2 illustrates BCIRA's views on the most suitable management structure, indicating the progressive build-up.

APCCL - PROPOSED MANAGEMENT STRUCTURE

TABLE 2



BCIRA. Oct 1986

RECRUITMENT PROGRAMME

PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5
		Technical Executive Manufacturing Controller	Company Secretary	Full Complement
Maintenance Manager Marketing Manager	Foundry Manager Materials Manager	Financial Controller Personnel Manager	Quality Manager	
Financial Accountant Civil Engineer Electrical Engineer Purchase Officer	Personnel Assistant	Employment Officer Mechanical Engineer	Methods Manager Chief Metallurgist	
Process Engineer Industrial Engineer Security Officer	Purchase Assistant	Stores Supervisor	Process Quality Assistant Pattn. Shop Supervisor	
Draftsman Clerk	Shift Security Officers Purchase Clerk Planning Clerk Marketing Clerk Wages Clerk A/C Clerk - Purchase Sales Clerk	Admin Officer Training Officer Personal Assit. to MD	Quotations & Contracts Senior Chemist Materials Inspector Office Services	

22. EXECUTION OF THE PROJECT

22.1 The Market

BCIRA applauds the objectives of APCCL in setting out to create an entirely new ironfoundry in India capable of standing alongside the world's leading automotive foundries in terms of technical excellence, casting integrity, dimensional accuracy and impressive finish. There is no doubt that fine quality of product will always find a market.

It is understood that the major international automobile manufacturers, who have licences to produce in India, are all committed to an increasing national content in the product. From 1990 onwards this need will become pressing and it will become necessary to manufacture engines in India where they are now imported. If it could be claimed that castings of appropriate quality were not to be obtained from within the country it might be possible to establish a case for continued importation. However, by that time APCCL would have an operating foundry capable of meeting the most stringent technical and quality requirements.

There are perhaps two Indian foundries with the experience and expertise to attack this market, but both have been long established and cannot boast the up-to-date technology and modern production equipment foreseen by APCCL. Nevertheless, the Company is not aiming to capture too large a share of the market initially, but is aiming to secure a reputation, on an economically sound basis, for specialist status in automotive engine castings of outstanding quality.

In setting up such a project there are four main avenues requiring action -

a) To determine the product range and establish the technology.

b) To build, equip and start-up the plant.

c) To 'sell' the philosophy and create the market.

d) To staff the enterprise and train the personnel.

APCCL has now determined the essentials of the technology to be employed and the market sector it will serve. The next step is to formulate in detail the equipment to be installed and the technological process documentation for operating the foundry.

However, the most important step is to begin immediately a programmed marketing strategy. The automotive manufacturer is one of the most demanding, conservative and quality conscious casting buyers in the marketplace. It will not be easy to break into this market especially for a new plant with no established reputation or history as a supplier.

It is important that the Company's name and intentions become widely known before the plant is ready to start producing. The right kind of publicity must be generated so that when APCCL is ready to begin operation there is sufficient confidence amongst potential customers to place orders for the supply of castings of the appropriate type.

A foundry cannot be started up without pattern equipment and someone must be willing to purchase patterns suited to the APCCL foundry processes and to buy the castings so produced. The use of existing patterns is not likely to be possible without extensive modification and even then the objectives of fine quality and dimensional accuracy could be compromised.

A new set of tooling for a cylinder head or block will take up to 12 months from the placing of an order to the commissioning of the patterns in the user's foundry. The marketing of the Company must begin without delay.

It has already been established that the new foundry is to serve the automotive industry sector and that eventually 80% of the grey iron capacity will be devoted to cylinder blocks and heads. The remainder will be used in producing ancillary automotive parts. The foundry is designed to produce the more complex castings of which a large proportion will require cores; simple non-cored castings will not economically support the foundry operation. Therefore the Company's publicity and pricing structure must be geared to this class of work.

22.2 Implementation

Although the building must be ready before the plant can be installed it is important that the building is designed to house the foundry, rather than the foundry made to fit the building. The broad product range has been determined and the main outlines of process technology and equipment established. The details must now be crystallised as quickly as possible so that the civil engineering can be started with well defined guidelines. It is essential that the building is regarded as part of the production equipment and it is just as important to the efficient running of the foundry as the melting or moulding plant.

The implementation phase of designing, building, equipping and starting up the foundry, must be done in parallel with the documentation of operating procedures and process technology and progressive recruitment and training of staff. The co-ordination of these activities should ensure a coherent and smooth start-up of the foundry.

22.3 Commissioning

The commissioning of the plant should take place in several phases.

Phase I - Installation, Completeness and Dry-Cycle Proving

All major items of equipment will be erected and installed under the supervision of the suppliers' engineers. The installation will then be inspected on behalf of APCCL to ensure that the erection and installation is satisfactory and the equipment is complete according to contract. The machine will then be dry-cycled, so far as is practicable, to ensure that all parts of the equipment are functional.

On satisfactory completion of these tests an Installation Acceptance Certificate will be issued to the supplier.

Phase II - Commissioning

Upon completion of the acceptance tests and as soon as various supporting services permit (i.e. availability of materials, functioning of conveyors and associated machinery etc.;) a single machine or group of machines will carry out the performance trials stipulated in the supplier's contract to ensure that the equipment functions at the rate and with the quality and accuracy guaranteed. On completion of performance tests a Certificate of Commissioning will be issued.

Phase III - Performance Guarantees

In the final stage of performance testing a complete department will undergo performance trials when all equipment will operate in concert for a given period (e.g. two consecutive shifts on two successive days). Each item of equipment will achieve a given utilisation at a guaranteed level of performance. Satisfactory performance will permit the issue of a 'Taking Over Certificate' when APCCL will assume ownership of the equipment subject to the extended warranty provisions of the supply contract.

22.4 Tooling

Tooling will be subject to inspection and test before shipment to site to verify that all the required features are present and castings and cores are dimensionally accurate. A certificate of 'Acceptance for Shipment' will then be issued. The supplier will be required to provide in his contract a specified number of man-days on site for 'fine tuning' the tooling to production machinery and materials in the foundry, as unforeseen dimensional differences may occur and compensation be required.

The production of sound castings is not the responsibility of the patternmaker, but resides with the consultant and/or methods engineers providing the running and feeding systems. Alterations to tooling, after consultation with the patternmaker's engineer, may be necessary to secure casting integrity.

22.5 Training

In a new enterprise such as is foreseen by APCCL, a completely new staff must be created and be ready to operate the plant at start-up of production. This must be done progressively from the start of the implementation programme. It is essential that technical staff competent in plant engineering are recruited early and that they become involved in building and equipping the foundry. Training of maintenance personnel in equipment suppliers' plants, during the final stages of manufacture, should be provided.

Direct training for technicians in operating foundries is likely to be difficult owing to the competitive situation, so classroom lectures and on-site training during commissioning is the more probable solution. It seems unlikely that any foundries in India would be able to provide training relevant to the technology proposed for APCCL.