UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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REPORT

TO

STATE GOVERNMENT OF ANDHRA PRADESH

AND

FEDERAL MINISTRY OF INDUSTRY

ON

SELECTION OF A PROPER DESIGN CONCEPT

FOR

ESTABLISHING A LARGE-SCALE AUTOMOTIVE FOUNDRY

BASED ON THE WORK OF

G.C.B. LAMB, CONSULTANT

ON BEHALF OF

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

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1. ABSTRACT

APCCL	Andhra Pradesh Core Castings Ltd.
MECON	Metallurgical & Engineering Consultants
BCIRA	British Cast Iron Research Association
FMD	Foundry Management & Design
The Counterpart	APCCL
Automotive	- relating to the wider sense of automobile/truck/ tractor production.
Castings	- in iron or aluminum for automotive and general trades supplied in semi-finished condition.
Energy Conservation	- Centred principally on preserving useful energy otherwise wasted from the metal melting process.
Novel Concepts	- APCCL is anxious to develop research into fields considered to be subjects of value to the economy of the project and to India.
Market	- export and domestic markets are considered by the counterpart, leading to categorization of the Project as an Export Oriented Enterprise under the definition of current Indian legislation.
Tooling	- provision of patterns to produce moulds, core boxes to produce cores, core assembly fixtures, measuring gauges, fittings for pressure tests, dies for fettling operations.
Sprue	- unwanted metal necessary in the casting process to introduce liquid metal into the mould cavity.
Tempering	- (of moulding sand) allow mixed sand to stand for 1 - 4 hours to promote flocculation of clay and obtain improved moulding performance.
Classify	- reduce silica sand to seperate grain-size (to assist in correct sand performance as a moulding medium).
Screen	- to remove unwanted components from foundry sand, e.g.:sand lumps, core pieces, metal flash etc.

2. INTRODUCTION

APCCL, the counterpart, in a joint venture with Andhra Pradesh Industrial Development Corporation, a group of state enterprises, is planning to build an automotive foundry, primarily for the production of cylinder heads and blocks. These castings will be required for the automotive plants to be set up in India, in collaboration with Japanese manufacturers, to manufacture the latest Japanese models. Ad-hoc UNIDO technical assistance has been sought for the project, since the beginning of 1985.

The intention is to provide a modern mechanized foundry, built in accordance with the world standards and incorporating the latest technical developments.

The project has been provided with two independent analytical reports from recognised authorities; these reports are evaluated in this present report.

Project Staff:

Mr. G.C.B. Lamb (U.K.) - Independent Consultant on behalf of UNIDO.

Report Object:

To present a co-ordinated view of the points raised by the two independent authorities and to rationalise or upgrade the conclusions of those reporting authorities, leading to firm recommendations for further action suggested to be taken by the Government and APCCL.

Distribution:

3. SUMMARY OF CONCLUSIONS

1. The reports received are of a technical nature only: the terms of reference leading to the reviews offered are also restricted to technical matters only.

2. Insufficient market information has been provided and therefore did not allow for any appraisal to be made of the financial justification for the project.

3. Before proceeding any further with the project, an independent market appraisal and study should be made by competent automotive foundry experts, to be followed by a pre-feasibility study. Should the pre-feasibility study produce adequate results, then a full feasibility study should be contracted.

4. The views of the two independent sub-contracted specialist organisations and those of the consultant, and the UNIDO back-stopping officer concur that no further action may be taken until the feasibility (market study) has been obtained.

5. The original report of MECON is a useful first concept and may be taken as a basis for building a more sophisticated solution.

6. The report and conceptual studies of APCCL is a substantial development of the MECON report and embodies most of the necessary technology in concept.

7. The APCCL and MECON reports contain insufficient material to justify an investment.

8. There is uniformity of view between the two independent expert authorities (BCIRA and FMD) concerning the concepts of:
   - metal melting
   - metal treatment and pouring
   - moulding production
   - core production
   - technology of sand preparation
   - casting shake-out and cooling
   - heat treatment
   - fettling, finishing, shot-blasting
   - quality control and inspection
   - introduction of micro-processor control
   - entry into market.

9. **Treatment of the Brief by the two authorities was different:**

   - **BCIRA provided significant detail responding to the lead proffered by MECON and APCCL and submitted a well prepared and documented report.**

   - **FMD supplied less detail in the body of the report, preferring to justify conclusions in appendixes, but have offered a very mature overall project comment. The layout prepared is considered superior to all the alternatives presented; it includes a sand plant concept which should be strongly recommended to the counterpart.**

10. Attempts at energy conservation have been accorded too high a significance in the overall concept by APCCL and constitute a threat to the successful implementation of the project by reason of:

    - development effort and cost
    - inclusion of proven unsound principles

11. The danger exists of management effort and financial resources being diverted to re-discovering production concepts favoured by APCCL which have been tried and abandoned by foundries in developed countries, e.g.:

    - attempts to classify shake-out return sand
    - recovery of core sand from shake-out castings
    - storage (in bunkers) of milled sand prior to use in moulding
    - substitution of shake-out profile cooling for a heat treatment operation.

12. Insufficient effort has been expended by the counterpart to date in accurately quantifying the status of raw material supplies.

13. The proposed site and location is considered suitable for the scope and aims of the projected production.

14. A confused picture of market prospects and scope is presented. No components or drawings have been offered for examination or consideration, therefore the project may need the capability to compete directly with local small-scale industry to be able to establish itself in the market-place, as a vehicle to prove its technical superiority. The uncertainty of the market position must again be stressed and caution given as to the need for proper financial feasibility studies to be contracted prior to contemplation of investment.

15. The counterpart has demonstrated energy and enthusiasm sufficient to carry through the project provided always sound technical concepts prevail and a realistic market opportunity exists.

4. SUMMARY OF RECOMMENDATIONS

The following represents the opinion of the consultant about points which have arisen during conversations with APCCL during the period 27th March to 4th April, 1987:-

1) Sand washing and drying facilities are expected to be necessary.

2) That E.O.T. cranes may be deleted as a means of reducing building and foundations costs.

3) Workers may in fact unload from lorries delivering melting raw materials and place these materials directly into the melting furnace: no intermediate handling is necessary or justified.

4) In the event APCCL decides to use E.O.T. crane in the Stockyard area, there is no need for a magnet or magnet control gear: skips holding approximately half furnace capacity would be loaded in the Stockyard area and transported alongside the melting furnaces where they will be tipped as a means of furnace loading.

5) Sprues, after cleaning by simple barrel cleaner, would be transported in circular skips forming part of the furnace charging operation.

6) Day bunkers are not necessary for the scale of operations envisaged. Steel skips of approximately 3-tonnes capacity, may be placed on the furnace platform to form the function of day bunkers and are thereby transportable if E.O.T. crane is to be included.

7) No justification can be seen for the temperature profile cooler and it is recommended that such unit is not included.

8) Heat treatment should be included. Fettling shop area is a convenient location for such heat treatment. Twin base 'top hat' heat treatment furnaces are recommended.

9) Following APCCL request to have flexibility to include aluminium cylinder heads and the capability to produce aluminium castings, there emerged from conversation the possibility of using a Disamatic moulding machine which would have the capability to produce cylinder blocks: in conformity with some of the latest practice (Daimler Benz and Cosworth), cylinder heads could be made in sand compacts produced on core-making machines. These sand compacts will be transported and poured in the air set area.

10) It is confirmed that in the event of aluminium being required as a major component of production, the installed electric furnace units are capable of melting the necessary alloys. Furnace type and rating would be modified if aluminium melting was specified in the first instance.

11) The auto-pour unit should have secondary transporter rails capable of moving into an area covered by EOT crane if this is to be used in the Stockyard and Melting area.

12) The notion to use pouring launders in front of the induction furnaces is not approved. The alternative was offered of pouring directly from the induction furnaces into transfer ladle or pouring ladle and using a launder when the EOT crane is being used as a substitute for the mono-rail pouring system.

13) In hot castings handling area the manually controlled, hydraulically powered manipulator should have a bridge crane system fallback installed.

14) APCCL notion to remove castings and sprue in the vicinity of the shake-out is unsound. It is regarded as wholly impracticable in terms of operator safety, access, working conditions for operators and the use of wedge type sprue breakers at the shake-out.

15) Consequent upon APCCL decision to include Disa machine it is recommended that a simple drum (Kuttner or similar) should be used thereby making practicable the simple sand plant layout such as demonstrated by FMD in their proposal for layout.

16) The APCCL idea to have a cellar or pit in which the rotary screen is installed is entirely condemned. It is expected that the working conditions in this unit will be completely impracticable by reason of temperature, water vapour and random dust.

APCCL proposes to have bag filter or dry dust collector units installed in this cellar: advice has been given to change this idea and instead to allow the dust extraction unit to be outside the area so that at least all the make-up air in the cellar area has to be drawn in from outside. This at least would give some chance of improving the atmosphere.

APCCL has been cautioned about the condition which will arise if flushing takes place in the rotary drum by reason of excessive cores which do not breakdown, unpoured moulds, accidental high moisture in sand or system malfunction which could have the effect of discharging

between 1-tonne and 2-tonnes per minute of sand into the tramp metal and oversize collecting bin. These bins are located on the cellar floor and have to be removed by lifting individually by means of mono-rail provided for that purpose.
APCCL has been advised to bring all of the equipment in the cellar above ground floor level.

17) It is believed that a cost analysis would show that if a shake-out and sand cooling drum is installed, the deletion of sand plant items consequent upon that decision would show a cost effective economic situation.

18) In core shop area advice has been given to include a minimum of four very small bench core blowers (e.g. Redford).

19) It is considered an omission that caution was not given of the need to produce strainer cores when producing moulds for horizontal joint flasks.

20) It is considered important to have an overbelt, rotary 'lawnmower' sand aerator for green sand at the delivery to the moulding machine, whether Disa or otherwise. The distribution of the dust control equipment is proposed outside the building in all cases: individual dust collection units have been recommended as distinct from major common unit particularly in the fettling areas.

21) The laboratory area is recommended to be located outside the building for reasons of simplicity of achieving vibration-free mountings for the absorbtion spectrometer.

22) The air set unit is presented as a self-contained arrangement with sand mixing and sand reclamation: the form of reclamation has not been specified: mechanical (impact) will serve adequately for most cases expected. No shake-out facility is provided since break-up in the attrition unit is foreseen.

23) Building design should feature the following:
   - avoid E.O.T. cranes
   - delete all internal walls
   - keep outside walls to a minimum compatible with climate

24) Market points to be bourne in mind:

- steering housings)
- inlet manifolds) are heavily cored items
- camshafts should be included

. SG iron - green sand mould-hardened
. Grey iron- core mould block-chilled

25) Marketing strategy may have to be tailored to suit local (low quality) items as means to start-up. Such items will probably be non-cored. Quantities may be small, say 50-400 batches.
The pattern-making facility must be suitable for this service.
Successful entry into cylinder head and block production may require 8-18 months of continual development and adjustments for EACH pattern! The need is stressed for proper account to be taken financially of these heavy charges during the start-up period. The point should be reflected when contracting a full feasibility study, if this is justified following the indications from the pre-feasibility study.

26) For automotive components a 200-tonne hydraulic press should be included for straightening of SG items such as hubs, differential carriers and steering boxes, where axes, mutually at right angles have to be true.

27) Core shop should include at least 1-off roll-over and dump shell core machine.

28) Automatic flash grinder is essential for fettling department. Could be reduced facility for initial start-up (i.e. 2-faces only at a single pass) and change-over set-up time accepted.

29) APCCL should not attempt to introduce computer line control until some 5-7 years of operating experience has been gained.

30) Prospect of selling high quality castings at a premium price is not in accordance with world-wide experience. When faced with quality/price conflicts, customers have always opted for price advantage. This situation must be properly reflected in the feasibility study which is advocated prior to any investment.

31) Mould machine supply contract should include (say) 3-sets of full pattern and tooling equipment as part of the performance guarantee liability.

32) Core making equipment need not be supplied in full complement at commencement so allowing "second ideas" as market scope manifests itself.

33) Training programme should commence at an early stage but caution is necessary to avoid over-recruitment of engineering staff who will not be adequately employed in the production phase.

5. REVIEW OF REPORTS AND DOCUMENTATION

The two reports, MECON and APCCL follow mainly the same concepts. APCCL report adds a number of project concepts.

Both reports have been well researched but there is a degree of limitation which has been taken to be the absence of experienced foundry assessment during the compilation.

Two prime aspects are not defined:

1. designed output
2. proposed market

The review of the consultant has been formulated in two modes:

1. the consultant's views of the presented work with respect to the declared aims.
2. assessment of the technology indicated by the sub-contractors either separately or in conjunction with the counterpart and comment on the techniques and methods which are common in the recommendation of both sub-contractors.

In the presented work from MECON and APCCL the bias of production was towards automotive grey iron with a proportion of SG iron. Latterly, during meetings in Hyderabad between the consultant and the counterpart, notice had been taken of earlier opinions expressed indicating that modern trends in automotive cylinder heads are in favour of aluminium. Subsequently, the counterpart has wished to take account of the posibility of aluminium featuring as a significant part of the output of the new foundry unit. This indefinite statement as to manufacturing intent, and the imprecise market situation reflected in the work to date raises a point of further caution regarding the need for a correct feasibility study to be carried out prior to the justification of investment.

6. CONSULTANT COMMENT ON THE FEASIBILITY OF THE PROJECT USING THE DESIGN CONCEPT PROPOSED BY APCCL

Overall the APCCL concept will give a satisfactory producing unit for the purposes defined: the capacity and proposed equipment are not in balance and need important review in a number of areas.

APCCL has done a lot of work and put much effort into the project concept but lack of practical foundry experience in the sources available to APCCL may have been responsible for producing a result where some of the capacities are seriously understated. However, the remedy is not difficult to recommend.

6.1. Metallics and melting

The basic concept of stockyard layout is capable of much simplification which is recommended in the appropriate section and alternatives of melting possibility for grey and SG iron are too numerous to mention. APCCL has decided to have two medium frequency furnaces and to transfer the metal to a holding unit; following discussion between BCIRA and APCCL a decision was made to amalgamate the holding unit and automatic pouring system which is a satisfactory thing for grey iron production. If SG iron production approximates 40% or 50% of the output APCCL could be embarassed by this decision because the major capital investment in the autopour unit with holding facility will be available for only one half of the proposed production, or dictates in-mold process, as has been pointed out by FMD.

During the development of the proposals in U.K., APCCL has indicated that an unattractive market price for SG iron is a pointer towards the continued predominance of grey iron in the projected production schedules; if this proves to be the case the amalgamation of holding furnace and autopour unit will have proved satisfactory.

6.2. Moulding

Moulding considerations have been limited to high pressure moulding machines with a leaning towards blow squeeze: this decision is endorsed by reasons of cleanliness and lack of noise and it has been pointed out to the counterpart that since such importance has been placed upon the conservation of energy then the vertical parting Disamatic machine concept has substantial advantages over the horizontal parted steel flask concept by others. The resulting quality of mould and casting are not affected by this decision.

It cannot be recommended that cylinder heads be manufactured on Disamatic machine but in keeping with APCCL's wish to have the most modern technology which is currently represented by a core block and mould block systems and 'accidental fit' occurs between the cylinder head manufacturing idea in core block and the practicability of choosing either aluminium or iron as the alloy.

6.3. Sand Processing

The Consultant is of the opinion that neither MECON or APCCL thoroughly understands the nature of foundry moulding sand nor the functions to be carried out in a sand reconditioning plant and therefore it is contingent upon the sub-contractor and the consultant to ensure that by means of the subject reports an adequate interpretation of the functions is passed over.

APCCL in a conceptual report on sand plant, outlines fundamental objectives aimed at. It is not easy to understand the concept of variable energy depending upon heat content of sand in the context of reconstituting a green moulding sand. Concerning Item 3 relating to temper a note is included below showing that the concept has been abandoned in practical production foundries for more than 20-years.

In the plant highlights, reference is made to a rotary breaker screen to crush and disintegrate the lumps of reclaimed sand but within the consultant's knowledge, this machinery refers only to air setting sand not to green moulding sand. There is reference under plant highlight Item 1 and elsewhere in the report to screening of the sand to desired grain fineness distribution. The consultant has informed APCCL that such an achievement is not possible with the type of equipment indicated in the report and on the layout drawing. Where reference is made to the direct addition of new sand to return sand this is a variable: when heavily cored work is being made, no need will arise for the addition of new sand because such new sand will be delivered by means of breakdown of cores. Wet cooling is introduced in the description and is taken to mean the spraying of water into heated sand to take benefit of the latent heat of evaporation of water.

Concerning the application of controls and their functional performance, APCCL has been informed that the most significant factor in the control of a green sand plant with automatic moulding is statistical examination of the sand performance when making each of the patterns forming the total product mix. The weight of casting related to the weight of sand is not significant as a means to determine residual moisture and temperature in shake out sand.

The introduction of a micro processor is a good idea and when coupled with readings from the sensors distributed around the plant and fed with data concerning the production taking place at present time and more especially the pattern which will follow and be the subsequent production, in which case, useful information can be obtained and the data applied.

Under APCCL item III.(5) the variation of sand to metal ratio is not of any direct consequence; it is the heat transferred to the sand that matters.

Paragraph V.(g) pre-mixer and dry cooler for mixing the sand with auxillary materials. If the pre-mixer can be in the form of a "paddle" mixer (sort of screw feeder) to distribute wet materials into the granular sand mass, it would have some advantage, indeed, this is the classic method of increasing the output of a sand plant to achieve increased mould production.

Concerning mixed sand stored in overhead bunkers for 2-23-hours, this has been extensively tried by General Motors, Albion Malleable, National Malleable and Steel Castings and all have failed. The systems were removed after between 2 and 5 years experience, in fact the sand is of much better quality but it cannot be got out of the hoppers.

A very important feature which seems to be missed is that bentonite and coal dust are normally added as a slurry with water. This is separate from and additional to the re-use of sludge from a wet arrestor.

Note that about 65% of the desired effect is reached when slurry is used for binder and coal dust (different from wet arrestor sludge.) The capacities in both reports are clearly too small. A revision connecting 140-moulds per hour, suggests 110/120 tonnes per hour. It is prudent to provide sand preparation capacity to match the machine output.

APCCL wish to use facings sand which the consultant completely condemns.

Reference APCCL item (g), the Pre-mixer cooler.
This is not really understood. APCCL must appreciate the danger of carrying away fines when air passes through sand body.

Reference Item (h), Sand storage. If sand storage is proposed between two mixer units then the consultant entirely disagrees.

Item V.(i) final mixer. It is not agreed that high intensity mixer avoids the need for final aerator. A final aerator is considered essential whatever the form of mixer.

The concept under Item VI, a micro computer is very good and is much to be encouraged but a lot of work will have to be developed within the plant to achieve this. It is hardly worthwhile to specify the parameters to which such a system has to be coupled in the design stage. Equipment should be provided within the scope expected and the detail worked out in practice.

Reference Sand Plant description (sand plant list), the following major points arising from the consultant's experience are highlighted for attention:

- Item 3 - Rotary Breaker Screen.
  Specifies screen opening - 21 perforated. If this means 21mm dia. it will result in excessive quantities of sand being rejected.
  N.B. It will not be possible to screen the sand for grain fineness distribution. Fines may be removed by air flow (including clay and coal dust).

- Item 4 - Wet Sand Cooler.
  Repeat caution about screen opening; 5 x 25mm would not normally be effective.

- Item 5 - Bucket Elevator.
  Of course cannot use nylon buckets, they would be melted by the sand and the specification should be much more advanced. The material of the reinforcement of the belt must be mentioned. It is better if there are two rows of buckets staggered intermittently and overlapped.

- Item 6 - Hoppers.
  Capacities to be revised.

- Item 9 - New Sands Conveyi metering system.
  Care must be taken about us an elevator in this context since the sand may be up to 16% water. It would be desirable to use chain and bucket elevator and not a belt to achieve effective discharge. Nylon buckets or polypropylene would be an advantage.

Item 10 - Vibrating Conveying Tube.
APCCL must be warned that damp silica sand flushes on a vibrating system in the absence of bentonite and a more positive form of feed will have to be considered, e.g., screw feeder.

Item 12 - Feeder Screws.
Neither coal dust or bentonite feeds properly due to flushing through screw feeders, recommend rotary plate feeders.

Item 15 - Weighing and Metering system for the muddy water.
If this means water returned from wet arrestors then it is best measured in a glass or plastic tube with external capacitance limit switches. If it is slurry it is best measured by a timed opening of a valve against a pre-set pump pressure in a circulating ring main.

Item 16 - the Wet Type Dust Collector.
Each manufacturer has his own normally very tightly patented system. APCCL would be wise to invite alternative quotation and take the system which best suits its needs.

The APCCL specification attempts to show a lot of detail but misses out a number of critical elements such as draining, sludge level control, scraper shear drive, broken-down scraper recovery, cleaning access and the need to duplicate level probes to deal with capacitance change from build-up.

Item 17 could well be achieved by gravity when the final layout is considered.

Item 18 - Electric Switch and Control Plant.
APCCL should consider a system that steady light means motor in operation and light extinguished means motor stopped. If there is a total electrical failure it will not give the flash.

A point not specified is the need to provide isolators for safe maintenance purposes in addition to the lockable load disconnectors which are specified as housed in the cabinet.

Elements discussed in detail with APCCL during the visit of the consultant to Hyderabad:

Concept of sieving foundry return sand cannot be recommended since it is not practicable.

For the control of grain size distribution APCCL should expect that a proportion such as 5-tonnes of sand per day should be discarded and submitted to treatment through a separate sand washing, drying and grading plant. This item was coupled with a question of quality of sand which can be purchased locally.

Caution was given to APCCL that sand delivered to the foundry could be expected to have high moisture content: workers employed by delivery firms would have found out that if dried silica sand is wetted it is less prone to dribbling and leakage from cracks or splits in the load carrying compartment of a road vehicle. Since the distance of hauling sand is stated to be approximately 500 km, the point is quite significant.

When making cylinder blocks and heads it is likely that excess sand will have to be discarded from the sand system and may be as high as 120-tonnes per week.

Provision should be made to store dumped sand during periods of excess core load so that the same sand can be washed, dried and graded and returned to the plant when required.

Pointed out that characteristics of a shake-out return sand are quite different from virgin silica sand by means of residual bentonite plus dead clay, some coal dust, burned coal dust and ash and probably 1.2% to 1.8% moisture.

Where washing, drying, and grading facility does not exist a quantity of sand daily (5-tonnes/10-tonnes) would need to be discarded as a means of removing unwanted fines and dead clay from system.

Specifically discussed the storage of shake-out sand prior to re-use and re-constitution: the advisability of using a wide area distribution was discussed and the basis pointed out, principally that if the proposals from APCCL is followed where sand will be separated and delivered by individual chutes, segregation would result and heavy particles roll down sides of the cone formed under the chutes thereby giving two grades of sand in the same hopper with no means of control at the outlet.

Discussed alternative procedure of mounting a plain rotating screen over the top of the hopper: the screen should be tapered to be larger towards the discharge end and that improvements in distribution are achieved by blanking off some parts of the screen according to experience. Sketches made to show that the rotation of the screen influences the distribution of the sand in the hopper which must be taken into account.

Discussed design of ploughs serving discharge points from conveyor belts: mentioned alternatives of horizontal pivot and vertical ploughs, their different functions and points where they should be allocated to various parts of a sand system.

Discussed at length the improvements in a moulding sand after mixer due to the effect of tempering on the distribution belts: this is an argument in favour of long inclined belts to deliver sand from the intensive mixer to the moulding machine temporary storage hopper: the use of wide, slow-moving belts was mentioned and that an advantage accrues from an over-belt sand aerator (lawnmower type).

Discussed at length and offered considerable detail relating to the experience of a North American and European Companies in attempting to mill sand and store for a tempering period of up to 4-hours and commented that these systems have now been entirely abandoned and that no report of such use has occurred in the literature for more than 20-years.

Pointed out that if clay and bentonite are mixed with water in a proportion to reflect the expected additions in the intensive mixer, that much of the achievement by sand tempering is thereby obtained.

Recommended that in the plant layout, the travelling time for sand after leaving the intensive mixer should be between 5 and 7 minutes and that the moulding machine supply hopper could carry approximately 10 minutes or 12 minutes sand supply.

Stated that tempering is difficult to measure in terms of mouldability but that green compression strength will rise and shatter index will arise.

Advised APCCL to place less reliance upon instrumentation in the sand plant and to regard the instruments and sensors as an indicator only, it has been the experience of the consultant that a mouldability index obtained with a BCIRA/Dietert measuring unit fitted to a Beardsley & Piper speed muller were found to be not applicable to the moulding performance of the sand: this point may be a useful introduction to APCCL to the fact that the process of measurement of sand performance and mould making performance can be related to instrumentation but not measured directly to it. Instrument readings are a useful guide only when related to observed good performance.

6.4 CORE MAKING PROCESSES

APCCL was advised that in the opinion of the consultant the general approach to core making was too lightly handled throughout. Most extensive discussion is given to type and selection of moulding machines and hardly any consideration to the technology of core making.

The core machine specifications of MECON confuse air set and core making.

Primarily, the number of machines is grossly insufficient, secondly, the specification of machines and processes should be modified. MECON suggestion of 600 x 600 heater plates for solid shell is not practicable for automobile work, unless for multiples of small cores.

Choice of hot box is sound technically but may not be comfortable for operators in the prevailing climatic conditions.

APCCL machine complement will also need expanding possibly to 12 or 14 machines ultimately.

Advice was given to include a number of hand core making benches and 4-off small bench core blowers (e.g. Redford).

Two batch mixers are inappropriate. The batch mixer should serve for special mixes only with the continuous mixer up-rated for the main core sand processes. Extra mixers would be added as production develops. The uncertainty of the market further underlines the need for caution before making investment in the face of an undetermined product mix.

Concerning the specifications, many detailed points may be improved:

- vertical split should apply to 1-off 6-litre machines
  all shell 12-litre machines
- horizontal split should apply to 1-off 6-litre machines
  all 25-litre machines
- minimum box for 6-litre should be 2 x 75
- maximum box for 25-litre should be 900 x 700 approx.
- electrical heating is most unsatisfactory. Since it is likely that only shell will be retained as the hot process, serious consideration is necessary to introduce gas process heating.
- core removal from vertical 6-litre machine should be by sliding ejector. (i.e. mechanical)

The foregoing points are offered to suggest process improvements to APCCL - in fact if the recommendations for cold-box are adopted heat related factors fall away. Nontheless, the point about gas heating for shell is most important and every endeavour should be made to achieve it.

Opportunity was taken during the visit of APCCL directors to the offices of the consultant in the U.K. to indicate the effect of different degrees of efficiency in core blowing on the resultant casting surface finish and casting dimensions: constraints upon casting dimensional integrity arising out of core making limitations were also demonstrated by means of drawings and plaster models.

Concerning the core machine layout, advice was given that the space between the machines as envisaged in various layouts is inadequate and that a minimum of 2.3 metres between adjacent machines is necessary and a space of 2.5 metres from the rear of a machine and an adjacent wall should be regarded as minimum.

An extensive discussion was held considering general and detail points of core shop layout and the general theme indicated in the FMD drawing was endorsed as convenient for core shop layout. Certain details were changed to suit the configuration of an envisaged building, APCCL were recommended to follow the basic concept of the FMD presentation.

Advice was given that the effective utilisation of core making machines can be as low as 35% and will very rarely rise higher than 65% and that in the light of such advice the number of core making machines proposed by MECON and APCCL in the original reports falls substantially short of the minimum considered necessary.

The unlikelihood of a single core making system was explained and APCCL advised that experience would show that different core making processes ultimately became necessary to achieve user satisfaction and quality in cylinder blocks and heads. Whilst there cannot be a certainty it is possible that shell process cores would be necessary for reasons of strength and rigidity and that otherwise a gas hardening, cold-box system may be chosen. Alternatives were discussed and a strong indication given by the consultant that the amine hardened iso-cure (Ashland) may find favour by reason of its world wide application: ester hardened phenolic resins have been shown to be very popular in Europe for motor cylinder work: ester hardened phenols have the merit of being less affected by moisture than some of the alternatives.

During the lifetime of the projected foundry it is quite likely that continuing research will produce a silicate based cheap core making material suitable for the climatic conditions projected in the Hyderabad area. The consultant has experience of successful gas hardened, sodium silicates in Malaysia and in Indonesia in tropical rain forest climatic conditions and further development of the processes should be expected. If such development occurred and was widely used the proposed core making machines would be adequate.

The alternatives of applying a core coating were discussed. APCCL has a distinct bias towards electro-static spraying of coatings. Advice was given not to abandon the concept of dipping the core in certain specified instances where a good refractory cover proved necessary in practice.

As a point of reducing initial capital expenditure, advice was given to APCCL not to install the full complement of core blowing machines in the first instance so that any special demand for core making process or type of core making machine could be established prior to the purchase and installation of the full anticipated machine complement.

The core shop equipment was discussed in full and a schedule of plant and equipment studied: it was advised that as a means of reducing costs the locally produced 'flip up' core racks could be replaced in the early stages. Transport of the cores between storage and moulding machine was discussed, alternatives mentioned, and APCCL indicated a preference for manually pushed rubber-tyred core rack. The superiority of the 'flip up' core storage racks mentioned by BCIRA is confirmed with the suggestion that they introduce at a later time during the life of the project.

Core box cleaning has not been included. Build-up of resin deposits occurs in core boxes and changes to dimensions of the cores. Removal is by blasting with glass beads in case of cast iron core boxes and by chemical solvent in case of epoxy or urethane core boxes.

Following a decision as to process route a suitable cleaning procedure can be outlined.

6.5. Automatic Temperature Profile Cooler

This element is a salient feature of the operation which is being strongly sought after by APCCL, principally on the basis of energy conservation, and improved metallurgical quality.

The concept is a worthy goal but execution is likely to prove impractical. If the foundry produced only a single product or narrow product range, the likelihood of success would be greater.

Placing castings into a tunnel (muffle) furnace has been practiced for many years, but recent experience shows that almost the same effect is achieved from placing castings in a fork-truck container.

Following shake out at about 900 deg.C. the thinner parts (e.g. skirt of cylinder blocks) cool rapidly to 450/500 deg.C., say in 3-minutes, whilst the cored bores and water passages will probably be 770/830 degC., after 3-minutes, therefore internal stresses will result. Practical solutions to the problem could be:

1. Place in container so that a temperature-levelling "soak" occurs.
2. Pour moulds at end of shift and allow castings to cool for 4-8 hours, as may suit the plant operations, and shake out at 250/400 deg.C., when most of the stresses will have been resolved.

Practical factors should be considered by APCCL when using the profile cooler as described in the report include,

1. Temperature loss from castings:
   - whilst being punched-out or dumped.
   - during pick-up and transfer by manipulator.
   - whilst waiting in container/furnace charge carrier for full loading.
2. Need for closed bottom and sides of charge carrier to contain sand.
3. Heat transfer barrier created by charge carrier.
4. Limitation on air circulation inside furnace to avoid blowing about core and mould sand.
5. Acceptance of a dump-out operation somewhere in the circuit to discharge loose sand.
6. Castings must be picked out of container by manual hoist or manipulator or alternatively dumped when sand is discharged (which will repeat the condition applying if castings were dumped into container at shake out .

In terms of energy conservation some points may be mentioned:

1. Profile cooler would require <u>heat input</u> to bring cooled parts of castings above 760 de .C.

2. To achieve Item 1 above, the furnace would involve:
   - charge carriers
   - castings
   - sprue
   - unknown weight of core sand
   - unknown weight of moulding sand

3. Of the load defined in Item 2 above, the following would be entirely unproductive and thus <u>consuming energy unnecessarily</u>:
   - 80% of charge carrier weight (without sand problem carrier would be only 20% of weight)
   - 6-8% reject castings
   - sprues
   - core sand
   - mould sand

Analysis of sub-contractor and consultant response to the profile cooler concept:

- FMD is not convinced that the automatic temperature profile controlled cooling furnace is either necessary or advisable.
- BCIRA considers that 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 consultant recommends that for the reason outlined above the automatic temperature profile cooler concept should be abandoned and that cooling with some soaking in containers should be substituted and necessary heat treatment performed in the fettling shop.

A suitable layout indicating the function of a cooling unit was drawn and described to APCCL in Hyderabad and subsequently in U.K. where photographs were examined of two similar systems designed by the consultant and operating for more than 15-years.

7. ASSESSMENT OF SUB-CONTRACTOR TECHNOLOGY

7.1. Tooling and Pattern Design

The MECON and APCCL reports do not adequately cover the aspects of tooling:

design
manufacture
procurement
maintenance

Further more FMD points out the serious under-estimation of expected costs shown by MECON, although acknowledging that the component is not specified.

BCIRA note a procedure for tooling and its relationship to responsibilities for verification and the casting quality.

The consultant has demonstrated pattern design, technical provisions and component/tooling design interaction during a visit of APCCL to the consultant offices in U.K. and emphasised the significance of this phase in securing the success of a foundry project.

Advice has been given to APCCL to specify 3-sets of tooling to be delivered with the moulding machine and at the responsibility of the machine manufacturer.

The extent of the training to be budgeted for has also been emphasised.

APCCL is also advised that pattern repair facilities alone are not sufficient to sustain the projected output. Continual adjustment and refurbishing of tooling is to be expected and for long-run production items a minimum of 2-sets up to 6-sets of toolings are to be anticipated.

7.2. Melt treatment, metal pouring and innoculation

On the salient points FMD and BCIRA agree, principally:

- medium frequency melting furnaces
- metal holding unit
- automatic pouring
- late metal stream innoculation

The FMD report deals more fully with different types of mould pouring units available and gives arguments and technical support in favour of its use; BCIRA concentrates more on the specification of such unit and lists the ancillary equipment to be specified.

BCIRA discusses different sizes of autopour unit and concludes that 2.5 tonnes capacity is advisable. FMD point out that the product detail is not known but estimate that a minimum size would be 2.0 tonnes capacity.

The alternatives of channel type furnace and coreless furnace are discussed by both sub-contractors and an examination made of varying capacities. The advantage of being able to empty a coreless furnace is pointed out by BCIRA who finally recommend a 12-tonnes capacity combined holding and pouring unit. FMD take an alternate route and mention the disadvantages of applying power to a coreless furnace at low levels of heating and thus loss of superheating efficiency and caution that with less than one third of crucible capacity, the metal can actually lose temperature even on full power. By adding these points to the increased expected refractory cost per tonne of throughput, in the case of a coreless furnace, FMD recommend that the holding unit should be channel induction.

For metal innoculation the concept of a late metal stream innoculation is endorsed by both sub-contractors and the merits of using compressed air or nitrogen as a pressure medium are discussed; FMD considers the advantages of nitrogen when pouring SG be insufficient to warrant the additional plant equipment and consumables.

The pouring of SG iron as well as grey iron poses a problem which BCIRA and FMD would overcome by means of a separate metal pouring runway for manual pouring and FMD would retain the advantages of the autopour unit and effect the nodularisation by means of the 'in-mold' process.

Discussion on the choice of detail concerning melting was obscured in discussions with APCCL during the consultants visit to Hyderabad. During those discussions the intention to offer an aluminium capability was raised in discussions between the consultant and APCCL and at other times between APCCL and the Andra Pradesh Industrial Development Corporation, it was clearly indicated that the capability of moulding, core making, melting and shake-out and fettling facilities would be applicable to aluminium castings.

Until a resolution is reached concerning the final product mix, the consultant has to recommend that initial expense be saved by omitting the autopour unit and indeed omitting the holding furnace, thereby relying upon direct melting until the predominant alloy emerges following which a reappraisal of the metal handling system can be made.

The recommendation of the consultant that if aluminium is to be seriously contemplated in the plant it could be commenced by installation of a small (500 kg) melting furnace attached to the air set area so that mould and core blocks could be assembled and a secondary casting unit established.

Since APCCL indicated its serious intention to examine the Disamatic moulding principal and to contemplate whether such unit should be applied to aluminium, final decisions concerning the metal melting unit will have to be deferred.

7.3. Sand Processing

The necessary function of reconditioning green moulding sand has been practiced throughout the world for many decades and certain formats have emerged which are proved to be flexible and reliable. Many of these formats may be lacking in finesse of efficiency in the areas of power consumption, heat recovery and finite sand quality control but these have emerged throughout the world on the grounds of their general applicability to the manufacturing process. The consultant makes the point that it may not always be practicable to explore to the absolute limit any one abstract section of the sand reconditioning plant performance.

A very definite and simple presentation of the moulding sand reconditioning process is given in FMD report page 17, item 3.3.3.1. The attention of APCCL has been drawn to the FMD layout on account of its simplicity, small size and capability to achieve sand screening and cooling.

BCIRA page 29, item 7.4 summarizes recommendations for development of the sand plant. The expected capacity in the range of 100-120 tonnes per hour is mentioned as being consistent with the moulding machine capability.

BCIRA recommends the use of inclined conveyor belts in order to avoid elevators. This is a traditional problem in temperate and cold countries but is not expected, in the opinion of the consultant, to exist in Hyderabad. FMD is satisfied with the inclusion of elevators.

Both sub-contractors recommend high intensity mixers, both specify separate aeration of the sand on the belt after the sand mixer.

APCCL is recommending some form of pre-mix in order to develop temper in sand. It has previously been mentioned that this is a good concept but is self-defeating in terms of mechanical handling. The alternative of using a clay and coal dust slurry in the high intensity mixer has been previously mentioned: the point is here further developed.

In simple terms the benefit of allowing mixed foundry sand to remain unused for periods of up to 4-hours after mixing has been shown to promote the development of good moulding characteristics: these are difficult to define but relate to green compression and shatter. If coal dust and clay are pre-mixed as a slurry (not to be confused with the recovery of sludge from dust extraction units) flocculation of the clay commences before addition to the sand and a marked improvement in moulding performance can be measured.

BCIRA recommends that return sand from the hopper should be delivered to a weigh hopper and to a pre-mix unit and that the pre-mix sand would be fed into a batch hopper set above the intensive mixers. Thereafter, final additions of water, clay, coal dust and dextrin should be made into the intensive mixer. By suitable design of the batch hopper the concept is expected to work.

BCIRA specifically condemns the use of large storage bunkers for pre-mix sand, the consultant condemns the concept outright on the basis of 30/35 years reported experience in many countries of the world. FMD states (3.3.4.2.) that it is not aware of any iron foundry currently using a pre-mixing process for green moulding sand.

For the return sand cooler MECON proposes fluidised bed but APCCL includes a cooler drum: both work effectively. The consultant endorses BCIRA report that, if available from local manufacturers, may as well use the drum. However, APCCL must accept that the control of temperature or temperature reduction in the fluidised bed can also be associated with a degree of sand grain size classification.

BCIRA capacity recommendation of 240 tonnes for return sand hopper (being nominally two hours), is traditional and effective and is endorsed.

APCCL should recognise that in fact the sand is not evenly conveyed and stored for two hours. The sand is used as the demand requires. Normally two return bunkers would be used and would become part of a sand control system e.g. when a certain type of casting is being produced a recognised burn-out of coal dust and binder is to be accepted whereas with another type of casting different burn-out is experienced.

Sands are segregated in the bunkers especially when a pattern change is envisaged and their re-use is a blending from the two bunkers with compensating additions of binder and coal.

Concerning the belt and bucket elevators there are two points. What BCIRA says about blockage is without dispute, elevators do suffer from blockage, but since up to 11 deg.C. cooling can be achieved through each elevator and removal of fines is also easily achieved, there is just about equal merit in including the elevatcr. The point should be left either to the choice of APCCL engineers or as dictated by the final layout.

BCIRA page 28, caution about one overband magnetic separator is endorsed. It is recommended that in-line magnetic separators should be used and the plant layout made to achieve it. Four magnetic separators mentioned in BCIRA report will prove to be practical in the final system.

BCIRA page 30 onwards gives good recommendations for sand plant equipment specification:

The Stand Storage hopper reference to 'free flow' page 35 item 8.5, can mean epoxy resin paint associated with correct design detail. Reference page 36 item 8.7, (new sand additions equipment), it is not really significant as to how the hopper is loaded: hand shovelling is satisfactory direct from road vehicle.

FMD deals with the APCCL concept on page 18, the comments and points raised include:

- query rotary breaker screen: mention not applicable in green sand
- wet silica sand cannot be put through classifying screens.
- states FMD not aware of any iron foundry currently using a pre-mixing process for moulding sand.
- mentions recovery of coal dust and bentonite from wet dust arrestor sludge: gives caution that burned coal dust, dead clay and unwanted sand fines will also be taken into the sand mix. Alternative application for dry dust collectors is mentioned and FMD agrees the proposal.
- agrees use of load cells for weighing sand and additives.
- agrees electronic moisture controllers which are considered to be standard.
- following agreement with the principal of using high intensity mixer points out necessity to provide a separate unit to aerate the sand after mixing.
- agrees with the proposal to install equipment of sufficient capacity to meet phase 2 output: considers it necessary to install full mixer capacity during phase 1 to effect overall economy and avoid duplication of metering systems and loss of production when second mixer installation has to be added for phase 2.
- points out that unless dried and classified silica sand can be obtained then equipment will have to be installed to dry and classify sand and possibly to wash it.
- reflects nervousness about the suitability of rotary type dryers recommended by MECON and stated to be available in India: makes point that rotary dryers may not be as efficient as fluidised bed types.
- makes the point that raw sand is better tipped directly from delivery vehicles and processed through drying, cooling and classifying and then stored inside suitable silos in order to be available for make-up requirement.

7.4. Layout of Plant and Buildings

Foundry plant layouts should carry bias toward simple material flow and management communication between departments.

These desirable goals are met by:

- straight line flows
- avoidance of internal walls or partitions

Some foundries specify separation of:

- sand plant: because of dust (especially when using coal-dust additive)
- fettling shop: because no noise.

There are no general guidelines in this area. Most modern foundries are contained in a single building.

The MECON and APCCL layouts are derivatives one from the other, show compound flow routes and have many internal divisions, therefore they are considered poor.

BCIRA layout follows MECON/APCCL but rationalises relative areas and is regarded as an improvement, but the FMD layout showing absolute simplicity and logical flow must be regarded as completely the best scheme offered. Additionally, the FMD comment concerning layouts must be seriously accepted....."layouts are not final at the tender stage. Layouts are of a general nature and whilst it is expected that the total number of pieces of equipment will be the same (or reduced by one or two items) the overall cost will be the same."

A decision as to whether the sand plant should be housed in a separate building is entirely a matter for APCCL preference. The advantages of a separate building are about equal to the disadvantages and it is recommended that APCCL considers making an integrated building layout and that the sand plant occurs in its natural location dictated by the moulding machine shake-out arrangements.

The fettling shop may be placed in a separate area but there are no advantages. Protection has to be given from health hazards of dust and noise in the fettling shop in the same way as in other departments: if the working conditions are suitable for fettling shop operators they may be likewise expected to suit moulding and core making operators.

It is not correct to dismiss the fettling shop as a dirty and noisy part of the works: it must be remembered that the quality of castings is finally inspected, measured and confirmed in the fettling shop. It is very important to recognise that well-trained, highly skilled and alert fettling shop operators can diagnose casting faults and bring to the notice of management before final inspection occurs, thereby saving considerable amounts of money, energy and time by avoiding subsequent fettling operations and preventing further errors occurring during moulding.

The disposition of ancillary work places such as pattern shop, electrical and mechanical maintenance, stores and administrative offices have no bearing on the function of the foundry plant as a castings producing unit. Allowance should be made for metal particles and sand falling from delivery vehicles and a "dirty roadway" may be considered. Offices, canteen and social amenities are normally grouped in an area because they are without the need for heavy transportation, wide roadways or lifting gear etc., and no noise arises in consequence of their normal use.

APCCL is advised to have a works entrance and an office entrance separated one from the other and approximating to the suggested idea of a dirty roadway and clean area in the site layout. Transformer houses, compressor houses and pumping stations will be located as required by the demands of their function for minimum power loss and good accessability for cooling and maintenance.

There is no need for buildings in association with the dust and fume extractor units which can be free standing in open air with a weather protection for electric motors as appropriate.

7.5. Mechanisation And Automation Of The Whole Process

A discussion of mechanisation has to be related to local labour costs and government policies with regard to employment of labour.

BCIRA note that the counterpart proposals have handling limited to E.O.T. cranes and then goes on to state that mono-rail can be used for delivering hot metal following which a general review is offered concerning sand handling (15.4.7.). In connection with laying of core assemblies, the reference is made to a light overhead crane. Fork-lift trucks are foreseen for general castings handling and other materials within the plant.

FMD references to handling occur within the text and as part of the process description.

Generally speaking the consultant's view of the proposed handling system is that it is not in keeping with best modern practice. It is recommended that as a policy all work stations are fitted with under-slung bridge cranes and in some instances, although very much less preferable, with jib cranes so that each operator can work independently of other factors within the shop thereby maximising productivity.

The use of E.O.T. cranes is condemned by the consultant as being wasteful in time, capital investment, and enhanced building and foundation costs.

Handling of heavy bulk of material such as charging furnaces is very conveniently done from a mono-rail and can of course be totally automated: such automated systems have very little advantage and certainly in the expected case of APCCL with the local labour cost, it is unlikely that capital investment in automation of charge handling could ever be recovered.

Automation in the whole foundry manufacturing process is not widely practiced. Within the knowledge of the consultant all on-line computerised systems have failed and the computer controlled approach dismantled in favour of discrete microprocessor (PLC) controls in defined areas. Subsequent connections between PLC are developed as experience indicates.

The foundry production process lends itself to solid automation i.e., the use of dedicated equipment, but since APCCL forsees short production runs the yield could fall short of acceptable expensive automated installations.

7.6. Quality Inspection

FMD outlines a normal standard procedure relating to specifications for grey iron castings. These usually include:

hardness (brinell)
dimensional accuracy
pressure testing

A proportion of castings should be marked out and sectioned. Other tests include:

test bars for tensile strength
micro-structure
chemical analysis

FMD points out tests are to be carried out in laboratories and tests are carried out in the inspection of the finishing (fettling) department.

Sonic testing is proposed for flaw detection and its use if required in checking nodularity of SG castings is mentioned.

BCIRA devotes Section 13 to the use of semi-automatic ultra-sonic testing equipment for cylinder heads. The matter was taken up in detail in U.K. and found to be based on experience in very high volume cylinder head manufacture: on the basis of the supporting data presented the BCIRA recommendation for cylinder head ultra-sonic testing should be accepted.

7.7. Control Laboratories

The extensive review offered by BCIRA in Section 12 and relating to chemical and rapid test laboratories for metallurgical and moulding materials examination is summarized in table 1 pp.71 and 72.

FMD is not convinced that some of the moulding materials equipment is necessary e.g., hot distortion tester, but this is a matter of opinion, since an effective practical hot distortion test is easily arranged by means of a core box.

BCIRA includes the optical emission spectrometer as complementary equipment: this is not the view of the consultant and it is recommended that the spectrometer be included as first-choice equipment and that if necesssary costs saved by reducing the scope of a wet chemical laboratory to a supporting role only.

The mechanical test laboratory equipment may be capable of reduction if a local university or test house can offer the normal mechanical tests of tensile and rupture measurement.

A brinell hardness tester should be maintained in the fettling department. The consultant does not accept the statement by FMD that a brinell tester may be portable, and believes that apart from patrol inspector convenience, 100% brinell of significant production items should be tested by a properly mounted full-load machine.

7.8. Equipment Maintenance

FMD gives their review under 3.6.2. of a scope of work to be carried out and in the following paragraph mentions the principal activities ranging from machining, fabrication, hydraulics etc. and electrical functions which have to be provided for within the unit. A similar approach is not offered by BCIRA but the point is not very serious.

Establishment of mechanical and electrical maintenance facilities will be well understood within India.

8. ASSESSMENT OF AUXILLARY OPERATIONS

8.1. Energy Conservation

APCCL is placing great stress on achievement of energy-effective operations.

Numerous points are included in the reports which are aimed at specific energy improvements, and great stress has been laid on these elements during discussions at APCCL offices in Hyderabad.

It is considered necessary to advise APCCL that the danger exists of placing such a degree of emphasis on energy conservation that constraints will be introduced, causing difficulties in practical plant operation. This statement is emphasised most firmly.

Considering the areas specified by APCCL:

1. Metal melting and holding.
   Choice of medium frequency furnaces endorsed by FMD and BCIRA is to be recommended. If a particular manufacture of furnace is chosen, high electrical efficiencies may be achieved.

   The suggestion from BCIRA that holding furnace and pouring device are amalgamated is a very good idea and is to be recommended.

2. Molten metal transfer, distribution and pouring.
   By adopting a common pouring device and holding furnace, transfer between the two units is achieved. Use should be made of the available electrical capacity in the holding furnace so that metal may be transferred from the melting furnace at relatively low temperature and held at low temperature until planned production commences, in anticipation of which, the temperature in the holding furnace/pouring device can be raised on a programmed basis. APCCL should note that temperature in metal transfer is lost in the transfer stage and not significantly in the distance of travel. Temperature loss on transfer may be assumed to be 40 deg.C at each transfer and temperature loss whilst holding (e.g. travelling) is about 4°C per min for a large container and 11°C per min for smaller containers.

Ladle covering must be approached carefully: there is often merit in allowing the surface of the ladle to be exposed to air as a means of coagulating slag. Energy conservation element of ladle covering must be carried out only in relationship to the function being performed. All the cost savings in energy conservation may be lost by lining replacement if undue slag attack is present especially in the autopour unit. Cylindrical or drum ladles are well known and widely favoured.

3. Energy saving in moulding and coremaking.

Within moulding and core making the major energy users may be shared between:

1) compressed air
2) movement of moulding flasks in the mould making operation.

Remote controls to reduce either running of compressors may easily be installed: normally they relate to the pressure in a remote air receiver. With main and back-up compressors operating, the main compressors continue on load and the back-up units cut in and out under programmed control. On-demand compressor start-up and shut down is not practicable and starting a compressor against full load will consume more electrical energy than allowing it to continue running for many minutes. Therefore micro processor anticipatory controls need to be included.

In order to avoid the considerable energy wasted in transferring flasks during the mould making and cooling period serious consideration should be given to the Disamatic concept of moulding. Energy comparisons in favour of the Disamatic principle as compared to other flask type moulding machines are sufficiently impressive to warrant investigation in depth.

Cold box core making avoids the use of energy at the core making machine: instead the energy is applied at the manufacturing works of the consumables supplier so that in the foundry the cost is represented as a consumables cost and not an energy cost. Caution is given that the core making process is frequently dictated by the component being made and not by the preferences of the foundry.

APCCL Item II.4 is very well in theory. Care must be taken not to include many constraints of an energy saving nature as to preclude the efficient manufacture of castings.

4. Savings in heat treatment.

The use of low thermal mass furnace construction materials is to be recommended. Flexible curtains are mentioned but usually an independently opened vestibule is included at the loading and unloading section of a furnace.

The automatic temperature profile controlled cooling tunnel features continually in discussions with APCCL. The unnecessary consumption of fuel which may be forecast from this unit is likely to defeat the concept of energy conservation. FMD, BCIRA and the consultant recommend that the concept be dropped and all three parties advise APCCL to discontinue this section of the project: see .6.5.

5. Energy wastage in castings cleaning and fettling.

APCCL places emphasis on elements of shot-blasting, the statements made are obvious but it must be borne in mind that one of the important requirements in a shot-blasting machine is to protect the machine from destroying itself, and where a small number of castings may need to be reblasted, there is merit in fully loading the machine so that the internal faces of the shot-blast cabinet are protected from direct shot-throwing by means of other castings placed in the machine for that purpose.

6. Ventilation

Advice has been given that the building may only need to be a covered area with short sides and that normal building walls may be omitted.

Forced ventilation is necessary in certain areas for the avoidance of health hazards and the moving air also serves as a cooling media in selected places e.g. in a sand plant extraction air from rotary screens and elevators and at the discharge between conveyor belts contributes a measurable cooling effect.

Some ideas mentioned in the APCCL report will be found to be not worthwhile e.g. shut-off of extraction points for core machines when not in use: such action will throw the ventilation system out of balance and different performance characteristics will result. It is difficult to see what saving can be made in electrical power consumption by changing the configuration of a ventilation system at random. The likely effect will simply be a change in power factor of the drive motor.

7. Savings in lighting.

Good housekeeping is mentioned in respect of a cleaning of lamps and reflectors. The general advice is to use sodium vapour lamps at high level within the building for safety purposes at night time and for individual work stations, to have twin (split phase) tubular strip lighting, individually controlled by the operator.

8. Compressed air energy.

All competent compressor house designs envisage bringing air from outside the building if for no other reason than to avoid grit laden air entering the compressor with consequent internal damage to the moving components. The replacement for pneumatic tools by electric tools will give an obvious improvement in electrical efficiency but APCCL must be warned about the notoriously unreliable performance of electrical tools experienced by many users throughout the world.

9. Power factor correction.

The proposal to monitor and control maximum demand is confirmed as being good practice and an obvious way to reduce costs. Power factor correction normally exists as part of electric furnace melting package.

8.2 Computers Application

Reference is make elsewhere to the position of computers in foundries. So far as is known to the consultant no case has yet emerged where on-line computer operation has been successful. A number of cases exist where the concept has been tried out but according to published work the arrangements have been dismantled after some one or two years of experience.

The application of computers to forward programming and detailed hour by hour programming of moulding has been shown to achieve savings in melting energy of up to 15% in the U.S.A. (Caterpillar Peroria) and as the APCCL foundry is developed advantage may be taken of this established procedure.

Computers are useful in determining the out of balance consumption of raw materials and additives and cases are reported in the literature where quality control leads have been established from the monitoring of consumables. The identification and reporting of rejects (especially reject cores) proves always a problem. It would be unrealistic to stop production of a moulding line on account of the shortage, perhaps due to breakage in transport, of some small cores, therefore, it is more convenient to supply an excess of small cores to the core assembly or core laying point.

The consultant has experience of using magnetic tape indicators in fettling operation indicating content, count and weight of batches of castings which were then related to foundry quality measurement i.e., number of rejects, and to storage and shipping requirements.

The firmest and no doubt the earliest computer type application would come from process controllers (PLC). These may be applied at the early stages to a number of repetitive functions:

- melting
- metal holding, superheating, autopour
- moulding machine operation
- moulding sand preparation
- core machine operation (justifiable in larger machines only)
- core sand preparation (if associated with a print outgives valuable core quality feed-back)
- heat treatment furnace cycles
- component pressure testing when using an advanced handling rig in cases of volume production

Of course the normal administrative functions of finance and personnel control are an obvious case for computerisation. A stock control, raw materials consumption, spare parts and wearing parts would normally be under computer control.

Manufacturing programmes, work in progress, stock held at customers works and delivery schedules can be usefully programmed to a computer base and interrogated daily according to production performance or, in the event of unforeseen delays in the manufacturing programme.

A very valuable asset in the foundry situation is individual performance data logging of machinery and can give useful information concerning costs of inspections, repairs and replacements and ultimately when a suitable data base has been compiled, maintenance requirement forecasting becomes possible.

APCCL staff already has extensive experience in computer operation and application in other fields and therefore would not be expected to require assistance in setting up a computer system once the framework as outlined in the foregoing has been suggested.

8.3. Long-term planning of foundry development

Long-term planning is difficult to define and the temptation to forecast what may occur some twenty years hence must be resisted. However, some positive lines of development are now on the horizon.

For a cylinder head and block foundry the cost of core making must feature as a very significant factor and for more than 100-years the sodium silicate/CO_2 gas system has been available although not very well understood. In the last 10-years two world renowned foundry chemical systems producers have devoted much research aimed at bringing this cheap core making system up to a level of competition (largely in the field of quality) against well established, more complex systems.

During the lifetime of the projected foundry it is quite likely that continuing research will produce a silicate based cheap core making material suitable for the climatic conditions projected in the Hyderabad area. The consultant has experience of successful gas hardened, sodium silicates in Malaysia and in Indonesia in tropical rain forest climatic conditions and further development of the processes should be expected. If such development occurs and becomes widely used, the proposed core making machine outlined in the sub-contract reports are expected to prove adequate.

Continuing with the theme of the significance of core making in cylinder head and block manufacture, the consultant draws attention to current work now at an advanced stage in producing two important derivitives of traditional internal combustion engine design:

- cylinder block without any cores
- normal reciprocating engine without cylinder head

The foregoing must point to the need for APCCL to maintain flexibility because of the existance of alternatives in manufacturing techniques which are now established at the research stage and undergoing intensive development in Europe. The influence of these factors on cost calculations systems is quite profound because a foundry having to cost a heavy overhead liability for core making installation would be at a disadvantage when the cost enhancement value of cored work is lost.

Improvements in melting technology in the long-term are quite likely to be centred more in the area of continuous development increasing the overall energy efficiency of the melting units. Such efficiency improvement may stem from the mechanics of electrical application and equally importantly, development in insulating materials. There is not a lot of precautionary planning which a foundry can undertake in these fields but the need for flexibility in the short-term and middle-term future is an important factor for the consultant's advice to avoid the use of E.O.T. cranes connected to the building structure.

One important element of long-term development which should be of significance to APCCL is to monitor Indian Government funding of research and development into the winning of indigenous raw materials. Now private sector activity in this field is also important. Present constraints on imports will certainly have some influence on the core binders and core coatings to be used and developments in this area would be most significant to the foundry.

Detailed manufacturing operations such as fettling are likely to be the subject of continuous improvement. Perhaps the development will be along the lines of operator comfort leading eventually to operator elimination and this development could occur very suddenly with APCCL if a successful tie up occurred with a major engines producer thereby reducing the number of different patterns in work and permitting an enhanced degree of mechanisation leading to automation.

Usually automation results in a contraction of the floor area required, increasing mechanisation also reduces floor space therefore extensive provision for buildings extension is not recommended as a major factor in the planning stages of the foundry. It is wise to restrict the secondary functions such as maintenance, pattern shop, offices, canteen and welfare facilities to occupy two sides only of a supposed rectangular site thereby making it possible for the manufacturing unit to be extended along two axes without the need for demolition and re-siting of these secondary buildings and services.

Until a resolution is reached concerning the final product mix, the consultant has to recommend that initial expense be saved by omitting the autopour unit and indeed omitting the holding furnace, thereby relying upon direct melting until the predominant alloy emerges following which a reappraisal of the metal handling system can be made. The serious effect on the equipment to be installed caused by the absence of a firm market appraisal further highlights the need for further investigation leading to a feasibility study before investments are made.

APPENDIX 1.

REVIEW OF MARKET SURVEY PREPARED BY CORE CONSULTANCY SERVICES - DECEMBER, 1986

The following significant points are noted:

1. The Indian Government in January 1985, instituted a relaxation of licencing restrictions in the automobile industry with the aim to encourage operation of competitive forces within the industry.

2. Quoted published surveys by various agencies (not specified) in 1983, estimated the production by 1989/90 as being of the order of 2.7 million vehicles: this implied an average growth rate of about 18% as against an achieved growth rate of 13% between 1971/83.

3. The cited number of vehicle manufacture was given as follows:

Trucks/Buses	8
Passenger cars	5
Jeeps	2
3-Wheelers	3
Motor cycles	7
Scooters	7
Mopeds	7
Tractors	9

4. Additional investment in the automotive related industrial sector between 1985/90 would be of the order of US $ 205 billion: the scope and objective of the statement is not understood.

5. Two-wheeler industry is expected to have the highest growth ranking in India.

6. A recessionary trend which has been going on for 'some time', especially in the case of commercial vehicles; the report cites companies Swaraja Mazda, DCN Toyota and Allwyn Nissan

7. Negative indications regarding heavy commercial vehicles likewise recorded; Telco production is recorded as 1982: 45,949 vehicles, 1985: 40,523 vehicles. Ashok Leyland is cited as 'also not doing well'.

8. The slow pace of indigenisation (as indicative from the automotive manufacturers with Japenese collaboration).

The Core Consultancy Review includes examination of demand patterns for iron castings. As part of the review their automotive castings were segregated into 2-groups.

Group A

1. cylinder heads
2. cylinder blocks
3. gear box housing
4. clutch housing
5. transmission case
6. rear axle housing

Group B

1. brake drum
2. flywheel
3. cylinder lever
4. fan pulley
5. oil pump housing
6. water pump body
7. exhaust manifold

On the basis of the technical content and applicable technology (for known designs), it is considered that the list is poorly drawn. It is suggested that a more suitable list would be as follows:-

Group A

1. cylinder heads
2. cylinder blocks
3. gear box housing
4. transmission case
5. rear axle housing
6. oil pump housing
7. water pump body
8. exhaust manifold

Group B

1. brake drum
2. flywheel
3. cylinder lever
4. fan pulley
5. clutch housing

Concern must be expressed because of the failure of the analy to understand the technology implication of the different components as listed.

In analysis of details of the projected manufacture 1989/90 of a number of manufacturers, there is some confusion about the inclusion of the tonnage forecast for diesel engines; the diesel engines mentioned are for large earth moving vehicles so that there is danger of distortion of figures although only a proportion of the diesel engine production is included in the analysis. It is disturbing that the analysis has included annually 10,000 tonnes of castings for the earth moving vehicles and excavators.

Similarly in the analysis for agricultural tractors, a tonnage is included for transmission case (125 kg) and axle housing (100 kg) which will have a significant effect upon the size of moulding flask, and justifies the suggestion of a flask size of 1000 x 850 x 300/300, by FMD.

The summary analysis considers only 1,000 tonnes of the specified 10,000 for earth moving vehicles: the transfer of figures is not really understood.

In the summary, nett demand for grey iron castings is calculated:

estimated tonnage for year 1989/90.	30,550
assumed spares (10%).	3,055
projected total (say).	35,000 tonnes
assessment of existing production.	27,000
assumed available market share which APCCL might meet (but strictly not mentioned in the report).	8,000 tonnes

The survey includes a capacity analysis. This reviews the manufacture from a number of companies, their estimated capability to supply castings, and makes assumptions about competence of these companies. There is no indication that the actual companies named and reviewed have been consulted: statements include "Ghatge Patil.......already in the market with high pressure moulding.......supplying castings like brake drums.......in order to stabilise their production in this specified area they shall have to bring about considerable changes in their existing operations":"Autokast.launched their project two years ago... reported that high pressure moulding project not satisfactory." It is not known to what extent these comments may be supported by actual production performance from the suppliers named.

SG iron is reviewed under a separate heading and refers largely to machine tool producers and other miscellaneous hardware manufacturers and mentions the conversion of steel and malleable castings to SG. Reference is made to licenced capacity and installed capacity; specifically note that actual production capabilities of the mentioned foundries is not indicated. It is implied that APCCL "proposed plan for production of SG in batch quantity" will allow the Company to establish a market and be regarded as one of the "very few reliable suppliers of SG castings." The justification for these statements is not offered. The market share which is assumed to accrue to APCCL is 2,000 tonnes per year.

The conclusion of the Core Consultancy Services Report is repeated in its entirety.

7.00 Conclusion:

"Long time recession of machine tool industries and the delay in policy decision on the part of the Government regarding the automobile industries has caused temporary set back for the Indian foundries. In spite of these problems a specialised foundrv dedicated to the production of high technology castings has its own place in domestic as well as international markets Core Consultancy Services believes that India has a disproportionately large number of ordinary grade cast iron foundries comparing to the number of negligible existence of potentially sound modern foundry. So APCCL's decision to install a modern foundry of the latest foreign know-how and a specific objective to tap the overseas market is highly commendable. It will fill up a major gap in the technology currently available and thus should be implemented expeditiously."

An annex to the report relates to the quality and accuracy of cylinder body and cylinder head castings and includes a table giving the reason for rejection of castings. The document is poorly presented and does not appear to be based on any experienced foundry assessment. Rejections are recorded at the rejection level for: foundry, hydraulic testing and machine shop and assigns an assumed level of rejects to each area.

The total number of rejects offered is 8%; of which the foundry (i.e., moulding and core) proportion is 5%. It is extremely fortunate for foundries in India if such figures can be achieved and maintained; 7%-9% is the norm in advanced production, 9%-16% is more realistic for the first 2-years of start-up.

From the foregoing brief analysis it has to be assumed that the Core Consultancy Service Market Survey is not a reliable source on which to base production expectations from a new project.

APPENDIX 2.

REVIEW OF MARKET SURVEY PREPARED BY TATA ECONOMIC CONSULTANCY SERVICES - MADRAS

Access was given to an extensively researched document produced by the Tata Consultancy Services on behalf of Karnataka Industrial, Investment and Development Corporation Ltd.

The document is outstanding by reason of the information contained on specific and individual vehicles, giving component name, weight and existing producer for a very wide range of vehicles country-wide. It is considered that APCCL may have done well to have analysed this information and to have drawn conclusions from the detail; presented detail implied a factual and realistic approach to the ferrous material content of the vehicles listed.

Much historical material and casting process review is not considered to add worthwhile value to the report.

The same statistical data appears in this report as in the other two reports reviewed e.g., growth rates of 12.5% and 17-18% in appropriate sections. It must therefore be supposed that the reports reviewed either have had access to the same published (possible government economic survey) or that subsequent reports have been influenced by earlier reports.

The scope and recommendations however are quoted as follows:-

Estimated gap in foundry production for grey iron castings	1986/87	-	63,800 tonnes
	1989/90	-	143,700 tonnes
The anticipated gap indicated for SG iron castings	1984/85	-	5,500 up to 10,200 tonnes
	1986/87	-	14,700 up to 21,700 tonnes
	1989/90	-	28,300 up to 38,000 tonnes

The formal recommendation by Tata to the client (Karnataka Industrial, Investment and Development Corporation Ltd) is repeated "based on the study (the consultant) recommends that the client should go ahead with its plan for setting up an iron foundry using high pressure moulding facilities."

APPENDIX 3.

REVIEW OF MARKET SURVEY PREPARED BY MECON REVIEW - JANUARY, 1985

Report includes a lot of material which appeared in the Core Consultant Review e.g., rate of growth 1971/83 = 12.9 per cent and projected rate of growth 1985/90 = 17/18 per cent.

Reference is made to a projected growth of various agencies envisaging a total production of 1.39 million motor vehicles by 1984/85 and pointing out there was a shortfall and the achieved production was approximately 1.0 million. Reference is made to a number of studies e.g., a sub-group on automobile industries but careful reading implies this work by different organisations consisted only of a desk study. It may also be inferred that the rates of growth relate to actual vehicles produced whether heavy commercial vehicles or mopeds.

The survey goes on to examine the likely content of grey and SG iron in specified types of vehicles but fails to distinguish between the various technologies and the suitability of the ferrous castings for APCCL purposes. Hence, crankshafts are included in the weights cited without recognition of the fact that they are not expected to form part of the APCCL product mix.

A section is devoted to examining the current production claimed by various manufacturers, described as existing capacity; intended additional capacity by existing manufacturers; licences/letters of intent issued by various Government Departments and a segregation of grey and SG castings.

In a table (03.30) the likely unsecured demand for castings in 1989/90 is derived as:-

Grey iron	-	57,000 tonnes
SG iron	-	18,000 tonnes

Such figures are arrived at by purely arbitrary allocation of performance and plant utilisation. These vary between 54% and 90% in different parts of the report.

It may be concluded that whilst the figures presented are somewhat arbitrary and many of them lacking in substance, there is a conviction on the part of the compilers that a market opportunity, country-wide, exists for grey iron and SG iron castings ranging between the figures previously given and lower figures which may apply if existing plant utilisation is increased.

At a 90% plant utilisation the likely unsecured demand for castings in 1989/90 is:

grey iron	-	26,000 tonnes
SG iron	-	15,000 tonnes

In the conclusion the report carries the following paragraph:-

"From the above gaps it is evident that there is sufficient scope for installing a medium/large size foundry for the production of automotive grey/alloy iron and SG iron castings."

APPENDIX 4. Local Specification for:

BENTONITE

S.F.S. 41102
Ref: IS 6186 - 1971.

1. Use:

1.1. Bentonite is used as binder for moulding sand in foundry.

2. It shall conform to the following requirements:

2.1. Characteristics:

Specific Gravity:	2.70
Fusion Temperature:	1250 to 1300°C
PH of 6% suspension:	8.8 to 9.6
Base exchange capacity: (Meg per 100 gms)	80 to 95
Na/Ca Ratio.	2:7
Base.	Sodium Base
Swelling of 1 gm of bentonite in 100 cc distilled water	4 times
Gelling index 1.4 gms. in 100 cc as per ISI specifications.	50 to 65 cc
Swelling power (East Zone method)	18 to 30 mts. (5 gms/100 cc)
Liquid limit	450 (min)
Green strength	0.65 to 0.73kg/cm^2
When 7% Bentonite in Silica Sand of 55 AFS is mixed it should give:	
a) Dry strength:	8.4 to 10.5 kg/cm^2
b) Permeability No.120 to 150.	

3. Packing:

3.1. Material shall be packed in polythene lined gunny bags.

4. Marking:

4.1. Packing to be marked with the following details:

4.1.1. Supplier's name and trade mark.

4.1.2. Specification and grade.

5. Sample:

5.1. For each enquiry, sample to be obtained from supplier for approval by C.W.

APPENDIX 5. Local specification for:

HIGH SILICA SAND S.F.S. 41101

Ref: IS 1987-1974.

1. Use:

   1.1. High Silica Sand is used as synthetic Moulding Sand in foundry.

2. It shall conform to the following requirements:

   2.1. Composition:

SiO_2	98% (min.)
Alkalies	0.5% (max)
CaO + MgO	1.00%(Max)
Fe_2O_3	1.00%(Max)
Clay content	1.00%(Max)
Fusion point	1700°C.

3. Physical Characteristics:

   3.1. Grain shape - semi angular to angular.

   3.2. AFS Fineness number 40-45.

   3.2.1. Percentage retained on IS Sieve Nos. 425, 300, 212, is 70% (min).

   3.2.2. Percentage retained on IS Sieve Nos. 150 and lower should not exceed 10% max.

   3.3. Moisture should not exceed more than 5% in rainy seasons and 3% in other seasons.

4. Packing:

   4.1 Material shall be supplied in truck load.

5. Marking:

   5.1. Material certificate to be given for each consignment regarding quality.

6. Sample:

   6.1. For each enquiry, sample to be obtained from the supplier for approval by C.W.