IRON FOUNDRY BASICS

What is ironfounding?

Ironfounding is fundamental to modern industry, yet it can be equally well operated on a small scale by small numbers of people in rural areas.

Iron shapes or "castings" are made by pouring molten metal into moulds made of sand. Small parts which cannot easily be shaped by the method of forging are cheaply and simply produced in this way.

Cast iron is a brittle material which is strong when compressed, but relatively weak when pulled or bent. These qualities determine the uses of cast iron, which are very numerous.

Cast iron is found in motor cars, tractors, ships, factories (sic), mines, houses, in the streets and roads, and almost any place one cares to look. For example, the cylinder head, water pump and exhaust manifold of a car; the grid, manhole cover and lamp post in the street; parts of a compressor, many parts of agricultural, building and textile equipment - all are made of cast iron. Every day of our lives, something made of this material is used by most people.

A decision on the level of technology - or the size and type of foundry to be set up - must depend on such factors as the capital available, raw materials supply and labour availability, the characteristics of the market and the size and type of castings required.

When one has chosen the size and type of furnace, one must also make sure that there are enough moulds to take the quantity of metal melted, and that there is always enough metal to complete a pour once it is started.

Sequence of operations
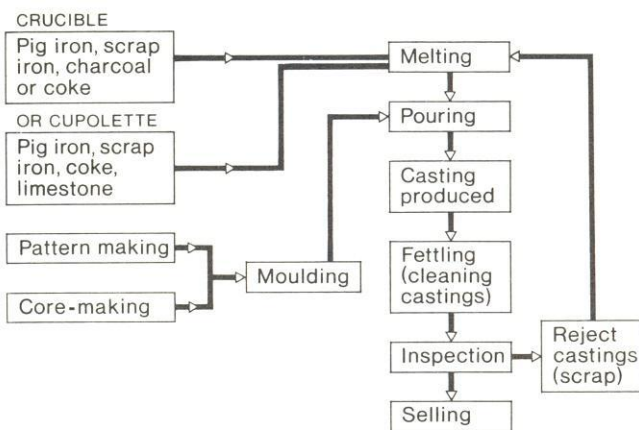
For ironfounding there are three main levels of technology:

(1)   Simple operations needing low capital and low power resources, utilizing the crucible furnace.

(2)   More elaborate operations for longer runs, requiring more expertise and labour, capital and power, and using the small cupolette type of furnace.

(3)   Elaborate operations requiring high capital investment, high power resources, and expensive melting equipment.

The present pamphlet covers the first two of these three possibilities. Information on the mechanised foundry can be easily obtained from any large foundry equipment manufacturer.
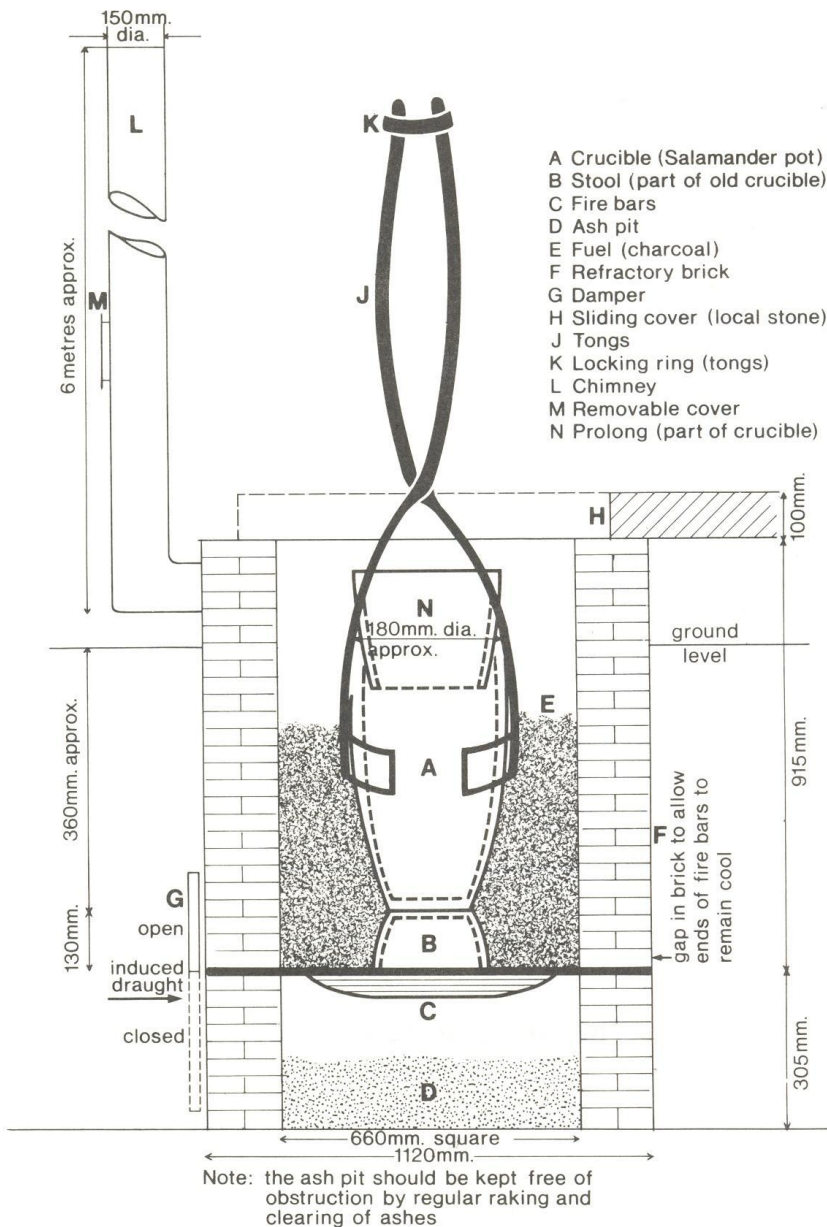
The Crucible Iron Furnace

The crucible furnace is the easiest method of melting iron.

Figure 1 shows details of the arrangement and the different parts of a crucible furnace, using the induced or "natural" draught method. Figure 2 showing the forced draught method has, in addition, a blower, operated by a hand-wheel or motor.

Figure 1: Crucible Furnace (Induced draught)

A Crucible (Salamander pot)
B Stool (part of old crucible)
C Fire bars
D Ash pit
E Fuel (charcoal)
F Refractory brick
G Damper
H Sliding cover (local stone)
J Tongs
K Locking ring (tongs)
L Chimney
M Removable cover
N Prolong (part of crucible)

Note: the ash pit should be kept free of obstruction by regular raking and clearing of ashes

Equipment required for induced draught method

A.	Crucible (salamander pot)	To be purchased. Made of a special composition of clay, carbon and silicate.
B.	Stool	Suggest original purchased, replacements from used crucibles
C.	Fire-bars	Originals of steel bar obtained from local metal merchants. Replacement bars of cast iron, which are more durable, as shown in

		Fig. 4.
D.	Ash pit	Part of construction
E.	Refractory	Made from local clay, which would be cheaper to obtain and be immediately available for any repair required.
F.	Chimney	Constructed of local clay or used kerosene drums, the bottom sections to be lined with clay.
G.	Tongs	Can be purchased along with salamander pot, or made by local blacksmith.
H.	Sliding cover	Local refractory stone
I.	Fuel	Charcoal obtained locally is recommended. Other fuels such as coal, coke, oil, etc., can be used.

Figure 2: Crucible Furnace (Forced air)
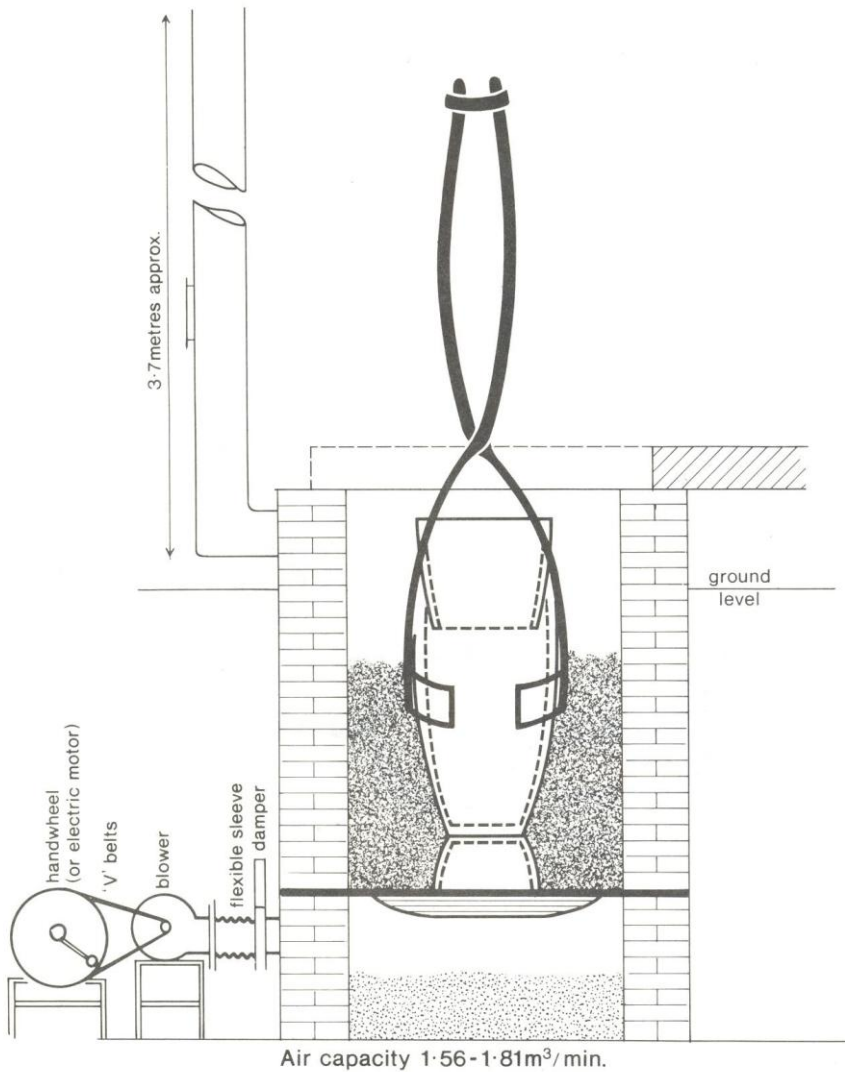
Additional equipment required for forced-air system

Blower or Fan	Purchased (possibly locally) together with suitable drive belts.
Handwheel or Motor	Probably obtainable locally, handle to be added. To drive blower, Instead of operating manually with handwheel. Pulleys for motor and blower shafts required, together with suitable drive belts (V belts)
Damper	Obtained and made locally.

If an increased melting capacity is required, a cupolette can be used (Figures 5, 6 and 7).

Although the induced draught furnace is a well-proven method of melting cast iron, it is very dependent on weather conditions, and the control of melting cannot be entirely accurate. The forced draught system shown in Fig. 2 is preferable, because it allows for much more accurate control of temperature. If electric power is not available, a centrifugal fan, manually operated, can provide sufficient blast for melting.

It is normal to build the furnace below ground level, and to provide a trench access for removal of ash. This arrangement has the dual advantage of a) supporting the refractory bricks, thus avoiding the need for a complicated structure, and b) providing the operator with a working platform at ground level - this reduces the physical effort required to lift the crucible.

The crucible "A" made of clay graphites (salamander pots) is 180 m/m outside diameter and 360 m/m high. It sits on a stool, "8" (130 m/m high), which can be made from a used crucible. The stool is supported by fire-bars, "C", which are placed about 300 m/m from the bottom of the ash pit. These fire-bars are originally made of steel round bar, purchased from a local steel merchant, but when they
need replacement, they can be cast in the foundry (cast iron bars are actually more durable).

The sliding cover, "8" can be of local refractory stone. This cover should be in the closed position when the melting is in operation. The walls of the furnace, "F", are of refractory brick. The quality of bricks is directly related to their life. The furnace is of square construction, to the dimensions shown, the thickness of the walls being 230 m/m. Two spaces are left, one at the bottom of one wall for induced draught and for the clearance of ashes, and the other at the top of the same wall, for the chimney ("L") outlet. A
damper is inserted in the bottom space to regulate air flow or draught.

Description of Operation

Wood shavings, together with some charcoal, are placed on the fire-bars around the stool and fired, *before* the crucible is placed on the stool by the tongs, "J". This is important because if the bottom of the crucible is cold when it is placed on the stool, the iron may not melt properly. After placing the crucible in position, a full charge of charcoal is added.

The crucible is now ready to receive a charge of pig and scrap iron. It is recommended, however, that an extension or "prolong" "N" be fitted to the top of the crucible before loading. This not only helps to support the pieces of pig iron; it also helps to keep the heat in the crucible, and thus assist the melting process. This prolong can conveniently be made by knocking out, or cutting, the bottom of an old crucible, so that it fits neatly into the top of the crucible proper.

Method of Loading

It is not necessary to break the pig iron into small pieces, because suitable lengths can be loaded in a vertical position, providing the top ends do not project beyond the top edge of the prolong (extension).

Iron recovered from scrapped machinery should be broken into small pieces, and packed closely round the large pieces of pig. Pig and scrap iron must be carefully loaded to avoid damage to the crucible. Some loading could be done before the crucible is loaded into the furnace.
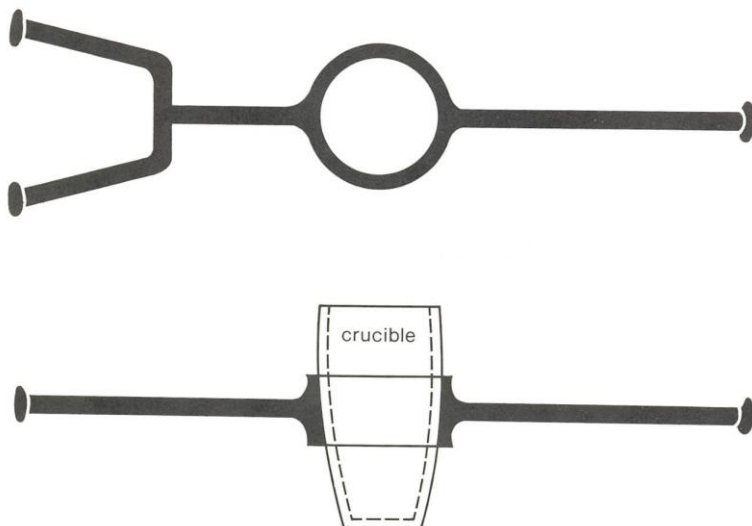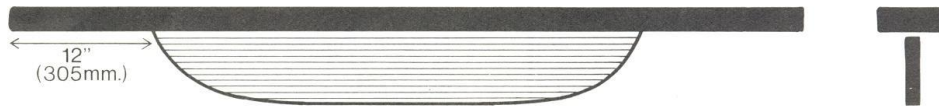

Figure 3: Carrier for crucible (for pouring)

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Figure 4: Cast iron fire bar

As melting proceeds, the material in the prolong slowly sinks into the charge already melted in the crucible itself. The rapid melting of the charge should be encouraged by working the furnace nearly "flat out". There is a tendency for the hot, but not yet melted charge in the prolong, to stick, and by poking and prodding with a long steel bar (about 10/15 m/m in diameter), the pieces will drop into the crucible.

It is advisable to keep the furnace very full of charcoal, and it does not matter (indeed it is desirable) if some pieces of charcoal fall into the crucible with the iron, as this tends to reduce oxidation. At quite an early stage it is good practice to have a lid sitting on the top of the prolong; and as soon as the charge has melted down, and is contained entirely in the crucible, the prolong itself should be removed, and the sliding cover on the furnace should be closed. The charcoal must be replenished as it burns - the speed of the stoking has a significant effect on the speed of melting. Normal melting time is approximately two hours, but this may differ considerably with the type of fuel used. Approximately 56Ibs (25 kg) of iron can be melted in the crucible furnace shown in Figs. 1 or 2 at each melt.

Although the object of this profile is to concentrate mainly on the melting of cast iron, it is worth mentioning that non-ferrous alloys, such as aluminium, can also be used with this system. The fact that these types of alloy become molten at a much lower temperature than cast iron does not diminish the need to take very great care in carrying out the melting operation (see Safety).

Carrier for Crucible
To be purchased. Recommended to be of safe construction and correct fit for crucible, can be made by local blacksmith.

The Cupolette Iron Furnace

Although the cupolette has greater melting capacity, its output could prove to be more than is required. For economy reasons, the cupolette should operate for at least an 8 hour period, after which it will require re-lininq, or repairs to the lining. Estimating an output of approximately one ton per hour, this gives 8 tons of molten metal, available in one cycle of operation. It is essential, therefore, that sufficient moulds are available to take a pour of this quantity. Any surplus molten metal can be poured into open moulds, or sand trenches, and can then be fed back into the cupolette in future melts. This surplus should be
kept to a minimum, as the greater amount of metal re-melted, the greater the cost of the product.

The cupolette consists of a steel shell "A" (Figs. 5, 6 & 7) in an upright position on a base-plate, which is usually supported on four steel joists or tubular columns "J". The shell is lined with good quality refractory brick "R". At the base of the steel shell are dropped doors, "S". These are hinged doors, which after the furnace has completed operation, are opened to allow the debris to be discharged.

The steel shell is 1/4 (6 m/m) thick plate of riveted or welded construction. A wind belt "G" is provided at a height of 2 or 3 feet (610 to 915 m/m) above the base plate. The air is supplied to the wind belt from a fan or blower "N" and the blast is conveyed to the interior of the furnace by tuyeres (nozzles) which may be situated in, or under, the wind belt. The number of tuyeres used depends on the size of the furnace. It is usual to allow one tuver o for each 6" (150 m/m) of internal diameter. The height at which the tuyeres are set above the working bottom of the furnace depends on the capacity of molten metal required.

The working bottom in the cupolette is made up with moulding and a fettling hole "0", provided at the bottom of the shell. The fettling hole is usually about 18" (450 m/m) square, and is covered by a plate held in position by a bar during the operation of the furnace.

Tuyeres "H" are the nozzles (usually made from cast-iron) which feed the air supply needed for the combustion to the correct position in the cupolette.

A metal tapping spout "F" is provided at the front of the cupolette and the working bottom is made to slope towards this, thus giving a supply of molten metal when the hole is tapped. When no molten metal is required, this hole is plugged.

A slag hole "E" is provided at the back of the cupolette, positioned about 8" (200 m/m) or 9" (230 m/m) below the centres of the tuyeres and midway between two tuyeres, to prevent the slag chilling, thus allowing it to run freely.

A charging hole "C" is positioned in the upper section of the cupolette. Coke, pig-iron, scrap iron and flux is loaded through hole from the charging floor "K".

Cupolette Operation
A fire is first lit on the working bottom of the furnace and coke is added in small quantities until it reaches the level of the tuyeres. The fire is drawn up by natural draught until the coke is at white heat, the air for this being drawn in through the open fettling and slag holes. This operation may take some considerable time, particularly with new furnaces, which are being warmed for the first time.

When the coke has reached white heat, the fettling hole is closed with sand and covered with the steel plate. More coke is added to bring it to its final level about 1 metre above the level of the tuyeres and the height is checked by a measuring rod, or for convenience a chain, inserted at the charging hole. Care should be taken to see that the coke is at white heat, before any charges are loaded.

Cupolette Charges
Charges are put on to fill the furnace to the level of the charging hole. Alternatively charges of mixed pig and scrap iron and coke (mixed with limestone at about 20% of the coke weight) are made. When the cupolette is full (level with charging hole), the air blast is switched on and in 5 to 7 minutes, molten metal will be seen passing the tuyeres.

Note: Scrap iron should be broken into pieces not more than 12" long, before loading into cupolette, with a mixture of pig.

Ratio of charges:
35 Ibs (15 KG) of good quality coke, together
with 7lbs (3 KG) of limestone, for every charge
of *2'12* cwts (125 KG) of pig and scrap iron.

Metal is allowed to collect in the well, until sufficient has accumulated for a tap to be taken. A 'tap' which is taken from "F" (tapping spout) means allowing a flow of molten metal from the cupolette into a
ladle, which has been carefully positioned at the end of the chute. This is done by perforating the refractory plug with a pointed end steel bar, and replacing it after drawing off the amount of metal required, with a new plug of damp clay inserted in to the tapping spout with a mushroom headed steel bar.

In the meantime, further charges of piq-iron and coke are added through the charging hole to replace the metal melted. This procedure continues until the end of the melt. Slag is tapped from the slag spout at intervals of 45 to 60 minutes, or whenever it is considered that too great an accumulation of slag has built up in the furnace. It is desirable to bott (close) the slag hole with ordinary moulding sand, rather than refractory clay as used elsewhere, the reason being that because of the infrequent tapping that is required through the slag hole, refractory clay tends to set very hard and may be difficult to penetrate for the next tap.

End of Melt

At the end of the melt, charging is stopped, but the air blast is maintained at a decreasing rate until all the metal is drawn off. The drop-bottom doors are then opened, to drop the remaining debris. This is quenched with water, the remaining coke can be recovered for future use.

After the cupolette has cooled, it will be necessary to carry out repairs to the fire bricks, to make the furnace ready for the next melt. New fire bricks may be required in some places, but it is usually sufficient to patch with a suitable clay or ganister, bringing the lining back to its original dimension.

There are approximately 700 ferrous small scale foundries having cupola or pit crucible furnaces as melting media in Punjab, mostly concentrated at Batala, Ludhiana and Jullundur. They make such products as machine tool castings, sewing machine parts, agricultural implements such as chaff cutting machines, hand and power operated, malleable pipe fittings, hand tools, forging hammers, ingot moulds, soil and drain water pipes, pipe fittings and pipe specials.

Pouring
Pouring methods depend upon the type of furnace and the size of casting.

The crucible can be lifted from the furnace and the metal poured direct into the mould by two men using a carrier. For small castings a small ladle can be used.

A Cupolette shell
B Stack or chimney
C Charging hole
D Fettling hole
E Slag spout
F Tapping spout
G Wind box
H Sight holes, tuyères
J Cupolette support
K Chequer plate floor
L Handrails & stancher
M Staircase
N Fan & motor
P Duct
Q Fan & motor support
R Refractory lining
S Drop bottom doors

PLAN
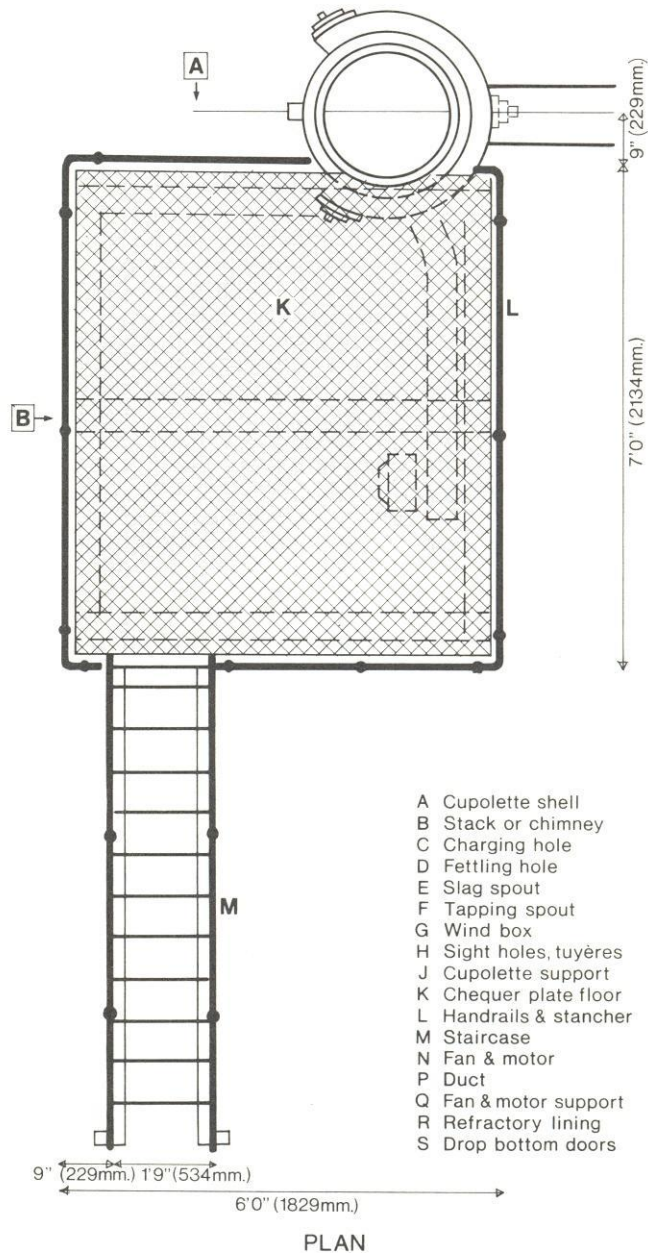
Figure 5: Cupolette
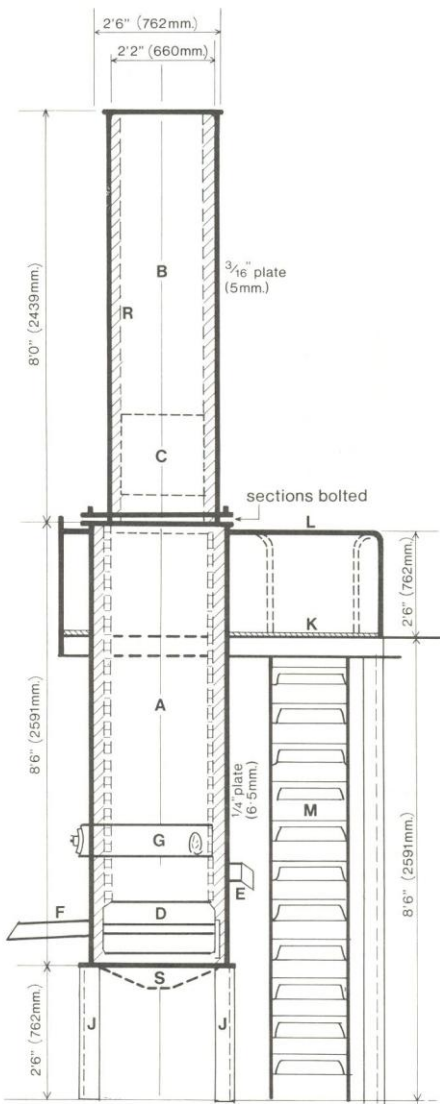
Metal can be run from a cupolette into ladles from which it is poured into the moulds.

An uninterrupted pour into each mould is essential to ensure no discontinuity in the final casting. If the size of the casting is such that one ladle's contents are not sufficient, a second ladle of molten metal must be available. Pieces of slag found floating on the metal should be skimmed off before the metal is poured into the mould. Normally those who tend the furnace also pour the metal into the moulds.

Safety

This is a major consideration. Protection for head, eyes, feet, legs and hands is essential, and the discipline of those handling the metal is equally important.

Knocking Out and Fettling

However accurately the moulds have been made, castings will require cleaning and trimming before they can be passed on for other operations, such as immediate use, or machining.

Figure 6: Cupolette View on arrow A

When the castings have cooled off, they are removed from the moulds. Any sand or clay is cleaned from the castings. This is done by rapping the casting with a light hammer and finishing off with a wire brush. Surplus iron pieces, such as runners and risers are knocked off (Fig 9) and any irregularities at the mould joints are trimmed with a file or grindstone.

The amount of fettling required depends on the quality of the mould, and the customer's requirements.

Equipment Required (Fettling)
Light Hammers
Files - various shapes, i.e. flat, half round, round etc.
Chisels
Wire Brushes
Goggles - for fettlers

These can normally be obtained from local purchase.

As far as foundry work is concerned the product has now passed through all stages for completion. It is necessary however for the articles to be inspected, to detect any flaws or errors in the castings that could affect the use for which they are intended. Any rejects are returned to the furnace area for future melts. Those that pass the inspection are ready for sale.
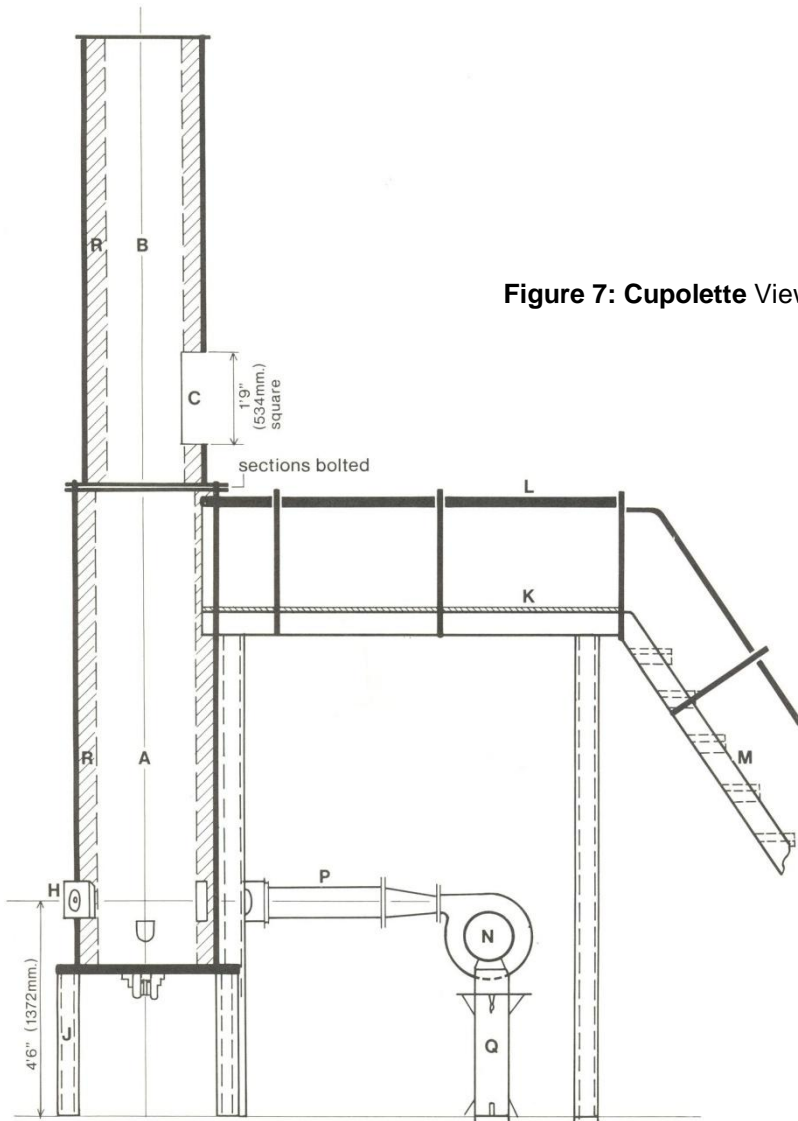
Figure 7: Cupolette View on Arrow B

1'9"
(534mm.)
square

sections bolted

4'6" (1372mm.)

Figure 8: Mould ready for pouring
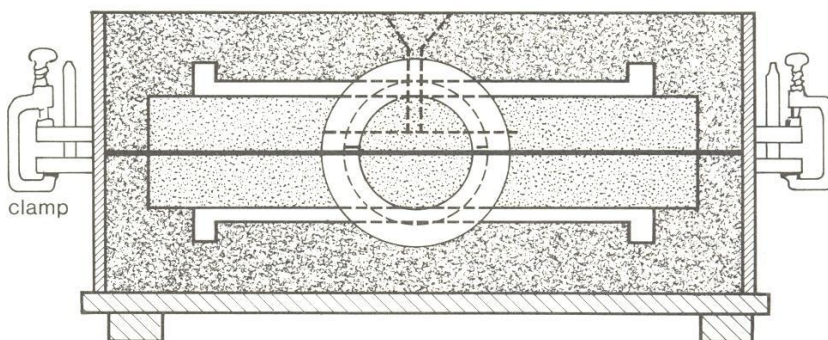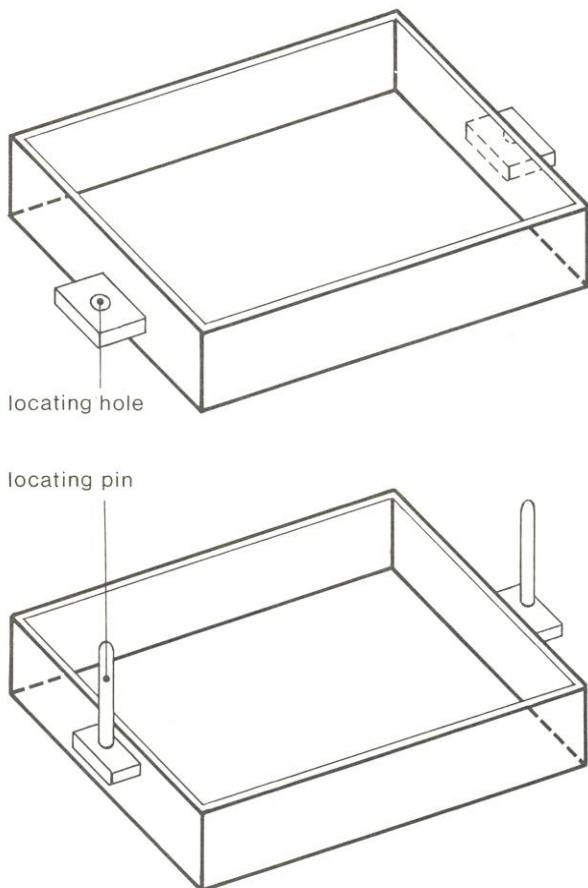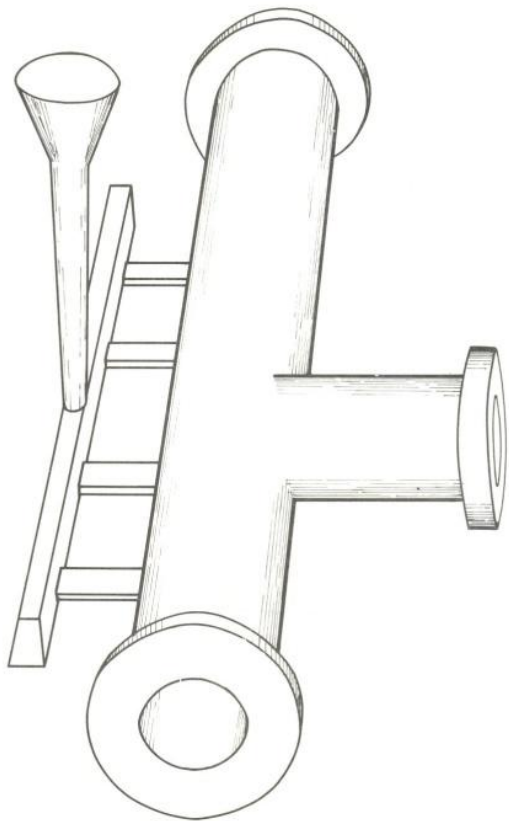
clamp

Figure 9: Casting and runner system

locating hole

locating pin

Bottom half box (drag)

Moulding

Moulding, in simplest terms, consists of burying or pressing a pattern into specially prepared sand, which will retain the shape or imprint of the pattern when the latter is removed. Into the impression that is left, molten metal is poured and allowed to cool, after which it is removed in a solid state. The making of the mould, however, is not quite as simple as it would appear from this description. Sometimes, in fact, castings are required with hollow portions and this is done by inserting cores, which adds to the intricacy of the mould. Other problems can arise, which make moulding a highly skilled and exact art. For example, gases are generated, both in the mould and the cores, when molten metal comes into contact with the damp or green sand, as it is known in the foundry. For certain castings where sand is not sufficiently permeable, these gases have to be led away through fine vents so that they do not find their way into the metal and cause bubbles or blow holes. Again, the rush of molten metal may cause the two halves of the mould to separate, or the cores to float, with the result that castings are obtained which are thicker than they should be, or not true to pattern. To avoid these problems, the art of moulding will be explained in more detail, but will only cover small moulds, that is those which are easily handled by one man and made in a moulding box.

Figure 10: Top half box (cope)

A moulding box consists of two rectangular frames of equal size, each of which is open at the top and bottom. The bottom box, or drag, has a fixed locating pin at each end, which fits into two holes in the top box or cope. Boxes are usually of metal construction and vary in size.to suit the size of pattern to be used (Figs. 10, 11 and 12).

When choosing a moulding box, care must be taken to allow sufficient room around the pattern to obtain a good solid mass of sand, between the edges of the pattern and the sides of the box and also in depth. A flat board is required on which to place the moulding box. The half pattern (without the dowel pins) is placed on the board and the bottom half of the moulding box (the

technical brief

drag) is placed around it, making sure the jointing side is to the board. The board should be of sufficient area to cover the full face of the moulding box being used, and have battens fixed to the underside which must be deep enough to give clearance for the locating pins which are part of the moulding box (drag). Moulding sand is added, until the box is almost full. The sand must be rammed hard, so that it forms a solid mass around the edges of the moulding box and pattern, and completely fills the box with sand by ramming hard with a flat rammer. Any excess sand which projects above the upper edge of the moulding box is   then scraped level (Fig. 13).

Figure 11: Alternative method of box selection
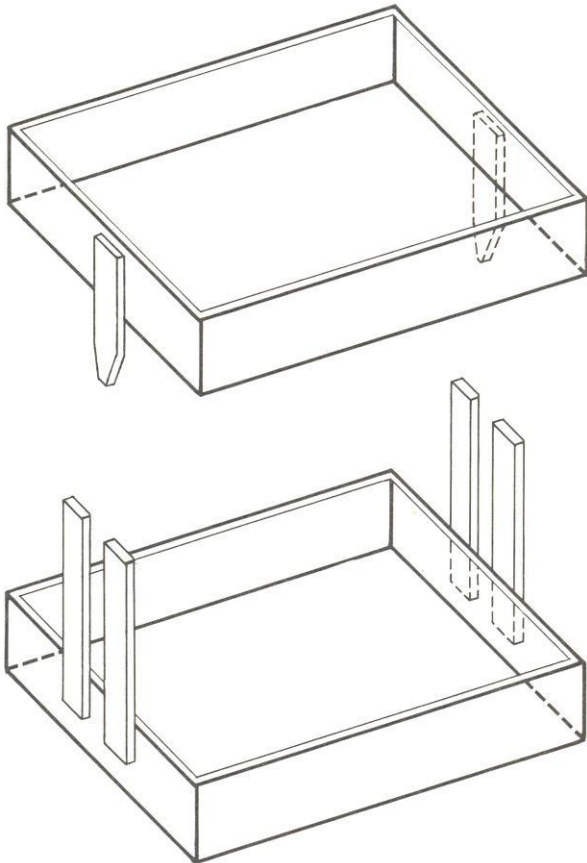
The half mould is turned completely over exposing the half pattern which is left fixed to the mould. The second half of the pattern is placed on the half that is already in the mould, being located and aligned by means of the dowel pins in the pattern. The top half (the cope) of the moulding box is positioned to the bottom half and aligned by the lugs and corresponding holes.

Parting powder, a dry fine refractory powder (preferably alumina) is then dusted over the joint fact, to prevent the two faces from adhering. Moulding sand is now added to this half of the moulding box, using the same method that has been previously explained (Fig. 14).

The moulding box is now split and two halves are placed on the board side by side, exposing the patterns.

The two half patterns are removed from the moulds. This is done by driving or screwing a small metal rod into the patterns and gently tapping the patterns in a horizontal plane until they are loosened, so that they can be carefully drawn out. Care must be taken so that the moulds are not damaged during this operation.

Channels or runners are cut into the horizontal exposed faces of one or both of the moulds and in the *top half mould only* a vertical channel is cut, connecting from the horizontal channel to the upper surface of the mould. This is to allow the molten metal to be poured into the impressions left in the sand. Normally a thin walled tube of the correct diameter, with a sharp edge at one end, is used for the purpose of making the vertical channel, as it can be pushed straight through the mould. Any core or cores are
now carefully placed in the required positions.

The top half mould can now be replaced onto the bottom and the two boxes are clamped together.

The mould is now ready to receive molten metal (Fig. 8).

Sands

Various sands are available for the making of moulds and cores. The nature of the sands is important, as they can affect the type and quality of castings produced. Information on sands that are available locally, and their suitability for foundry work should be sought from a University, in the area where it is intended to set up the industry. I.T.D.G. can also provide additional general information on the subject. The following definitions of some foundry terms are included for the benefit of readers who are not familiar with their precise meaning.

Figure 12: Alternative method of box collection
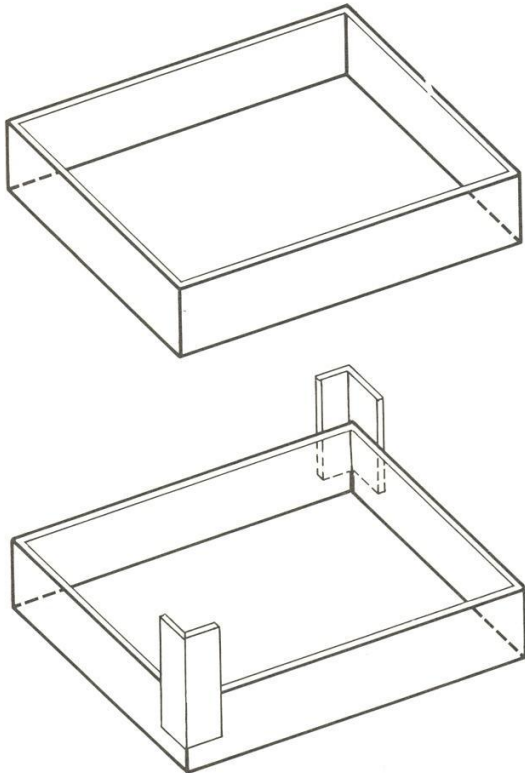
the pattern, which forms the face of the mould.

Green Sand

New sand at a moisture content sufficient to mould. Casting into green sand is common practice for the majority of small and medium sized ferrous and non-ferrous castings. When this sand is used, the amount of water in the sand is particularly critical. If there is too much or too little, the sand would become weak, and if the amount is really excessive, the hot metal would spit when it came in contact with the sand. Any steam generated could enter the metal and cause holes in the finished casting, which are called blow holes. In a severe case, metal could be blown right out of the mould.

The best type of green sand is used as facing sand against the pattern where it will form the ultimate working surface of the mould. It is usually a mixture of old and new sand, and is prepared for use by riddling (sieving) and tempering with the right amount of water in order to give a smooth, firm impression of the pattern and a surface that will not wash or crumble away when the molten metal enters the mould. The sand is used against the face of

The remainder of the mould can be filled up with less carefully prepared sand known as the backing sand.

Figure 13:

Dry Sand
Sand from which all the free, or uncombined moisture has been removed, usually by heating in a drying oven, is used mainly for larger castings where dimensional accuracy and soundness are particularly important. The sand mould is completely dried before the metal is poured in.

Core Sand
Used for making cores. Usually a high silica sand, that is sea, river, lake or desert sands, used with special core binders. Ordinary moulding sand cannot generally be used for core making.

Oil Sand
Sand bonded with organic binder, frequently containing a proportion of linseed oil or other drying oils. Mainly used for core making.

Core Making
Cores are those parts of a mould which,

Figure 14: Complete mould with pattern in position

in order to produce a required casting, have to be made as separate sand shapes. These sand shapes, or cores, are assembled and inserted into the mould in such a way that they form internal shapes, undercut contours, or isolated hollow pockets in the finished casting.

A core box has to be made (from wood) which will produce a core corresponding to the hollow shape required in the casting. The core box consists of two half-blocks, into which is cut the shape of the core, including the core prints. Core prints are essential so that a seating is provided, to position the core in the sand mould correctly.

Locating dowels are provided in each half of the core box, to ensure correct alignment of the two halves and complete core (Fig. 15).

The two halves of the box are first closed together, using the locating dowels to ensure correct alignment. The box is then filled with sand which is rammed firmly and evenly. The open ends of the core are finished off by ramming, tucking and making firm. The core is now one firm mass of sand of the required shape and can be removed from the core box and transferred to a metal support or carrier that has been shaped to receive it. A gentle tap on the outside of the box will help to loosen the core for transfer.

The core in its carrier has to be treated or baked at a temperature of 520°F for a period of 1 ½ to 4 hours, depending on the size of the core. During this baking operation, the sand becomes hard (Fig. 16). It can therefore be handled safely and placed into the bottom half of the mould, which has already been prepared. The top half of the mould is then placed in position.

After casting, the core must disintegrate to a degree rendering it capable of being removed from the casting with the minimum of effort and without damaging or distorting the casting.

Only certain types of sands can be used for core making and must possess the following qualities:

Green Bond or Green Strength
This is the bond which the sand possesses, when green or in its natural or undried state. Green bond is the power of the sand to hold together, and keep any shape into which the core may be formed. It also enables a core to keep its shape after it has been withdrawn from the core box.

Figure 15: Core box top half
Bottom half core box similar except holes to match dowels

dowels
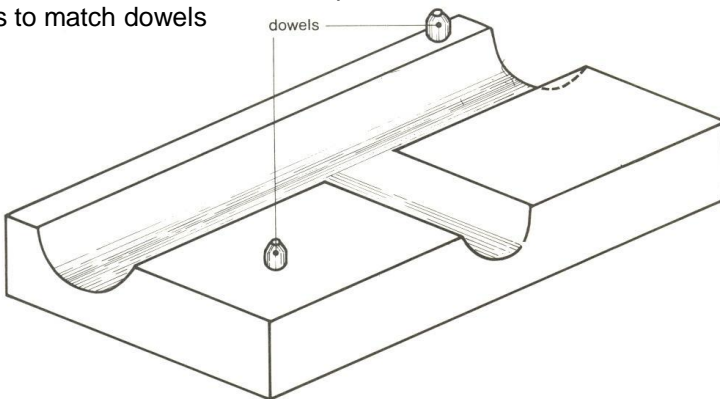
This is the strength that exists after the core has been allowed to remain in the core oven for a suitable time at the required temperature.

Permeability
A core-sand must be permeable so that gases generated during casting may escape quickly to the atmosphere. Vents or passages are formed in cores, but the sand between the face of the core and the vent passage must be such that the gases can get into the vents quickly.

Figure 16: Finished core dry bond or dry strength
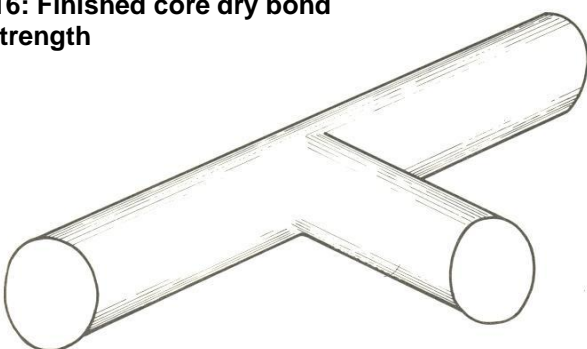
Ease of collapse after casting
This means that the core must be able to break into small pieces or grains to enable it to be separated freely from the casting. Every trace of sand must be removed from intricate internal jackets, without undue treatment to the castings.

Core sands to meet the above conditions have been developed over the years.

Pattern Making

Patterns, which are simply copies of the shapes of casting required are made of wood. Preferably a hard wood is used and finished with a covering of good quality, water-resisting varnish or paint. This helps to resist damage to the mould when withdrawing and also tends to be less affected by moisture picked up from the moulding sand which is always damp.

Figure 17: Split wooden pattern halves located by dowels
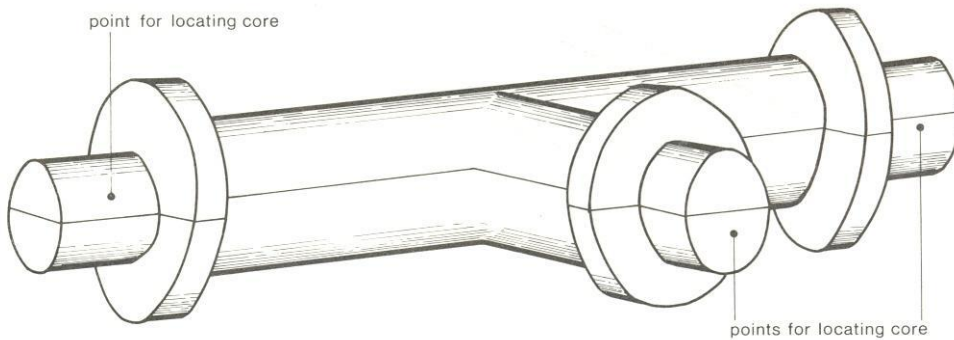
Patterns should be made very carefully to the required dimensions, but allowing (1 % of length) oversize, to compensate for the shrinkage of metal as it cools.

Patterns are usually in two halves, which are correctly aligned to each other by the use of dowel pins. More advanced patterns made of metal, cast-iron, brass, aluminium alloy, or white metal can be used, but these are more difficult to produce, because of the accuracy required and are therefore more costly. It is much easier and quicker to work with wood than metal, though of course, the metal patterns are more durable (Fig. 17).

Equipment Required

Core Boxes	Wood	To requirement – made locally
Patterns	Wood	To requirement – made locally
Small oven for 520°F (270°C)		For baking cores
Moulding Boxes	Metal/wood	Various sizes

Moulders Tools

Peg Rammer	Wood/Metal	Locally Made
Flat Rammer	Wood/Metal	Locally Made
Strickle (wooden (Straight edge)	Wood	Locally Made
Vent Wire	16g wire	Purchase locally
Trowel	imported Ex UK	Available locally
Sieve (or riddle) 3/16" mesh	imported ex UK	Available locally

Conclusion

Readers are reminded that this profile is not intended as a technical instruction, but only as a guide or introduction to the lower levels of the foundry industry. For those interested a list of

technical instruction manuals and books is included on the final pages.

Further reading

Blacksmithing Practical Action Technical Brief
The Blacksmith and the Farmer, Poston D, Practical Action Publishing, 1994
Blacksmith, Baker, Roofing Sheet Maker, Carr M, Practical Action Publishing, 1984
Iron Foundry Basics Practical Action Technical Brief
Metalworking Practical Action Technical Brief
Blacksmithing, Welding and Soldering, Van Winden J, TOOL, Amsterdam, 1989
Basic Blacksmithing: An introduction to toolmaking, David Harries, Practical Action Publishing, 1993
Blacksmithing Instructors' Guide: Sixteen lesson plans with teaching advice, David Harries, Practical Action Publishing, 1993

technical brief