

# Trade of Metal Fabrication

Module 4: Structural Steel  
Fabrication

Unit 10: Gates and Railing

Phase 2



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## Document Release History

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06/02/07	First draft	
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## Module 4 – Structural Steel Fabrication

### Unit 10 – Gates and Railing

Duration – 9 Hours

#### Learning Outcome:

By the end of this unit each apprentice will be able to:

- Read and interpret drawings
- Mark out, cut, drill, assemble, tack and weld parts to fabricate a section of railing

#### Key Learning Points:

<b>Rk</b> <b>Sk</b>	Setting out, marking, cutting, assembly. (For more information see Module 4 Unit 9).
<b>M</b>	Arithmetic - calculations. (Instructor covers in class).
<b>Rk</b>	Galvanising, shot blasting, weather proofing (recap). (For more information see Module 4 Unit 3).
<b>Rk</b>	Materials used - wrought iron -ornamental castings.
<b>Rk</b>	Masonry fixings - different types in general use.
<b>H</b>	Safety procedures, clothing, eye-care, lifting procedures. (For more information see Module 4 Unit 9).
<b>P</b>	Work planning, initiative, quality of work.

#### Training Resources:

- Fabrication workshop, apprentice toolkit, P.P.E.
- Cutting equipment, M.A.G.S. welding equipment
- Materials stated on drawing

#### Key Learning Points Code:

**M** = Maths      **D** = Drawing      **RK** = Related Knowledge      **Sc** = Science

**P** = Personal Skills      **Sk** = Skill      **H** = Hazards

## Decorative Ironwork

Much of the skilled and artistic work done by blacksmiths in the last few centuries can be seen in gates, railings, grills, church screens, and similar objects where the assembly was a mass of individually shaped parts joined together to make a pleasing pattern. In some cases, the blacksmith's work was linked with cast iron. There are a great many surviving examples of work executed entirely by the smith at his forge with quite simple equipment. His skill and creativity were his most important tools. He could not call on precision machinery, and any jigs used were made by the blacksmith himself as needed.

The material was iron, and the type of work is collectively called wrought-iron work. The work wrought in this instance is used in the sense of meaning worked, although the material was also called wrought iron.

Some modern wrought-iron gates and similar things are very different from the traditional work. They are made of bars all of a uniform section. The majority of parts in a traditional piece of wrought-iron work, on the other hand, are tapered and twisted and changed section in their length to get the effect the smith wanted. The scrolls of modern work are not very thin and are all identical, showing that they were pulled cold around standard shapes, probably in a machine. Although such gates and other assemblies might be attractive, they are machine-age imitations of the products of real craftsmen.

Like many seemingly complex things, a gate or length of railings is built up from a series of comparatively simple steps. If the steps are understood and each performed properly, the final assembly should be very satisfying. Although the assembled construction might be quite heavy, the individual parts are not. There are some stages where a helper is essential, but much of the work can be done single-handedly. The amount of heat required at any time is not great and a small hearth should be adequate. It is always easier to work on a large anvil, but if the work is schemed to suit, much of the shaping can be done on a small anvil. For some of the details, such as twisted leaves, a small anvil might actually be better than a large one.

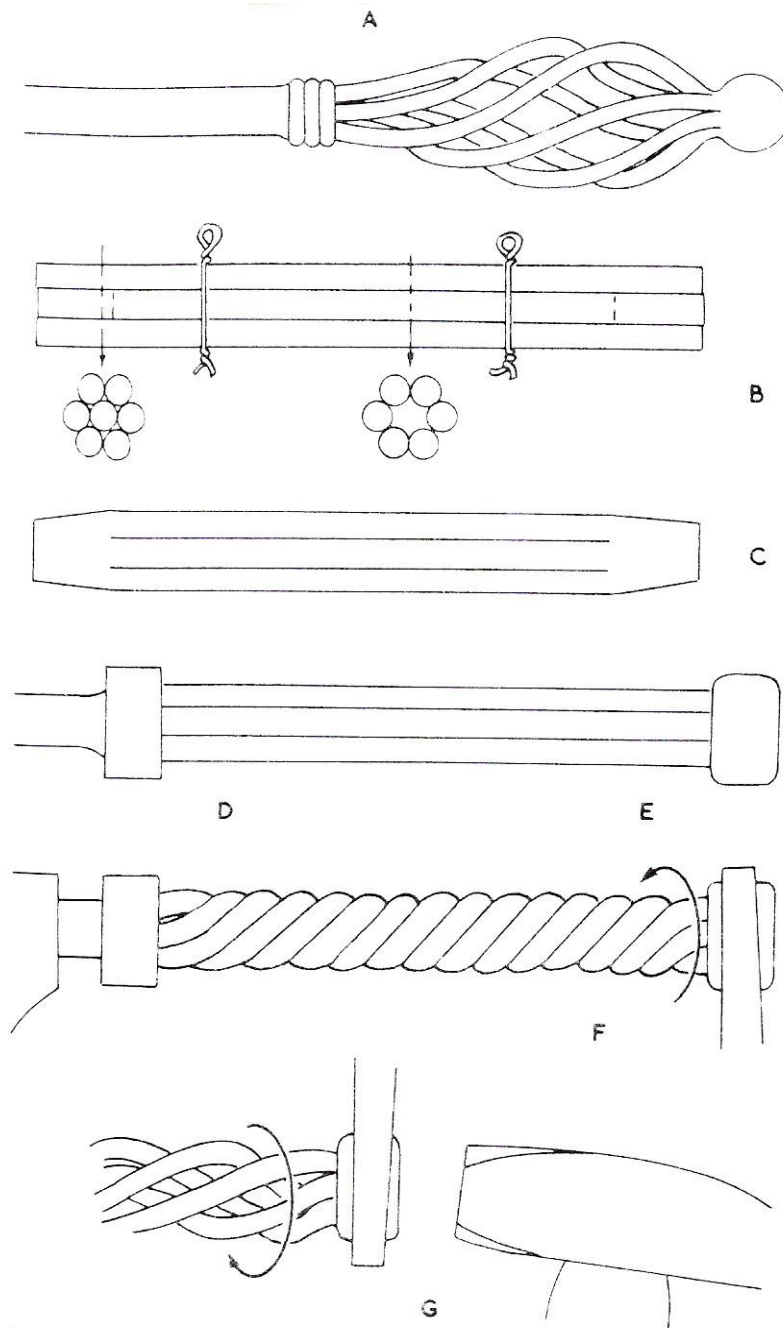
Much of the work involves applying techniques already covered in earlier chapters. If you think about what is happening to the steel when you hit or bend it, almost anything is possible as you direct your blows to get the best effect and the maximum result from each action.

Look at examples of wrought-iron work made by a blacksmith. If you cannot find an actual gate or similar object, examine photographs. Old churches might have a gate or screen. After you have enjoyed the object as a whole, look at some of the details. Try to visualise how various pieces were made. Notice how the parts are joined. See how sections have been changed, how the smith has thinned sections down to make ornamental twists and twirls. There are a large number of ways of shaping the ends before curling them. Think out the shape that was made before the end was rolled tightly. Finishing an end in the form of a leaf is common. Note how the bar is thinned, shaped, and twisted or crinkled in leaf form. Look for the leaf veins that have been cut in it.



## Cage Handle

A handle that looks like a spiral cage has the advantage of remaining cool as well as being an attractive decoration (Figure 1A). Because making it involves welding, the work would be easier in iron than in steel. The handle and shaft are separate parts welded together.



**Figure 1 - Cage Handle Built up from Rods and Welded to a Shaft**

- |                                       |   |  |
|---------------------------------------|---|--|
| A) Spiral cage                        | D) Fit roll collars over the ends of the handle | F) Twist the handle  |
| B) Rods wired together                | E) Form the top collar into a knob              | G) Place in a vise and unwind slightly while tapping with a hammer |
| C) Ends are hammered slightly smaller |   |  |

The handle itself is made of six pieces of identical rods. Diameters of 3/16 inch would be suitable. They could be 5 inches long. Pieces about 1 inch long are put between their ends so that they can be tied together with iron wire in a regular hexagonal section (Figure 1B). Weld each end in turn while holding the other end with hollow-bit tongs. Remove the binding wire. The ends will be slightly smaller, due to hammering (Figure 1C).

Upset one end of the handle enough to allow a welding scarf to be made. Do the same with the rod that is to be the shaft and weld the handle to it. Roll collars from 3/4-x-3/16-inch strip and fit them over the ends of the handle (Figure 1D). Weld them on. That completes the welding. Further steps involve forging the handle to shape.

The end collar looks best if formed into a knob. Heat the end to bright red and shape this by hammering around the edges of the collar while rolling it on the anvil (Figure 1E).

The twist is made mainly in the upper half of the length of the rods. Heat evenly from the end knob to within about 1 inch of the lower collar. When ready, quickly grip the shaft in the vise and use tongs or a pipe wrench on the knob to twist the handle (Figure 1F). Give enough twists to make a close screw-like shape, with the rods tightly touching.

Heat again for the same length. Quickly put the shaft back in the vise. Use the wrench the other way on the knob to unwind partially, while at the same time tapping with a hammer on the knob. (Figure 1G). This will open the cage and spread the parts. It is unlikely that they will form a perfect shape first time, but after a further heating, pliers can be used to get all the rods into a balanced form.

The bottom collar could be left as it is or decorated by filing grooves around it. An interesting variation is to introduce a ball into the cage by forcing two rods apart to let it in, then bringing them back to the pattern. The ball should be larger than any gaps, but loose enough to move about.

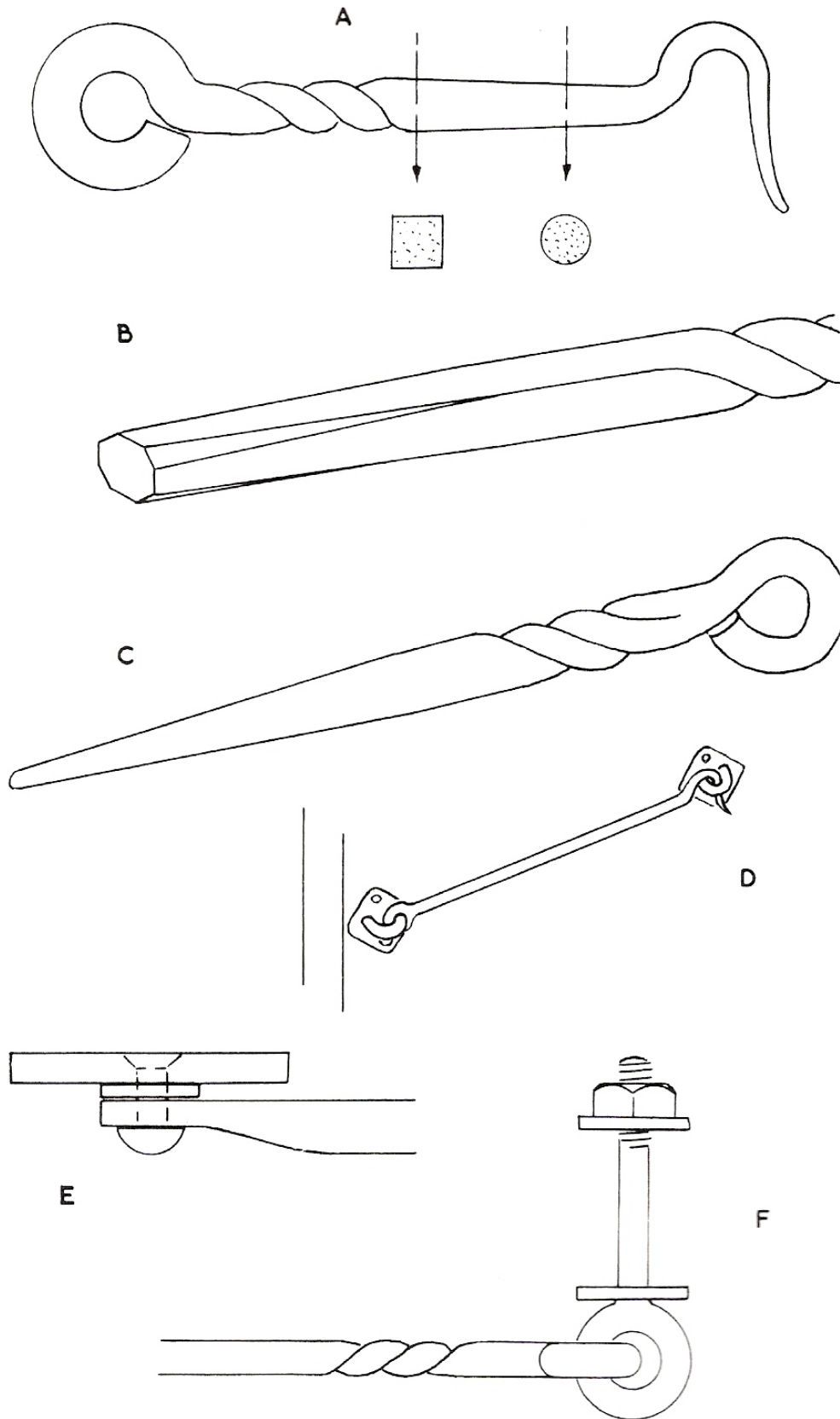
## Added Handles

The handle does not have to be one with the shaft and need not be steel. If it is for a tool that will get hot, a wooden handle would provide insulation from heat. Brass, copper, and plastics can be used to provide colour and brightness to contrast the steel.

For a wooden handle, the end of the shaft can be finished as a spike or tang, usually square, even if the rod is round. Teeth could be raised by cutting into the spike with a cold chisel to give the maximum grip. The best handle is made of hardwood and fitted with a ferrule to resist splitting. The hole is then drilled slightly undersize and made with two or three drills, to reduce in steps.

Some plastics can be softened with heat, and a handle made of this material can be shrunk on. Leave the shaft round except for a slight taper near its end. Drill the plastic only slightly undersize. Soften it with boiling water or in an oven, depending on the amount of heat required for the particular plastic. Warm the end of the shaft to about the same temperature. Tap the handle on with a wooden or rubber mallet. Leave to set and shrink.

Another wooden handle can be made by putting cheeks each side of the steel. The end of the shaft is flattened and given a curved outline so that it can be drilled for two or more rivets. Usually the handle is the end, but it is possible to add a decorative twirl that might also serve for hanging the tool.



**Figure 2 - Hooks can be Twisted (A, B), Tapered (C) and Pivoted (D, E, F) in Several Ways**

## Collars

Scrolls are best tackled boldly, with the whole length of the shape heated and pulled or hammered around quickly. In wrought-iron work, many scrolls are enclosed in other parts, so they have to be carefully worked to match a drawing. This is particularly so if both ends of the same piece are scrolls, the same or opposite ways. If the end is free from anything around it, exact sizes are not so important.



**Figure 3 - The Top of the Previous Gate Showing How the Design Rises to an Apex with Flame Effect at the Peak**

Although the main structure will have more substantial joints, the decorative parts between the primary parts are held to them and to each other with straps or collars. Collars are sometimes welded and they are made from bar of lighter section than the parts they are to join. A collar can go around parts of similar size or they might have to accommodate a stout part of the framing with the thinner scroll bar. To forge collars, use a bar of the same section that has to be enclosed. Double back a piece of scroll bar or hold together thick and thin of other sizes. Usually there are a large number of collars in an assembly and it is easier to make them all at the same time.

A collar could have the ends meeting a butt joint, but it is more usual to cut them diagonally or to overlap the ends.





**Figure 4 - This Church Gate Shows How Scrolls and Leaves can be Built up into a Very Effective Whole Design**





**Figure 5 - Sheet Steel is Formed into Leaves around a Drawn-Out Flamelike Centre in each Decoration**

## Castings

An alternative to forging and fabricating metal is to melt it and run it into a mold. When metal is extracted from ore it is run into molds, then the blocks are further worked during manufacture to form the bars and sheets we use. If sufficient heat is available, most metals and alloys can be melted again and poured into molds of any shape. It is the amount of heat necessary that limits the choice of metals that can be cast in a small shop.

If some decorative ironwork is examined, much of it will be found to be a combination of forged and cast iron. Castings are used where an animal or human face has to be included, or where there are floral representations too complicated for forging. The gate to a medieval castle might have the coat of arms of the owner as a centrepiece cast to shape. Many small decorations, such as a cast-iron flower finial come at the end of a forged bar. Cast iron of this type is rather brittle, but used for decoration without fine detail, this does not matter. In the industrial production of cast iron and steel, there are techniques that overcome any tendency to brittleness and other faults. Many steel tools start as castings. Casting is also valuable where weight is important. Anything bulky, and therefore heavy, is almost certainly cast.

Unfortunately, the heat required to melt iron and steel is more than can be achieved in a blacksmith's shop. The end of a bar might be heated enough to melt away, but what is required is enough heat to melt a quantity of metal in a container to a state where it is fully liquid and can be poured. The heat limit restricts the casting done in a small shop to those metals and alloys with low melting points.

Lead is the metal in general use with the lowest melting point. This is a good choice for practice castings. It does not cast with very sharp angles, but if it is alloyed with antimony it becomes printers' type metal and will cast sharply. Proportions are four parts lead to one part antimony. Old printing type could be used. Aluminium has about twice the melting temperature of lead, but that heat should be possible using a blacksmith's hearth. Some fires might only melt brass. Zinc is not readily available, but if it can be obtained, it can be alloyed with lead and antimony to make a good casting metal that is within the heat range of a smith's shop. A suitable proportion is 14 parts lead, five parts zinc and one part antimony. Typical melting points are shown in Table 1.

Metal	Degrees Fahrenheit	Degrees Celsius
Lead	621	327
Zinc	787	419
Antimony	1166	630
Aluminum	1214	660
Brass	1650	900
Iron	2768	1520

**Table 1 - Melting Points**

Most metals and alloys shrink as they cool. This will have to be allowed for in making a casting. A shrinkage of about 1/8 inch per foot is probable. An alloy containing antimony keeps its size or expands slightly on cooling.

Lead and type metal can be melted in an iron container. A ladle could be used for small quantities, but a handled iron pot with a spout is needed for larger quantities. Metals that require a higher temperature should only be melted in a crucible, which is made of fireclay or plumbago. Special long tongs with jaws are used to embrace the crucible. Obviously, molten metal has to be handled with great care, and early experience is best gained with lead or its alloys melted in a ladle. If a metal runs where it should not, smother it with sand. Never pour water on it.

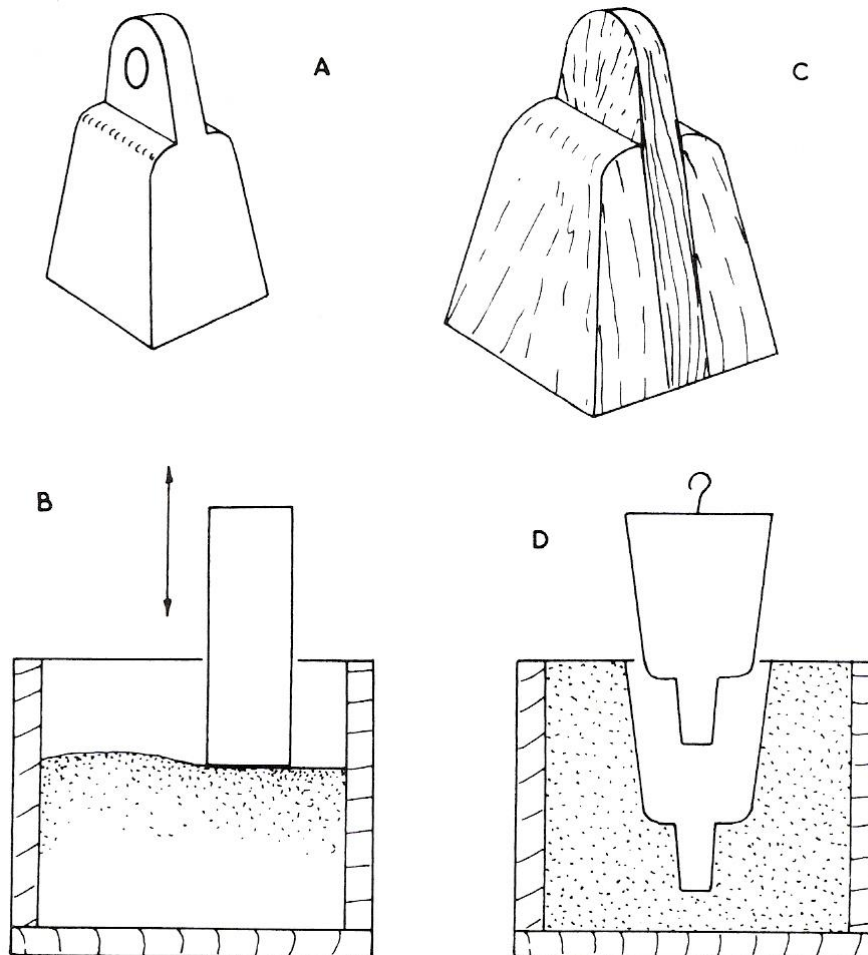
Metal can be melted repeatedly. Old castings can be melted to make new things. Cutting or breaking into small pieces will speed melting. Once there is some molten metal, anything solid lowered into it will soon melt. Impurities will rise to the surface and this dross should be skimmed off with a small ladle before pouring. When metal is poured, do not break the flow.

Casting is done in a mold; sometimes the whole process is described as molding. For metal casting, the mold is usually made of sand. Sea sand or builders' sand is not really suitable, although you can experiment with whatever sand is available. The best material is sold as foundry sand or green sand, which has the right proportions of clay and silica to give a good bond combined with ventilation. It is used slightly damp. Having it too wet could be dangerous when the moisture comes into contact with the hot metal. A mixture with five percent water is about right. To test for the right amount of moisture, squeeze a handful of sand tightly. It should keep the shape of your hand when released. If much sand adheres to your hand, it is too wet.



## Single Mold

For most casting, the mold has to be in two parts. But some simple things that have a flat part pointing upward can be made in a single mold. An example is a lead block to be used as a weight (Figure 6A). In a simple example, the hole is not cast, but is drilled or punched afterward.



**Figure 6 - A Weight (A) can be Cast from a Wooden Mold (C) in a box of Sand (B, D)**

Use any wooden box that is big enough to hold enough sand and stout enough not to burst when the sand is rammed tight. Put sand in the box and ram it down a little at a time with a flat-ended piece of wood (Figure 6B) or even the handle of a hammer.

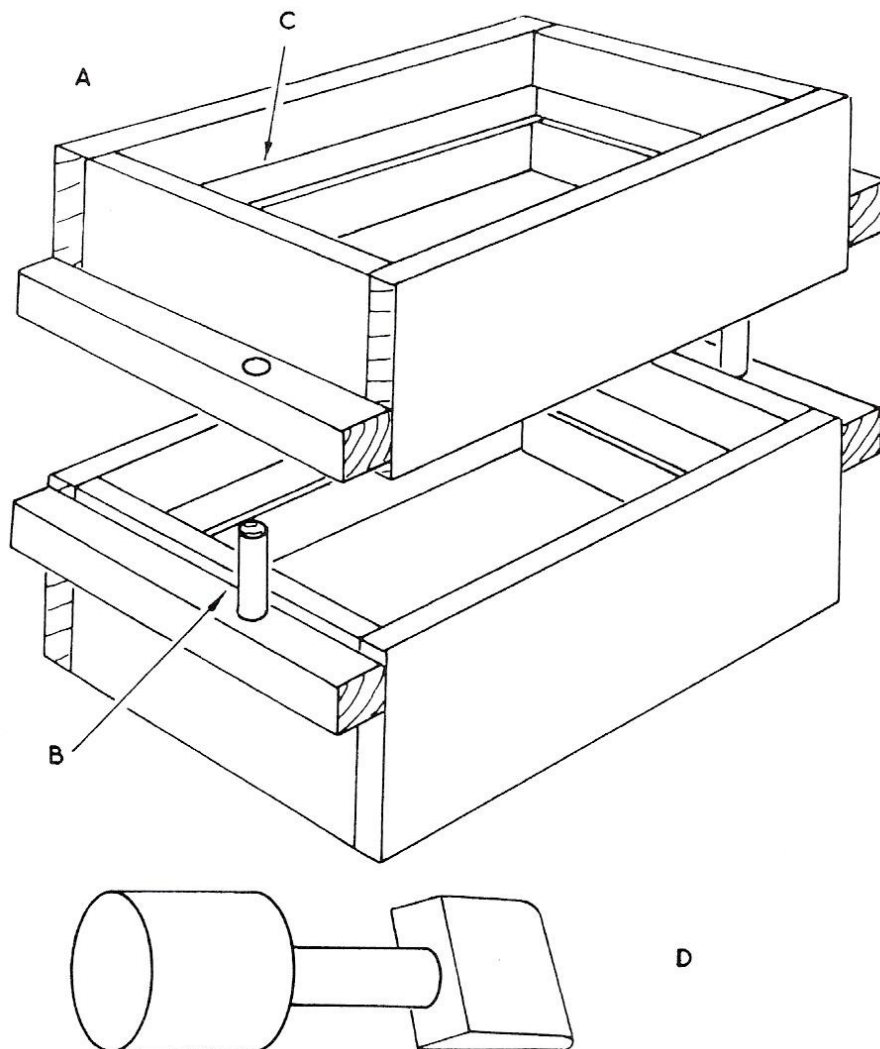
Make a wooden pattern of the weight. It must be tapered so that it can be withdrawn from the sand. This applies to the narrow part for the hole as well as the main body. It could be cut from solid wood or built up (Figure 6C). If a lathe is available, a round pattern can be turned. Finish the surface smooth. It does not matter what kind of wood is used. For general patternmaking in industry, pine and mahogany are used. For this weight, the wood can be used as it is. When a pattern is to be used many times, it is usual to seal its surface with shellac or varnish.

Scoop out some sand from the middle of the box and press the pattern in. It helps to put a screw eye in its base so it can be withdrawn (Figure 6D). Ram the sand tight around the pattern and level its top. When you are certain it is closely packed, withdraw the pattern and examine the mold. Pour lead in until it is level and let it cool. Then remove some sand so that you can lift it out. Punch or drill the hole. File or hammer the bottom level.

This is the basic method that can be used for the simplest castings. For most casting, the mold is made in two parts even when one surface of the finished work is to be flat.

### Flat-Faced Castings

Molding is done in flasks, which are boxes open top and bottom, and arranged to fit against each other. In production work, the flasks are cast iron. However, small work can be done in wooden flasks. The lower one is called a drag and the other is the cope or top part.



**Figure 7 - Wooden Flask for Casting can be Made as Two Open Boxes**

- A) Identical size boxes
- B) Dowels

- C) Grooves
- D) A narrow tapered end

Wooden boxes can be made in identical sizes (Figure 7A). Pieces across the end act as handles and provide positions for locating dowels that stand up from the drag and engage easily in holes in the top part (Figure 7B). So that the parts cannot be reversed in relation to each other, have the dowels off-centre so that they will not match the other way. It will help to have grooves on the insides of the box to provide a key to grip the sand (Figure 7C). Sizes will depend on the work to be done, but the wood should be thick enough to remain stiff and the corner joints should be strong.

Although green sand is used in the flask, there has to be another sand to sprinkle between the meeting surfaces to prevent them from bonding together. The parting sand is used dry and can be bought as such, but brick dust can also be used. It is sprinkled through a fine sieve or riddle (mesh about 1/16 inch) over the sand in the drag, and sometimes on the pattern before it is put in.

A rammer is a sort of straight-ended mallet that can be wood or iron. A narrow tapered end will get into smaller spaces (Figure 7D). Have a trowel available for dealing with sand.

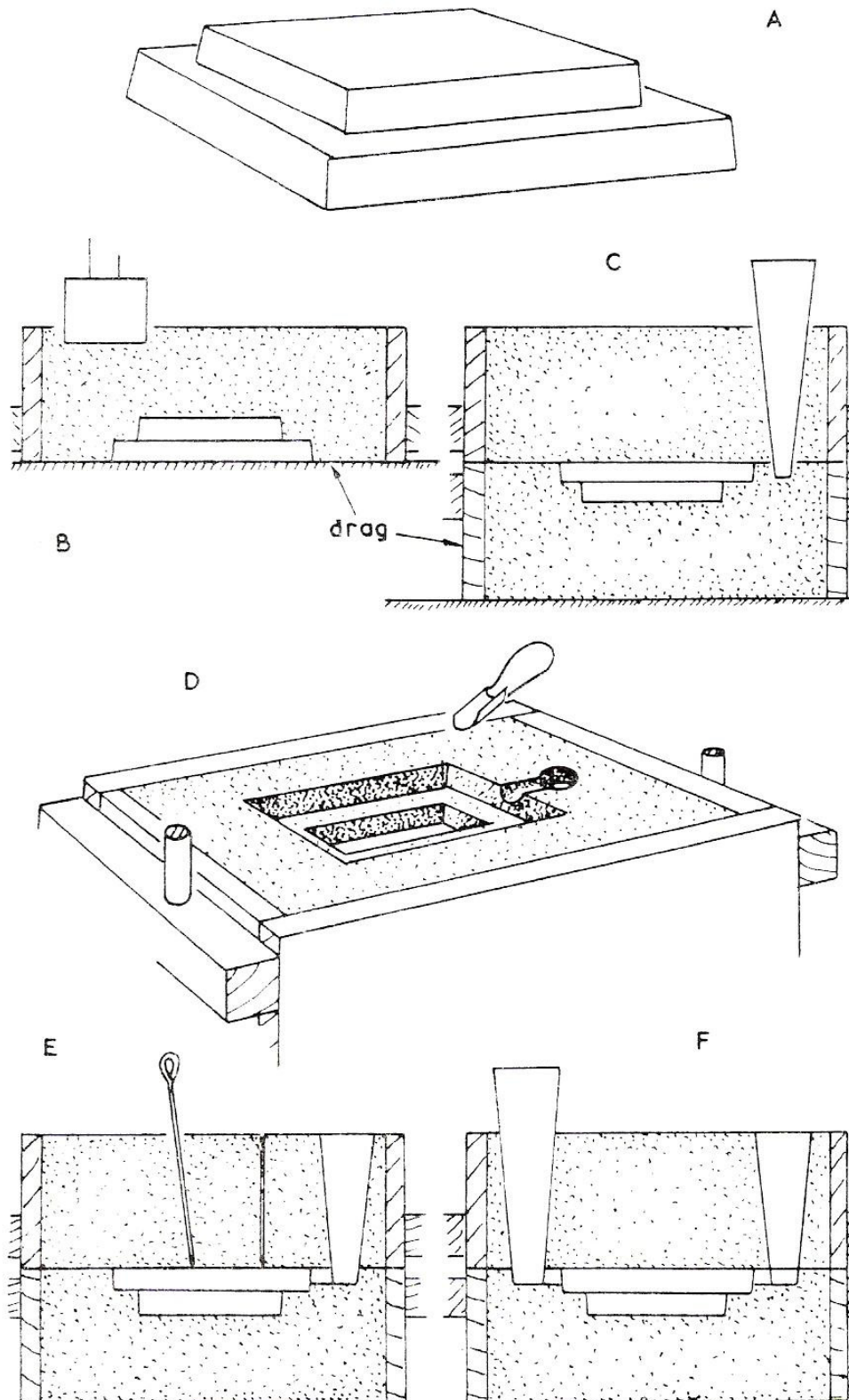
If the object to be made has a flat face and the rest of the shape can be tapered to withdraw from the sand, the whole shape can be arranged in one half of the flask. The weight previously described could be made in this way; a stepped pedestal would be another example. Make a pattern and include a slight taper to all edges. Surfaces can be flat because they do not affect withdrawal (Figure 8A).

Put the pattern on a flat board and have the drag face downward around it. Sprinkle facing sand through the sieve on the board and pattern. Put in green sand with the trowel and press it down at intervals with the rammer (Figure 8B). Make sure the whole box is filled. See that sand is forced into the corners. Fill to overflowing and then scrape the surface level with a straight-edged piece of wood.

Lift and turn the drag over. Put the top part in place, and sprinkle facing sand in. Stand a tapered rod slightly to one side of the pattern so that the metal can be poured in (Figure 8C). This is called a gate stick and can be wood or metal. It could be round, a tapered square, or octagonal. Fill the top part with sand, ramming it tight in the same way as the drag and then scrape its top level.

Ease out the gate stick, tapping it gently at the side to loosen it. The top of the hole left can be made into a funnel shape for ease in pouring metal.

Lift away the top part and put it aside, face up. Cut a small channel from the gate stick position to the pattern, to serve as a runner for the molten metal when it is poured. A piece of sheet metal folded into a deep scoop or gouge will cut the runner (Figure 8D).



**Figure 8 - Flat Pattern**

A flat pattern (A) goes into one part and is covered with sand in the other part (B). Then the sand is cut to allow pouring molten metal (C). A deep scoop (D) will cut the metal. A pointed wire (E) allows air to escape or you can use a riser (F).

To get the pattern out, enter the point of a screw in it, so that it can be used as a handle. There will almost certainly be a few flaws in the mold where sand has fallen or broken away. Bellows can be used to blow away loose sand. If repairs have to be made, there are molders' tools that are used like small trowels for pressing sand into place. They can be made by a smith and are bars with opposite ends formed into small trowel shapes (Figure 9).

If the work is small, all that has to be done now is to put the parts of the flask back together and pour the metal. There will be enough ventilation in the sand to carry the air away, but the pouring metal will put pressure on the whole mold, so the top part should be weighted or attached to the drag to prevent it from lifting. For a clean casting, the inside of the mold can be dusted with graphite.

If the work is larger, it is advisable to provide some escape for air as the metal is poured in. This can be done while the pattern is still in place by pushing in a pointed wire pricker at several places until it is felt pressing against the pattern (Figure 8E). For a very large casting, it might be better to provide a hole called a riser. A riser is really a repeat of the gate stick hole at the side remote from it (Figure 8F). Excess metal that has run off that way or into ventilating holes will have to be cut off after the casting is removed.

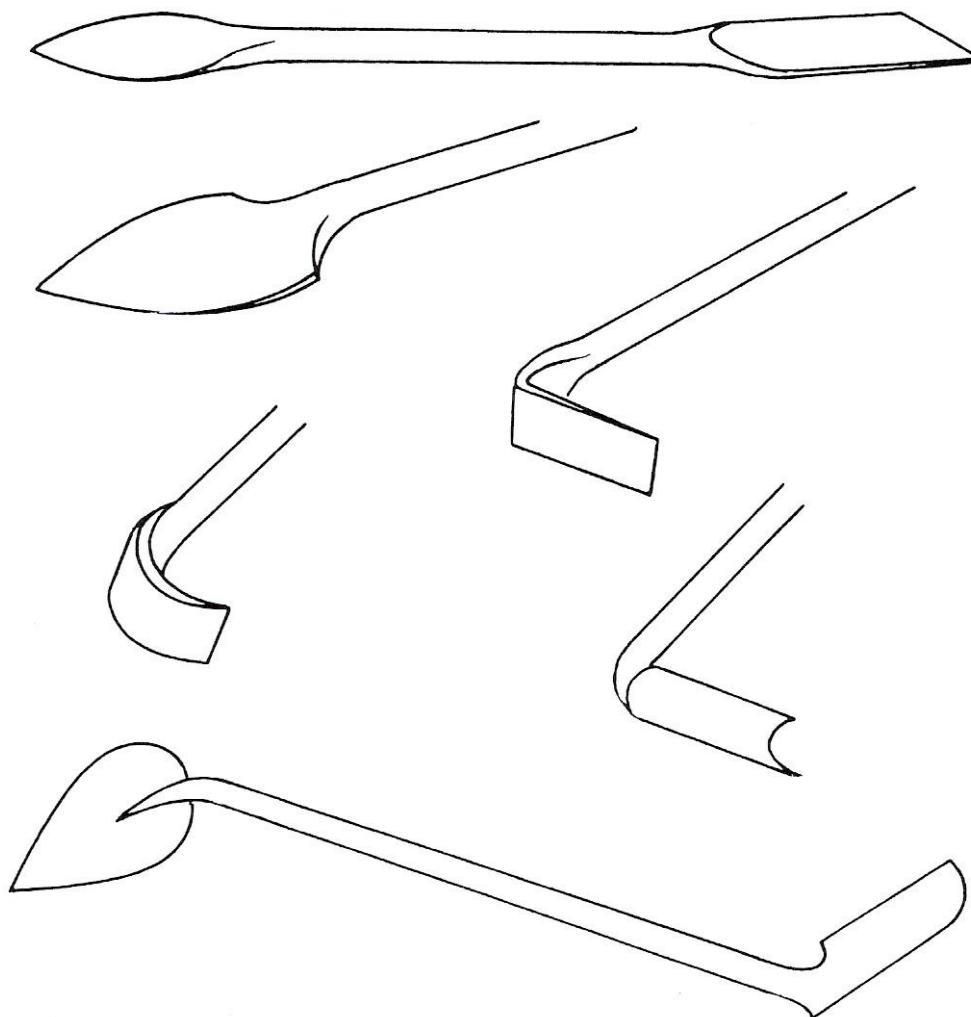


Figure 9 - Small Steel Hand Tools are used to Correct a Mold

## Symmetrical Castings

Many things that have to be cast could not be made in one half of the flask because it would be impossible to withdraw the pattern. Many castings have a cylindrical form. The only way they can be cast is to have half in each part of the flask so that the curves are into the sand, which should not be disturbed when the pattern is removed.

To get a tight pack of sand in each part when a solid symmetrical pattern is being used, preparation has to start with a temporary filling of the top part of the flask. Place the top part with the side that will be toward the drag upward, and fill it with sand. Pack it reasonably tightly and press the pattern halfway into it (Figure 10A). If it is a big pattern, cut out some of the sand first and finish the sand surface level.

Put the drag on and sprinkle on parting sand. Fill the drag and ram the sand tightly. Scrape it level (Figure 10B). Turn over the flask to bring the drag underneath. Separate the boxes carefully to leave the pattern in the drag. Knock out the sand from the top part. Put it back on the drag, sprinkle in parting sand, and repack the top part tightly. Then scrape it level. Having this extra stage is necessary because the first filling of the upper part cannot be done tightly enough.

With both parts of the flask properly packed, use the gate stick and make ventilating holes if they are needed. Then separate the parts and remove the pattern (Figure 10C). Cut a runner and clean up the mold if necessary. Dust with graphite. Put the parts back together and pour the metal.

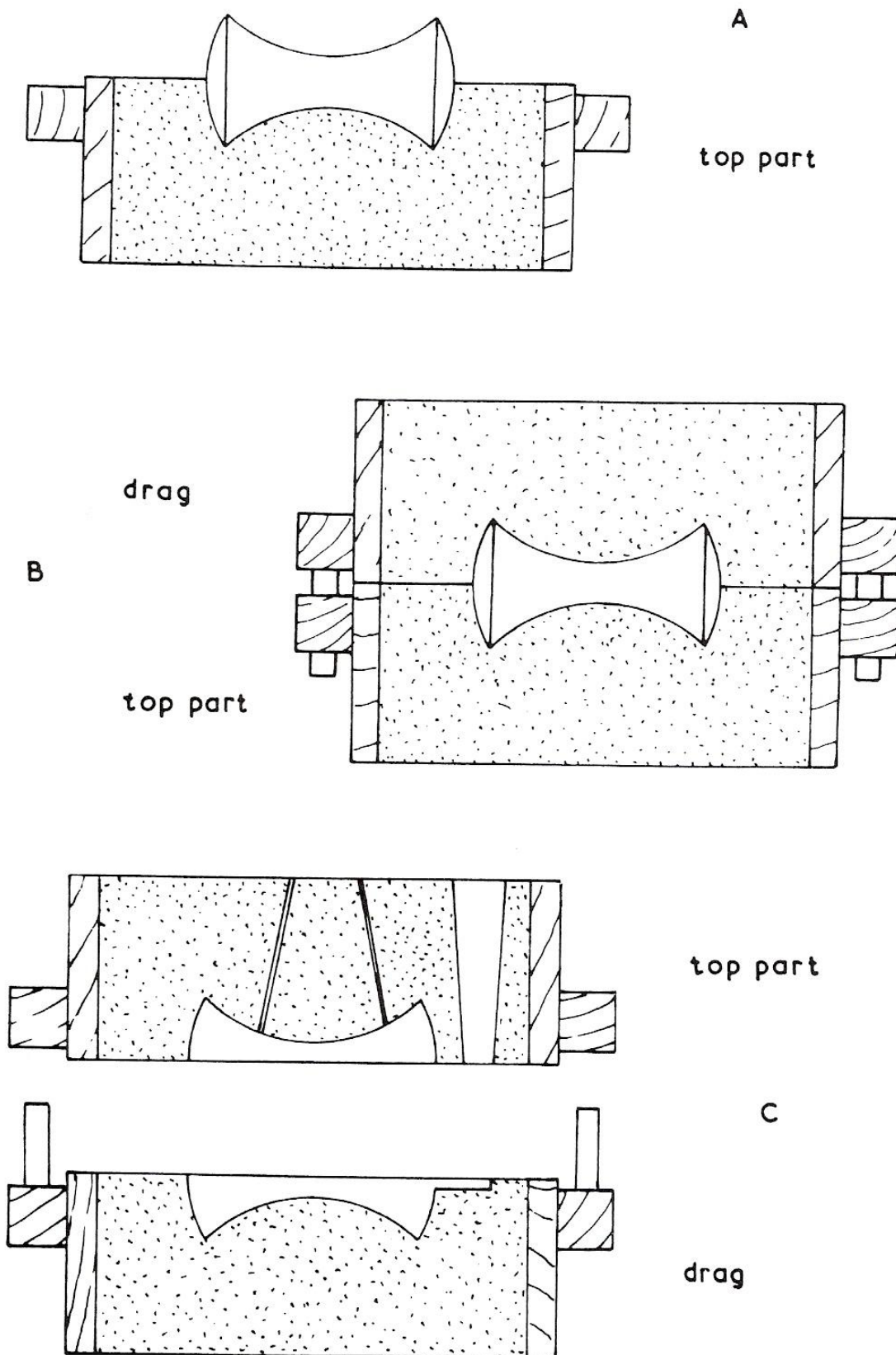


Figure 10 - Symmetrical Item is Arranged in Both Parts of a Flask

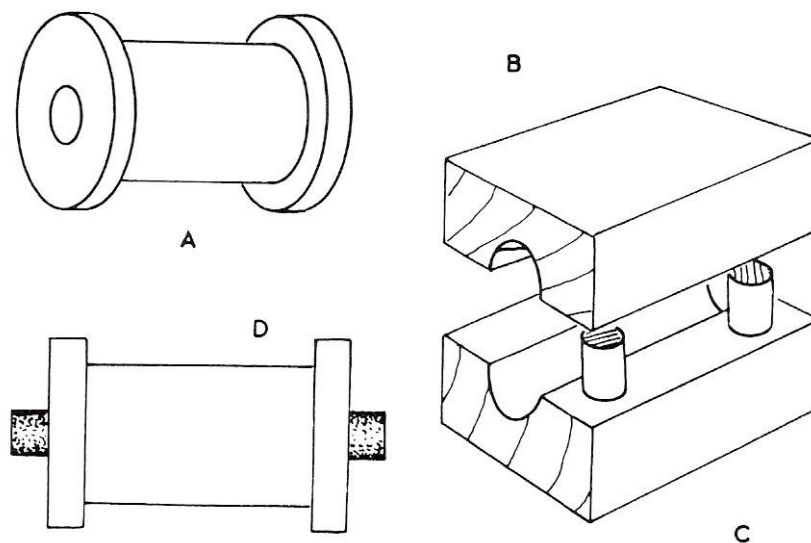


## Cored Castings

Many castings have to be made with holes through them. Sometimes holes are drilled, but it is helpful to cast the hole when the metal is poured. For many purposes, that is all that is needed. For more precision, the cast hole can be opened to size. To make a hole, there has to be a core arranged in the mold so that the metal flows around it and the core can be removed from the casting after it has set.

Suppose a cylindrical casting is required with a hole through that will be machined to make a bearing (Figure 11A). A core must be made longer than the final length of the casting so that it can be supported in the molded sand. This is built up in a core box, which is a two-part mold, into which the sand mixture can be packed (Figure 11B). Make it from wood, with half the diameter gouged from each part. Use dowels or other pegs to keep the two parts correctly located in relation to each other (Figure 11C).

The core will go into the sand so it is supported outside the main hollows left by the pattern. To allow for this, the pattern is given core prints (Figure 11D) that are the diameter of the core and that extend far enough to make the recesses in the sand. In pattern making, it is usual to stain the core prints so that they are a different colour from the main pattern, to indicate that they are not part of the final shape. Of course, the overall length across the core prints should be the same as the length of the core.



**Figure 11 - Hollow Casting Requires a Core that is Formed in a Core Box**

- A) Cylindrical casting
- B) Two-part mold
- C) Dowels are used to position the parts
- D) Core prints are used to make patterns



## **Self Assessment**

Questions on Background Notes – Module 4.Unit 10

**No Suggested Questions and Answers.**

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