

United States Patent

[11] 3,534,803

- [72] Inventors **Robert Lewis Bickerdike;
Garyth Hughes, Farnham, England**
- [21] Appl. No. **632,277**
- [22] Filed **April 20, 1967**
- [45] Patented **Oct. 20, 1970**
- [73] Assignee **National Research Development
Corporation
London, England**
- Continuation-in-part of application Ser. No.
541,975, April 12, 1966, now abandoned.
This application April 20, 1967, Ser. No.
632,277**

- [50] **Field of Search**..... 164/34, 41,
43, 138; 249/134; 106/38.9

- | | | | |
|------------------------------|--------|-------------------------|---------|
| [56] | | References Cited | |
| UNITED STATES PATENTS | | | |
| 1,185,252 | 5/1916 | Sheldon..... | 164/138 |
| 3,229,338 | 1/1966 | Kopera..... | 164/41 |
| 2,239,530 | 4/1941 | Langenohl et al. | 164/41X |
| 3,166,808 | 1/1965 | Moore..... | 164/41X |
| 3,241,200 | 3/1966 | Lirones..... | 164/34X |
| 3,367,393 | 2/1968 | Lenahan et al. | 164/34 |
| 3,374,825 | 3/1968 | Johnson..... | 164/34X |

Primary Examiner—J. Spencer Overholser

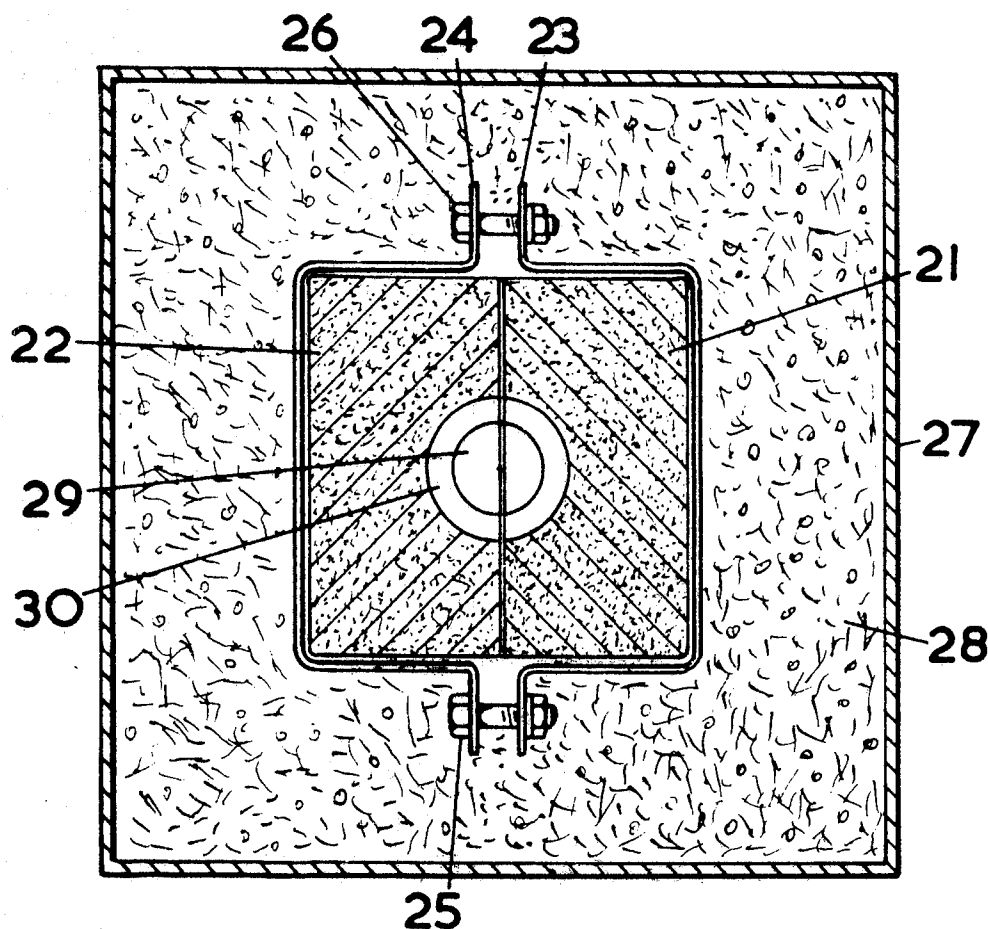
Assistant Examiner—R. Spencer Annear

Attorney—Larson and Taylor

- [54] METHOD OF CASTING IN A PERMANENT
CARBON MOLD**
5 Claims, 3 Drawing Figs.

- [52] U.S. Cl..... 164/138,
164/41, 249/134, 106/38.9
[51] Int. Cl..... B22c 1/00

ABSTRACT: A carbon casting mould for metals is provided which has low conductivity and high thermal shock resistance. The moulds, which comprise fibrous carbon bonded with non-fibrous carbon, can be repeatedly used to cast grey iron.



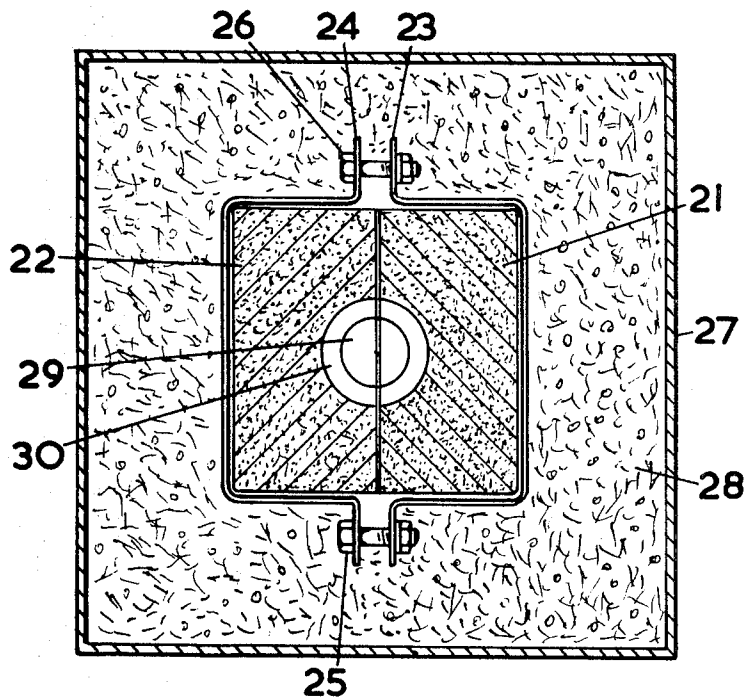
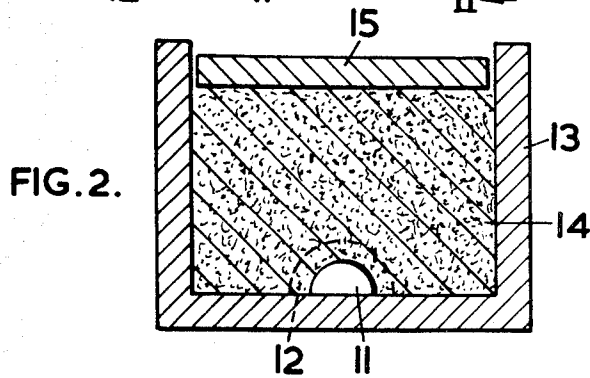
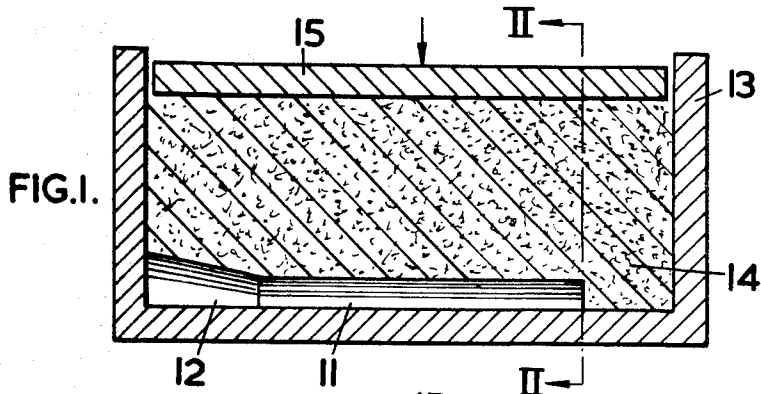


FIG. 3.

Inventor
By
Attorney

METHOD OF CASTING IN A PERMANENT CARBON MOLD

This application is a continuation-in-part of copending application Ser. No. 541,975 filed April 12, 1966 and now abandoned.

This invention relates to carbon casting moulds and to a method of casting metal in carbon moulds and is particularly concerned with a method of casting metals such as iron or steel or nonferrous metals and alloys in carbon moulds and to moulds useful for such casting methods.

In the well known method of casting, for example casting iron, a sand mould is formed by the use of a pattern, the pattern is removed and molten iron is poured into the mould and allowed to solidify. The mould is then removed from the cast iron article.

This method of casting suffers from the disadvantage that the mould can only be used once but does enable so called 'grey' iron castings to be produced which do not require subsequent heat treatment.

It has also been proposed to use a cast iron mould lined with ceramic material for casting iron with the object of providing a mould that could be reused.

This method of casting iron suffers from the disadvantage that because of the high thermal conductivity of the mould material, and hence rapid cooling of the casting, only so called 'white' iron castings can be produced which require subsequent heat treatment with corresponding cost disadvantages.

In the development of the present invention consideration was given to the use of known nonfibrous industrial carbon materials of the powdered carbon form to manufacture a mould for casting. Accordingly moulds were made firstly by a process comprising the steps of mixing a graphite powder with a resinous binder, shaping a charge of the mixture, curing the resin to effect a bond, carbonising the article, and depositing carbon in the interstices of the article by pyrolytic deposition in a hydrocarbon atmosphere, and secondly, by the same process but using petroleum coke instead of graphite.

Moulds formed by the former process were used for casting iron. The moulds were strong enough to resist thermal cracking but were found to have a high thermal conductivity with the result that only 'white' iron, which needed subsequent heat treatment, could be produced.

Moulds made by the latter process were found to have the desirable low thermal conductivity but in use cracked when the temperature of the casting surface of the mould approached that of the cast iron melt and no useful castings could be produced.

It is an object of the present invention to provide reusable carbon moulds for casting metals which have low thermal conductivity, adequate strength at high temperatures and resistance to thermal cracking and which can thus be repeatedly used for casting grey iron. It is a further object of the invention to provide methods of casting metals using these moulds.

It is a further object of the present invention to provide carbon moulds and to provide a method of casting metal in carbon moulds which may be reused.

It is still a further object of the invention to provide carbon moulds and to provide a method of casting iron in carbon moulds which can be reused and in which 'grey' iron castings can be produced.

These and other objects which will become apparent in light of the present specification are achieved according to the invention by providing a casting mould for metals the moulding surface of which is at least in part constituted by one or more carbon components comprising a mass of carbon fibres bonded together by nonfibrous carbon. These carbon moulds can be very accurately dimensioned and, because of their porous open structure and low thermal conductivity, the moulds resist cracking at high temperatures and thus can be repeatedly used, for example, to cast grey iron.

To form a mould for use in a method of casting according to the invention a mould is made by forming to the desired shape,

in a container a charge comprising a mixture of resin and carbon fibres lightly consolidating the charge, curing the resin to bind the fibres together, removing the bonded shape from the forming container, slowly heating in a nonoxidising atmosphere to a temperature to carbonise the binder to form a porous carbon mass and then depositing further carbon in the pores. The mould is then used by introducing a charge of molten metal into the mould, allowing the charge to solidify and removing the cast article from the mould.

Alternatively the charge may comprise a mixture of resin binder with carbonisable fibres which latter are carbonised with the resin.

The resin treated fibres are conveniently packed around a pattern in a core box to form a mould or part mould, or into a core box to form a core, as in sand moulding; a sand core may however be used in a carbon mould.

The carbon mould may be graphitised by heating to a temperature of of 1,800°—2,800°C. prior to use as a mould.

The resin treated carbon fibre charge may include a fugitive filler such as polyethylene powder which assists in the consolidation of the charge and evaporates during carbonisation of the charge under nonoxidising conditions.

In either case the resin treated carbon fibres are advantageously obtained by mixing together short carbon fibres, a solution of a phenolformaldehyde resin dissolved in industrial methylated spirits and a hardener such as hexamethylene tetramine until all the methylated spirits has evaporated and raw material is formed in which resin is dispersed throughout the mass of fibres.

The short carbon fibres and the solution of phenolformaldehyde resin dissolved in industrial methylated spirits are preferably mixed together prior to adding the hardener.

The starting material must be capable of being carbonised under the action of heat to form a fibrous carbon and may comprise a cellulose material such as paper or an artificial fibre such as rayon. Where nonfibrous material is present in the starting material, such as the filler in paper, this may be retained.

The necessary bond between the carbon particles and fibres is obtained in two main stages. Firstly, a carbonisable resin binder holds the charge together during the moulding process and subsequent handling; the carbon derived from this resin holds the charge together during heating in the furnace up to the deposition temperature. Secondly, the charge is reinforced by carbon deposited in the interstices of the charge from hydrocarbon vapours. The proportion of resin binder is kept low commensurate with achieving successful binding as carbonisation of the binder gives rise to dimensional shrinkage. The necessary final strength and density of the article is obtained by carbon deposition during which there is negligible dimensional change.

Paper may be used as a starting material in which case the paper is teased apart by beating in a rotary mill or by pulping in a liquid to obtain a fibrous material. The paper fibrous material is carbonised by heating slowly in a nonoxidising atmosphere so that severe oxidation of the carbon produced is avoided. This is achieved by passing trays containing the material through a continuously operating furnace or heating boxes containing the material in a furnace. This provides a mainly fibrous carbonised material which is mixed with a solution of resin in industrial methylated spirit solvent in a ribbon bladed mixing machine. During mixing a hardener such as hexamethylene tetramine is added and the solvent is allowed to evaporate leaving a loose liquid free carbon material suitable for moulding. Any bonding of the material into lumps can be removed by sieving through coarse wire mesh.

The carbon material is then loaded into a moulding tool and pressurised whilst heating at from 100—180°C. to cure the resin. As the temperature is raised the resin goes through a soft stage prior to hardening and this aids the moulding process. A fugitive pressing lubricant such as polyethylene powder may be mixed with the charge of carbon material. The known techniques such as splitting of the tool and the use of a

parting agent to facilitate easy release are used as required. Whilst pressures to up to 2,000 p.s.i. may be used, in general, pressures of less than 100 p.s.i. are satisfactory. Also sufficient consolidation may be achieved simply by vibration.

The moulded charge is next removed from the moulding tool and slowly heated in a furnace in a nonoxidising atmosphere to first carbonise the resin bond and subsequently, at a temperature within the range of 750°—1,000°C. a hydrocarbon vapour is introduced into the furnace. A continuous furnace is used in which the moulded charges pass on trays from one end of the furnace to the other in the opposite direction to the gas flow. The furnace temperature is raised to the 750°—1,000°C. level so that carbon deposited from the hydrocarbon forms on the main internal surfaces of the moulded charge structure, i.e. on the surfaces of the main pore system, where it strengthens the charge by assisting in bonding the particles together. Temperatures, partial pressures and gas flows are selected so that the formation of soot is minimised. Settling of soot is inhibited by using a fast gas flow particularly over horizontal surfaces and/or by covering such surfaces with a protective layer of coarse pieces of inert material such as carbon.

After cooling and removal from the furnace the moulded charge comprised a carbon mould for use in for casting metals such as iron, steel or nonferrous metals. In use the carbon mould is preferably backed with an unbonded powder or mixture such as a mixture of sand and coal dust or powdered coke or it can be fitted directly into a metal shell or casting box. The object of the shell is to facilitate handling and together with the backing to restrict the access of air to the outside of carbon mould.

A mould dressing which may conveniently comprise a liquid containing finely dispersed carbon or graphite particles may be sprayed or painted on the casting surface of the mould to resist deterioration by oxidation and by attack from the molten metal.

The casting mould can consist of a metal outer case (in several parts) containing the moulded carbon insert or inserts, or containing moulded carbon inserts backed by another material.

Moulds made according to this invention can be used for precision casting, or they can be used repeatedly as semipermanent moulds. They can also be used for making thin castings because of the low thermal diffusivity which is attainable.

The paper is carbonised first because the fibres shrink during carbonisation and when making accurate mould shapes it is desirable that this shrinkage should have taken place prior to final formation of the carbon mould.

However, where the shape of the carbon mould is not critical the fibrous paper may be mixed directly with resin, the mixture being then moulded and carbonised prior to carbon deposition.

We have also found that resins of the thermosetting or cold setting type can be used as the bonding agent. Thus, resins which can be cured by the action of a catalyst vapour such as resin based on furfuryl alcohol may be used.

Hydrocarbon gases such as benzene, hexane, methane or propane may be used for carbon deposition.

As an alternative to the use of a continuous furnace for the carbon deposition hydrocarbon vapour may be periodically introduced into an evacuate furnace containing the shaped carbon charge the furnace being periodically evacuated by means of pumps to remove the free products of hydrocarbon decomposition.

A reusable mould made in accordance with the invention can be very accurately dimensioned and, because of its high porosity open structure and low thermal conductivity or diffusivity its resistance to cracking under temperature induced stresses is high.

Several specific examples of the invention will now be described in which a reusable mould was made and used for the direct casting of grey iron articles.

EXAMPLE 1

220 g. of carbonised coarse grade Whatman cellulose fibrous powder was mixed with 35 g. of Leicester Lovell Thor TPR7 resin, a phenolformaldehyde novolac resin, dissolved in 26 g. of industrial methylated spirits. After mixing for 2 minutes 2.5 g. of hexamine was added and the mixing continued until all the methylated spirits had evaporated. The dry material was then sieved through a 25 mesh sieve B.S.S. The above powder was used to make two halves of a split mould for casting iron bars 1 inch diam. $\times$ 4½ inch long, the mould being provided with a pouring head 1½ inch diam. at the top tapering over a length of 1½ inch to 1 inch diam. The outer dimensions of each half of the mould were 1½ inch deep $\times$ 2 inch wide $\times$ 6½ inch.

The half moulds were prepared as illustrated by the accompanying FIGS. 1 and 2.

FIG. 1 is a cross-sectional elevation of a moulding box used to form a carbon mould according to the invention. FIG. 2 is a cross-sectional view on the line II-II of FIG. 1.

As shown a mould pattern having a semicircular cylindrical section 11 and a semifrustoconical section 12 was placed in the bottom of a metal moulding box 13. 70 g. of the mixed powder 14 were poured into the box 13 to cover the pattern. A load of 0.5 p.s.i. was applied to the powder through a pressure plate 15 and the box and contents heated to 150°—180°C. After cooling, the box and pattern were removed leaving a half mould with an average density of 0.35 g./cc. This half mould was then slowly heated under an atmosphere of nitrogen to about 900°C. to carbonise the resin, after which the temperature was lowered to 840°C. and the half mould was heated for 15 hours in a flowing gas mixture of nitrogen and benzene, the partial pressure of the benzene being 26 cm. After this carbon deposition treatment the half mould had a density of 0.68 g./cc.

Two similar half moulds were made. The half moulds were then located in a metal moulding box as illustrated at fig. 3.

FIG. 3 is a sectional plan view of a moulding box utilizing carbon moulds as shown in FIGS. 1 and 2. As shown at FIG. 3, two carbon half moulds 21, 22 were held together by locating bands 23, 24 which were secured by nuts and bolts at 25, 26 and were then placed in a larger box 27 and surrounded by a mixture of sand and coal dust 28. Molten iron was then poured into the mould cavity 29 formed between the half moulds 21, 22 and allowed to set. It will be noted that the mould cavity 29 has a frustoconical entrance 30 which facilitates pouring of the molten iron into it and which corresponds to the section 12 of FIGS. 1 and 2. The resulting cast iron article was then removed from the mould by separating the carbon half moulds. The half moulds were then reassembled and used again.

It was found that 45 'grey' iron castings having acceptable physical dimensions and surface finish could be produced using the same pair of carbon half moulds.

EXAMPLE 2

220 g. of carbonised coarse grade Whatman cellulose powder was mixed with 35 g. of Leicester Lovell Thor TPR7 resin dissolved in 26 g. of industrial methylated spirits. After mixing for 2 minutes 2.5 g. of hexamine was added and the mixing continued until all the methylated spirits had evaporated. The dry material was then sieved through a 25 mesh sieve B.S.S. and for every 60 g. of 25 mesh B.S.S. resin treated carbonised cellulose powder 40 g. of 25 mesh B.S.S. polyethylene powder was added and both powders were thoroughly mixed. The above powder was used to make two halves of a split mould for casting iron bars 1 inch diam. $\times$ 4½ inch long, the mould being provided with a pouring head corresponding to the section 12 of FIGS. 1 and 2 1½ inch diam. at the top tapering over a length of 1½ inch to 1 inch diam. in a similar manner as that described above with reference to example 1. In this case the half moulds were prepared by using 150 g. of the mixed powders and a pressure of 10 p.s.i. was applied while heating the metal box and contents to 150°—180°

0°C. After cooling, the box and pattern were removed leaving a half mould with an average density of 0.64 g./cc. This half mould was then slowly heated under an atmosphere of nitrogen to about 900°C. to evaporate the polyethylene and carbonise the resin, after which the temperature was lowered to 840°C and the half mould was heated for 15 hours in a flowing gas mixture of nitrogen and benzene, the partial pressure of the benzene being 26 cm. After this carbon deposition treatment the half mould had a density of 0.68 g./cc.

Two similar half moulds were made and used as described with reference to Example 1 to cast grey iron articles.

EXAMPLE 3

220 g. of carbonised Wood Flour was mixed with 35 g. of Leicester Lovell Thor TPR7 resin dissolved in 26 g. of industrial methylated spirits. After mixing for 2 minutes 2.5 g. of hexamine was added and the mixing continued until all the methylated spirits had evaporated. The dry material was then sieved through a 25 mesh sieve B.S.S. The above powder was used to make two halves of a split mould for casting iron bars 1 inch diam. $\times$ 4 $\frac{1}{2}$ inch long, the mould being provided with a pouring head 1 $\frac{1}{2}$ inch diam. at the top tapering over a length of 1 $\frac{1}{2}$ inch to 1 inch diam. The outer dimensions of each half of the mould were approximately 1 $\frac{1}{4}$ inch deep $\times$ 2 inches wide $\times$ 6 $\frac{1}{2}$ inches long. The half moulds were prepared as described with reference to Example 1 using 73 g. of the powder. A pressure of 1 p.s.i. was applied while heating the metal box and contents to 150°—180°C. After cooling, the box and pattern were removed leaving a half mould with an average density of 0.32 g./cc. This half mould was then slowly heated under an atmosphere of nitrogen to about 900°C. to carbonise the resin, after which the temperature was lowered to 840°C. and the half mould was heated for 15 hours in a flowing gas mixture of nitrogen and benzene, the partial pressure of the benzene being 26 cm. After this carbon deposition treatment the half mould had a density of 0.62 g./cc.

Two similar half moulds were made and used as described with reference to Example 1 to cast grey iron articles.

EXAMPLE 4

Newspaper was ground in an overhung beater-cross type machine to produce a uniform material. 1,000 g. of this material was slowly heated to 900°C. in an inert atmosphere to produce approximately 250 g. of carbon fibres. The 250 g. of carbon fibres were then mixed with 41 g. of a phenolformaldehyde resin in solution in methylated spirits, and 4 g. of hexamine, until all the methylated spirits had evaporated. The dry material was then sieved through a 25 mesh sieve B.S.S. and the powder used to make two halves of a split mould for casting iron strip 1 $\frac{1}{2}$ inch wide $\times$ 9 inch long $\times$ 40 thou' thick, the mould being provided with a pouring head 1 $\frac{3}{4}$ inch $\times$ 1 $\frac{3}{4}$ inch at the top tapering over 1 $\frac{1}{2}$ inch to the section of the strip. The half moulds were prepared as described with reference to Example 1 using 112 g. of the powder into a metal moulding box in the bottom of which was located with pattern to form the internal shape of the mould. A pressure of approximately 100 p.s.i. applied while heating the metal box

and contents to 150°—180°C. After cooling, the box and pattern were removed leaving a half mould with an average density of 0.26 g./cc. This half mould was then slowly heated under an atmosphere of nitrogen to about 900°C. to carbonise the resin after which the temperature was lowered to 840°C. and the half mould heated for 4 $\frac{1}{2}$ hours in a flowing gas mixture of nitrogen and benzene, the partial pressure of the benzene being 26 cm. After this carbon deposition treatment the half moulds had a density of 0.45 g./cc.

Two similar half moulds were made and used as described with reference to Example 1 to cast grey iron articles.

EXAMPLE 5

Resin treated carbon fibres similar to those mentioned in Example 4 were used to produce a mould for casting iron bars 1 $\frac{1}{2}$ inch diam. $\times$ 1 foot 9 inch long. In this case a shorter fibre was used near the surface of the pattern resulting in a better surface finish to the carbon moulding, and consequently to the iron bar cast in this mould. The as-pressed density of this mould was 0.3 g./cc, and after 5 $\frac{1}{2}$ hours' carbon deposition treatment at 840°C. with a benzene partial pressure of 26 cm. the density was 0.4 g./cc.

Further reusable moulds have been made using the process of the invention in which, for cheapness, the carbon fibres have been made from newspaper and wood pulp. The newspaper or wood pulp is pulped up and the water then dried off. The dried pulp is then heated up under nonoxidising conditions to carbonise the fibres. The carbonised pulp is then lightly crushed to obtain the carbon fibres.

We claim:

1. A method of casting a metal article comprising the steps of:

- providing a reuseable carbon mold comprising a mass of carbon fibers bonded together by nonfibrous carbon and having a casting surface defining a mold cavity;
- introducing a charge of molten metal into the mold cavity;
- allowing the molten metal charge to set in said mold cavity to form a cast metal article; and
- separating said mold from said cast article in such a manner that the separated mold is reuseable for subsequent casting operations.

2. A method according to claim 1 wherein the mold separated from the cast article is reused to make a further cast article as in steps *a*, *b*, *c*, and *d*.

3. A method of casting as claimed in claim 1 wherein said metal comprises iron.

4. A method of casting as claimed in claim 1 wherein said mass of carbon fibres comprises carbonised fibrous cellulose material and said nonfibrous carbon comprises, first, the carbon product resulting from the carbonisation of a carbonisable resin, and, second, carbon deposited from a hydrocarbon gas in the interstices of said carbon product.

5. A method of casting as claimed in claim 4 wherein said carbonised fibrous cellulose material comprises carbonised wood flour.