

As: 88.303

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
Rad: 02-049640-00014-0000
FOLIO 2007-04-11 15:33:17 Dep. 2007 NUEVEACIONES
100.2 PATENTES
EYE: 1 NEGOTIABLE
ACTUAL RETIRO TITULO FOLIO 1

Señor

SUPERINTENDENTE DE INDUSTRIA Y COMERCIO

DELEGADO PARA LA PROPIEDAD INDUSTRIAL

SECRETARIA GENERAL

E. S. M.

REF.: RETIRO TITULO DE PATENTE A NOMBRE DE
OWENS-BROCKWAY GLASS CONTAINER INC.
EXPEDIENTE No. 02 049640

JUAN PABLO CADENA SARMIENTO, identificado como aparece al pie de mi firma, obrando como apoderado dentro del expediente de la referencia, me permito solicitar la numeración y entrega de Resolución No. 4807 del 28 de febrero de 2007, que concede este derecho.

Ruego a usted proceder de conformidad.

Señor Superintendente,



JUAN PABLO CADENA SARMIENTO
C.C. No. 80.410.337 de Usaquén
T.P. 57492 del C.S.J.

Bogotá, 4 de abril de 2007

MEV/aac

Superintendencia de Industria y Comercio

Otorga la Patente de Invención a:
Owens - Brockway Glass Container, Inc.
Toledo, Ohio, Estados Unidos de América

A la Creación denominada:
"Moldo de formación de artículos de vidrio y método de fabricación"

Inventor(es):
David L. Lewis

Certificado No. 23647

Clasificación Internacional: B23D 17/22
de Patentes

2 Reivindicaciones
Vigente Desde: 11/06/2002
Hasta: 11/06/2022

Prioridad No. US 09/879,495 12/06/2001

Que la solicitud de Patente de Invención No. 2 49640 cumple con los requisitos previstos en las disposiciones legales vigentes, Resolución No. 4307 de 26/02/2007, en testimonio de ello se otorga la firma del funcionario competente y el sello de esta Entidad.

Superintendente de Industria y Comercio



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11) EP 1 084 994 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.03.2001 Bulletin 2001/12

(51) Int. Cl.⁷: C03B 9/38

(21) Application number: 00118551.1

(22) Date of filing: 28.08.2000

(84) Designated Contracting States: AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE Designated Extension States: AL LT LV MK RO SI (30) Priority: 20.08.1999 US 400123 (71) Applicant: OWENS-BROCKWAY GLASS CONTAINER INC. Toledo, Ohio 43086 (US)	(72) Inventors: • Lewis, David L. Sylvania, OH 43560 (US) • Hambley, David L. Sylvania, OH 43560 (US) (74) Representative: Zwirner, Gottfried, Dipl.-Ing. Dipl.-W.-Ing. Blumbach, Kramer & Partner Patentanwälte Alexandrastrasse 5 65187 Wiesbaden (DE)
--	--

(54) Liquid cooling of glassware molds

(57) A glassware forming mold that includes a body (30 or 32) of heat conductive construction having a central portion with a forming surface (32 or 32a) for shaping molten glass and a peripheral portion spaced radially outwardly of the central portion. A plurality of coolant passages (34a to 34h, 54 to 70) extend in a spaced array through the peripheral portion of the mold body, and liquid coolant is directed through such passages for extracting heat from the body by conduction from the forming surface. A plurality of openings (36a to 36q) extend axially into the body radially between at least some of the liquid coolant passages and the forming surface for retarding heat transfer from the forming surface to liquid coolant in the passages.

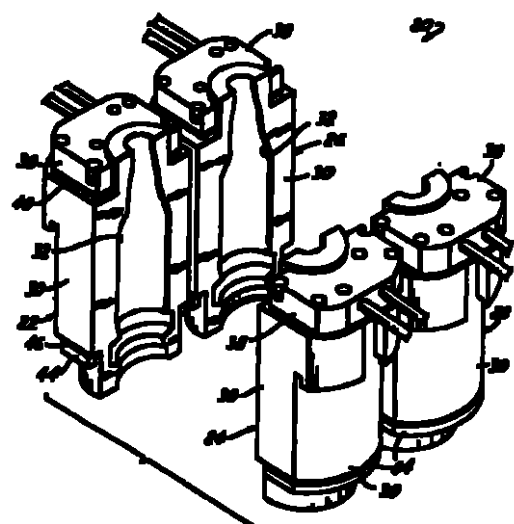


FIG.1

EP 1 084 994 A2

Description

[0001] The present invention is directed to cooling of molds in a glassware forming machine, and more particularly to liquid cooling of the blank molds and/or blow molds in an individual section machine.

Background and Objects of the Invention

[0002] The science of glass container manufacture is currently served by the so-called individual section or IS machine. Such machines include a plurality of separate or individual manufacturing sections, each of which has a multiplicity of operating mechanisms for converting one or more charges or gobbs of molten glass into hollow glass containers and transferring the containers through successive stations of the machine section. Each machine section includes one or more blank molds in which a glass gob is initially formed in a blowing or pressing operation, one or more invert arms for transferring the blanks to blow molds in which the containers are blown to final form, tongs for removing the formed containers onto a deadplate, and a sweepout mechanism for transferring molded containers from the deadplate onto a conveyor. U.S. Patent 4,382,544 includes a background discussion of both blow-and-blow and press-and-blow glassware forming processes, and discloses an electropneumatic individual section machine adapted for use in either process.

[0003] In the past, the blank and blow molds of a glassware forming machine have generally been cooled by directing air onto or through the mold parts. Such techniques increase the temperature and noise level in the surrounding environment. Furthermore, productivity is limited by the ability of the air to remove heat from the mold parts in a controlled process, and process stability and container quality are affected by the difficulty in controlling air temperature and flow rate. It has been proposed in U.S. Patents 3,887,350 and 4,142,884, for example, to direct a fluid, such as water, through passages in the mold sections to improve heat extraction. However, heat extraction by liquid cooling can be too rapid and uncontrolled, at least in some areas of the mold, so steps must be taken to retard heat transfer from the inner or forming surface of a mold section to the outer periphery in which the liquid cooling passages are disposed. Various techniques for so controlling liquid-cooling heat extraction have been proposed in the art, but have not been entirely satisfactory.

[0004] Mold material for manufacture of quality glassware must have the following characteristics: good wear properties, good thermal cycle resistance to cracking, good mechanical properties, good glass release properties, ease of machinability, ease of repair and economic feasibility. Ductile iron, which is defined as an iron in which free microstructural graphite is in the form of spherules, has been proposed for use as a mold material to manufacture glassware in which reduced thermal

conductivity (as compared to gray iron for example) is desired. Specific examples of glassware in which ductile iron is employed as the mold material are small containers that require a small amount of heat removal in the mold equipment, such as cosmetic and pharmaceutical bottles. However, ductile iron has not been employed in manufacture of larger glassware because of its reduced heat transfer and thermal cycle resistance capabilities. NI-Resist ductile iron has been proposed for glassware manufacture. The increased nickel content of NI-Resist ductile iron contributes to improved glass release properties. However, standard austenitic NI-Resist ductile iron does not exhibit desired thermal conductivity and resistance to thermal cyclic cracking.

[0005] It is therefore a general object of the present invention to provide a glassware forming mold, and a method of cooling such a mold, that improve temperature control stability at the mold forming surface. Another and more specific object of the present invention is to provide a mold and method of cooling in which mold surface temperature can be adjusted and dynamically controlled during the glassware forming operation. Yet another object of the present invention is to provide a mold and method of cooling in which more uniform temperature and temperature control are obtained both circumferentially and axially of the mold forming surface to tailor the overall heat transfer characteristics of the mold coolant system to achieve efficient glass forming. Yet another object of the present invention is to provide a mold cooling technique that is characterized by reduced corrosion in the cooling passages and improved operating life of the entire mold and cooling system. A further object of the invention is to provide a material for construction of a glassware mold, including either a blank mold or a blow mold, that exhibits the desirable mold properties listed above.

Summary of the Invention

[0006] A glassware forming mold in accordance with presently preferred embodiments of the invention includes at least one body of heat conductive construction having a central portion with a forming surface for shaping molten glass and a peripheral portion spaced radially outwardly of the central portion. At least one passage extends through the peripheral portion of the mold, and liquid coolant is directed through the passage for extracting heat from the body by conduction from the forming surface. At least one opening is provided in the mold body extending into the body and positioned radially between the coolant passage and the forming surface for retarding heat transfer from the surface to liquid coolant in the passage. The mold preferably comprises a split mold having a pair of mold bodies with identical arrays of passages and openings. The mold may be either a blank mold or a blow mold.

[0007] In the disclosed embodiments of the invention, the openings have a depth into the body, either part

way or entirely through the body, coordinated with contour of the forming surface and other manufacturing parameters to control heat transfer from the forming surface to the coolant passages. The openings may be wholly or partially filled with material for further tailoring heat transfer from the forming surface to the coolant passages. In a mold body having a plurality of coolant passages and a plurality of openings, the heat transfer properties of the openings may be tailored circumferentially around the mold body, such as by partially filling every other passage. Thus, the heat transfer characteristics of the mold body can be tailored both radially, axially and circumferentially of the mold to obtain desired heat transfer and forming surface temperature characteristics.

[0008] Endplates may be carried by the mold body for controlling flow of coolant in multiple passes through the coolant passages in the mold body. In the preferred embodiments of the invention, one of the endplates contains a fluid inlet and a fluid outlet, and channels for directing the fluid to the mold passages. The other endplate contains channels for routing fluid from the end of one coolant passage to the end of an adjacent passage. In the disclosed embodiments of the invention, liquid coolant makes four passes through the mold body before returning to the fluid sump. The number of passes through the mold body may vary upwardly and downwardly depending upon mold size, the amount of heat to be extracted, etc. It is also anticipated that the number of coolant passes for cooling a blank mold will be less than for a blow mold.

[0009] In accordance with yet another feature of the present invention, the liquid coolant comprises water, preferably mixed with a heat transfer fluid such as propylene glycol. Other heat transfer fluids include silicon-based heat transfer fluids, synthetic organic fluids, and inhibited glycol-based fluids. The coolant fluid control system preferably includes facility for detecting and controlling coolant composition (e.g., propylene glycol concentration), coolant temperature and coolant flow rate, and an electronic controller for controlling composition, temperature and/or flow rate to achieve optimum cooling and temperature control at the mold forming surfaces. In this way, mold surface temperature can be dynamically adjusted and controlled.

[0010] In accordance with a further feature of the present invention, which may be employed either separately from or more preferably in combination with other features of the invention, the mold body or bodies are constructed of austenitic Ni-Resist ductile iron. Such ductile iron is preferably a Type D Ni-Resist ductile iron in accordance with ASTM-A438-84, but modified to possess increased silicon and molybdenum content. Type D2-C Iron is currently employed. Silicon content is preferably in excess of 3.0%, and most preferably is 4.20% $\pm$ 0.20%. Molybdenum content is preferably in excess of 0.5%, and most preferably 0.70 $\pm$ 0.10%. (All composition percentages in this application are in weight per-

cent.) The increased silicon content decreases the thermal conductivity of the mold material. The increased molybdenum content improves thermal cycle resistance to cracking. The increased nickel content characteristic to Ni-Resist materials improves glass release properties. The austenitic Ni-Resist ductile iron mold composition in accordance with this aspect of the invention also yields desirable wear and other mechanical properties, ease of machinability and repair, and desirable economic feasibility. Austenitic ductile Ni-Resist material also provides a more stable microstructure than gray iron, for example, up to a temperature of 1400°F.

[0011] A method of cooling a mold for a glassware forming machine in accordance with yet another aspect of the present invention contemplates providing a mold body of heat conductive construction having a forming surface, at least one coolant passage extending axially through the body, and at least one opening that extends at least part way through the body. The opening is disposed radially between the coolant passages and the mold forming surface. Liquid coolant is circulated through the passages. Heat transfer from the forming surface to the coolant is controlled in part by controlling diameter and depth of the opening, and by optionally at least partially filling the opening to modify the heat transfer characteristics across the opening. In the preferred embodiments of the invention, at least one, and preferably all of composition, temperature and flow rate of the liquid coolant are controlled.

Brief Description of the Drawings

[0012] The invention, together with additional objects, features and advantages thereof, will be best understood from the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is a perspective schematic diagram of a pair of liquid-cooled split molds in accordance with one presently preferred embodiment of the invention;

FIG. 2 is an exploded perspective view of one of the split mold segments or parts in FIG. 1;

FIG. 3 is a sectional view of one of the split mold parts in FIG. 1;

FIG. 4 is a top plan view of the upper endplate in the mold part assembly of FIGS. 1-3;

FIG. 5 is a bottom plan view of the upper endplate illustrated in FIG. 4;

FIG. 6 is a top plan view of the lower endplate in the mold part assembly of FIGS. 1-3;

FIG. 7 is a bottom plan view of the lower endplate in FIG. 8;

FIGS. 8-12 are schematic diagrams similar to that of FIG. 3 but showing modified embodiments of the invention;

FIGS. 13-15 are schematic diagrams similar to that of FIG. 3 but showing other modified embodiments of the invention;

FIG. 16 is a schematic diagram similar to that of FIG. 3 but showing implementation of the invention in connection with a glassware blank mold, as distinguished from the blow molds illustrated in FIGS. 3 and 8-15;

FIG. 17 is a top plan view of the mold body in the embodiment of FIGS. 2 and 3;

FIGS. 18-20 are top plan views similar to that of FIG. 11 but showing respective modified embodiments; and

FIG. 21 is a functional block diagram of a fluid coolant control system in accordance with a presently preferred embodiment of the invention.

Detailed Description of Preferred Embodiments

[0013] FIG. 1 illustrates a mold system 20 as comprising a first pair of split mold parts 22, 24 and second pair of split mold parts 26, 28. The specific mold parts 22 - 28 illustrated comprises blow molds in a dual IS machine. However, the invention is equally useful in conjunction with the cooling of blank molds (FIG. 16), and in conjunction with other types of IS or rotary machines, such as single, triple and quad machines. Each mold part 22 - 28 comprises a mold body and opposed endplates. Mold part 22 will be discussed in detail in connection with FIGS. 2-7 and 17, it being understood that mold part 26 is identical to mold segment 22, and mold parts 24, 28 are the mirror image of mold part 22.

[0014] Mold part 22 includes a mold body 30 having a central portion with a forming surface 32 that, together with the corresponding surface of opposed mold part 24, forms the surface against which molten glass is shaped in a pressing or blowing operation. The molten glass thus makes contact with surface 32, transferring heat energy at surface 32 into body 30, which must be dissipated. Mold body 30 also includes a peripheral portion spaced radially outwardly from the central portion in which forming surface 32 is disposed. A plurality of passages extend axially in a circumferentially spaced parallel array through the peripheral portion of mold body 30. In the embodiment illustrated, there are eight such passages 34a - 34h, which are angularly spaced from each

other. The angular spacing between passages 34a - 34h may be approximately equal increments, but would normally be in unequal increments because of non-symmetries in the mold body. Each passage 34a - 34h in FIGS. 9 and 17 is of cylindrical contour and of uniform diameter throughout its length, being entirely open from the top mold body surface 30a to the bottom mold body surface 30b. Positioned radially inwardly of each passage 34a - 34h is a corresponding opening 36a - 36h. In the embodiment of FIGS. 1-3 and 11, openings 36a - 36h extend entirely axially through body 30 from surface 30a to surface 30b, and are respectively positioned radially inwardly of the corresponding passage 34a - 34h.

[0015] Mold body 30 is preferably constructed of austenitic Ni-Resist ductile iron in accordance with another aspect of the present invention. Ni-Resist ductile iron is a ductile iron that has a high nickel content, typically in excess of 18%, and more preferably in excess of 21%. A presently preferred composition is a Type D2-C ductile Ni-Resist composition generally in accordance with ASTM-A439-84, but modified to possess increased silicon and molybdenum contents. The following table illustrates chemical composition of this preferred material:

Table I

CHEMICAL COMPOSITION			
		Target	Range
Carbon	(%)	2.80	± 0.20
Silicon	(%)	4.20	± 0.20
Manganese	(%)	2.10	± 0.30
Magnesium	(%)	0.050	± 0.010
Nickel	(%)	22.50	± 1.50
Sulphur	(%)	0.010	± 0.008
Chromium	(%)	0.00	+ 0.50
Phosphorus	(%)	0.00	+ 0.08
Molybdenum	(%)	0.70	± 0.10
Iron		(Balance)	

This material has low thermal conductivity, good corrosion resistance, good machinability and economy, and good glass release properties at the mold surface. The increased silicon content decreases thermal conductivity, while the increased molybdenum content resists thermal cyclic cracking.

[0016] Surfaces 30a, 30b are parallel to each other, being formed by associated parallel ledges on mold body 30. An upper endplate 36 and an intervening gasket 40 are carried on surface 30a, being secured to mold body 30 by a plurality of screws 42 and spring washers 43. A lower endplate 44 and an intervening

gasket 48 are secured to surface 30b by a corresponding plurality of screws 48 and spring washers 48. (The screw holes are not illustrated in FIG. 11 to highlight the relationship between passages 34a - 34h and openings 38a - 38h.) Upper endplate 38 (FIGS. 3-5) is arcuate, and has a radially opening inlet port 50 and a radially opening outlet port 52. Inlet port 50 opens to a triangular-shaped cavity 54 on the underside of plate 38. There are an angularly spaced pair of arcuate or chordal channels 58, 58 on the underside of plate 38, and a second pair of channels 60, 62 are formed on the underside of plate 38 in communication with outlet port 52. The angularly spaced ends of channels 62 and 58, pocket 54 and channels 58, 60 overlap the angularly spaced ends of coolant passages 34a - 34h in assembly to the mold body, as illustrated in FIG. 4. Lower endplate 44 (FIGS. 3 and 6-7) is likewise of arcuate contour, having an upper face in abutment through gasket 48 with surface 30b of the mold body. Four arcuate or chordal channels 64, 66, 68, 70 are formed on the upper face of lower endplate 44. In assembly, the angularly spaced ends of these channels underlie the angularly spaced ends of mold coolant passages 34a - 34h, as best seen in FIG. 7. It will be noted in FIGS. 4 and 7 that the channels in the endplates are wider than the passages in the mold body. This accommodates slight misalignment due to tolerance variation or differential thermal expansion.

[0017] In use, inlet port 50 of upper endplate 38 is connected to a source of liquid coolant under pressure, and outlet port 52 is connected to a coolant return line. Coolant is thus routed from inlet port 50 and inlet pocket 54 downwardly (in the orientation of FIG. 3) through passages 34d and 34e to lower endplate 44, thence by endplate 44 upwardly through passages 34c and 34f, thence by endplate 38 downwardly through passages 34b and 34g, and thence by endplate 44 upwardly through passages 34a, 34h and endplate channels 60, 62 to outlet port 52. The cooling liquid thus makes a total of four passes through the mold body before return to the sump. The number of passes may be tailored in accordance with the principles of the invention to achieve the desired thermal gradient across the mold/coolant interface using suitable conventional computer modeling techniques. Openings 38a - 38h retard heat transfer from forming surface 32 to coolant passages 34a - 34h and thus control the overall heat transfer rate from the glass to the coolant. In the embodiment of the invention illustrated in FIGS. 3 and 11, passages 38a - 38h extended entirely through the mold body at uniform diameter and substantially equal angular spacing. The upper and lower ends of the several passages 38a - 38h are blocked by gaskets 40, 48, as best seen in FIG. 3. Openings 38a - 38h thus form closed air pockets with lower heat transfer properties than the metal of the mold, and thus serve partially to retard and control heat transfer to the coolant passages by interrupting the heat transfer path. (Openings 38a, 38h are illustrated as being of lesser diameter in FIG. 11 because of the need

to accommodate endplate mounting holes, as best seen in FIGS. 4-7.)

[0018] The number and position of openings 38a - 38h are selected in accordance with desired heat transfer characteristics. For example, FIG. 18 illustrates a modification in which openings 38b, 38g are replaced by several smaller openings disposed between coolant passages 34b, 34g and forming surface 32. FIG. 19 illustrates the use of supplemental openings 34i - 34o between coolant passages 34a - 34h and forming surface 32 further to restrict heat transfer from the forming surface to the coolant passages. Thus, while in general openings 34a - 34h (and 34i - 34o) are disposed radially between the coolant passages and the mold forming surface, precise positioning and size of these openings, as well as a number of openings, are tailored to specific applications for obtaining desired heat transfer characteristics.

[0019] Openings 38a - 38h (and 38i - 38o) are illustrated as being of uniform diameter throughout their lengths, which facilitates manufacture. In accordance with another feature of the invention illustrated in FIGS. 8-12, these openings may have different heat transfer characteristics along their axial lengths through the mold for further heat transfer control. For example, FIG. 8 illustrates a modification to the embodiment of FIG. 3, in which opening 38d is partially filled with a material 70 of heat transfer characteristics that are different from those of air. For example, material 70 may comprise sand, which effectively forms a filler or plug within opening 38d. This plug of material 70 is illustrated as being positioned about mid-way along the length of the body portion of the container forming surface 32, and thus would conduct greater heat to coolant passage 34d from the mid portion of the container forming surface than would be the case from the upper and lower portions of the container forming surface. Corresponding fillers or plugs 70 may be positioned in the other openings 38a - 38c and 38e - 38h, or may be positioned in alternate openings, for example. FIG. 9 illustrates a modification in which opening 38d contains a first material plug 72 adjacent to the mid portion of the container forming surface, and a second plug 74 adjacent to the lower portion of the container forming surface at the container heel. Thus, the rate of heat transfer from the lower and mid portions of the container forming surface would be different from the rate of heat transfer at the upper portion of the container forming surface, and would be different from each other, in the modification of FIG. 9. FIGS. 10 and 20 illustrate a modification in which openings 38a - 38h extend only part way through the axial length of the mold body. In this modification, heat would be extracted more rapidly from the container neck area than from the container shoulder and body areas of the mold forming surface. The modification of FIGS. 10 and 20 may be employed to provide room for endplate mounting holes without substantially affecting operation. It is generally preferred that heat transfer

characteristics be circumferentially uniform.

[0020] As noted above, all of the embodiments thus far discussed possess openings 38a, etc. of cylindrical contour and uniform diameter. However, other passage geometries are contemplated. For example, FIG. 11 illustrates a mold body 30 in which opening 38p is formed by differential drilling, having end portions of greater diameter and a central portion of lesser diameter. The portion of lesser diameter may extend for a greater length than is illustrated in FIG. 11, and indeed may extend to either the upper or lower surface 30a, 30b. Thus, the embodiment of FIG. 11 achieves greater heat conductivity in the central portion of the mold, as does the embodiment of FIG. 8 for example, but without the use of additional materials. FIG. 12 illustrates another modification, in which the opening 38q is internally threaded and receives an externally threaded plug 75. Once again, plug 75 may be of any desired length, and may be variably positioned within opening 38q. The embodiment of FIG. 12 has the advantage of being adjustable on the manufacturing floor.

[0021] In short, the principles of the present invention provide opportunity for tailoring the heat transfer characteristics of a mold to accommodate any desirable operating conditions or situations. The heat-blocking openings may be positioned between the mold surface and each coolant passage, or between the mold surface and some coolant passages. Heat transfer characteristics of the blocking openings may be tailored both axially and circumferentially of the mold body to achieve any desired differential cooling properties. FIGS. 13-15 illustrate embodiments of the invention in which coolant is introduced and withdrawn at various locations. In FIG. 13, coolant is introduced and withdrawn from the radial direction at the upper end of the mold body, as in FIGS. 1-3. In FIG. 14, coolant is introduced and withdrawn from the radial direction at the lower end of the mold body, while in FIG. 15 the coolant is introduced and withdrawn from the axial direction at the lower end of the mold body. It will be appreciated of course, that coolant may be introduced, for example, at the upper end of the mold body and withdrawn from the lower end of the mold body in accordance with the principles of the invention. FIG. 16 illustrates application of the present invention in conjunction with a glassware blank mold 92. The principles remain the same as in the above discussions relative to blow molds, although less heat is normally extracted from a blank mold due to the desire to maintain elevated temperature at the glass blank, and consequently fewer coolant passages and heat-blocking openings would normally be provided in conjunction with a blank mold.

[0022] FIG. 15 illustrates two additional modifications in accordance with the invention. A pair of plugs 92, 94 close the respective ends of opening 38d in mold body 30. When employing mold bodies which are sufficiently porous that coolant can flow from passage 34d to opening 38d, plugs 92, 94 prevent contact of coolant

vapor with gaskets 40, 46. A pair of flow adjustment needles 96 (only one is illustrated) are threadably mounted on plate 38. Each adjustment needle has a needle point that enters a fluid passage channel in plate 38. Needles 96 thus provide for adjustment of resistance to fluid flow at each mold part.

[0023] FIG. 21 illustrates a coolant circulation system 80 in accordance with one presently preferred implementation of the invention. Coolant in the presently preferred implementation of the invention comprises a mixture of propylene glycol and water. This mixture helps prevent corrosion, reduces heat transfer from the mold bodies, lubricates the pump, and helps reduce two-phase boiling in the mold coolant passages. Other coolants and blends of coolants may be used as dictated by environmental and other factors. The relative percentages of propylene glycol and water are controlled by a coolant composition control unit 82 under control of an electronic controller 84. Likewise, there is a coolant temperature control unit 86 for sensing coolant temperature, and for heating or cooling the coolant as required under control of controller 84. A coolant flow rate control unit 88 includes a variable output pump and suitable means for measuring coolant flow rate (and pressure if desired). Coolant may be fed from unit 88 to all mold segments connected in parallel, or may be fed through individually controllable valves 90 to the individual mold segments. Valves 90 are controlled by electronic controller 84. Thus, controller 84 receives indication of coolant composition from unit 82, coolant temperature from unit 86 and coolant flow rate (and pressure) from unit 88, and provides corresponding control signals to the composition, temperature and flow rate controllers. Controller 84 also provides suitable signals to the individual valves 90, which gives facility for controlling coolant flow to the molds individually. In any given application, one or more of the control units 82, 86, 88 and 90 may be deleted if desired.

[0024] There have thus been disclosed a mold, and a method for cooling a mold, for use in a glassware forming system, that fully satisfy all of the objects and aims previously set forth. Specifically, openings are provided in the mold body at a number, position, depth and contour to control heat transfer between the mold surface and the coolant. This feature allows molds to be designed for specific temperature control and heat transfer characteristics. Further, control of coolant composition, temperature and/or flow rate provides dynamic control of mold surface temperature. Mold corrosion is reduced and operating life is extended. Several modifications and variations have been disclosed. Although the invention has been disclosed as being particularly useful in conjunction with individual section machines, the invention may be readily employed in conjunction with other types of glassware forming machines, such as rotary machines. Other modifications and variations will suggest themselves to persons of ordinary skill in the art. The invention is intended to embrace all such

modifications and variations as fall within the spirit and a broad scope of the appended claims.

Claims

1. A glassware forming mold that comprises:

at least one body (30 or 82) of heat conductive construction having a central portion with a forming surface (32 or 32a) for shaping molten glass and a peripheral portion spaced radially outwardly of said central portion,

at least one coolant passage (34a to 34h, 54 to 70) that extends through said peripheral portion,

means (38, 44, 80) for directing liquid coolant through said coolant passage for extracting heat from said body by conduction from said forming surface, and

at least one opening (38a to 38q) in said body that extends into said body and is positioned radially between said coolant passage and said forming surface for retarding heat transfer from said surface to liquid coolant in said passage.

2. The mold set forth in claim 1 wherein said at least one opening (38a to 38q) has a depth into said body coordinated with contour of said forming surface (32 or 32a) to control heat transfer from said forming surface to coolant in said coolant passage (34a to 34h, 54 to 70).

3. The mold set forth in claim 1 or 2 wherein said at least one opening (38a to 38q) is a blind opening (FIG. 10) that extends part way into said body (30 or 82).

4. The mold set forth in claim 3 wherein said forming surface (32 or 32a) has a first portion for forming a container body and a second portion for forming a container neck, and wherein said at least one opening (38a to 38q) has a depth disposed between said container body-forming portion of said forming surface and said coolant passages.

5. The mold set forth in claim 1 or 2 wherein said at least one opening (38a to 38q) extends axially through said body (30 or 82).

6. The mold set forth in claim 1 or 2 further comprising means (72 to 75) at least partially filling at least some of said at least one opening (38a to 38q) so as to vary heat transfer radially through said opening.

7. The mold set forth in claim 6 wherein said means (72 to 75) fills a mid portion of said at least one opening.

8. The mold set forth in claim 6 or 7 wherein said opening (38q) is internally threaded, and wherein said means (75) comprises an externally threaded plug in said opening.

9. The mold set forth in claim 1 or 2 wherein said opening (38a to 38q) has a uniform cross section throughout its length.

10. The mold set forth in claim 9 wherein said openings (38a to 38q) are of uniform cylindrical diameter and entirely open throughout their lengths.

11. The mold set forth in claim 1 or 2 wherein said opening (38p) has a cross section that varies along its length.

12. The mold set forth in claim 1 or 2 comprising a plurality of said coolant passages (34a to 34h, 54 to 70) extending in a spaced array through said peripheral portion.

13. The mold set forth in claim 12 wherein said body (30 or 82) has first and second end surfaces (30a, 30b) at which said coolant passages open, and wherein said means (38, 44, 80) for directing liquid coolant comprises a first endplate on said first end surface and a second endplate on said second end surface, said endplates having means in alignment with said passage (34a to 34h) for directing cooling fluid through said coolant passages.

14. The mold set forth in claim 13 wherein said first endplate (38 or 44) comprises fluid inlet means for directing fluid into an end of one coolant passage and fluid outlet means for receiving fluid from an end of another of said coolant passages.

15. The mold set forth in claim 13 further comprising means (88) on one of said endplates for adjustably varying cross section of said fluid directing means to fluid flow.

16. The mold set forth in any preceding claim comprising a split mold having a pair of said bodies (30 or 82) with identical arrays of coolant passages and openings.

17. The mold set forth in claim 16 wherein said mold comprises a blow mold.

18. The mold set forth in claim 16 wherein said mold comprises a blank mold.

19. The mold set forth in any preceding claim wherein said body (30 or 82) is of ductile iron.

20. The mold set forth in claim 19 wherein said ductile iron is an austenitic Ni-Resist ductile iron having a silicon content in excess of 3.0% and a molybdenum content in excess of 0.5%.

21. The mold set forth in claim 20 wherein said silicon content is $4.20 \pm 0.20\%$, and said molybdenum content is $0.70 \pm 0.10\%$.

22. The mold set forth in any preceding claim wherein said means for directing coolant comprises means (80) for controlling at least one of the variables temperature, flow rate and composition of said coolant.

23. A mold for a glassware forming machine that comprises at least one body (30 or 82) having a central portion with a forming surface (32 or 32a) for shaping molten glass, and a peripheral portion spaced radially outwardly from said central portion, said body being of austenitic Ni-Resist ductile iron having a silicon content in excess of 3.0% and a molybdenum content in excess of 0.5%.

24. The mold set forth in claim 23 wherein said silicon content is $4.20 \pm 0.20\%$, and said molybdenum content is $0.70 \pm 0.10\%$.

25. The mold set forth in claim 23 or 24 wherein said mold comprises a blow mold.

26. The mold set forth in claim 23 or 24 wherein said mold comprises a blank mold.

27. A method of cooling a mold for a glassware forming machine, which comprises the steps of:

- (a) providing a mold body (30 or 82) of heat conductive construction having a forming surface (32 or 32a), at least one coolant passage (34a to 34h, 58 to 70) extending through said body, and at least one opening (38a to 38q) that extend at least part way through said body, said opening being disposed radially between said passage and said forming surface, and
- (b) circulating liquid coolant through said passage (34a to 34h, 58 to 70).

28. The method set forth in claim 27 wherein said step (a) includes the step of controlling heat transfer from said surface to said coolant in said step (b) by selecting diameter and depth of said opening (38a to 38q) in said step (a).

29. The method set forth in claim 28 wherein said step (a) includes the step of at least partially filling said

at least one opening (38a to 38q) so as to vary heat transfer radially of said body as a function of axial position in said body.

30. The method set forth in claim 29 wherein said step of at least partially filling said opening comprises the steps of internally threading said opening (38q) and threading an externally threaded plug (75) into said opening.

31. The method set forth in any one of claims 27-30 wherein said step (b) includes the step of controlling at least one of composition, temperature and flow rate of said liquid coolant.

32. The method set forth in any one of claims 27-31 wherein said step (a) comprises the step of adjustably varying cross section of said passages (34a to 34h, 58 to 70) to fluid flow.

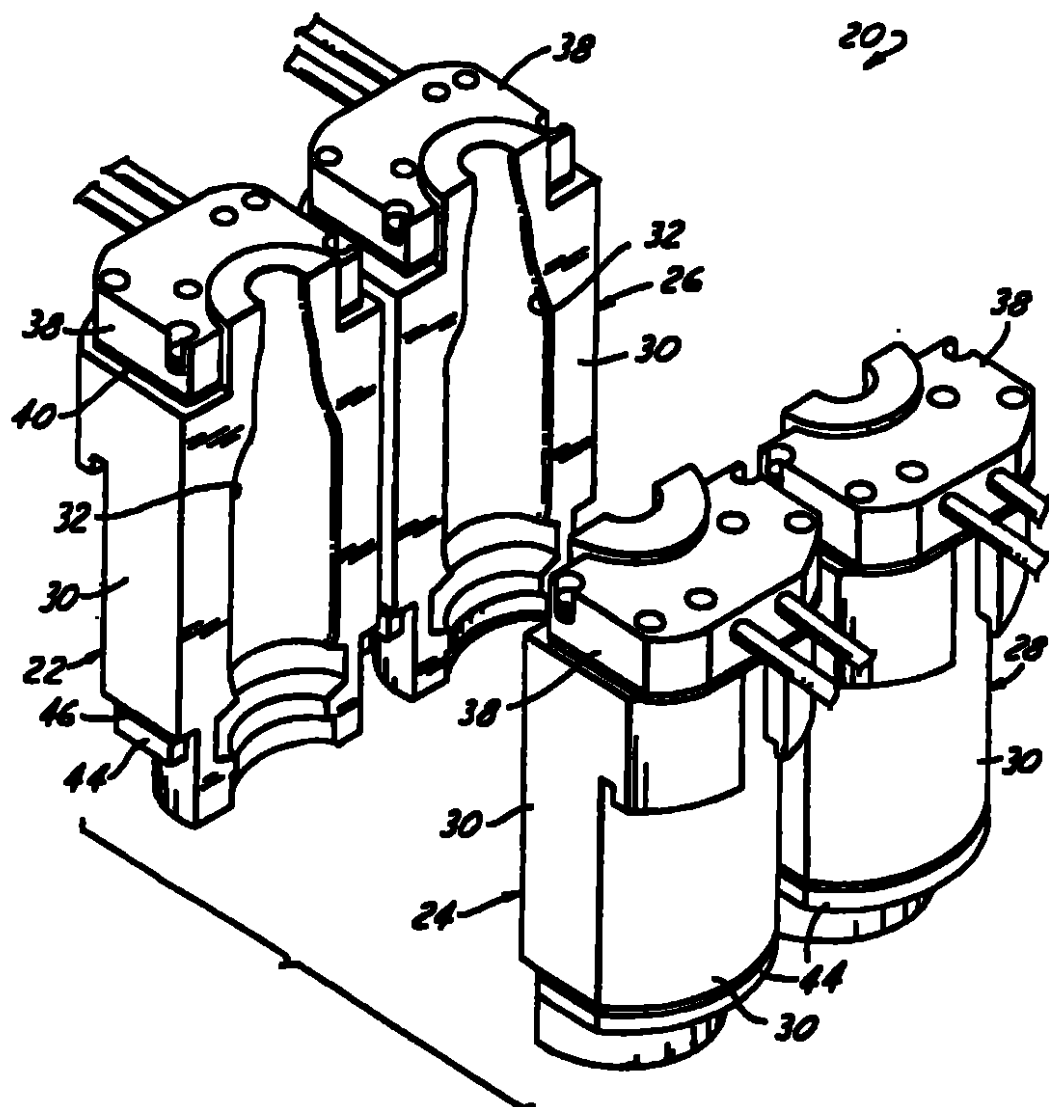


FIG.1

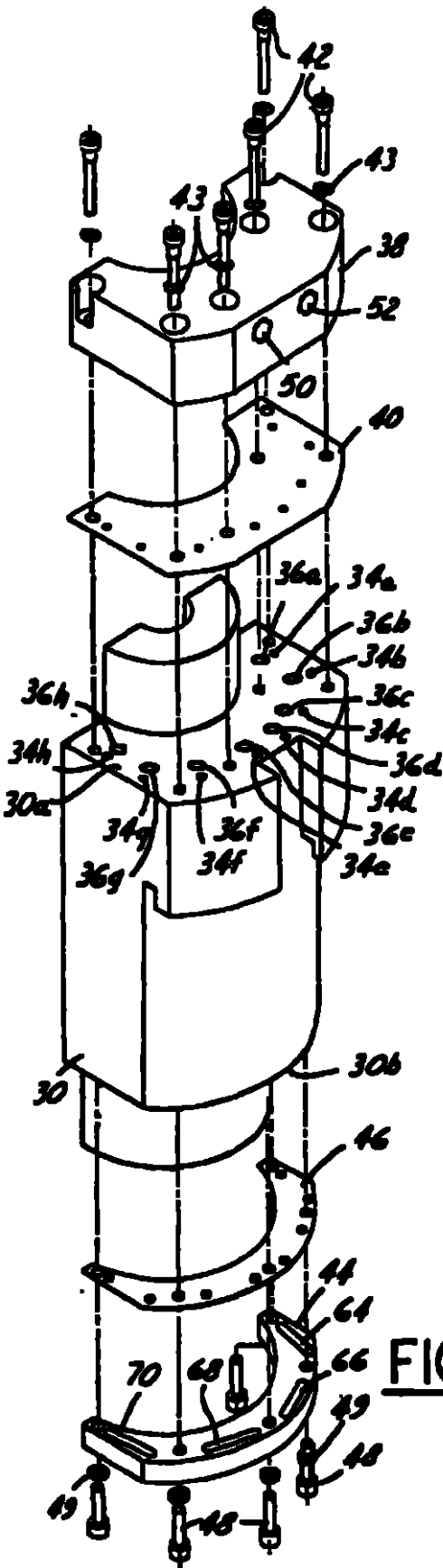


FIG. 2

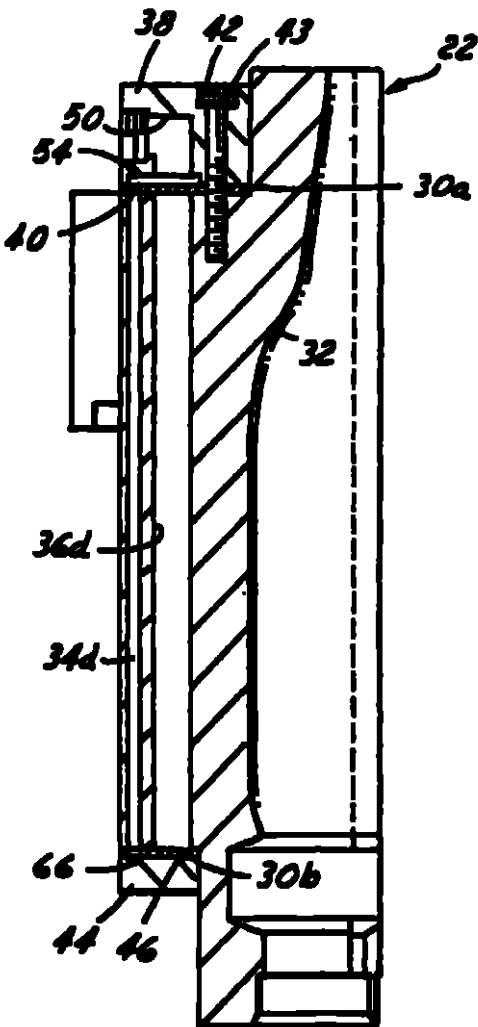


FIG. 3

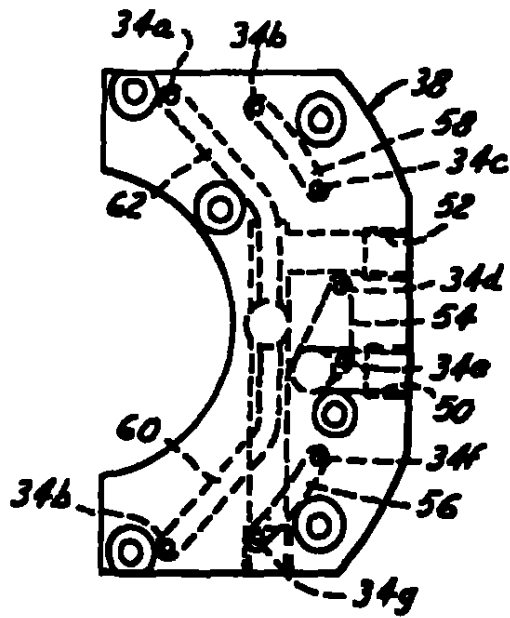


FIG. 4

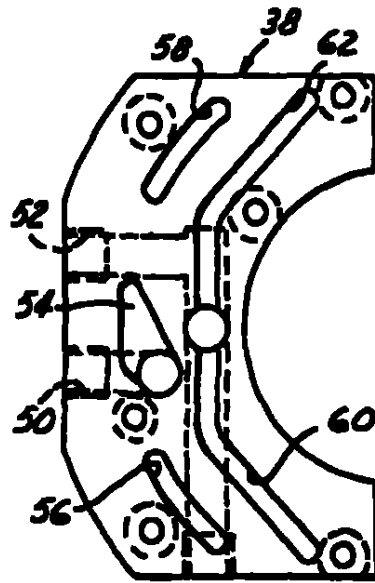


FIG. 5

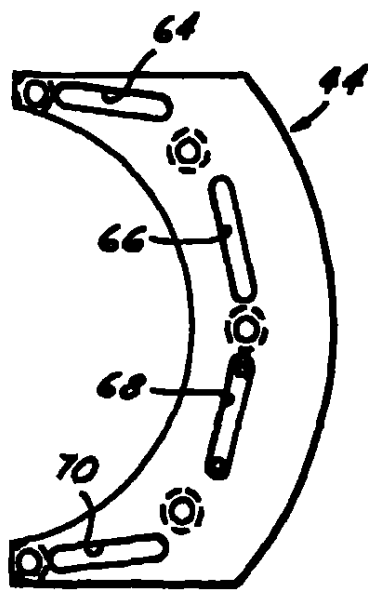


FIG. 6

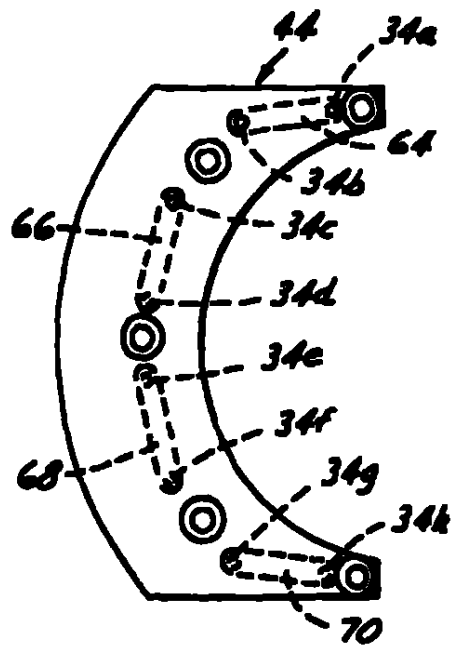


FIG. 7

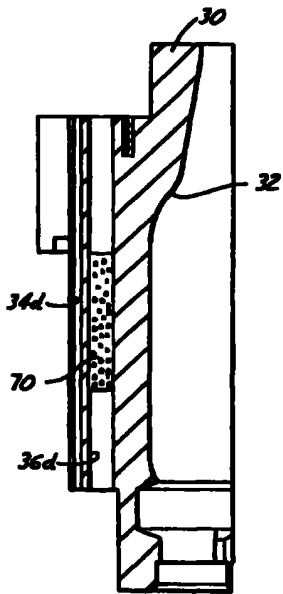


FIG. 8

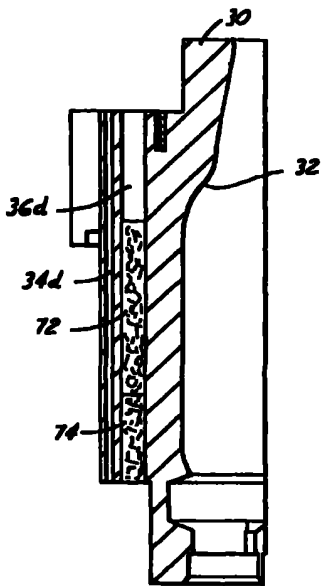


FIG 9

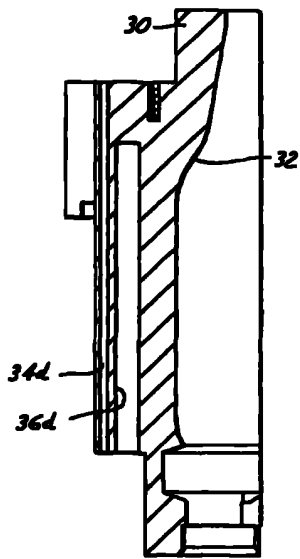


FIG 10

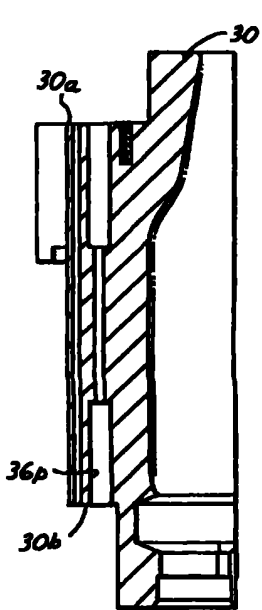


FIG. 11

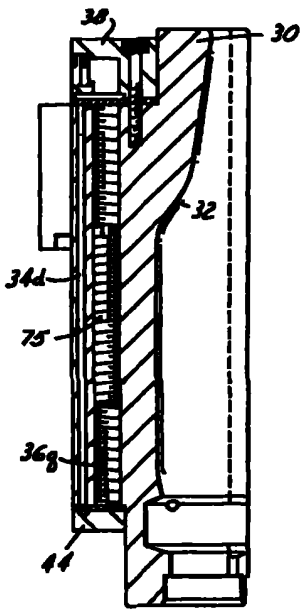


FIG. 12

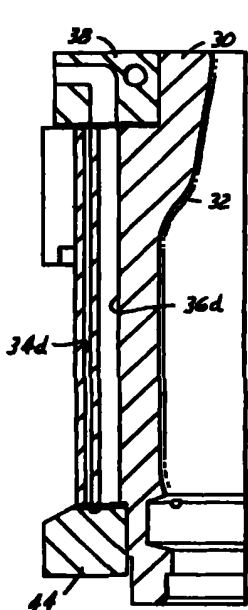


FIG. 13

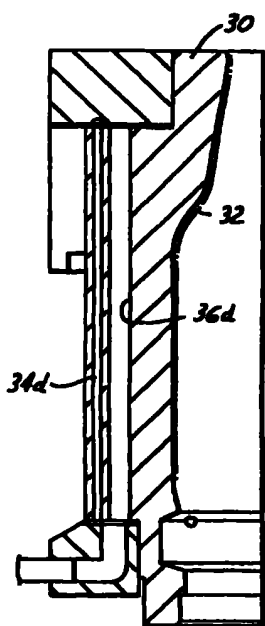


FIG. 14

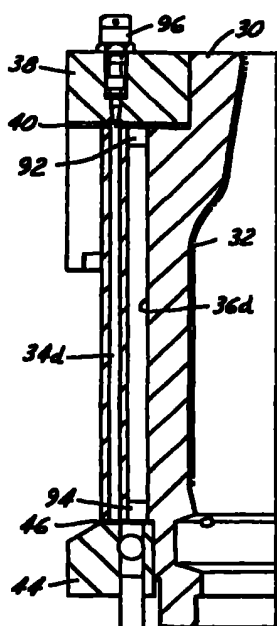


FIG. 15

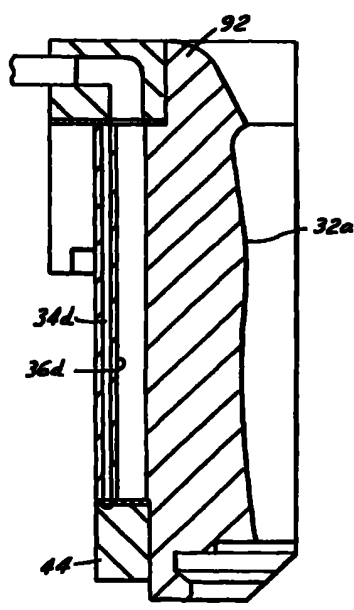


FIG. 16

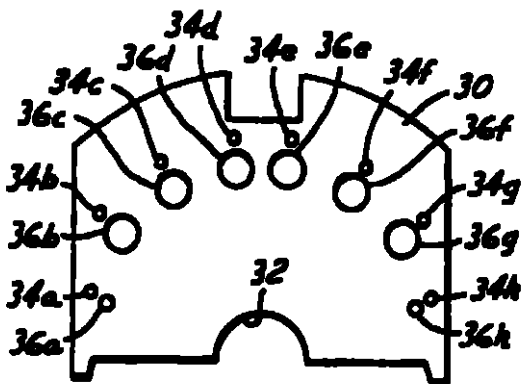


FIG. 17

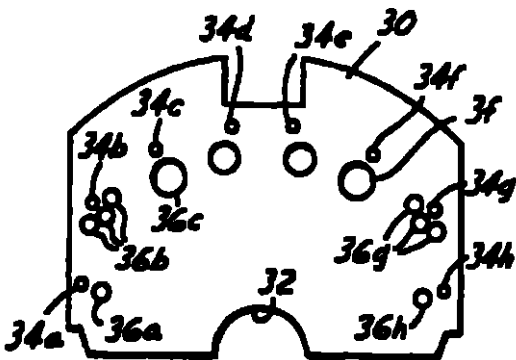


FIG. 18

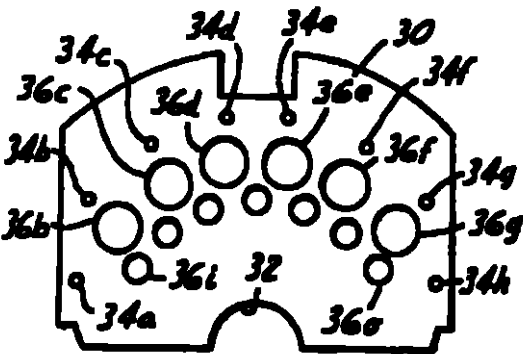


FIG. 19

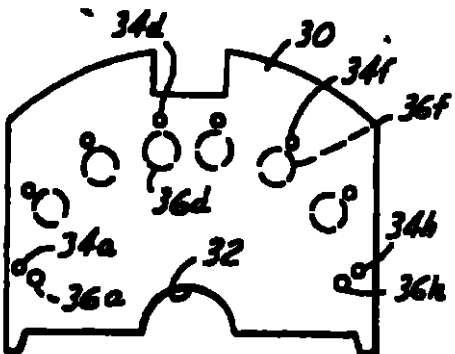


FIG. 20

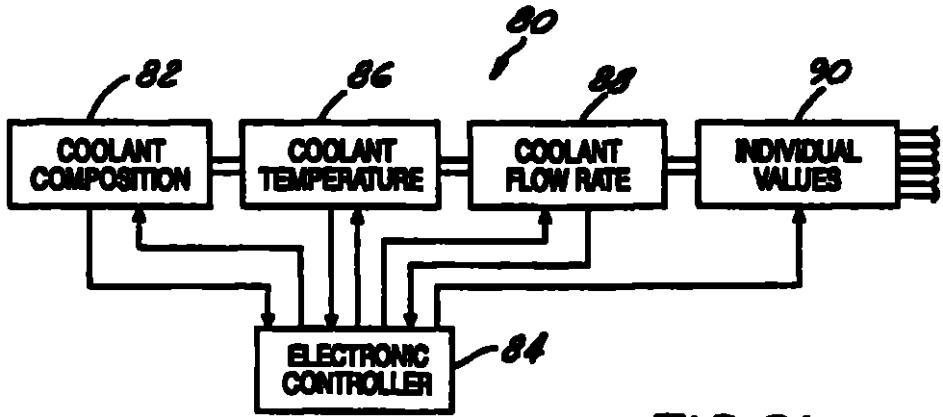


FIG. 21

Jan. 14, 1969 R. D. SCHELLING 3,421,886
CAST IRON WITH AT LEAST 50% OF THE GRAPHITE IN
VERMICULAR FORM AND A PROCESS FOR MAKING SAME
Filed March 15, 1968 Sheet 1 of 3

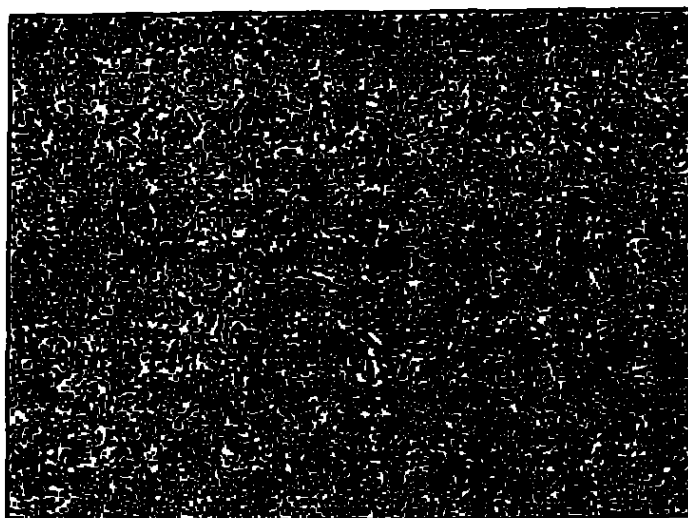


FIG. 1

INVENTOR
ROBERT DOUGLAS SCHELLING
M. L. Pines
ATTORNEY

Jan. 14, 1969

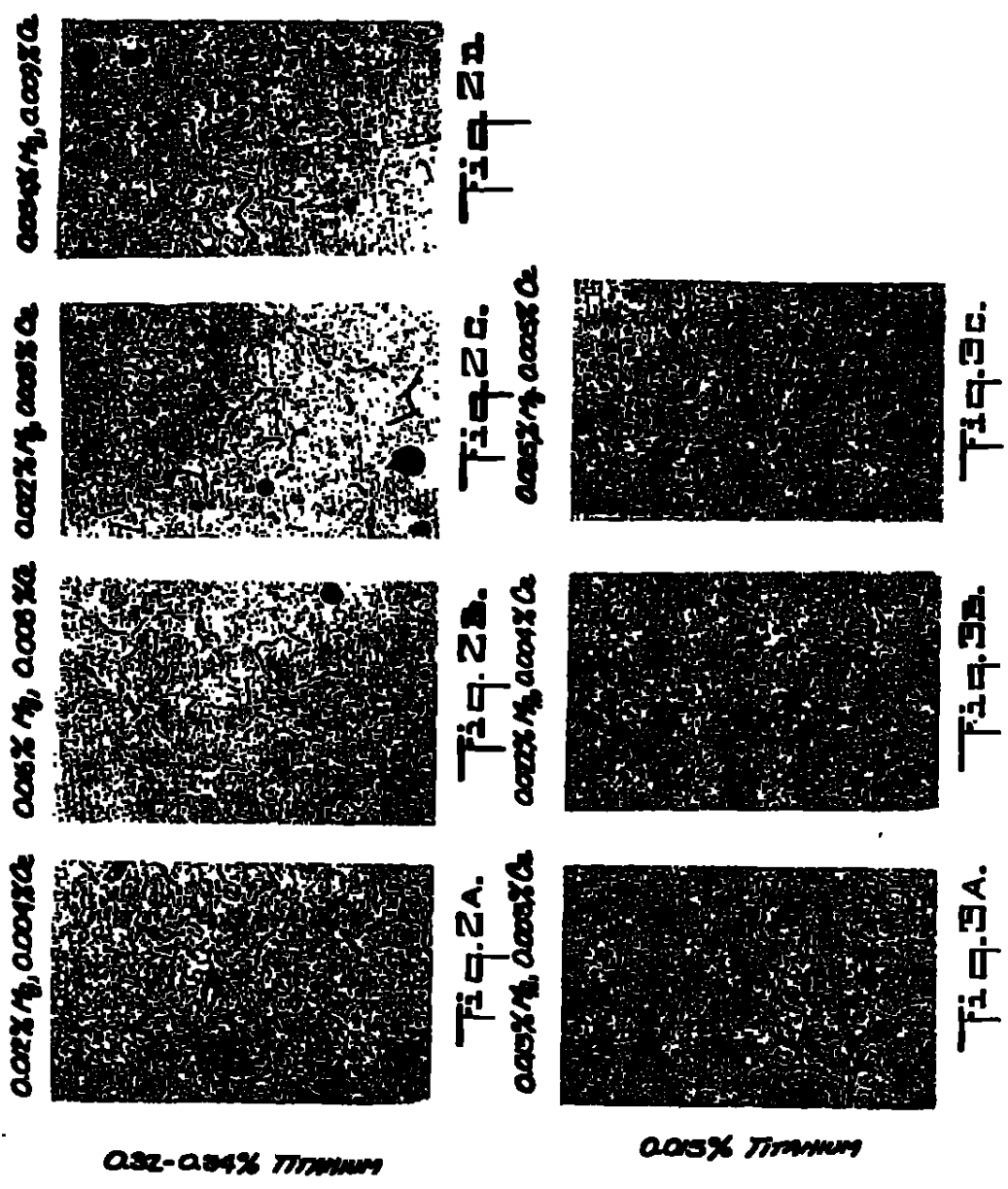
R. D. SCHELLENG

3,421,886

CAST IRON WITH AT LEAST 50% OF THE GRAPHITE IN
VERMICULAR FORM AND A PROCESS FOR MAKING SAME

Filed March 13, 1968

Sheet 2 of 3



INVENTOR
ROBERT DOUGLAS SCHELLENG
M. L. Pinal
ATTORNEY

(1)

Jan. 14, 1969

R. D. SCHELLENG

3,421,886

CAST IRON WITH AT LEAST 80% OF THE GRAPHITE IN
VERMICULAR FORM AND A PROCESS FOR MAKING SAME

Filed March 15, 1968

Sheet 3 of 5

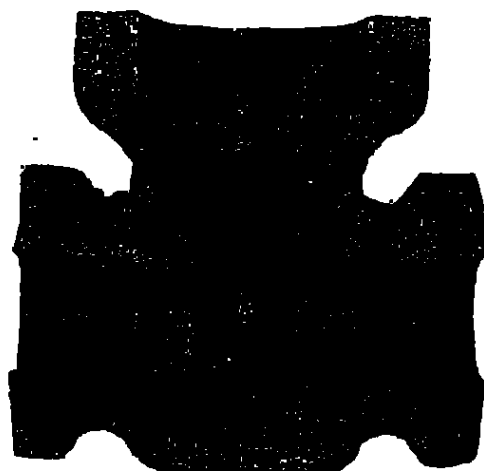


FIG. 4

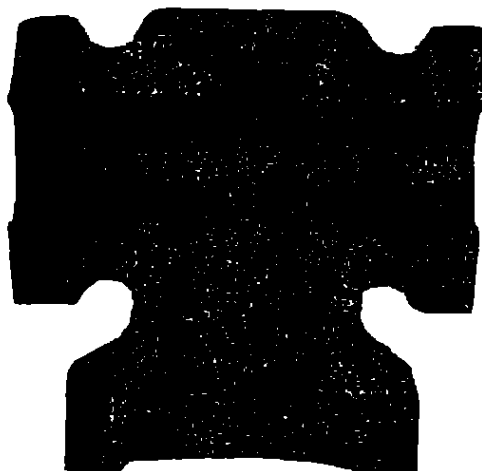


FIG. 5

INVENTOR
ROBERT DOUGLAS SCHELLENG

M. d. Pines
ATTORNEY

1

3,421,886

CAST IRON WITH AT LEAST 50% OF THE GRAPHITE IN VERMICULAR FORM AND A PROCESS FOR MAKING SAME

Robert Douglas Scheffing, Ramapo, N.Y., assignor to The International Nickel Company, Inc., New York, N.Y., a corporation of Delaware

Continuation-in-part of application Ser. No. 453,223, May 4, 1965. This application Mar. 13, 1968, Ser. No. 713,280

U.S. Cl. 75-123
Int. Cl. C21c 1/00

7 Claims

ABSTRACT OF THE DISCLOSURE

A graphitic cast iron consisting essentially of about 2% to about 4% carbon, about 1.5% to about 3.5% silicon, up to about 36% nickel, about 0.005% to about 0.06% magnesium, about 0.001% to about 0.015% of a metal from Group III-B of the periodic table, about 0.15% to about 0.5% titanium, with said magnesium, Group III-B metal and titanium contents being effective to control the occurrence of graphite in said cast iron predominantly in the vermicular form and the balance of said cast iron being essentially iron with other elements and impurities in small amounts which do not materially interfere with the occurrence of graphite in said vermicular form. A process for making said cast iron is also claimed.

The present application is a continuation-in-part of my copending U.S. application Ser. No. 453,223 filed May 4, 1965, now abandoned.

The present invention is directed to improved graphitic cast iron and, more particularly, to an improved stronger cast iron having a controlled vermicular graphite structure and having essentially the foundry characteristics of flake graphite cast iron.

Since the advent of ductile iron, i.e., cast iron containing graphite in a spheroidal form, as described in U.S. Patent No. 2,485,760, the foundry industry has undergone a revolution in regard to the ability of the industry to provide castings having very high strength and useful levels of ductility as compared to gray cast iron containing graphite in the flake form. Ductile iron is now well established as a foundry product and the use of this material in the form of castings in industry is expanding each year. The increased tonnage of ductile iron which is sold each year may properly be taken as an indication of the acceptance which castings made of the material have secured in industry. As is well known, however, ductile iron exhibits inferior foundry characteristics as compared with gray cast iron, and for that reason has not found favor in those applications where good foundry characteristics are of paramount importance. The expression "good foundry characteristics" is used in the industry to include such factors as fluidity, improved resistance to the formation of shrinkage cavities in sections which are difficult to feed, freedom from dross defects, low chilling tendency, etc. It is considered in the foundry industry that flake graphite gray cast iron has good foundry characteristics. With particular reference to the problem of shrinkage in castings, it is unquestionable that the shrink properties of gray cast iron castings are more favorable than is the case in

2

the higher strength ductile iron castings. As used in this application, the expression "gray cast iron" is used to denote cast iron having its uncombined carbon in the form of ordinary, unmodified flakes. A demand accordingly exists for a cast iron having greater strength and ductility than gray cast iron, but also having better foundry characteristics than ductile iron. For example, the automotive engine block has traditionally been produced as a gray iron casting. In recent times, foundries producing engine block castings have been required to produce lighter and lighter castings having thinner and thinner wall sections in response to demands of automotive designers for lighter engines having higher power-to-weight ratios and in response to a powerful competitive thrust from die cast aluminum engine blocks. In order to supply the demand for such castings, it would be desirable to employ ductile iron therein so that the markedly higher strength and modulus of elasticity of this material as compared to gray iron could be used with advantage. However, the foundry characteristics of ductile iron are such that it is difficult to produce sound and leak-proof thin-walled castings of complicated configuration in the material on a production basis. The high strength of ductile iron as compared to gray iron would also appear to be useful in other castings such as lightweight brake drums and ingot molds. However, it has been found from experience that the thermal conductivity of ductile iron is lower than that of gray iron and this undesirable characteristic has inhibited the adoption of ductile iron in such applications and in other applications requiring high thermal conductivity and resistance to thermal shock.

A cast iron material having its uncombined carbon in the vermicular form is capable of satisfying this demand. On the one hand, because its graphite is in vermicular rather than flake form such a material possesses substantially greater strength and ductility than gray cast iron of the same composition, and, on the other hand, because the form of its graphite is more nearly flake-like than nodular such a material possesses substantially better foundry characteristics than ductile iron. The term "vermicular graphite" is used in this application to denote the type of graphite identified by that name and depicted in the paper by Donoho published in *Modern Castings* for July, 1961 at pages 65-71, inclusive.

Vermicular graphite structures have sporadically and on rare occasions been observed in connection with unsuccessful attempts to produce ductile iron in which insufficient or incorrect nodularizing treatments were employed. Such structures have, however, been of unpredictable occurrence and unknown cause. Being thus uncontrollable and unreproducible, vermicular structures have not heretofore been regarded by the foundry industry as being of any practical utility. The vermicular graphite form has, rather, been looked upon as a manifestation of failure in the production of ductile iron.

I have now discovered a new cast iron composition and a method for producing the same, which material has a controlled vermicular graphite structure and is characterized by strength properties intermediate between gray cast iron and ductile iron of essentially the same base composition and which is further characterized by improved foundry characteristics, improved thermal conductivity, and improved thermal shock resistance as compared to ductile iron.

3

It is an object of the present invention to provide gray iron castings containing vermicular graphite.

It is a further object of the invention to provide castings having a gray iron composition which are characterized by vermicular graphite and by a strength intermediate between gray cast iron and ductile iron having essentially the same base composition.

Still another object of the invention is to provide a gray cast iron product having improved strength while having improved thermal conductivity and thermal shock resistance as compared to a ductile iron of the same base composition.

A further object of the invention is to provide a casting having the basic composition of gray cast iron, having improved strength as compared to gray cast iron of the same base composition and having improved foundry characteristics as compared to ductile iron of the same base composition.

It is a further object of the invention to provide a process for consistently and reliably producing vermicular graphite structures in cast iron.

Other objects and advantages of the invention will become apparent from the following description and the accompanying drawing in which:

FIGURE 1 is a reproduction of a photomicrograph taken at 100 diameters depicting the vermicular graphite microstructure which it is the object of the invention to produce;

FIGURES 2A, 2B, 2C and 2D are reproductions of photomicrographs taken at 100 diameters depicting vermicular graphite structure in cast iron produced in accordance with the invention over a range of magnesium contents;

FIGURES 3A, 3B and 3C are reproductions of photomicrographs taken at 100 diameters depicting the production of spheroidal graphite structures when an element essential to the present invention is omitted from the cast iron composition;

FIGURE 4 is a reproduction of a photograph taken at three-fourths actual size depicting the longitudinal section of a poorly fed complicated valve body casting demonstrating, in comparison to FIGURE 5, that improved soundness is obtained in castings produced in accordance with the invention; and

FIGURE 5 is a reproduction of a photograph taken at three-fourths actual size depicting the longitudinal section of a similar casting to that shown in FIGURE 4 to illustrate the foundry characteristics of ductile iron under the same conditions.

I have found, first, that the addition of cerium to a cast iron containing slightly less magnesium than will produce spheroidal graphite therein changes the form of the graphite from flake to vermicular. Thus, FIG. 1 shows the structure of cast iron containing about 0.01% magnesium which was converted from Type A flake graphite to vermicular graphite by the addition of about 0.005% cerium.

However, in order for this phenomenon to occur, the retained magnesium content of the cast iron must be maintained within a very narrow range lying just below the spheroid-producing amount for the particular composition being treated. Increasing the magnesium content above this range results almost immediately in a predominantly or fully spheroidal structure. Because of the extreme difficulty of maintaining the magnesium content within the requisite limits, the inevitable variability of the composition of cast iron from heat to heat, and for other reasons as well, vermicular structures cannot be obtained through the use of magnesium-cerium treatments alone on other than an uncontrollable, hit-and-miss basis.

I have also found, however, that the addition of titanium to the cast iron suppresses the formation of spheroidal graphite therein while in no way interfering with or suppressing the vermicular-inducing effect of the magnesium and cerium. Thus, titanium, if added in sufficient quantity;

4

enables the production of predominantly vermicular graphite structure in cerium-magnesium treated irons over a relatively wide range of magnesium content. Thus, for example, at a low titanium level such as is normally considered tolerable in the manufacture of ductile iron, a 90% spheroidal graphite structure was obtained with 0.025% retained magnesium and a small amount of cerium. With 0.3% titanium in the base iron, however, the iron contained a large proportion of vermicular graphite at this and even higher magnesium contents. The addition of titanium thus provides a means whereby the desired vermicular graphite can be obtained safely, reliably and reproducibly.

Broadly stated, the present invention comprises a graphitic cast product having the graphite predominantly in a vermicular form and containing about 0.003% or about 0.01% to about 0.06% magnesium, about 0.15% to about 0.5% titanium, about 0.001% to about 0.01% or 0.015% of a metal, e.g., cerium, from Group III-B of the periodic table, not more than about 0.02% or 0.025% sulfur, and the balance a gray cast iron composition. In the special cast material provided in accordance with the invention, the carbon content is about 2% to about 4%, the manganese content is about 0.1% to about 2.5%, or more when nickel is high enough to make the alloy austenitic, and the silicon content is about 1.5% to about 3.5%, more advantageously, not exceeding 3%. The product may contain up to about 1.0% chromium, up to about 2% molybdenum, up to about 0.5% vanadium, up to about 0.2% phosphorus, up to about 0.2% zirconium, up to about 0.05% aluminum, etc. The nickel content of the alloy may optionally be as high as about 36% as, for example, in castings having an austenitic matrix and containing about 20% or more nickel. In the presence of nickel in amounts sufficient to render the matrix austenitic, the contents of carbide-forming elements such as chromium, molybdenum, vanadium and manganese may be higher than those set forth hereinafore. Thus, for example, austenitic castings may contain about 2% of chromium. The elements copper, tin, lead, antimony and bismuth are undesirable impurities in the special cast material provided in accordance with the invention since these elements interfere with the controlled production of vermicular graphite in castings contemplated by the invention in that they undesirably increase the tendency to form spheroidal graphite. Thus, the copper content should not exceed about 0.5% and the tin content should not exceed about 0.03% when the magnesium content is about 0.04% or higher. As the magnesium content is decreased below 0.04%, the tolerance for copper and tin are increased until at a magnesium content of about 0.02% a copper content up to about 2% and a tin content up to about 0.15% may be permitted without an undesirable formation of spheroidal graphite being encountered. In all cases, the lead content should not exceed about 0.01% and the antimony and bismuth contents should not exceed about 0.01% each. While aluminum opposes the spheroid-inducing effect of magnesium in a manner similar to titanium, this element is detrimental to foundry characteristics in that it produces a sticky, slaggy melt of decreased fluidity and yields a drossy casting having a poor surface, particularly on the cope side. Castings in accordance with the invention accordingly contain less than about 0.05% aluminum. Boron is another undesirable element in castings produced in accordance with the invention since it strongly tends to form massive cementites and/or other undesirable carbide forms which are difficult to remove by annealing the castings. Accordingly, this element is not present in amounts exceeding about 0.002%. Zirconium appears to act in the same manner as titanium in the special cast iron of the invention, but only about 0.05% of this element can be introduced with the cast iron under usual conditions.

More advantageously, the special cast material provided in accordance with the invention contains 3% to 3.6%

carbon, about 2% to 2.6% silicon, about 0.2% to about 0.7% manganese, about 0.2% to about 0.5% titanium, about 0.01% to about 0.04% magnesium, not more than about 0.01% or 0.02% or 0.025% sulfur, and about 0.001% to about 0.01% cerium or other element from Group III-B of the periodic table. Castings produced within the more advantageous ranges of composition exhibit freedom from shrinkage porosity and low chilling tendency in combination with moderately high strength.

Nickel is an important alloying element in the special cast material since it provides an improvement in matrix properties, particularly strength, and does not detrimentally affect the graphite structure. Thus, at nickel contents up to about 5%, each additional percent of nickel will provide an increase in tensile strength of the castings of about 6,000 pounds per square inch (p.s.i.). The carbide-forming elements chromium, molybdenum and vanadium do not appear to affect the formation of the desired vermicular graphite structure but do increase the chilling propensity of castings containing these elements. Accordingly, in any application in which chill control is a factor, the use of these elements generally is avoided.

The special cast material provided in accordance with the invention may have any matrix structure characterizing corresponding alloyed and unalloyed gray cast irons in the as-cast and/or heat treated conditions. Thus, the as-cast matrix microstructure may be ferritic, pearlitic, austenitic, martensitic, acicular, etc.

The three elements magnesium, titanium and cerium or other Group III-B element employed in combination within the ranges set forth hereinbefore cause and control the occurrence of graphite to the vermicular form and each of these elements is maintained within ranges given to secure the special control of graphite structure contemplated in accordance with the invention. Thus, with magnesium contents less than about 0.005%, the graphite is no longer in the predominantly vermicular form but instead assumes the flake form and the strength of the alloy is reduced. On the other hand, when more than about 0.06% magnesium is present, unduly increased amounts of spheroidal graphite occur in the structure with an accompanying undesirable increase in chilling propensity and in solidification shrinkage together with an increased tendency to form dross inclusions which cause surface defects. More advantageously, the magnesium does not exceed about 0.04%, since in such iron occurrence of undesired graphite forms such as spheroids with the resulting occurrence of undesirable solidification shrinkage is avoided and increased chilling propensity is minimized. When less than 0.15% titanium is present, the control of graphite predominantly in the vermicular form becomes difficult and uncertain to the point of impracticability. More advantageously, the titanium content is at least about 0.2%. On the other hand, when the titanium content exceeds about 0.5%, oxide films form on the surface of the liquid iron which tend to cause surface defects on the castings produced. When cerium is absent, flake graphite forms and the strength of the iron is low. On the other hand, when the cerium content exceeds approximately 0.01%, e.g., about 0.012% or 0.015%, control of the occurrence of graphite predominantly in the vermicular form again becomes difficult and uncertain. Occurrence of excessive spheroidal graphite in the structure is encountered and the shrinkage of the resulting castings is undesirably increased. In such irons, the chilling propensity is markedly increased even in moderately thick castings. The graphite structure of castings containing only magnesium and titanium exhibit only flake graphite or mixtures of flake graphite and spheroidal graphite, while irons containing only cerium and titanium or only magnesium and cerium tend to transform abruptly from the flake form to the spheroidal form as either magnesium or cerium is increased above a critical value. The formation of vermicular graphite in the absence of the required amount of titanium is a matter of difficulty

and uncertainty. As a result, inferior properties are produced in castings produced using combinations involving only two of the significant elements either from the standpoint of strength properties or of foundry characteristics. Provided the aforementioned control of the three essential elements titanium, magnesium and cerium (or other Group III-B element) is accomplished, graphite structures which are predominantly vermicular will be obtained.

The special castings containing vermicular graphite are characterized by a higher tensile strength as compared to that of gray cast iron having the same base composition. In addition, the castings have a true modulus on the order of about 20 to about 22×10^6 p.s.i. and have a useful ductility. The castings have improved fatigue resistance as compared to gray cast iron castings of the same base composition. As indicated, other elements from Group III-B of the periodic table, such as yttrium, lanthanum or other element of the lanthanide or rare earth metal series may be employed in the place of cerium. Mischmetal, e.g., an alloy containing about 50% cerium and about 25% lanthanum with the remainder being comprised of other rare earth elements, is a satisfactory cerium-containing addition material for the production of castings in accordance with the invention. It is found in practice that, when such a mischmetal alloy is added to molten cast iron, lanthanum recovery is only about one-half as great as is the cerium recovery. Those skilled in the art will appreciate that cerium or other Group III-B metal can be added to the molten cast iron both in metallic form or in the form of a compound, e.g., oxides, etc., which are reducible to metal in the bath.

In order to give those skilled in the art a better understanding of the invention, the compositions of a number of castings produced in accordance with the invention are set forth in the following Table I and the tensile properties determined from 1-inch heel bar castings in the as-cast condition are set forth in the following Table II. In each case, the melts were inoculated with 0.5%, by weight, of a calcium-bearing grade of ferrosilicon containing about 85% silicon.

TABLE I
[Percent]

Alloy No.	C	Si	Mn	Mg	Ti	Ce	S	Other
1.....	2.84	2.53	0.23	0.033	0.15	0.004	0.008	
2.....	2.44	2.39	0.24	0.033	0.23	0.003	0.008	
3.....	2.23	2.39	0.23	(0.007)	0.23	0.003	0.004	<0.002 Pb
4.....	2.45	2.37	0.23	0.035	0.27	0.003	0.007	<0.002 Pb
5.....	2.45	2.41	0.23	0.039	0.27	0.003	0.005	<0.002 Pb
6.....	2.31	2.37	0.24	0.033	0.23	0.003	0.003	(0.005) Pb
7.....	2.35	2.34	0.23	0.031	0.23	0.003	0.003	(0.005) Pb
8.....	2.35	2.34	0.23	0.033	0.23	0.007	0.001	(0.005) Pb
9.....	2.31	2.30	0.14	0.033	0.23	0.007	0.013	
10.....	2.33	2.19	0.23	0.035	0.23	0.003	0.003	
11.....	2.37	2.23	0.21	0.034	0.27	0.003	0.017	0.75 Ni
12.....	2.33	2.23	0.23	0.033	0.23	0.003	0.015	1.25 Ni
13.....	2.33	2.41	0.23	0.033	0.23	0.007	0.015	
14.....	2.33	2.23	0.23	0.037	0.23	0.003	0.015	
15.....	2.37	2.23	0.23	0.037	0.23	0.003	0.015	
16.....	2.33	2.21	0.23	0.037	0.23	0.003	0.015	0.12 Cr
17.....	2.33	2.23	0.23	0.037	0.23	0.003	0.015	0.15 Mo
18.....	(2.5)	(2.5)	(0.5)	0.033	0.23	(0.003)	0.003	
19.....	2.33	1.75	0.23	0.037	0.23	(0.003)	0.015	
20.....	2.33	1.93	0.23	0.037	0.23	(0.003)	0.003	
21.....	2.37	2.23	0.41	0.033	0.23	(0.003)	0.003	
22.....	(2.3)	(2.3)	(0.2)	(0.003)	0.23	0.003	0.007	

*Single analysis, all others are the average of two analyses.
Note.—The melts set forth in the above table were produced using a mischmetal alloy containing about 50% cerium and about 25% lanthanum and specified cerium and lanthanum in a ratio of about 4 to 1. Numbers in parentheses are estimated.

7

TABLE II

Alloy No.	Tensile strength, k.s.i.	Yield strength, k.s.i.	Elongation, percent	Modulus, p.s.i.	BRN	Structure
1.....	37.4	32.1	2.5	20.7X10 ⁶	137	80% V bal. s.
2.....	43.4	32.9	2.5	20.8X10 ⁶	140	80% V bal. s.
3.....	46.2	32.3	4	20.8X10 ⁶	143	80% V bal. s.
4.....	52.1	40.8	2.5	20.8X10 ⁶	145	80% V bal. s.
5.....	51.3	41.3	7.5	20.7X10 ⁶	146	70% V bal. s.
6.....	42.6	34.8	4.5	19.1X10 ⁶	131	80% V bal. s.
7.....	45.4	35.5	2.5	20.8X10 ⁶	131	70% V bal. s.
8.....	42.9	32.5	2.5	17.5X10 ⁶	127	80% V bal. s.
9.....	47.3	35.6	6	21.0X10 ⁶	135	80% V bal. s.
10.....	44.6	35.0	6	20.7X10 ⁶		80% V bal. s.
11.....	40.1	42.4	2.3	22.6X10 ⁶	155	80% V bal. s.
12.....	52.6	42.6	1.5	22.8X10 ⁶	153	80% V bal. s.
13.....	52.7	50.7	1.5	21.6X10 ⁶	157	80% V bal. s.
14.....	54.3	43.9	1.5	22.0X10 ⁶	174	80% V bal. s.
15.....	52.3	42.0	2.0	22.3X10 ⁶	179	80% V bal. s.
16.....	51.1	42.7	1.5	21.5X10 ⁶	179	80% V bal. s.
17.....	52.1	44.3	2.0	22.7X10 ⁶	163	80% V bal. s.
18.....	52.5	43.9	6.3		143	70% V bal. s.
19.....	52.8	41.7	2.5		175	80% V bal. s.
20.....	51.1	40.7	2.0		153	80% V bal. s.
21.....	47.4	44.0	1.0		170	100% V.
22.....	52.7	43.9	7.5		140	80% V bal. s.

V=vermicular. S=spheroidal.
NOTE.—Structures were observed in 2-inch section castings and tensile and hardness properties were determined on 1-inch keel block castings.

The special cast material provided in accordance with the invention is characterized by improved thermal conductivity and damping capacity as compared to ductile iron and data demonstrating the foregoing are set forth in the following Table III:

TABLE III

Material	Thermal Conductivity, cal./cm ² /sec./cm. ² /°C.	Relative Damping Capacity
Iron of this invention.....	About 0.11.....	0.6
Gray iron.....	About 0.12.....	1.0
Ductile iron.....	About 0.08.....	0.94

NOTE.—Damping capacities were determined by applying to specimens of the test materials a vibrational stress initially varying between 4,000 p.s.i. in compression and 1,000 p.s.i. in compression and measuring the relative rates at which the amplitude of vibration decreased initially when the imposed vibration was shut off.

The vermicular graphite structure of the special cast product produced in accordance with the invention is not materially affected by variations in section size over the range from about 1/4 inch up to about 4 inches as illustrated by data set forth in the following Tables IV and V.

TABLE IV
[Percent]

Alloy No.	C	Si	Mn	Mg	Ti	Ca	Ni
23.....	2.53	1.36	0.47	0.018	0.31	(0.005)	
24.....	2.48	1.30	0.49	0.028	0.26	(0.005)	1.53

8

TABLE V

Alloy No.	Section Size, inches	Tensile Strength, k.s.i.	Yield Strength, k.s.i.	Elongation, Percent	BRN	Percent Vermicular (incl. spheroidal)
25.....	1/2	65.0	45.3	3.0	194	80
	1	62.5	42.4	4.0	187	73
	2	54.5	42.4	2.0	168	65
	3	49.2	37.3	2.0	149	50
10 24.....	1/2	62.1	45.0	3.0	228	80
	1	72.3	52.2	4.0	207	60
	2	61.9	47.6	2.5	195	70
	3	55.5	44.9	2.0	178	50

The data in Table V also demonstrate that the properties of the special cast product are not affected by variations in section size to any greater extent than are the properties of common gray cast irons.

In order further to illustrate the effect of titanium according to the invention in broadening the magnesium compositional range over which vermicular graphite is obtained in the copresence of cerium, substantially identical melts were produced containing about 3.5% carbon, about 2.3% silicon, about 0.3% manganese and the balance essentially iron. The melts were desulfurized to about 0.005% sulfur by calcium carbide injection. Titanium was introduced into one series of melts in an amount of about 0.32% to 0.34% while the titanium content of the other series was about 0.015%. Various amounts of magnesium and cerium were employed. The treated metal in each case was inoculated with about 0.5% by weight of calcium-bearing ferrosilicon containing about 85% silicon and cast into various castings including step bars and 1-inch keel blocks. The micro-structure obtained in the 2-inch section of the step bars was examined and the structure for the titanium-bearing series are shown in FIGURES 2A, 2B, 2C and 2D of the drawing while the structures for the essentially titanium-free series are shown in FIGURES 3A, 3B and 3C of the drawing. The keel blocks were annealed for 2 hours at 1650° F., furnace cooled to 1275° F. held for 5 hours and then air cooled so as to eliminate matrix effects upon the tensile properties. The proportions of vermicular graphite in the structures, the magnesium, cerium and titanium analyses and the tensile properties are shown in the following Table VI.

TABLE VI

Alloy No.	Percent		Graphite Structure*	Fig. No.	Tensile properties		El. Percent	BRN
	Mg	Ca			U.T.S., k.s.i.	Yield, k.s.i.		
Titanium 0.32-0.34%								
26.....	0.015	0.004	100% V	2A	42.2	40.0	6.5	142
27.....	0.016	0.005	80% V	2B	42.6	41.4	6.6	144
28.....	0.028	0.008	80% V	2C	42.3	42.3	6.0	145
29.....	0.034	0.009	80% V	2D	38.0	42.0	5.5	151
Titanium 0.015%								
30.....	0.015	0.003	80% V	3A	51.5	39.2	1.5	143
31.....	0.022	0.004	50% V	3B	57.4	41.6	12.5	148
32.....	0.028	0.005	10% V	3C	55.0	43.2	10	149

*Balance spheroidal graphite.

The data in Table VI and the structures shown in FIGURES 2A, 2B, 2C and 2D of the drawing demonstrate clearly that the graphite structure of castings produced in accordance with the invention are caused to appear in the predominantly vermicular form due to the required presence of titanium even though magnesium is increased substantially. On the other hand, in the essential absence of titanium, the graphite structure rapidly is converted to spheroids as magnesium increases only slightly as is shown in FIGURES 3A, 3B and 3C. The high elongation figures obtained in the tensile tests conducted from alloys 30 and 31 as shown in Table VI confirm that these alloys

contained a large proportion of graphite in spheruloidal form.

The chilling propensity of the special cast material is lower than that of a ductile iron casting and is approximately proportional to the magnesium content, in the absence of other carbide-forming elements. It is accordingly advantageous in applications in which chilling propensity is to be minimized, as, for example, in thin-sectioned castings having wall thicknesses on the order of 1/4 inch or less, to operate at magnesium contents in the lower end of the range set forth hereinbefore. In such instances, it may also be advantageous to desulfurize the molten iron to a level not exceeding about 0.02% prior to treatment with magnesium, titanium and cerium or other Group III-B element. It will also be appreciated that when the magnesium content is low, e.g., on the order of about 0.01%, precautions must be taken to insure that at least an effective magnesium content not combined with sulfur as MgS is present in the iron.

In order to demonstrate the improved feeding characteristics which characterize the special cast product of the invention as compared to ductile iron, valve body test castings of complicated configuration were made using the two materials in identical molds designed to provide poor feeding conditions. The special casting of the invention contained 3.73% carbon, 2.21% silicon, 0.18% manganese, 0.010% magnesium, 0.25% titanium, 0.009% cerium and had graphite in the vermicular form. The ductile iron casting was made in the same base iron, contained about 0.05% magnesium and had spheruloidal graphite. The castings were sectioned longitudinally and were photographed with the casting in accordance with the invention being depicted in FIGURE 4 and the ductile iron casting being depicted in FIGURE 5. As shown in FIGURE 4, the casting according to the invention was almost completely sound while the ductile iron casting was characterized by severe shrinkage cavities in the poorly fed areas.

In producing castings in accordance with the invention, melt of gray cast iron composition is established, i.e., a cast iron melt having such graphitizing power that is cast, at least after a graphitizing inoculation, it would be a gray cast iron substantially devoid of massive carbides such as occur in white cast iron. If the sulfur content of the melt exceeds about 0.02%, it is advantageous to reduce the sulfur content of the melt to about 0.02% or lower by means of common desulfurizing techniques, including the use of magnesium. Any of the common furnaces employed in the production of foundry gray cast iron can be employed to produce the special cast material provided in accordance with the invention. The melt is brought to a proper temperature for casting, e.g., a temperature in the range of about 2600° F. to about 2800° F. Additions of cerium or other Group III-B element, magnesium and titanium are then made to provide residual contents of these elements within the ranges set forth hereinbefore. Titanium in small amounts less than required by the invention is commonly found in cast iron whereas magnesium, cerium and other Group III-B elements are not. The amount of titanium contained in the molten cast iron should be ascertained and only the amount of titanium required to adjust the bath titanium content to the required final level should be incorporated in the bath. Shortly before casting, an addition of a graphitizing inoculant such as ferroaluminum, e.g., an alloy containing 85% silicon, about 0.5% calcium, and the balance essentially iron, in an amount sufficient to introduce about 0.5% silicon, e.g., about 0.3% to about 0.7% silicon, is made to the treated melt and the melt is then cast. In instances wherein thin-section castings are to be made, for example, castings as thin as one-eighth inch or less, the "instant inoculation" procedure, wherein a few grams of powdered inoculating alloy, e.g., ferroaluminum, is introduced into the feeder gate prior to pouring the casting, advantageously may be employed. Usual heat treating procedures em-

ployed in the art to decompose carbides and/or pearlite may also be applied to the castings produced in accordance with the invention.

It is to be understood that the expression "predominantly" is used herein in conjunction with the description of the vermicular graphite structure produced in accordance with the invention to mean that at least 50% of the graphite particles in the structure are in the vermicular form. The remainder of the graphite particles may be spheruloids. The presence of flake graphite in the structure is to be avoided as low strength properties are then encountered. It is further to be understood that references to the "periodic table" herein are made to the "Periodic Chart of the Elements" set forth at pages 56 and 57 of "Handbook of Chemistry," compiled and edited by Norbert Adolf Lange, Tenth Edition, McGraw-Hill Book Company, 1961.

Applications in which the special cast material provided in accordance with the invention may be employed with advantages include ingot molds, brake drums, particularly brake drums cast integrally with the hub, pumps and valves, cam shafts, gears, gear boxes and gear carriers, engine blocks and heads, piston rings, sealing rings, heat-treating pots, paper mill rolls, machine beds and frames, transmission cases, etc.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A graphitic cast iron consisting essentially of about 2% to about 4% carbon, about 1.5% to about 3.5% silicon, up to about 36% nickel, about 0.005% to about 0.06% magnesium, about 0.001% to about 0.015% of a metal from Group III-B of the periodic table, about 0.15% to about 0.5% titanium, with said magnesium, Group III-B metal and titanium contents being effective to control the occurrence of graphite in said cast iron so that at least 50% is in the vermicular form and the balance of said cast iron being essentially iron with other elements and impurities in small amounts which do not materially interfere with the occurrence of graphite in said vermicular form.

2. A graphitic cast iron according to claim 1 wherein the Group III-B metal is cerium.

3. A graphitic cast iron according to claim 2 containing about 3% to about 3.6% carbon, about 2% to about 2.6% silicon, about 0.2% to about 0.7% manganese, about 0.01% to about 0.04% magnesium, about 0.2% to about 0.5% titanium and about 0.001% to about 0.01% cerium.

4. A graphitic cast iron according to claim 1 containing about 0.01% to about 0.04% magnesium and about 0.2% to about 0.5% titanium.

5. A process for producing graphitic cast iron having at least 50% of the graphite in the vermicular form which comprises establishing a bath of gray cast iron containing about 2% to about 4% carbon, and up to about 36% nickel, adjusting the titanium content of said bath to about 0.15% to about 0.5%, incorporating about 0.005% to about 0.06% magnesium and about 0.001% to about 0.015% of a Group III-B metal into said bath the contents of titanium, magnesium, and the Group III-B metal being effective to control the occurrence of graphite in said cast iron so that at least about 50% is in the vermicular form in the finishing casting, and casting metal from the resulting bath in an inoculated condition to provide a casting consisting essentially of about 2% to about 4% carbon, up to about 36% nickel, about 1.5% to about 3.5% silicon, about 0.005% to about 0.06% magnesium, about 0.001% to about 0.015% of Group III-B metal

3,421,886

11

and about 0.15% to about 0.5% titanium, not more than about 0.025% sulfur, and with the balance except for small amounts of incidental elements and impurities being essentially iron.

6. The process according to claim 5 wherein the Group III-B metal is cerium.

7. The process according to claim 6 wherein the casting contains about 0.01% to about 0.04% magnesium, about 0.2% to about 0.5% titanium, about 0.001% to about 0.01% cerium, and not more than about 0.02% sulfur.

References Cited

UNITED STATES PATENTS

2,485,761	10/1949	Mills	75-123	15
2,488,511	11/1949	Morrogh.		
2,542,633	2/1951	Gagnebin.		

12

2,749,238	6/1956	Mills	75-123	XR
2,841,488	7/1958	Morrogh.		
2,841,489	7/1958	Morrogh.		
2,841,490	7/1958	Steven.		
2,867,553	1/1959	Curry	75-123	
2,873,188	2/1959	Bieniossek	75-130	
2,877,111	3/1959	Barnes	75-130	

OTHER REFERENCES

Physical & Engineering Properties of Cast Iron, H. T. Angus, 1962, pages 121, 230, 231, 241, 287, 307, and 308.

L. DEWAYNE RUTLEDGE, *Primary Examiner.*

PAUL WEINSTEIN, *Assistant Examiner.*

U.S. Cl. X.R.

75-130; 148-35