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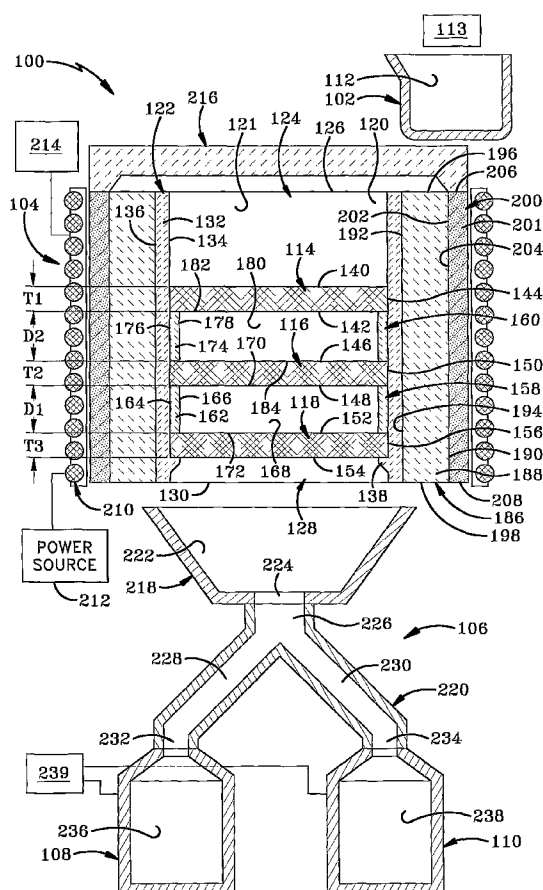
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(54) Title: DIRECT CASTING UTILIZING STACK FILTRATION



(57) Abstract: A casting system includes a filtration assembly including a filter vessel housing spaced filters pre-heated to a temperature approximating a pouring temperature of molten material to be filtered to prevent breakage of the filter due to thermal shock from contact with the molten material. Preferably, an induction coil is used to inductively heat a susceptor adjacent the filter vessel or inductively heat filters which themselves serve as susceptors. Typically, the filter vessel is disposed below a pouring vessel and above a mold, pour cup and any sprue system used and is heated independently from the same. The filters are heated during pouring to facilitate flow of the molten material therethrough whereby very fine filters may be used. Spacing of the filters enhances flow control and allows a head of molten material to form whereby cross floats to the top of the head to prevent its entry into the mold.



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DIRECT CASTING UTILIZING STACK FILTRATION

BACKGROUND OF THE INVENTION

1. TECHNICAL FIELD

The invention relates generally to the casting of molten metals or other molten/liquid materials. More particularly, the invention relates to a filtration system used for such melting and casting. Specifically, the invention relates to a filtration system wherein the filters are preheated to a temperature similar to a pouring temperature of the molten material to prevent breakage of the filters due to thermal shock and frozen metal clogging associated with temperature filtration.

2. BACKGROUND INFORMATION

In the melting, casting and/or other processing of metals or other materials, there is often a substantial amount of impurities within the metal or other materials to be melted. Separating these impurities from the desired material which is ultimately to be used in a finished product presents a host of problems. While filtering methods known in the art have addressed these issues to a certain degree, there remains a great deal of room for improvement. While the following background information pertains primarily to the melting and casting of metals and most particularly of super alloys, the filtration issues remain for other molten materials and the present invention is related to the filtering of essentially any type of molten material.

It has long been understood that the direct casting of super alloys and other metals for precision casting components has suffered from impurities entrapped in the master melt alloy. Most master alloys contain impurities such as dross, cut off and cleaning fragments, pipe scale, condensate and melting vessel fragments. Upon re-melting of the master alloy, crucible fragments, oxidized metal and condensate particles can enter the melt. The impurities become entrapped within the casting or on the surface thereof and often cause the casting to be reworked or scrapped. These impurities are identified as casting inclusions. Filtering is often used to help remove these impurities; however, conventional filtration techniques often cause more inclusions than they prevent.

Generally, in the casting of large equiaxed cast components, master melt alloy is re-melted in a melting vessel and poured directly into an invested shell. Often a filter is placed in the pour cup or mold cup of the invested shell to help reduce the amount of resultant inclusions in the cast component. In this system and method, the filter is maintained at or close to the shell temperature, which is significantly lower than the alloy pour temperature and thus can negatively effect the pour temperature and if the alloy freezes, the filters can become clogged. Because of the difference in temperatures, thermal shock can occur and cause fragments of the filter to break off and enter the shell of the mold. In addition, because pouring speed or fill rate is critical to the metallurgical properties of the castings, filter pore size must be relatively large so as not to impede the flow of metal into the shell. Often ceramic fiber gaskets are used to seal the filter within the pour cup. The fibrous nature of these gaskets can also contribute to inclusions within the cast component. Such problems greatly reduce the overall effectiveness of pour cup filtering. Alternatively, in-line gate filtering can be employed in the casting of equiaxed components. In this method, ceramic filters are placed in the metal feed runners of the mold. This type of system requires that the mold be configured so that a filter can be placed in the gating either during wax set up or after wax removal. In both techniques, the filters are held at shell temperatures and can be thermally shocked when the molten alloy is poured through them. The filters at these shell temperatures can negatively effect the pour temperature and clog the filters if the alloy freezes. Again the filter pore size needs to be large so as not to effect the fill rate. In addition, the material used to affix the filter in place may be a contaminant as well.

In the casting of directionally solidified castings, master melt alloy is re-melted in a melting vessel and poured directly into an invested shell. Filters are often placed in the bottom feed runners of the wax trees prior to investment. Viscous wax is injected through the filter so that the filters can be attached to the wax tree. This puts considerable stress on the ceramic filters leading to loose fragments that can enter the mold. Because the filter is located in the metal feed runner, alloy loss is a consideration. After solidification, metal is imbedded in the filter and cannot be readily reverted. Thus, bottom feeding is effective, but comes

at a significant alloy cost. In addition, the bottom feed filter system may prevent tight baffling of the components and affect grain quality.

Often in the manufacturing of master alloys, molten metal is poured from a melting vessel into a tundish that filters and funnels the alloy into a fixed solidification mold, tube or pig. However, the tundishes are typically equipped with coarse filters, in conjunction with alternating dams and weirs, over and under which the molten material respectively flows. In many cases, the tundish assembly is radiantly preheated off-line from the melt system and often to a temperature lower than the alloy pour temperature, and then moved into a pouring position where the tundish assembly is not further heated. Because the temperature of the tundish is lower than the alloy pour temperature, filtration needs to be coarse. Also, since the temperature is lower than the solidification point of the alloy, any interruption in pouring may cause the system to freeze prematurely, resulting in the need to replace the tundish or eliminate its use for the remainder of the pour. In addition, because the tundish assembly is preheated offline and then moved into the pouring position without additional heating, this configuration and method would not allow for the use of fine filters.

Thus, there remains a need for a method and system for eliminating impurities prior to molten metal entering a mold. The present system and method addresses this problem and is particularly useful for large equiaxed castings. However, the present invention may be employed on directionally solidified castings and master melt production as well as with essentially any type of molten material.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a method comprising the steps of pre-heating at least one filter to a filter temperature which will prevent breakage of the filter due to thermal shock from contact with molten material; and passing molten material through the at least one filter.

The present invention further provides a method comprising the steps of passing molten material through at least one filter disposed within a filter vessel; heating the at least one filter with a heat source other than the molten material during the step of passing to facilitate flow of the molten material through the at

least one filter; and transferring filtered molten material from the filter vessel into a containing vessel.

In general, the present invention provides a filtration system which prevent thermal shock of the filters, prevents the freezing of the molten material within the filters to prevent clogging thereof, minimizes or eliminates negative effects to the pour temperature to thus maintain a desired pour temperature, and removes impurities ranging even to extremely small sizes.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a sectional view of a first embodiment of the casting and filtration system of the present invention as viewed from the side.

Fig. 2 is similar to Fig. 1 and shows molten material being poured into the filter vessel, moving through the filters therein and pouring into the pour cup and sprue system into a pair of molds.

Fig. 3 is a view similar to Fig. 1 of a second embodiment of the casting and filtration system of the present invention.

Fig. 4 is a view similar to Fig. 1 of a third embodiment of the casting and filtration system of the present invention.

Similar numbers refer to similar parts throughout the specification.

DETAILED DESCRIPTION OF THE INVENTION

A first embodiment of the casting system of the present invention is indicated generally at 100 in Figs. 1-2; a second embodiment is indicated generally at 300 in Fig. 3; and a third embodiment is indicated generally at 400 in Fig. 4.

Casting system 100 includes a pouring vessel 102 which is often a melting crucible, a filtration system or assembly 104 disposed below vessel 102, a transferring system or shell or assembly 106 disposed below assembly 104 and first and second containing vessels in the form of molds 108 and 110 disposed below transferring assembly 106. Typically, assembly 106 and molds 108 and 110 are a single assembly.

Pouring vessel 102 defines a cavity 112 for containing molten material. Vessel 102 is typically either a main melt furnace in which material is melted or a

refining hearth which receives molten material from the main melt furnace. Pouring vessel 102 is disposed above filtration assembly 104 for pouring molten material into assembly 104 via any manner known in the art, such as bottom pouring, overflow pouring or tilting. A heat source 113 is positioned for melting material within cavity 112 of vessel 102 or within a melting furnace which pours molten material into cavity 112. Heat source 113 may be any suitable heating mechanism to include, for example, a plasma torch, an arc electrode, an electron beam apparatus, an inductive heating assembly, a resistance heating assembly and so forth.

In accordance with a feature of the invention and with continued reference to Fig. 1, filtration assembly 104 is located outside of assembly 106 and includes first, second and third filters 114, 116 and 118 which are spaced from one another and are heatable to a temperature which will prevent them from breaking due to thermal shock when molten material is poured therethrough. Filters 114, 116 and 118 may be formed of any suitable material which is appropriate to the temperature at which they will be used and the type of molten material which will be poured therethrough, along with other pertinent environmental factors. The material of which the filters are made is typically based on compatibility with the molten material, affinity for the capturing of dross and potentially for chemical cleaning and stabilization. Filters 114, 116 and 118 may, for example, be formed of ceramic materials such as alumina, mullite, silica, zirconia, calcia, titania and yittria. They may also be formed of various metals, graphite, carbon composites, resins, oxides, nitrides and so forth. Where appropriate, the filters may be used as a susceptor, as later explained, in which case the filters may be formed of such materials as graphite, an alumina-graphite mix, a silica-graphite mix, a clay-graphite, a silicon-carbide or other materials suitable to the purpose.

More particularly and with continued reference to Fig. 1, first filter 114 has an upper surface 140 and a lower surface 142 defining therebetween a first constant thickness T1. Filter 114 also has an outer perimeter 144. Similarly, second filter 116 has an upper surface 146 and a lower surface 148 defining therebetween a constant thickness T2. Filter 116 also has an outer perimeter 150. Likewise, third filter 118 has an upper surface 152 and a lower surface 154 defining therebetween a constant thickness T3. Third filter 118 also has an outer

perimeter 156. In the embodiment shown, each of filters 114, 116 and 118 have constant thicknesses T1, T2 and T3 which are the same as one another. However, this may vary as desired for the purposes for which the filters are used. In addition, the thicknesses T1, T2 and T3 are not necessarily constant, but may vary across the respective filters.

5 The filtration capability of the filters grows increasingly finer from top to bottom so that second filter 116 is finer than first filter 114 and third filter 118 is finer than second filter 116. The size of the pores used with such filters may vary greatly. For example, for rather coarse filtering, pores which are approximately one inch across may be used while on the other end of the scale, filters having
10 pores similar to that of tissue paper may be used. The filtration capacity of a given filter is commonly measured in pores per inch (ppi), which means pores per linear inch. Filters ranging from 5 ppi to 70 ppi are reasonably common. However, use of filters which are finer than 45 ppi in the melting of metals and other materials with relatively high melting points is not as common generally.
15 Filters ranging from 10 to 30 ppi are fairly common in the art. Thus, by way of example and especially for use with the melting of metals or various alloys, first filter 114 may be approximately 10 ppi, second filter 116 may be approximately 20 ppi and third filter 118 may range from 30 to 45 ppi. However, it is noted that with the use of the present invention, filters which are extremely fine may be used.

20 With continued reference to Fig. 1, filters 114, 116 and 118 are disposed within a passage 120 formed in a filter vessel 122. Passage 120 has an entrance opening 124 adjacent an upper end 126 of filter vessel 122 and an exit opening 128 adjacent a lower end 130 of vessel 122. Passage 120 of filter vessel 122 includes an upper reservoir 121 disposed above first filter 114. Filter vessel 122
25 includes a sidewall 132 having an inner surface 134 and an outer surface 136. Commonly, sidewall 132 is substantially cylindrical but may have any shape which is suitable to the purpose. Adjacent lower end 130, a shelf 138 is disposed adjacent sidewall 132 inwardly thereof. Shelf 138 may be formed integrally with sidewall 132 and preferably extends in a continuous manner all the way around
30 and in abutment with inner surface 134 of sidewall 132.

 The respective outer perimeters 144, 150 and 156 of filters 114, 116 and 118 are all of a mating configuration with inner surface 134 of sidewall 132. Third

filter 118 is seated on shelf 138 with lower surface 154 of filter 118 contacting shelf 138 adjacent outer perimeter 156 of filter 118. Second filter 116 is spaced upwardly from third filter 118 by a distance D1, which is more particularly defined between upper surface 152 of third filter 118 and lower surface 148 of second filter 116. Likewise, first filter 114 is spaced upwardly from second filter 116 by a distance D2, which is more particularly defined between upper surface 146 of second filter 116 and lower surface 142 of first filter 114.

More particularly, filtration assembly 104 includes first and second spacers 158 and 160 disposed within passage 120 of filter vessel 122 so that first spacer 158 spaces second and third filters 116 and 118 from one another and second spacer 160 spaces first and second filters 114 and 116 from one another. More particularly, first spacer 158 has a sidewall 162 having an outer surface 164 and an inner surface 166 defining a passage 168 extending from a top 170 to a bottom 172 of first spacer 158. Preferably, outer surface 164 of first spacer 158 is of a mating configuration with inner surface 134 of sidewall 132 of filter vessel 122. First spacer 158 at bottom 172 thereof is seated atop third filter 118 along upper surface 152 adjacent outer perimeter 156. Second filter 116 is seated along lower surface 148 adjacent outer perimeter 150 atop first spacer 158 at top 170 thereof.

Similarly, second spacer 160 has a sidewall 174 having an outer surface 176 and an inner surface 178 defining a passage 180 extending from a top 182 to a bottom 184 of second spacer 160. Second spacer 160 at bottom 184 thereof is seated atop second filter 116 along upper surface 146 adjacent outer perimeter 150. First filter 114 along lower surface 142 adjacent outer perimeter 144 is seated atop second spacer 160 at top 182 thereof. Thus, first spacer 158 has a height equal to distance D1 and second spacer 160 has a height equal to distance D2. Distances D1 and D2 may or may not be the same as one another depending on the desired spacing to be set between the various filters, as will be detailed further below.

Filtration assembly 104 further includes a host vessel 186 within which filter vessel 122 is disposed. More particularly, host vessel 186 includes a sidewall 188 having an outer surface 190 and an inner surface 192 defining a passage 194 extending from a top 196 to a bottom 198 of host vessel 186. Inner surface 192 of sidewall 188 of host vessel 186 is of mating configuration with outer surface

136 of sidewall 132 of filter vessel 122 so that filter vessel 122 is disposed within passage 194 of host vessel 186 with said outer surface 136 in abutment with said inner surface 192.

Filtration assembly 104 further includes a susceptor 200 including a sidewall 201 having an inner surface 202 which defines a passage 204 extending from a top 206 to a bottom 208 of susceptor 200. Host vessel 186 is disposed within passage 204 of susceptor 200 with outer surface 190 of sidewall 188 in abutment with inner surface 202 of sidewall 201 of susceptor 200. In one preferred embodiment, host vessel 186, filter vessel 122, filters 114, 116 and 118 and spacers 158 and 160 form a removable cartridge. The cartridge may be quickly removed or changed out for several purposes, to include a change in the material being melted within system 100, in order to change the flow control of a given set of filters, or when the filters have met their intended service life.

Filtration assembly 104 further includes an induction coil 210 surrounding susceptor 200 and a power source 212 in electrical communication with induction coil 210 for powering induction coil 210. Alternately, element 210 may represent a resistive heating element which is powered by power source 212. Alternately, a heat source 214 may be used in place of element 210 and power source 212 depending on the environment in which system 100 is used. Heat source 214 may, for example, be a gas-burning heat source.

Filtration assembly 104 further includes a cover 216 at least a portion of which is moveable in order to provide access to entrance opening 124 of filter vessel 122 so that molten material may be poured from pouring vessel 102 into passage 120 of filter vessel 122. Thus, cover 216 may have a door which is moveable to an open position to allow access to the entrance opening. Alternately, cover 216 may be moveable between closed and open positions or may be removable entirely in order to provide such access to entrance opening 124.

Transferring assembly 106 includes a pour cup or mold cup 218 and a sprue system 220 disposed below pour cup 218. Pour cup 218 defines a cavity 222 which is in fluid communication with passage 120 of filter vessel 122. Pour cup 218 defines a lower exit opening 224 in fluid communication with cavity 222. Sprue system 220 defines a main channel or passage 226 in fluid communication

with exit opening 224 of pour cup 218, with main passage 226 dividing into first and second branch passages 228 and 230 having respective exit openings 232 and 234. Containing vessels or molds 108 and 110 define respective cavities 236 and 238 which are respectively disposed below and in fluid communication with exit openings 232 and 234. Where the heating of molds 108 and 110 is desirable, system 100 may include a heat source 239 for that purpose. Heat source 239 may be any heating mechanism known in the art, to include an inductive or resistance heating assembly or a gas burning source. While containing vessels 108 and 110 are shown as molds, they may also be other types of vessels for containing molten material, such as a tundish/vessel from which semi-conductor crystals may be pulled.

In accordance with the invention and with reference to Fig. 2, the operation of system 100 is now described. Heat source 113 is operated to melt material to form molten material 240 and to heat molten material 240 to a pouring temperature. Generally, molten material 240 is poured or otherwise transferred through preheated filters 114, 116 and 118 in order to filter molten material 240 to whatever degree is suitable for the particular purpose. More particularly, cover 216 is moved or removed from above filter vessel 122 and molten material 240 is poured from pouring vessel 102 into passage 120 of filter vessel 122 via entrance opening 124.

More particularly, molten material 240, such as molten metal or a metal alloy, is poured into upper reservoir 121 and then passes from reservoir 121 through first filter 114 into passage 180 of second spacer 160 as indicated by Arrows A. Molten material 240 then flows from passage 180 through second filter 116 and into passage 168 of first spacer 158 as indicated by Arrows B. Molten material 240 then flows from passage 168 through third filter 118 and out of passage 120 via exit opening 128 into cavity 222 of pour cup 218 as indicated at Arrows C. Molten material then flows from cavity 222 into main passage 226 and branch passages 228 and 230 of sprue system 220 and into respective molds 108 and 110 as indicated by Arrows D and E.

More particularly, power source 212 is operated to pass an electrical current through induction coil 210 which then electromagnetically couples with susceptor 206 to inductively heat susceptor 206. Heat created within susceptor

206 is then transferred via host vessel 186 and filter vessel 122 to filters 114, 116 and 118. This is most preferably done while cover 216 is in the closed position covering filter vessel 122, as shown in Fig. 1. Alternately, where filters 114, 116 and 118 are of a suitable material to act as susceptors themselves, induction coil 210 may electromagnetically couple directly with the filters in order to heat them inductively in a direct manner. As previously noted, element 210 may also be a resistive heating element so that power source 212 may send an electrical current through the resistive heating element 210 in order to produce heat which may be transferred to filters 114, 116 and 118. In this alternative embodiment, susceptor 206 would not be needed. Likewise, alternate heat source 214 may be used in order to heat filters 114, 116 and 118.

In any case and in accordance with a feature of the invention, the filters 114, 116 and 118 are heated to a temperature which will prevent them from breaking due to thermal shock when molten material 240 is poured onto and through said filters. Molten material 240 is melted and heated to its pouring temperature via heat source 113 independently of the preheating of filters 114, 116 and 118. Once the filters are preheated to the desired temperature and molten material 240 is ready to pour at its pouring temperature, cover 216 is moved to its open position to allow the pouring of molten material 240. The temperature to which filters 114, 116 and 118 are heated is approximately the same as the pouring temperature of molten material 240. However, it will be understood that the preheated temperatures of said filters may vary to some degree while allowing them to avoid breakage due to thermal shock. Depending on the composition of the filters and the pouring temperature of the molten material, the range of the preheated temperature of the filters may be fairly narrow or somewhat broader. Typically, the filters will be heated to within 75°F above or below the pouring temperature of molten material 240. More preferably, the preheated temperature will be within 50°F of the pouring temperature and even more preferably within 25°F of the pouring temperature of the molten material. However, any suitable temperature above the pouring temperature may be used, especially with regard to maintaining fluidity of molten material 240.

Importantly, system 100 is configured so that filters 114, 116 and 118 may be heated independently of the temperature of the molds 108 and 110, which are

typically heated via heat source 239 to desired temperatures as well. Depending on the application, the preheated temperature of molds 108 and 110 will vary, as previously discussed in part in the Background section of the present application.

In addition to the preheating of filters 114, 116 and 118 to prevent their breakage due to thermal shock, said filters are also heated throughout the melting process in order to maintain fluidity of molten material 240 through the filters. This is especially important to allow for the use of finer filters. Unless the temperature of the filters is maintained sufficiently near and preferably somewhat higher than the pouring temperature of molten material 240, this fluidity is reduced enough to substantially affect the flow rate of molten material 240 or even stop the flow thereof altogether if the molten material 240 is allowed to freeze up within the filters. It will be understood that the finer the filter (i.e., the smaller the pore size), the more critical it is to maintain the temperature of the filters sufficiently close to the pouring temperature of the molten material in order to maintain a desired flow or pour rate. System 100 is thus configured for maximum filtration and sized to allow for an optimum pour rate.

Another advantage of filtration assembly 104 is the ability to produce a head 242 of molten material 240 within filter vessel 122. In the process shown, head 242 of molten material 240 is disposed within reservoir 121 of passage 120 of filter vessel 122. Head 242 may be formed using a single filter by selecting a filter having a suitable pore size to appropriately control the flow rate. Alternately, as here, filters 114, 116 and 118 are spaced at suitable distances D1 and D2 from one another and specific pore sizes are chosen for each of said filters in order to control the flow rate in a desired manner. Thus, as represented in Fig. 2, the molten material 240 which is disposed between first and second filters 114 and 116 and between second and third filters 116 and 118 it will preferably fill the respective spaces between said filters. That is, passage 168 of first spacer 158 and passage 180 of second spacer 160 is preferably completely filled with molten material 240 during the pouring process. However, heads of molten material 240 similar to head 242 may also be formed between first and second filters 114 and 116 and/or between second and third filters 116 and 118 so that multiple heads may be formed. Head 242 is disposed above first filter 114 so as to allow dross 244 and other like contaminants to flow out of the alloy or other molten material

atop head 242. Maintaining head 242 throughout the melting process thus allows the dross to remain on the top and then at the end of the pour to be captured before it enters molds 108 and 110. More particularly, dross 244 will ultimately remain in structure above said molds, more particularly within pour cup 218 or sprue system 220. Thus, dross 244 does not contaminate the molded bodies
5 produced by molds 108 and 110.

Filters 114, 116 and 118 may be used with a pressurized system if desired. As is well known, filtering surface area, pressure and degree of filtration determine flow rate and these may be tailored to a particular application of system 100. A variety of advantages are readily noted with the use of system 100. It reduces the
10 number of inclusions and castings as compared to conventional systems. It eliminates the need for fixing agents such as glues in order to hold filters in place, and thus eliminates contamination from such fixing agents. The use of filtration assembly 104 allows pour cup 218 and sprue system 220 to be free of filters and eliminates the need for filters elsewhere within system 100.

It is noted that filtration assembly 104 may be used with another such
15 filtration assembly or a plurality of other such filtration assemblies wherein each assembly 104 may be stacked on top of another in order to provide additional filtration during the pouring process. In addition, filtration assembly 104 may be adapted for use with a centrifugal apparatus so that the molten material is not
20 necessarily gravity fed nor fed by a pressurized atmosphere. Thus, the molten material does not necessarily flow downwardly through the filters although this would be the case in the embodiments as shown. In addition, filters may be chosen which are suited to the removal of microscopic particles. For instance, filters having a high surface area and a high affinity for gases or other constituents
25 may be used to remove said gases or other constituents from the molten material as it flows through the filters.

System 300 (Fig. 3) is similar to system 100 except for the configuration of the filter vessel and the filters and the elimination of spacers between filters. The pouring vessel and heat sources for the pouring vessel and molds are also not
30 shown for simplicity. More particularly, system 300 includes a filtration assembly 304 which includes first, second and third filters 314, 316 and 318 and a filter vessel 322. First filter 314 has an upper surface 340, a lower surface 342 and an

outer perimeter 344. First filter 314 has a width W1 which is equivalent to a diameter thereof when first filter 314 is circular when viewed from above. Similarly, second filter 316 has an upper surface 346, a lower surface 348 and an outer perimeter 350. Second filter 316 also has a width W2 which is smaller than width W1 of first filter 314 and corresponds to a diameter when second filter 316 is circular when viewed from above. Third filter 318 has an upper surface 352, a lower surface 354 and an outer perimeter 356 and a width W3 which is smaller than width W2. Width W3 also corresponds to a diameter when third filter 318 is circular when viewed from above.

Filter vessel 322 defines a passage 320 analogous to passage 120 of filter vessel 122 except that it is a stepped passage. More particularly, filter vessel 322 defines a passage 320 having an entrance opening 324 at an upper end 326 of filter vessel 322 and an exit opening 328 at a lower end 330 of vessel 322. Filter vessel 322 has a stepped sidewall 332 having a stepped inner surface 334 and an outer surface 336 which is substantially the same as outer surface 136 of filter vessel 122 and bears the same relation with respect to host vessel 186. Sidewall 332 has an upper first section 358 and a second section 360 disposed therebelow with an inwardly extending first shelf 362 therebetween whereby inner surface 334 of sidewall 332 is stepped inwardly. Second section 360 is thicker than first section 358. Sidewall 332 further includes a third section 364 disposed below second section 360 with an inwardly extending second shelf 366 therebetween whereby inner surface 334 is further stepped inwardly. Third section 364 is thicker than second section 360. Sidewall 332 further includes a lower fourth section 368 disposed below third section 364 with an inwardly extending third shelf 370 disposed therebetween whereby inner surface 334 is stepped further inwardly.

Thus, passage 320 of filter vessel 322 includes an upper first section 372 disposed above first shelf 362 which has a width which is substantially the same as or slightly larger than width W1 of first filter 314. Passage 320 further includes a second section 374 below first section 372 which is disposed between first shelf 362 and second shelf 366 and has a width which is substantially the same as or slightly larger than width W2 of second filter 316. Passage 320 further includes a third section 376 below second section 374 which is disposed between second shelf 366 and third shelf 370. Third section 376 has a width which is substantially

the same as or slightly larger than width W3 of third filter 318. Passage 320 further includes a fourth section 378 disposed below third section 376 or in other words disposed below third shelf 370. Fourth section 378 has a width W4 which is smaller than width W3 of third filter 318.

Thus, first filter 314 is disposed within first section 372 of passage 320 with lower surface 342 seated atop first shelf 362 of sidewall 332. Outer perimeter 344 of first filter 314 is disposed closely adjacent or in abutment with inner surface 334 just above first shelf 362. Width W1 may be selected so that first shelf 314 may be placed atop first shelf 362 without force or shelf 314 may be press fit into first section 372 of passage 320 so that it is held snugly in place with outer perimeter 344 frictionally engaging inner surface 334 of sidewall 332. Likewise, second filter 316 is disposed within second section 374 of passage 320 with lower surface 348 thereof seated atop second shelf 366 of sidewall 322. Like first filter 314, second filter 316 may be placed with or without frictional engagement between outer perimeter 350 thereof and inner surface 344. Similarly, third filter 318 is disposed in third section 376 of passage 320 with lower surface 354 thereof seated atop third shelf 370 of sidewall 332. Like the other filters, third filter 318 may be seated with or without frictional engagement between outer perimeter 356 of third filter 318 and inner surface 334 of sidewall 332. The operation of system 300 is essentially the same as system 100 and is therefore described only with regard to distinctions from system 100. It is noted, however, that the stepped passage 320 and differing widths of filters 314, 316 and 318 will require different calculations for controlling the flow rate of molten material through filter vessel 322. It is further noted that the elimination of spacers within the filter vessel for spacing the filters from one another of course means that molten material would not be flowing through passages and spacers, but rather will flow from first section 372 through first filter 314 and into second section 374, then through second filter 316 and into third section 376 and then through third filter 318 and into fourth section 378 before entering transferring assembly 106 as previously described with regard to system 100.

Casting system 400 (Fig. 4) is similar to system 300 except for the configurations of the filters, the filter vessel and the host vessel, and the elimination of the sprue system whereby the pour cup is seated atop a single

cavity. More particularly, system 400 includes a filtration assembly 404 which includes first, second and third filters 414, 416 and 418 each disposed in a passage 420 of a filter vessel 422. Passage 420 includes an entrance opening 424 adjacent an upper end 426 of vessel 422 and an exit opening 428 adjacent a lower end 430 of vessel 422. Vessel 422 includes a frustoconical sidewall 432 having a frustoconical inner surface 434 defining passage 420 and a frustoconical outer surface 436. Sidewall 432 tapers inwardly and downwardly, as do inner and outer surfaces 434 and 436.

First filter 414 has an upper surface 440, a lower surface 442 and an outer perimeter 444 which tapers inwardly and downwardly in mating relation to tapered inner surface 434 of sidewall 432. Likewise, second filter 436 has an upper surface 446, a lower surface 448 and an outer perimeter 450 which tapers inwardly and downwardly in mating configuration with inner surface 434 of sidewall 432. Second filter 416 is spaced downwardly from first filter 414. Similarly, third filter 418 has an upper surface 452, a lower surface 454 and an outer perimeter 456 which tapers inwardly and downwardly in mating relation to inner surface 434 of sidewall 432. Third filter 418 is spaced downwardly from second filter 416. Like systems 100 and 300, system 400 thus provides a plurality of filters which are seated on a sidewall of or otherwise disposed within a passage of a filter vessel without the need of any glue or fixing agents to secure the filters therein. While systems 100, 300 and 400 may use glues or other such materials, it is preferred not to do so in order to eliminate any additional contaminants to the molten material.

Filtration assembly 404 further includes a host vessel 486 having a inwardly and downwardly tapering frustoconical inner surface 488 and an outer surface 490 which is substantially the same as the outer surface of host vessel 186 and has the same relation with regard to susceptor 206. Inner surface 488 of host vessel 486 is in mating relation with outer surface 436 of sidewall 432 of filter vessel 422. As previously noted, system 400 includes a single mold 402 defining a cavity 404. Pour cup 218 is seated atop mold 402 with cavity 222 thereof in fluid communication with cavity 404 of mold 402.

In operation, system 400 works in substantially the same manner as described with regard to systems 100 and 300. However, system 400 shows the

use of filtration assembly 404 with a single mold 402, thereby eliminating the use of the sprue system. Thus, molten material is poured directly from pour cup 218 into cavity 404 of mold 402. As with systems 100 and 300, system 400 provides a filtration system in which pour cup 218 is free of filters as is the remainder of the system aside from the filters within assembly 404.

5 Thus, systems 100, 300 and 400 provide a filtration system for molten material wherein the filters are preheated to prevent breakage thereof due to thermal shock upon contact by molten material being poured through the filters. In addition, these systems provide assemblies which allow for the continued heating of the filters throughout the pouring process in order to maintain the fluidity of the molten material as it passes through the filters to provide a desirable flow rate and to prevent the clogging of the filters. The use of the filtration assemblies disclosed herein are useful in directional solidification and single crystal casting because it allows for the elimination of bottom feed runners and filters therein, which permits the use of tighter baffles and internal chill systems while maintaining good filtration of the re-melt alloy.

10 It will be appreciated that a number of variations may be made which are within the scope of the invention. It has already been noted that alternate heat sources may be used to heat the filters of the present invention. As also suggested by the various embodiments, the filters and filter vessels can be of a variety of shapes, including those shown as well as cubic, hourglass-shaped, torroidal, oval and so forth. Similarly, the shapes of the host vessel, the susceptor and the induction coil may vary as well. For instance, with system 400, each of the host, susceptor and induction coil could be configured in a substantially frustoconical shape or the like which more closely mimic the shape of the filter vessel and thus reduce the thickness of the host vessel walls adjacent the lower end thereof to allow for more efficient transfer of heat from the susceptor to the filters. It is also noted that the overall size of the filtration assembly can easily be as small as one foot in width and one foot in height, thus illustrating the adaptability of the invention for small spaces and the ease with which such assemblies may be stacked as previously discussed. Obviously, however, the size of the filtration assembly varies with the application.

The present invention is useful over a very wide range of melting temperatures and pouring temperatures. For instance, the melting temperatures of various materials which can be used with the present invention range anywhere from room temperature to upward of 4000°F. Typically in the case of super alloys, the temperature range is roughly 2400°F to 3200°F. But of course, the pouring temperature is established by the melting temperature of the given material.

In the foregoing description, certain terms have been used for brevity, clearness, and understanding. No unnecessary limitations are to be implied therefrom beyond the requirement of the prior art because such terms are used for descriptive purposes and are intended to be broadly construed.

Moreover, the description and illustration of the invention is an example and the invention is not limited to the exact details shown or described.

CLAIMS

1. A method comprising the steps of:

pre-heating at least one filter to a filter temperature which will prevent breakage of the filter due to thermal shock from contact with molten material; and
5 passing molten material through the at least one filter.

2. The method of claim 1 wherein the step of pre-heating includes the step of pre-heating the at least one filter to a temperature which is within 75 degrees Fahrenheit of a pouring temperature of the molten material.

3. The method of claim 2 further including the steps of melting a metal or metal alloy to form the molten material; and heating the molten material to the pouring temperature.

4. The method of claim 1 further including the steps of heating a mold; and transferring a portion of the filtered molten material into the heated mold; and wherein the step of pre-heating includes pre-heating the at least one filter independently of heating the mold.

5. The method of claim 1 wherein the step of passing includes the step of passing molten material through the at least one filter which is disposed within a filter vessel and further including the step of transferring molten material from the filter vessel into at least one mold.

6. The method of claim 5 wherein the step of transferring includes the step of transferring molten material from the filter vessel into the at least one mold via a transferring assembly which is free of a filter.

7. The method of claim 1 further including the steps of covering a filter vessel which houses the at least one filter with a cover to facilitate the pre-heating of the at least one filter; moving at least a portion of the cover to create access to an

entrance opening into the filter vessel; and pouring molten material through the entrance opening into the filter vessel.

8. The method of claim 1 wherein the step of pre-heating includes the step of heating a susceptor inductively and transferring heat from the susceptor to the at least one filter.

9. The method of claim 1 wherein the step of pre-heating includes the step of coupling an induction coil electromagnetically to the at least one filter to inductively heat the at least one filter directly.

10. The method of claim 1 wherein the step of pre-heating includes the step of pre-heating the at least one filter within a filter vessel to the filter temperature while the filter vessel is disposed in a pouring position for receiving the molten material from a pouring vessel.

11. The method of claim 1 further including the step of heating the at least one filter with a heat source other than the molten material during the step of passing to facilitate flow of the molten material through the at least one filter.

12. A method comprising the steps of:

passing molten material through at least one filter disposed within a filter vessel;

heating the at least one filter with a heat source other than the molten material during the step of passing to facilitate flow of the molten material through the at least one filter; and

transferring filtered molten material from the filter vessel into a containing vessel.

13. The method of claim 12 further including the steps of melting a metal or metal alloy to form the molten material.

14. The method of claim 12 wherein the step of transferring includes the step of transferring molten material from the filter vessel into at least one mold via a transferring assembly which is free of a filter.

5 15. The method of claim 12 wherein the step of passing includes the step of passing molten material through two filters which are spaced from one another.

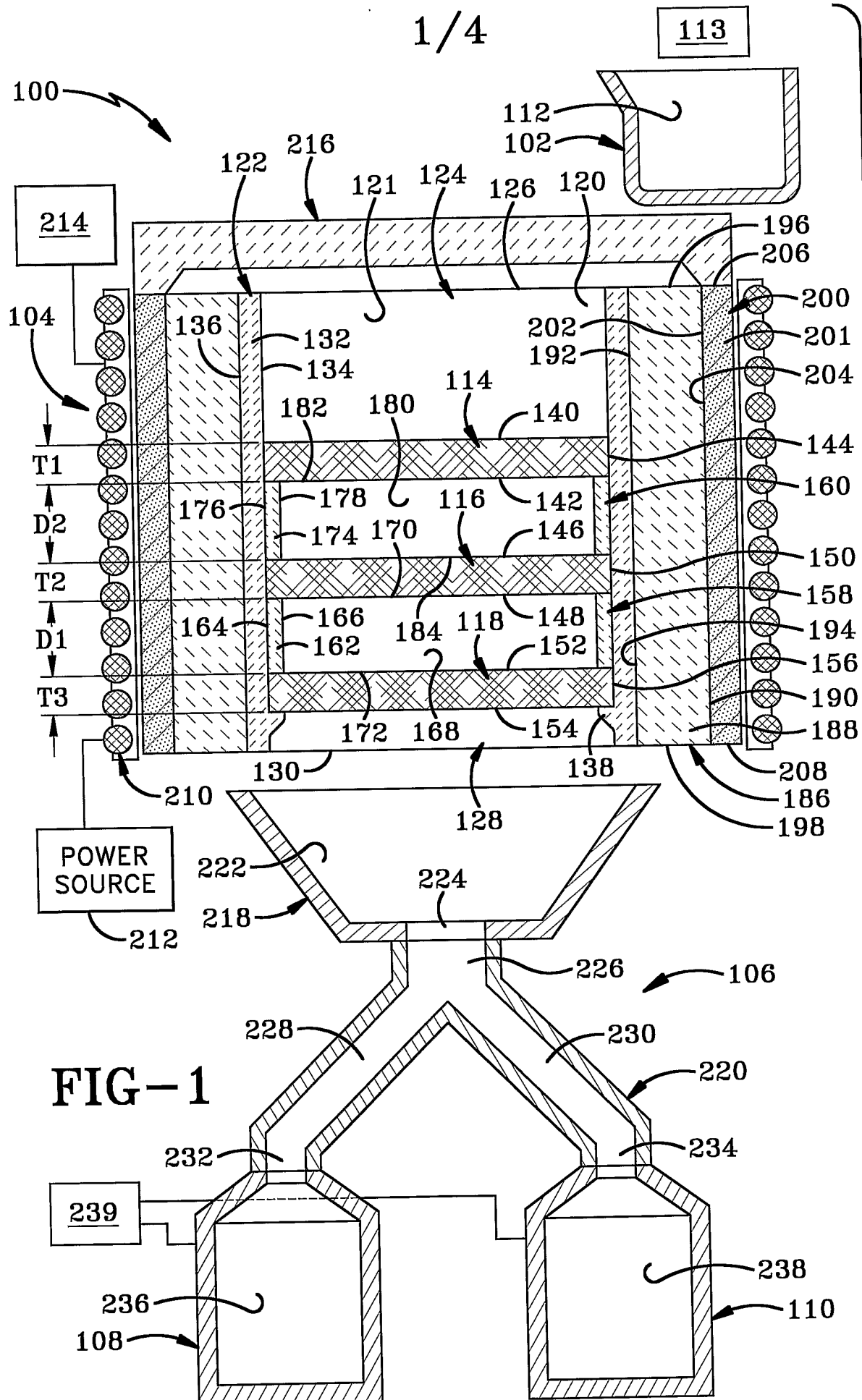
16. The method of claim 15 wherein the step of passing includes the step of passing molten material through two filters which are spaced from one another by a spacer disposed within the filter vessel between the two filters.

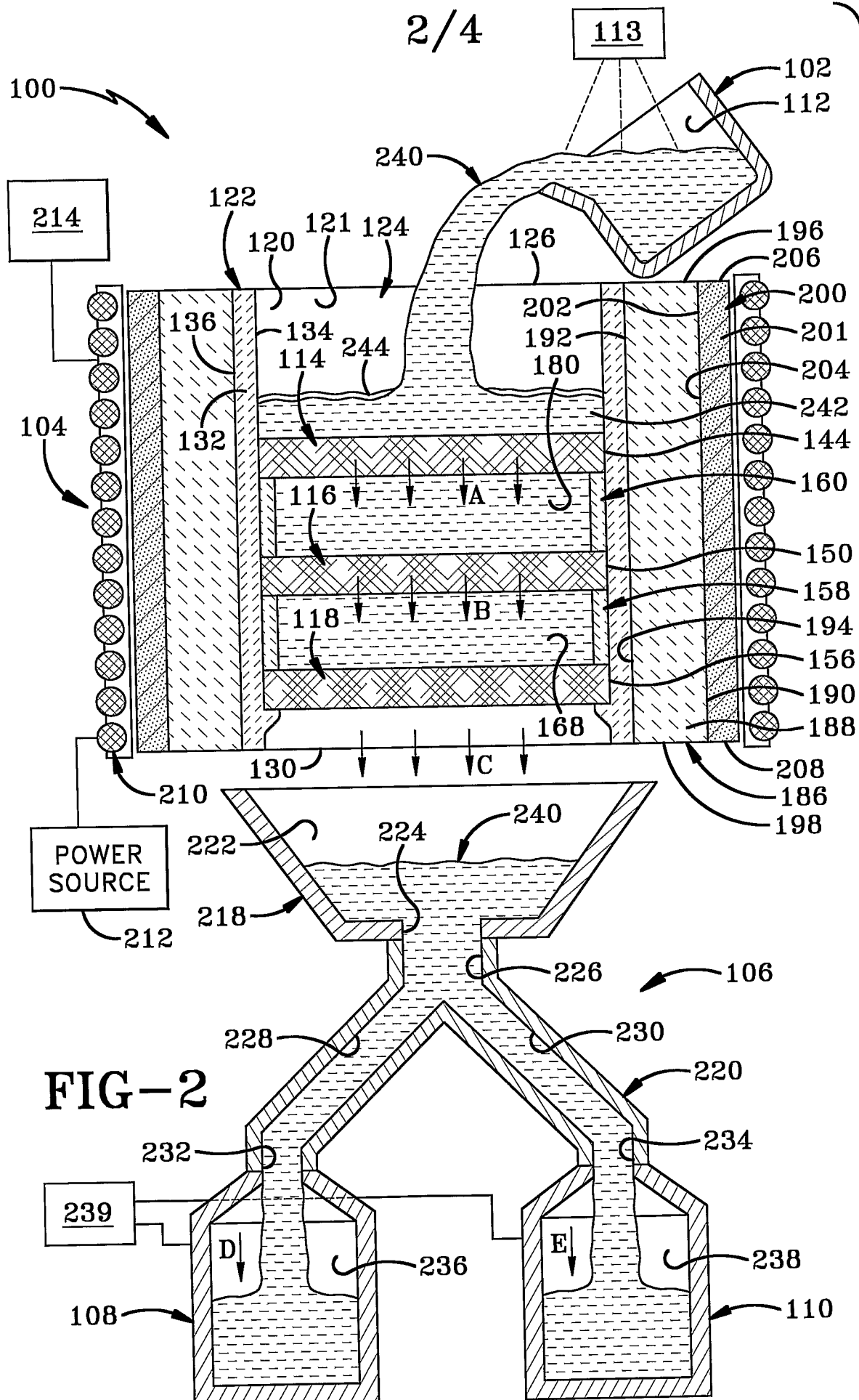
10 17. The method of claim 12 wherein the step of passing includes the step of passing molten material through at least one filter in such a manner to allow a head of molten material to form whereby dross floats to the top of the head of molten material.

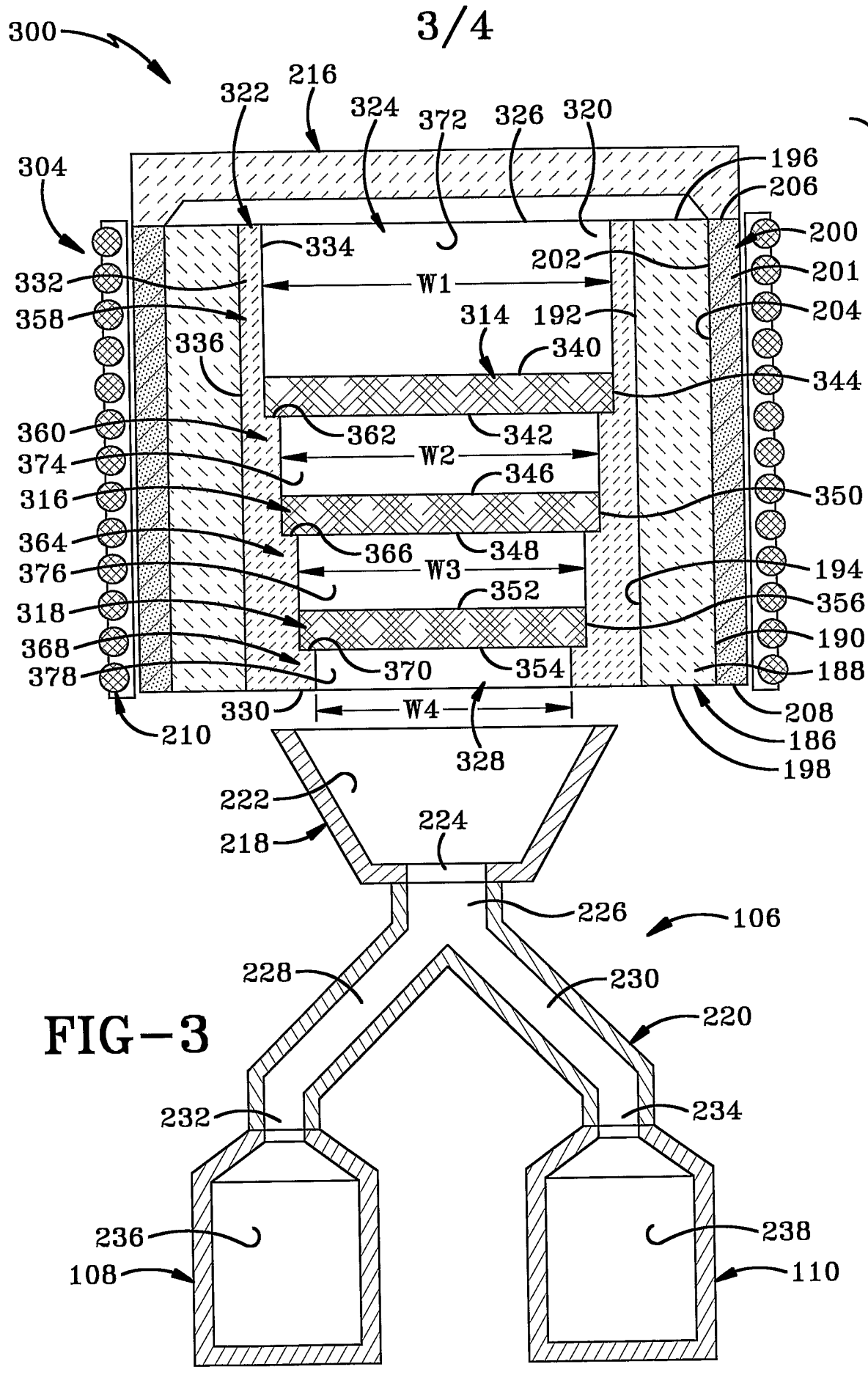
15 18. The method of claim 17 wherein the step of transferring includes the step of transferring molten material and the dross out of the filter vessel so that molten material enters a mold and the dross remains in a structure intermediate the filter vessel and the mold.

20 19. The method of claim 12 wherein the step of passing includes the step of passing molten material through at least one preheated filter having at least twenty pores per inch.

25 20. The method of claim 12 further including the step of pre-heating the at least one filter to a filter temperature which will prevent breakage of the filter due to thermal shock from contact with the molten material.







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