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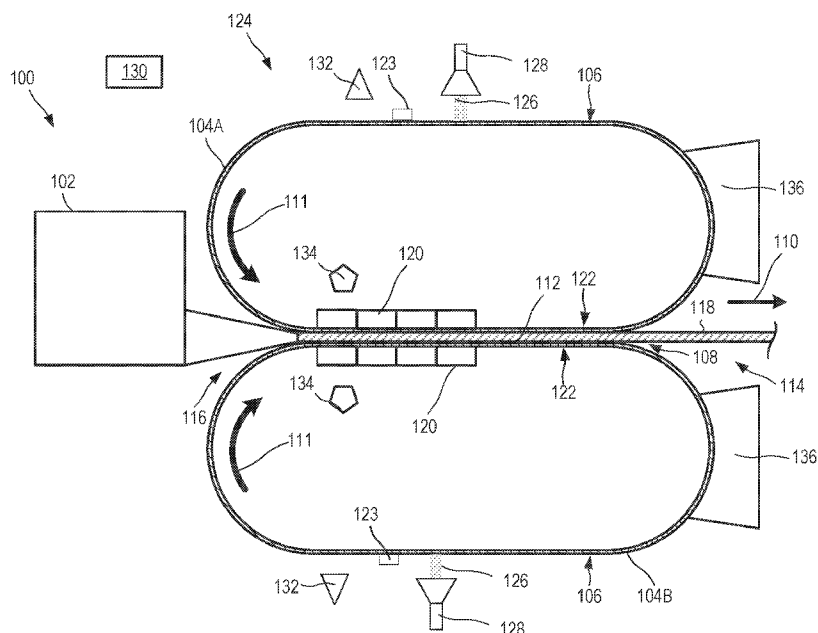


FIG. 1

(57) Abstract: A continuous belt casting system may control heat flux during casting by controlling an application of a parting agent on an elongated belt surface of a casting belt. A method of casting a metal slab includes introducing molten metal into a casting cavity defined by two casting belts, advancing the molten metal through the casting cavity by advancing the casting belts and such that the molten metal solidifies and while controlling heat flux by controlling an application of a parting agent on at least one of the two casting belts, causing the solidified metal to emerge from an exit of the casting cavity as a metal slab.

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BELT CASTING SYSTEMS AND METHODS WITH PARTING AGENT CONTROL**REFERENCE TO RELATED APPLICATION**

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/510,185, filed on June 26, 2023, and entitled BELT CASTING SYSTEMS AND METHODS WITH PARTING AGENT CONTROL, the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] This application relates to continuous belt casters, and, more specifically, to systems and methods for controlling heat flux and exit temperature in belt casting.

BACKGROUND

[0003] Continuous belt casters, such as twin belt casters, single belt casters, and recirculating block casters, are commonly used to produce cast metal articles from molten metal including but not limited to aluminum and aluminum alloys. In continuous belt casters, a casting cavity is formed between continuously moving casting surfaces. During the casting process, molten metal is introduced into the casting cavity (typically on a continuous basis). Heat is removed from the metal by the elongated belt surfaces and the metal solidifies into the metal article, which is continuously withdrawn from the casting cavity by the moving casting surfaces. Traditional belt casting techniques do not monitor heat flux during casting.

SUMMARY

[0004] Embodiments covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various embodiments and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings, and each claim.

[0005] According to certain embodiments, a continuous belt casting system includes a casting belt with an elongated belt surface and a parting agent control system with a parting agent applicator for applying a parting agent on the elongated belt surface and a controller for controlling heat flux during casting by controlling application of the parting agent on the elongated belt surface during casting.

[0006] According to various embodiments, a continuous belt casting system includes a sensor for detecting heat flux in a caster of the continuous belt casting system and a parting agent control system for controlling heat flux during casting by controlling an application of a parting agent on an elongated belt surface of a casting belt based on the detected heat flux.

[0007] According to certain embodiments, a method of casting a metal slab includes introducing molten metal into a casting cavity defined by two casting belts. The method includes advancing the molten metal through the casting cavity by advancing the casting belts and such that the molten metal solidifies while controlling heat flux by controlling an application of a parting agent on at least one of the two casting belts. The method further includes causing the solidified metal to emerge from an exit of the casting cavity as a metal slab.

[0008] Various implementations described herein can include additional systems, methods, features, and advantages, which cannot necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The specification makes reference to the following appended figures, in which use of like reference numerals in different figures is intended to illustrate like or analogous components.

[0010] FIG. 1 illustrates a continuous belt casting system with a parting agent control system according to embodiments.

[0011] FIG. 2 is a top view of a portion of the continuous belt casting system of FIG. 1.

[0012] FIG. 3 is a top view of a portion of another continuous belt casting system with a parting agent control system according to embodiments.

[0013] FIG. 4 illustrates a method of controlling heat flux during casting using the continuous belt system of FIG. 1 according to embodiments.

DETAILED DESCRIPTION

[0014] Described herein are systems and methods for controlling heat flux during casting of a metal slab using a continuous belt casting system. In various embodiments, the systems and methods described herein control heat flux during casting by controlling an application of a parting agent on an elongated belt surface of one or more casting belts of the continuous belt casting system. Compared to traditional approaches in which heat flux is not monitored or controlled during casting, the systems and methods described herein provide on-line, real time control of heat flux and exit temperature of the metal slab, thereby providing metal slabs with improved quality and uniformity. In various embodiments, the systems and methods described herein may allow for the creation of a desired temperature profile across a width of the metal slab by controlling the parting agent application in a width direction. Additionally, or alternatively, controlling the parting agent application using the systems and methods described herein may allow the system to minimize and/or eliminate temperature gradients in the width direction that are common issues of traditional systems. As an example, while a traditional system may produce a cast slab that is generally cooler in the center than in the edges, the systems and methods described herein may minimize and/or eliminate the cross-width temperature differences by applying different amounts or levels of parting agent across the width of the casting belt. The systems and methods described herein may allow an exit temperature of the cast slab to be more accurately controlled by applying a known amount of parting agent, which, in certain embodiments, may reduce the time required to get to a steady state exit temperature and thereby increase productivity. In various embodiments, the systems and methods described herein may allow for casting of a good quality slab independent of incoming metal temperature. Various other benefits and advantages may be realized with the systems and methods described herein, and the aforementioned benefits and advantages should not be considered limiting.

[0015] FIG. 1 illustrates an example of a continuous belt casting system 100. The particular arrangement or components illustrated in FIG. 1 should not be considered limiting. The continuous belt casting system 100 generally includes a molten metal source 102 and endless casting belts 104A-B.

[0016] In some examples, metal 112 from the molten metal source 102 may be an aluminum or an aluminum alloy in the 1xxx series, 2xxx series, 3xxx series, 4xxx series, 5xxx series, 6xxx series, 7xxx series, 8xxx series and/or any other aluminum or aluminum alloy as desired.

[0017] The endless casting belts 104A-B may be supported on pulleys or other suitable support structures and may be driven by various suitable driving mechanisms. The support structures and driving mechanisms have been omitted from FIG. 1 for simplicity. The casting belts 104A-B may be constructed from various suitable materials, and in some cases may be constructed from suitable metals that may be sufficiently tensioned. In some examples, the casting belts 104A-B may be constructed from steel, iron, iron alloys, copper, copper alloys, aluminum, aluminum alloys, and/or various other suitable metal or non-metal material for belt casting.

[0018] Each endless casting belt 104A-B includes an elongated belt surface 106 that at least partially forms a casting cavity 108. Although not shown, an edge or side dam is provided at each side of the system 100 so as to complete the enclosure of the casting cavity 108 at its edges. The endless casting belts 104A-B may be arranged substantially parallel, although they need not be parallel in other examples. In some examples, the endless casting belts 104A-B may converge towards an exit 114 of the casting cavity 108. In various cases, the endless casting belts 104A-B are run at substantially the same speed such that the casting cavity 108 forms a moving mold that is static relative to metal that is introduced into the casting cavity 108 and as the metal passes through the casting cavity 108.

[0019] One or more coolant nozzles 120 may be provided to cool a rear side or surface 122 of each casting belt 104A-B opposite from the elongated belt surface 106 by applying coolant. Applying the coolant in turn removes heat from the metal in the casting cavity 108. In various embodiments, the one or more coolant nozzles 120 may include one or more coolant inlets for introducing the coolant and one or more coolant outlets or drains for removing coolant. The coolant may be various types of coolant as desired suitable for cooling of the casting belts 104A-B, and in one non-limiting example the coolant may be water. The one or more coolant nozzles 120 may be provided in various arrangements both in the casting direction 110 and in a width direction relative to the casting belts 104A-B. As such, number, shape, and arrangement of the one or more coolant nozzles 120 should not be considered limiting.

[0020] During casting, the endless casting belts 104A-B may be rotated (represented by arrows 111) and molten metal 112 is introduced from the molten metal source 102 at an entrance 116 of the casting cavity 108. The molten metal 112 may be various metals as desired, including but not limited to aluminum, aluminum alloys, steel, or other metals as desired. The metal 112 advances through the casting cavity 108 in a casting direction 110 via the endless casting belts 104A-B. As the metal advances through the casting cavity 108, heat from the metal is transferred through the belts, and the molten metal becomes progressively solidified. The metal 112 may be fully solidified before it reaches the exit 114 and may emerge from the exit 114 as a continuous, solid cast metal substrate or slab 118.

[0021] In certain embodiments, the continuous belt casting system 100 includes a control system 124 for controlling the heat flux within the continuous belt casting system 100 and the exit temperature of the metal slab 118. In certain embodiments, and as discussed in detail below, the control system 124 controls the heat flux by controlling an application of a parting agent 126 on one or more of the casting belts 104A-B. The parting agent 126 may be various parting agents as desired, and in certain embodiments, the parting agent 126 is a fluid or liquid parting agent.

[0022] As illustrated in FIGS. 1 and 2, in various embodiments, the control system 124 includes one or more parting agent applicators 128 and a controller 130. In certain embodiments, the control system 124 includes one or more parting agent sensors 132, one or more temperature sensors 134, and one or more parting agent removal devices 136. In certain embodiments, each casting belt 104 may include at least one parting agent applicator 128, at least one parting agent sensor 132, and at least one parting agent removal device 136.

[0023] The parting agent applicator 128 may be various devices or systems suitable for applying the parting agent 126 on the belt surface(s) 106. The parting agent applicators 128 may be provided at various locations along the casting belts 104A-B suitable for applying the parting agent 126 on the belt surfaces 106. In the embodiment illustrated in FIGS. 1 and 2, the parting agent applicators 128 are on sides of the casting belts 104A-B opposite from the casting cavity 108. Optionally, the parting agent applicators 128 are more proximate to the entrance 116 than the exit 114, although they need not be in other embodiments.

[0024] As best illustrated in FIG. 2, the parting agent applicators 128 may be arranged to apply the parting agent 126 across a width 138 of each belt surface 106 and before the belt surface 106

contacts the molten metal 112. While a single parting agent applicator 128 is illustrated as extending across the complete width 138 of a particular casting belt 104, in other embodiments, two or more parting agent applicators 128 may extend across the width 138 of a particular casting belt 104. Moreover, where a plurality of parting agent applicators 128 are utilized, they need not necessarily be aligned along the width 138. As a non-limiting example, FIG. 3 illustrates another example of a continuous belt casting system 300 that is substantially similar to the continuous belt casting system 100 except that the control system 124 includes three parting agent applicators 128, and the parting agent applicators are not aligned across the width 138 of the belt surface 106.

[0025] Optionally, and as illustrated in FIGS. 1 and 2, the control system 124 includes one or more parting agent distributors 123 downstream or after the parting agent applicator 128. The parting agent distributors may further smooth and/or redistribute the parting agent 126 on the belt surface 106, e.g., to further provide a desired distribution, pattern, arrangement, coverage, etc. of the parting agent 126 on the belt surface 106. Non-limiting examples of parting agent distributors 123 include wipers, blades, rolls, combinations thereof, and/or other suitable devices as desired. In some non-limiting examples, the parting agent distributors 123 optionally distribute the parting agent 126 without contacting the belt surface 106 (e.g., they are offset a distance from the belt surface 106), although they need not be offset in other examples.

[0026] The parting agent sensors 132 may be various devices or mechanisms suitable for detecting the parting agent 126 on the belt surfaces 106 and/or characteristics of the parting agent 126 after the parting agent 126 is applied by the parting agent applicators 128. As non-limiting examples, the parting agent sensors 132 may be devices or mechanisms suitable for detecting a level or amount of parting agent 126 on the belt surfaces 106, a distribution or pattern of the parting agent 126 across the width 138, combinations thereof, and/or other devices or mechanisms as desired. The number and location of the parting agent sensors 132 illustrated should not be considered limiting. In some examples, the parting agent sensors 132 may be downstream from the corresponding parting agent applicators 128 along the direction of movement 111 of the casting belts 104, which optionally may be in an upstream direction relative to the casting direction 110. In the embodiment illustrated, the parting agent sensors 132 are on the same side of the casting belts 104A-B as the parting agent applicators 128 and between the parting agent applicators 128 and the entrance 116. In some embodiments, the parting agent sensors 132 may be movable relative

to the belts 104A-B. As non-limiting examples, the parting agent sensors 132 may traverse across the belts 104A-B via a sliding mechanism and/or other suitable mechanism as desired and allowing the parting agent sensors 132 to measure the parting agent level across the belt width.

[0027] The parting agent removal devices 136 may be devices or mechanisms suitable for removing the parting agent 126 the elongated belt surface before the application of the parting agent 126 by the parting agent applicator 128. In various embodiments, the parting agent removal devices 136 remove the parting agent 126 with every revolution of the casting belts 104A-B. In certain embodiments, the parting agent removal devices 136 may be downstream from the casting cavity 108. In other words, the parting agent removal devices 136 will encounter the belt surfaces 106 after they exit the casting cavity 108 (e.g., to remove the parting agent) before the belt surfaces 106 are recirculated to the parting agent applicators 128. The parting agent removal devices 136 make it possible to remove a contaminated or otherwise used layer of parting agent from the belt surface quickly, efficiently, and continuously so that the belt surface 106 of the belt 104 emerging from the casting cavity 108 is completely clean and ready for the application of a fresh new layer of parting agent before receiving molten metal once again. Non-limiting examples of parting agent removal devices 136 may include contact devices or mechanisms (e.g., wipers, scrapers, etc.) and/or non-contact devices or mechanisms. As a non-limiting example, the parting agent removal devices 136 may include a spray assembly with nozzles (optionally within a housing) that direct a high pressure spray of a cleaning liquid onto the belt surface 106. In such embodiments, any residual cleaning liquid or parting agent may be removed by a scraper, doctor blade, and/or other suitable device. In various embodiments, removal of the parting agent 126 by the parting agent removal devices 136 and application of fresh parting agent 126 by the parting agent applicators 128 may allow for improved control of heat flux by the control system 124 as the amount, distribution, and quality of the parting agent 126 may be controlled by the parting agent applicators 128.

[0028] The one or more temperature sensors 134 may be various devices or mechanisms suitable for detecting or calculating the heat flux at various locations within the casting cavity 108. In various embodiments, the temperature sensors 134 may directly measure the heat flux or may indirectly determine the heat flux. As such, the number, type, and location of temperature sensors 134 should not be considered limiting. In various embodiments, the one or more temperature

sensors 134 may be utilized to determine a heat flux across a width of the casting cavity 108. In the embodiment illustrated in FIGS. 1 and 2, the temperature sensors 134 may measure or detect a coolant temperature at the coolant inlet(s) and the coolant outlet(s) of the one or more coolant nozzles 120, and the heat flux may be determined based on the difference in coolant outlet temperature and coolant inlet temperature. In various embodiments, the temperature sensors 134 may allow for a heat flux map of the casting cavity 108 to be generated, which may illustrate and/or otherwise indicate locations where heat is removed and the amount of heat removal at such locations. The mapping of the heat flux may be generated for one or both sides (e.g., top and/or bottom) of the casting cavity 108.

[0029] The controller 130 may include one or more processing units and/or one or more memory devices. The processing unit may be various suitable processing devices or combinations of devices including but not limited to one or more application specific integrated circuits, digital signal processors, digital signal processing devices, programmable logic devices, field programmable gate arrays, processors, controllers, micro-controllers, microprocessors, other electronic units, and/or a combination thereof. The one or more memory devices may be any machine-readable medium that can be accessed by the processor, including but not limited to any type of long term, short term, volatile, nonvolatile, or other storage medium, and is not to be limited to any particular type of memory or number of memories, or type of media upon which memory is stored. Moreover, as disclosed herein, the terms “storage medium,” “storage” or “memory” can represent one or more memories for storing data, including read only memory (ROM), random access memory (RAM), magnetic RAM, core memory, magnetic disk storage mediums, optical storage mediums, flash memory devices and/or other machine readable mediums for storing information. The term “machine-readable medium” includes, but is not limited to, portable or fixed storage devices, optical storage devices, wireless channels, and/or various other storage mediums capable of storing that contain or carry instruction(s) and/or data. In certain embodiments, the controller 130 optionally includes an associated user interface, including but not limited to a graphical user interface or a human machine interface, such that the controller 130 may obtain information from a user and/or provide information to the user. In such embodiments, the user interface and/or human machine interface may be on the controller 130 itself or may be at a location remote from the controller 130.

[0030] The controller 130 may be communicatively coupled to the one or more temperature sensors 134 such that the controller 130 receives the temperature data and/or data corresponding to heat flux. Communication between the controller 130 and the one or more temperature sensors 134 may be various types of communication as desired, such as but not limited to wired communication and/or wireless communication (e.g., near field, cellular, Wi-Fi, Bluetooth®, Bluetooth Low Energy, etc.).

[0031] In various embodiments, the controller 130 may determine heat flux at one or more locations within the casting cavity 108 and/or may determine heat flux profile, mapping, etc. based on the information from the temperature sensors 134. In certain embodiments, the controller 130 may determine a heat flux profile across a width of the casting cavity 108 at one or more locations. In various embodiments, based on the determined heat flux, the controller 130 may determine a control response for the parting agent applicator 128 for controlling one or more characteristics of the application of the parting agent 126 on the belt surface 106. In some embodiments, the control response may be based on a comparison of the detected heat flux with a desired heat flux, which may be provided, calculated based on input data, and/or otherwise determined or input as desired. Non-limiting examples of the control response may include, but are not limited to, controlling a flow rate of the parting agent 126 from the parting agent applicator 128, an application profile or distribution of the parting agent 126 across the width of the belt surface 106, a type of parting agent 126, a location of the parting agent 126, combinations thereof, and/or as otherwise desired. In various embodiments, controlling the application of the parting agent 126 controls the amount of heat removed in the casting cavity 108, and an optimal and/or desired heat flux can be obtained. In one non-limiting example, the controller 130 may control the parting agent applicator 128 to minimize and/or eliminate a temperature gradient across the width of the casting cavity 108.

[0032] FIG. 4 generally illustrates a method 400 of controlling heat flux during casting using the continuous belt casting system 100. The method is for illustrative purposes, and other methods and controls may be implemented using the systems described herein. The method may be implemented in whole or in part by one or more computer systems. The one or more computer systems may comprise or be coupled with a system that monitors and/or controls casting operations and/or the parting agent application.

[0033] In a block 402, the method includes receiving information related to actual heat flux within the casting cavity 108. The actual heat flux may be the heat flux for a single location, a plurality of locations, a distribution (e.g., across a width of the casting cavity 108), a mapping of the entire casting cavity 108, and/or as otherwise desired. In various embodiments, block 402 includes receiving the information from the one or more temperature sensors 134 that directly or indirectly measures the heat flux within the casting cavity 108. In one non-limiting example, block 402 includes receiving a coolant inlet temperature and a coolant outlet temperature for the one or more coolant nozzles 120. In embodiments where the heat flux is not directly measured by the temperature sensors 134, block 402 may include determining an actual heat flux. As a non-limiting example, block 402 may include determining an actual heat flux based on a difference between the coolant outlet temperature and the coolant inlet temperature.

[0034] In a block 404, the heat flux received and/or determined in block 402 is compared to a desired heat flux. In block 404, the desired heat flux may be provided (e.g., by an operator) and/or determined by the system as desired.

[0035] In a block 406, the method includes determining whether a parting agent control response is needed based on the comparison in block 404. Block 406 may include determining that a parting agent control response is needed based on a difference between the desired heat flux and the actual heat flux. Optionally, block 406 is based on additional heat flux information. Additional heat flux information may include, but is not limited to, a material of the casting belts 104 and/or a texture of the belt surfaces 106.

[0036] In a block 408, the method may include determining and implementing the parting agent control response. Block 408 may include, but is not limited to, controlling a type of parting agent, a location of application of the parting agent, a coverage of the parting agent, an amount of the parting agent, a distribution of the parting agent, combinations thereof, and/or other control responses as desired.

[0037] In a block 410, the method may continue while control of the heat flux is desired.

[0038] Other controls may be implemented using the systems described herein, and the aforementioned examples should not be considered limiting. As a non-limiting example, a nominal strip temperature may be controlled by controlling the parting agent and/or application of the parting agent on the belt surfaces. In this example, a temperature sensor may measure, calculate,

and/or monitor a temperature of the metal substrate 118 exiting the belt casting system 100. In certain embodiments, the measured, calculated, and/or monitored temperature of the metal substrate 118 may be compared to a desired strip temperature. Based on a deviation of the actual strip temperature from the desired strip temperature (e.g., the actual temperature is outside of a threshold), the amount, location, pattern, and/or general distribution of the parting agent 126 dispensed may be controlled such that the metal substrate 118 has a desired temperature.

[0039] A collection of exemplary embodiments is provided below, including at least some explicitly enumerated as an “Illustration” providing additional description of a variety of example embodiments in accordance with the concepts described herein. These illustrations are not meant to be mutually exclusive, exhaustive, or restrictive; and the disclosure not limited to these example illustrations but rather encompasses all possible modifications and variations within the scope of the issued claims and their equivalents.

[0040] Illustration 1. A continuous belt casting system comprising: a casting belt comprising an elongated belt surface; and a parting agent control system comprising: a parting agent applicator configured to apply a parting agent on the elongated belt surface; and a controller configured to control heat flux during casting by controlling application of the parting agent on the elongated belt surface during casting.

[0041] Illustration 2. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, further comprising a parting agent sensor configured to detect the parting agent on the elongated belt surface, wherein the parting agent sensor is downstream from the parting agent applicator along a direction of movement of the casting belt.

[0042] Illustration 3. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, further comprising a sensor configured to detect a heat flux within the continuous belt casting system, wherein the controller is configured to control the application of the parting agent based on the detected heat flux.

[0043] Illustration 4. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the controller is configured to control the application of the parting agent across a width of the elongated belt surface.

[0044] Illustration 5. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the casting belt at least partially defines a casting cavity, and wherein the parting agent application is configured to apply the parting agent on the elongated belt surface opposite from the casting cavity.

[0045] Illustration 6. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, further comprising a parting agent removal device configured to remove the parting agent from the elongated belt surface downstream from the parting agent applicator.

[0046] Illustration 7. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the parting agent removal device is configured to remove the parting agent with every revolution of the casting belt.

[0047] Illustration 8. A continuous belt casting system comprising: a sensor for detecting heat flux in a caster of the continuous belt casting system; and a parting agent control system configured to control heat flux during casting by controlling an application of a parting agent on an elongated belt surface of a casting belt based on the detected heat flux.

[0048] Illustration 9. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the sensor is configured to detect heat flux across a width of the casting belt.

[0049] Illustration 10. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the sensor is configured to detect heat flux based on a difference between a coolant inlet temperature and a coolant outlet temperature for one or more cooling nozzles.

[0050] Illustration 11. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the parting agent control system comprises: a parting agent applicator configured to apply the parting agent on the elongated belt surface; and a controller configured to control application of the parting agent on the elongated belt surface during casting.

[0051] Illustration 12. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the parting agent control system further

comprises a parting agent sensor configured to detect the parting agent on the elongated belt surface, wherein the parting agent sensor is movable relative to the elongated belt surface.

[0052] Illustration 13. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the controller is configured to control the application of the parting agent across a width of the elongated belt surface.

[0053] Illustration 14. The continuous belt casting system of any preceding or subsequent illustration or combination of illustrations, wherein the parting agent control system comprises: a parting agent applicator configured to apply the parting agent on the elongated belt surface; and a parting agent removal device configured to remove the parting agent from the elongated belt surface before the application of the parting agent by the parting agent applicator.

[0054] Illustration 15. A method of casting a metal slab, the method comprising: introducing molten metal into a casting cavity defined by two casting belts; advancing the molten metal through the casting cavity by advancing the casting belts and such that the molten metal solidifies while controlling heat flux by controlling an application of a parting agent on at least one of the two casting belts; and causing the solidified metal to emerge from an exit of the casting cavity as a metal slab.

[0055] Illustration 16. The method of any preceding or subsequent illustration or combination of illustrations, wherein controlling the heat flux further comprises detecting heat flux; and controlling the application of the parting agent on an elongated belt surface of at least one of the two casting belts based on the detected heat flux.

[0056] Illustration 17. The method of any preceding or subsequent illustration or combination of illustrations, wherein controlling the application of the parting agent comprises applying the parting agent on an elongated belt surface of at least one of the two casting belts; and detecting the parting agent across a width of the elongated belt surface.

[0057] Illustration 18. The method of any preceding or subsequent illustration or combination of illustrations, further comprising removing the parting agent from the at least one of the two casting belts after a portion of the at least one of the two casting belts exits the casting cavity.

[0058] Illustration 19. The method of any preceding or subsequent illustration or combination of illustrations, wherein controlling the heat flux further comprises detecting the heat flux based on a coolant inlet temperature and a coolant outlet temperature for one or more cooling nozzles.

[0059] Illustration 20. The method of any preceding or subsequent illustration or combination of illustrations, wherein controlling the application of the parting agent comprises applying the parting agent on the at least one of the two casting belts opposite from the casting cavity.

[0060] As used herein, the terms “invention,” “the invention,” “this invention,” and “the present invention” are intended to refer broadly to all of the subject matter of this patent application and the claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below.

[0061] In this description, reference is made to alloys identified by AA numbers and other related designations, such as “series” or “5xxx.” For an understanding of the number designation system most commonly used in naming and identifying aluminum and its alloys, see “International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys” or “Registration Record of Aluminum Association Alloy Designations and Chemical Compositions Limits for Aluminum Alloys in the Form of Castings and Ingot,” both published by The Aluminum Association.

[0062] As used herein, the meaning of “a,” “an,” and “the” includes singular and plural references unless the context clearly dictates otherwise.

[0063] The subject matter of embodiments of the present disclosure is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described. Directional references such as “up,” “down,” “top,” “bottom,” “left,” “right,” “vertical,” “horizontal,” “lateral,” “longitudinal,” “front,” and “back,” among others, are intended to refer to the orientation as illustrated and described in the figure (or figures) to which the components and directions are referencing.

[0064] The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate embodiments of the invention, and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0065] The above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Many variations and modifications can be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure. Moreover, although specific terms are employed herein, as well as in the claims that follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described embodiments, nor the claims that follow.

CLAIMS

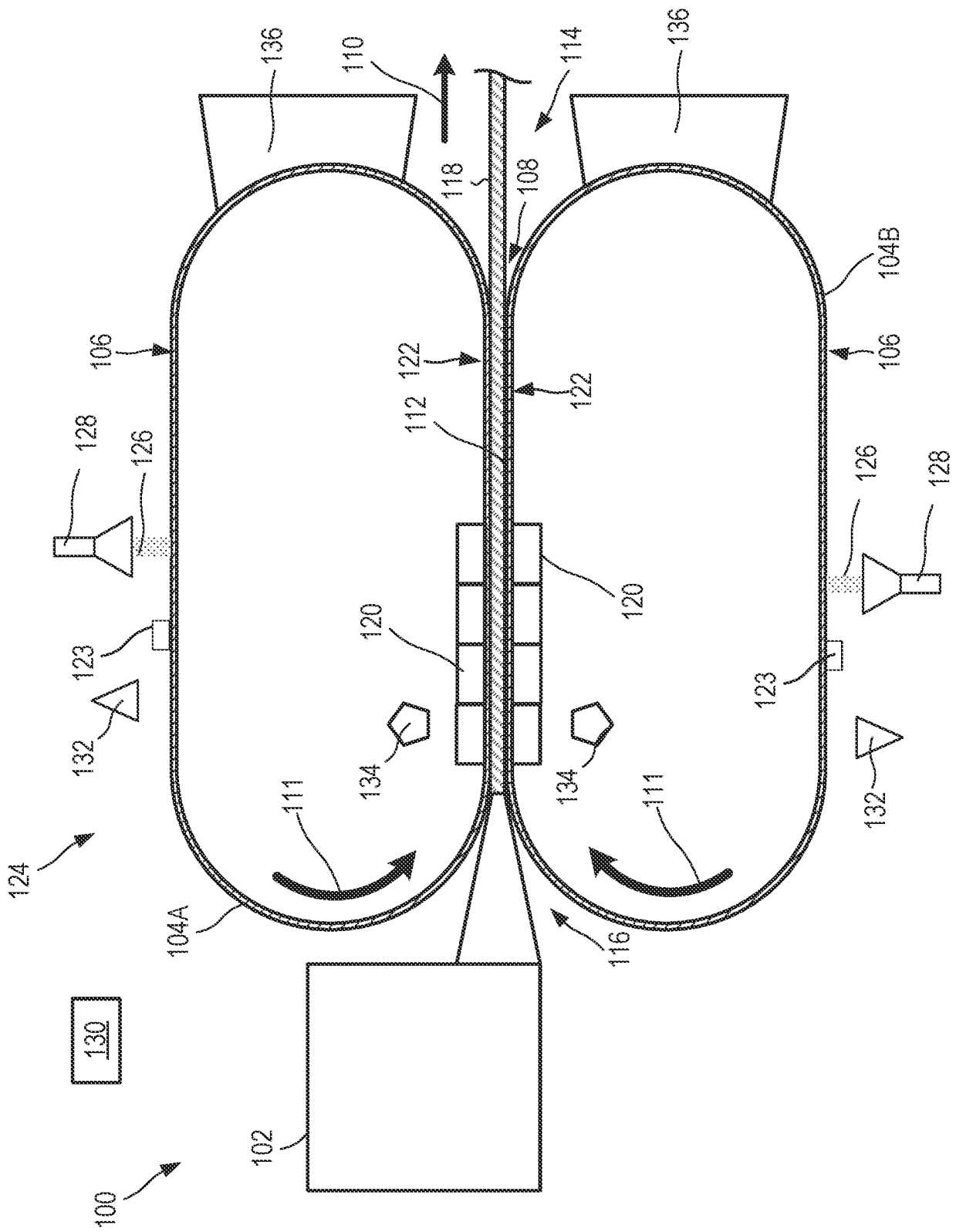
That which is claimed:

1. A continuous belt casting system comprising:
 - a casting belt comprising an elongated belt surface; and
 - a parting agent control system comprising:
 - a parting agent applicator configured to apply a parting agent on the elongated belt surface; and
 - a controller configured to control heat flux during casting by controlling application of the parting agent on the elongated belt surface during casting.
2. The continuous belt casting system of claim 1, further comprising a parting agent sensor configured to detect the parting agent on the elongated belt surface, wherein the parting agent sensor is downstream from the parting agent applicator along a direction of movement of the casting belt.
3. The continuous belt casting system of claim 1, further comprising a sensor configured to detect a heat flux within the continuous belt casting system, wherein the controller is configured to control the application of the parting agent based on the detected heat flux.
4. The continuous belt casting system of claim 1, wherein the controller is configured to control the application of the parting agent across a width of the elongated belt surface.
5. The continuous belt casting system of claim 1, wherein the casting belt at least partially defines a casting cavity, and wherein the parting agent application is configured to apply the parting agent on the elongated belt surface opposite from the casting cavity.
6. The continuous belt casting system of claim 1, further comprising a parting agent removal device configured to remove the parting agent from the elongated belt surface downstream from the parting agent applicator.

7. The continuous belt casting system of claim 6, wherein the parting agent removal device is configured to remove the parting agent with every revolution of the casting belt.
8. A continuous belt casting system comprising:
 - a sensor for detecting heat flux in a caster of the continuous belt casting system; and
 - a parting agent control system configured to control heat flux during casting by controlling an application of a parting agent on an elongated belt surface of a casting belt based on the detected heat flux.
9. The continuous belt casting system of claim 8, wherein the sensor is configured to detect heat flux across a width of the casting belt.
10. The continuous belt casting system of claim 8, wherein the sensor is configured to detect heat flux based on a difference between a coolant inlet temperature and a coolant outlet temperature for one or more cooling nozzles.
11. The continuous belt casting system of claim 8, wherein the parting agent control system comprises:
 - a parting agent applicator configured to apply the parting agent on the elongated belt surface; and
 - a controller configured to control application of the parting agent on the elongated belt surface during casting.
12. The continuous belt casting system of claim 11, wherein the parting agent control system further comprises a parting agent sensor configured to detect the parting agent on the elongated belt surface, wherein the parting agent sensor is movable relative to the elongated belt surface.
13. The continuous belt casting system of claim 11, wherein the controller is configured to control the application of the parting agent across a width of the elongated belt surface.

14. The continuous belt casting system of claim 8, wherein the parting agent control system comprises:
 - a parting agent applicator configured to apply the parting agent on the elongated belt surface; and
 - a parting agent removal device configured to remove the parting agent from the elongated belt surface before the application of the parting agent by the parting agent applicator.
15. A method of casting a metal slab, the method comprising:
 - introducing molten metal into a casting cavity defined by two casting belts;
 - advancing the molten metal through the casting cavity by advancing the casting belts and such that the molten metal solidifies while controlling heat flux by controlling an application of a parting agent on at least one of the two casting belts; and
 - causing the solidified metal to emerge from an exit of the casting cavity as a metal slab.
16. The method of claim 15, wherein controlling the heat flux further comprises:
 - detecting heat flux; and
 - controlling the application of the parting agent on an elongated belt surface of at least one of the two casting belts based on the detected heat flux.
17. The method of claim 15, wherein controlling the application of the parting agent comprises:
 - applying the parting agent on an elongated belt surface of at least one of the two casting belts; and
 - detecting the parting agent across a width of the elongated belt surface.
18. The method of claim 15, further comprising removing the parting agent from the at least one of the two casting belts after a portion of the at least one of the two casting belts exits the casting cavity.

19. The method of claim 15, wherein controlling the heat flux further comprises detecting the heat flux based on a coolant inlet temperature and a coolant outlet temperature for one or more cooling nozzles.
20. The method of claim 15, wherein controlling the application of the parting agent comprises applying the parting agent on the at least one of the two casting belts opposite from the casting cavity.



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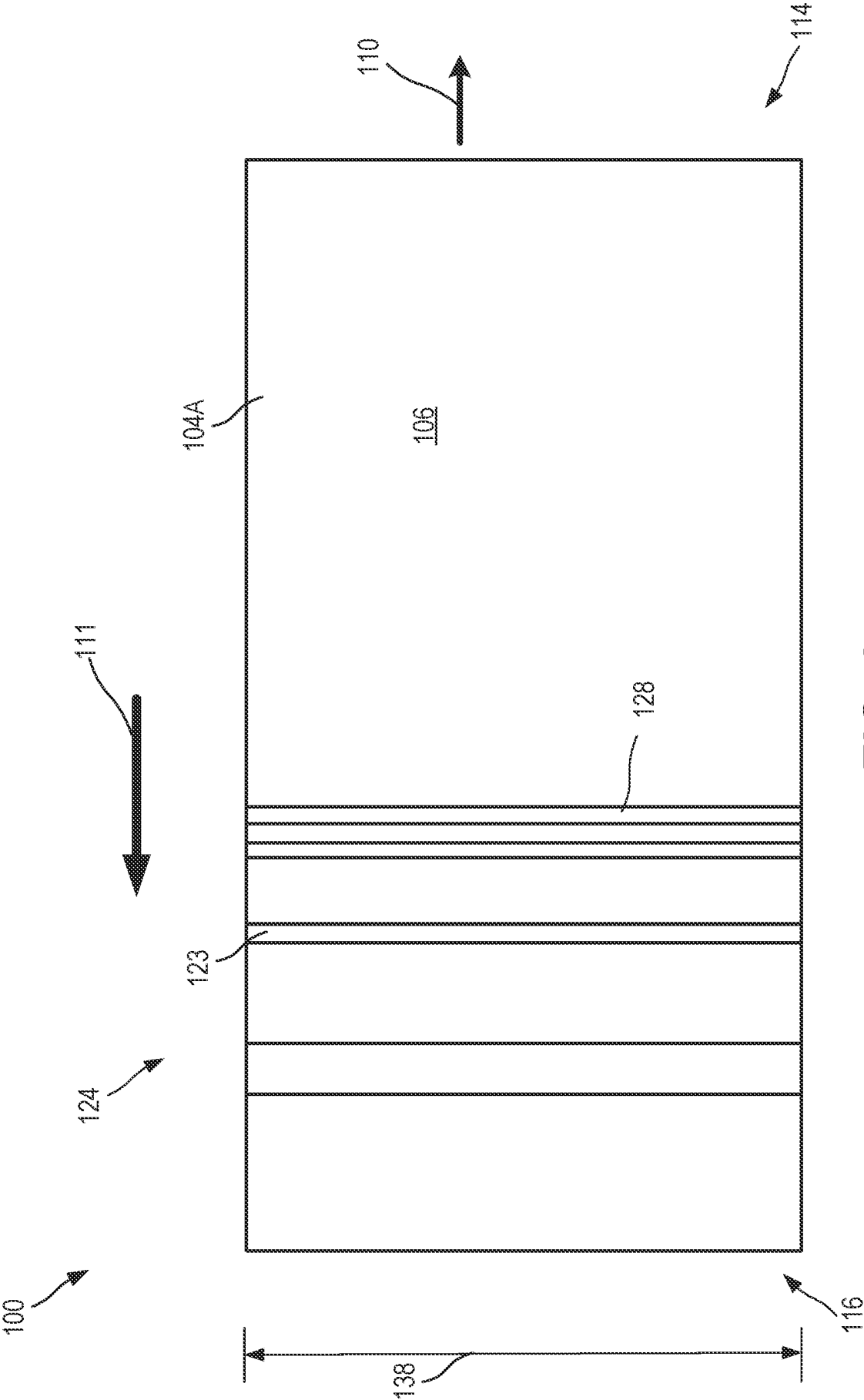


FIG. 2

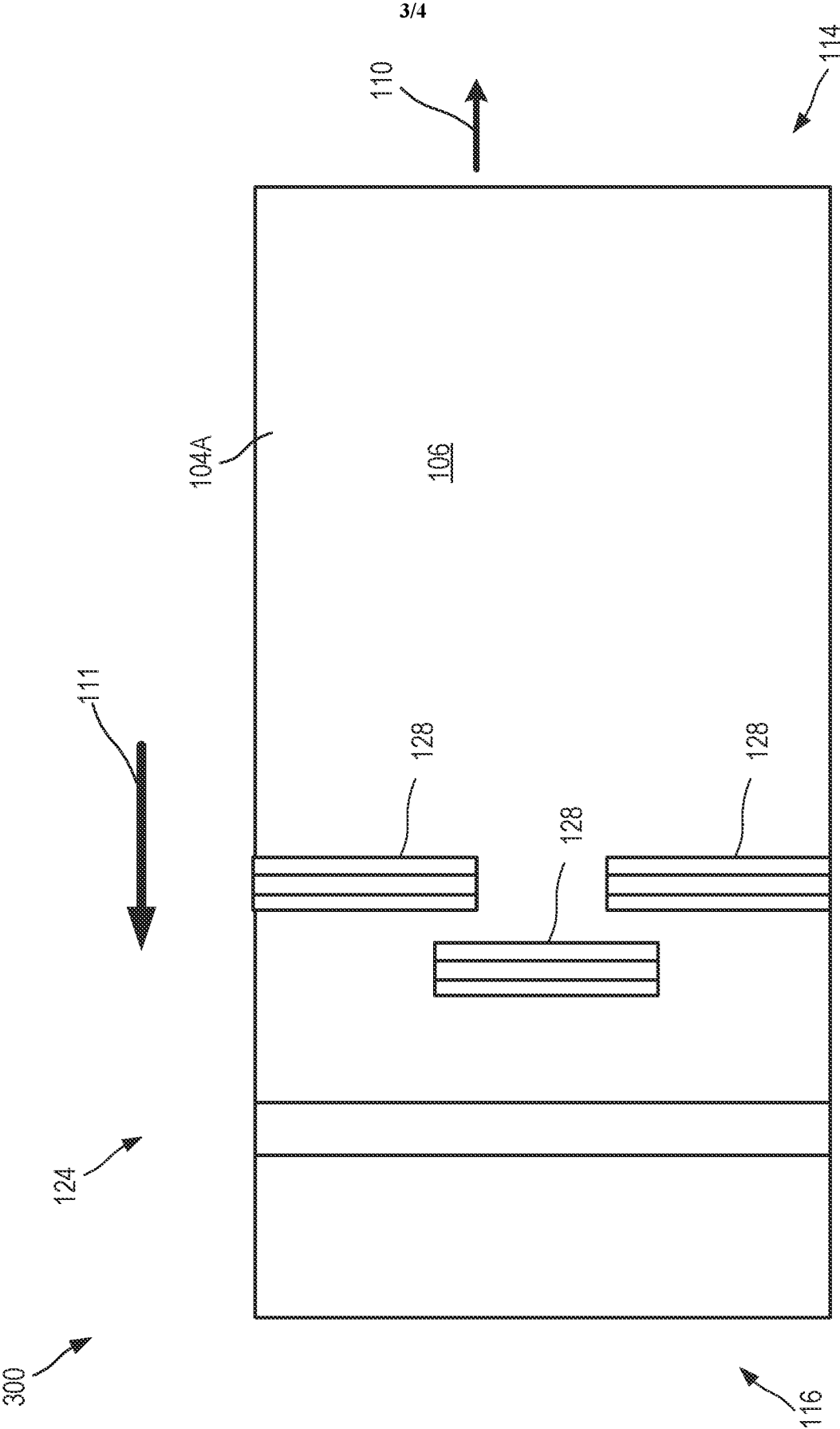


FIG. 3

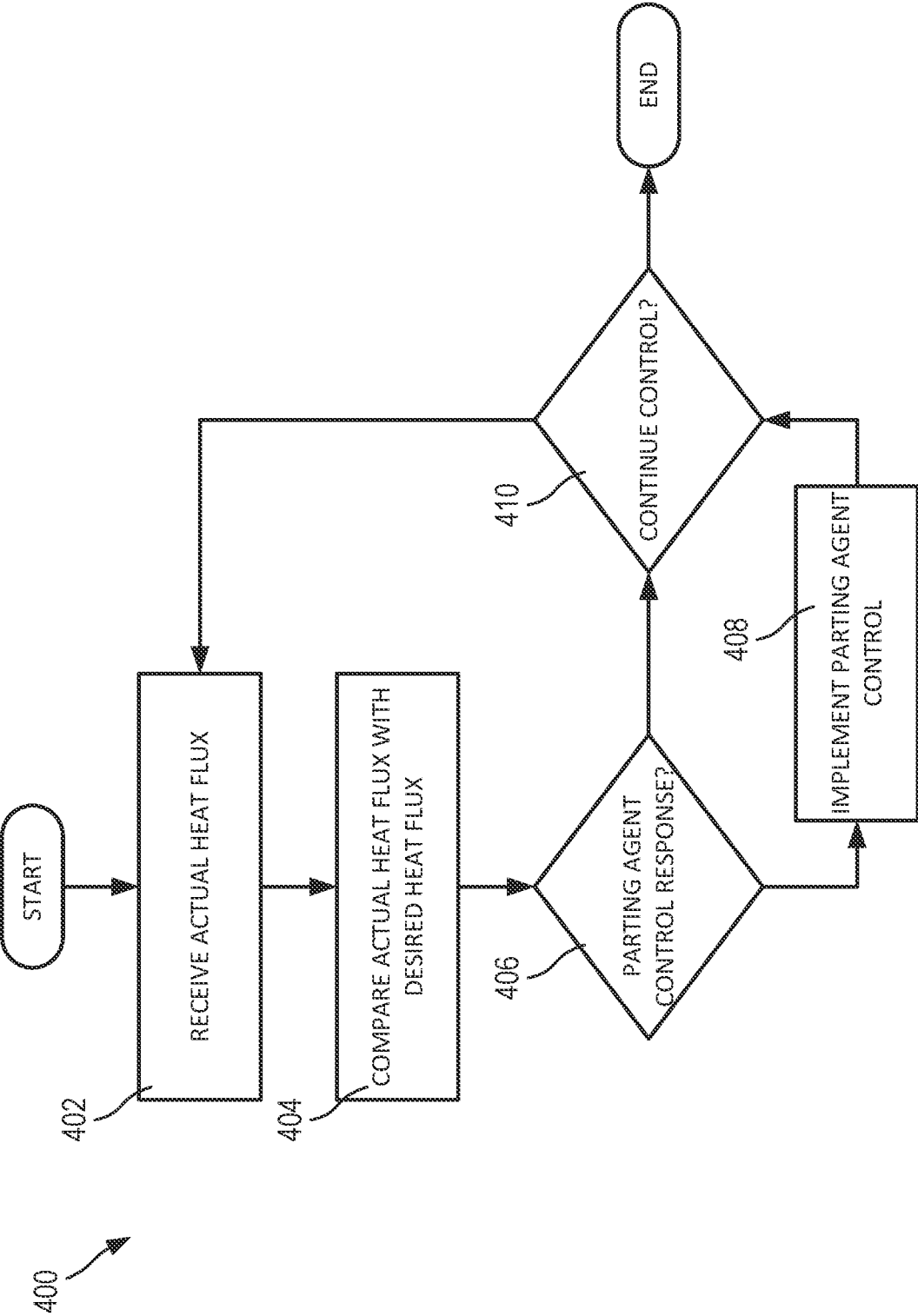


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/035323

A. CLASSIFICATION OF SUBJECT MATTER

INV. B22D11/06 B22D11/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP H01 249250 A (SUMITOMO HEAVY INDUSTRIES) 4 October 1989 (1989-10-04) claim 1; figure 3 see the machine translated appendix -----	1 - 20
X	US 6 354 364 B1 (RODER RUDOLF [CH] ET AL) 12 March 2002 (2002-03-12) figure 5 column 1; lines 12-28 column 14; lines 4-10 column 14; lines 29-42 -----	1 - 20
X	JP H01 313155 A (HITACHI LTD; KAWASAKI STEEL CO) 18 December 1989 (1989-12-18) claim 2; figure 1 see the machine translated appendix -----	1 - 20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

1 October 2024

Date of mailing of the international search report

30/10/2024

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/035323

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H01249250	A	04-10-1989	NONE
US 6354364	B1	12-03-2002	NONE
JP H01313155	A	18-12-1989	JP H059186 B2 04-02-1993
		JP H01313155 A	18-12-1989