(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
04 January 2024 (04.01.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/006604 A1

(51) International Patent Classification:
B22D 7/06 (2006.01) *B22D 11/055* (2006.01)
B22D 11/04 (2006.01) *B22D 11/06* (2006.01)
B22D 11/049 (2006.01) *B22D 11/124* (2006.01)

(21) International Application Number:
PCT/US2023/067743

(22) International Filing Date:
01 June 2023 (01.06.2023)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/367,061 27 June 2022 (27.06.2022) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,

(54) Title: SYSTEMS AND METHODS FOR STEAM CONDENSATION IN ALUMINUM DIRECT CHILL CASTING PIT

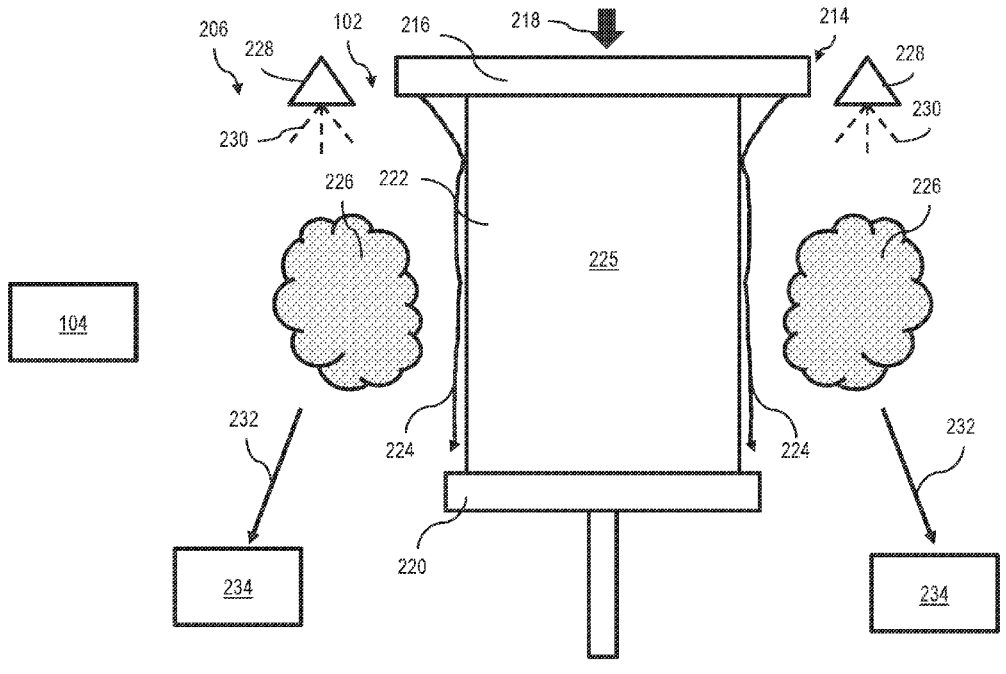


FIG. 2

(57) Abstract: A direct chill (DC) casting system may be used to cast a metal ingot from a molten metal such as aluminum or aluminum alloys. The DC casting system includes a steam condensation system that condenses steam generated during a DC casting process as recycled water. The recycled water may be used for subsequent cooling of the metal ingot during the DC casting process.

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[Continued on next page]

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

SYSTEMS AND METHODS FOR STEAM CONDENSATION IN ALUMINUM DIRECT CHILL CASTING PIT

REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/367,061, filed on June 27, 2022, and entitled SYSTEMS AND METHODS FOR STEAM CONDENSATION IN ALUMINUM DIRECT CHILL CASTING PIT, the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] This application relates to metal processing generally, and more specifically to steam-generating metal processing such as, but not limited to, direct chill casting.

BACKGROUND

[0003] Steam may be generated during various metal processes. As an example, a casting process such as direct chill (DC) casting may generate steam as the system directs water onto an ingot being cast for purposes of cooling the ingot. Some water may not turn into steam during such processing, and such water in liquid form may be re-cooled by a cooling system and used again during the casting process. Other water may turn into steam during cooling of the ingot. Within the casting pit, such steam may provide a safety hazard by reducing visibility before it is traditionally vented to the environment. Steam also may rise out of the casting pit and re-condense on the equipment around the casting pit and/or above the molten metal, which may reduce the life cycle of the equipment and potentially cause product defects on the head of the ingot. New or make-up water must be introduced into the system on a regular basis to compensate for the water that is lost as steam. Such new or make-up water requirements are costly from both a monetary perspective and a resource perspective.

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 various embodiments, a metal processing system for processing a metal substrate includes a steam condensation system for condensing steam generated during metal processing of the metal substrate.

[0006] According to certain embodiments, a DC casting system includes a steam condensation system for condensing steam generated during a DC casting process.

[0007] According to some embodiments, a DC casting system includes a cooling system that at least partially cools the metal ingot during a DC casting process. In certain embodiments, the cooling system may cool the metal ingot by directing water from a coolant supply onto the metal ingot. The cooling system may include a steam condensation system for condensing steam generated during a DC casting process.

[0008] According to various embodiments, a method of DC casting a metal ingot includes cooling the metal ingot emerging from a mold by directing water from a coolant supply onto the metal ingot and condensing steam generated by the cooling of the metal ingot as recycled water. The method includes providing the recycled water to the coolant supply.

[0009] According to certain embodiments, a metal processing system for processing a metal substrate includes a steam condensation system for directing a flow of steam generated during metal processing of the metal substrate by spraying water relative to a direction of the flow of the steam.

[0010] Various implementations described herein may 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

[0011] 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.

[0012] FIG. 1 is a block diagram of a metal processing system with a steam condensation system according to embodiments.

[0013] FIG. 2 illustrates a steam condensation system according to embodiments.

[0014] FIG. 3 illustrates a steam condensation system according to embodiments.

[0015] FIG. 4 illustrates a steam condensation system according to embodiments.

DETAILED DESCRIPTION

[0016] Described herein are systems and methods for condensing steam produced by a metal processing system, such as but not limited to a casting system such as a DC casting system. The systems and methods described herein may condense the steam as recycled water, and in some embodiments, the recycled water may be returned to a cooling system of the metal processing system such that the recycled water can be used for cooling of a metal substrate. The systems and methods described herein may reduce the amount of water that is conventionally lost to the environment, thereby reducing the amount of new or make-up water that needs to be introduced into the system. As such, the systems and methods provided herein may be less costly and less resource intensive compared to traditional metal processing systems that vent any steam generated as a byproduct of metal processing. The systems and methods described herein may also return the recycled water back to a cooling system of the metal casting system, thereby allowing the recycled water to be used as a coolant during a casting process. Various other benefits and advantages may be realized with the systems and methods provided herein, and the aforementioned advantages should not be considered limiting.

[0017] FIG. 1 illustrates a metal processing system 100 according to various embodiments. The metal processing system 100 includes one or more metal processing stations 102, a cooling system 104, and a steam condensation system 106.

[0018] The cooling system 104 provides a coolant such as liquid water to the metal processing station 102 (represented by arrow 108). The metal processing station 102 may be various metal processing devices, stations, workplaces, etc. as desired that utilize the water from the cooling system 104 to cool a metal substrate. The metal processing performed by the metal processing station 102 may generate steam (represented by arrow 110), and the steam condensation system 106 condenses the steam into recycled water. Optionally, and as represented by arrow 112, the steam condensation system 106 may provide the recycled

water back to the cooling system 104 such that the recycled water can be supplied to the metal processing station 102 as liquid water. The steam condensation system 106 may be various systems and devices for condensing the steam from the metal processing station 102, and non-limiting examples of steam condensation systems are discussed in detail below and illustrated in FIGS. 2-4.

[0019] FIG. 2 illustrates a non-limiting example in which the metal processing station 102 is a DC casting system 214. As illustrated in FIG. 2, the DC casting system 214 generally includes a casting pit with at least one open-ended mold 216 that defines a casting cavity, and molten metal may be introduced into the casting cavity as represented by arrow 218. The mold 216 is initially closed at a lower end by a bottom block 220, and the bottom block 220 remains in place until a certain amount of molten metal has built up in the casting cavity and begun to cool. The bottom block 220 is then moved away from the mold 216 such that an ingot 222 gradually emerges from the lower end of the mold 216. The ingot 222 may be produced with a desired length by movement of the bottom block 220 and correspondingly continuous supply of molten aluminum to the mold 216, limited only by the space available below the mold 216.

[0020] In various embodiments, the cooling system 104 may be in fluid communication with the mold 216 for supplying water or other coolant to the mold 216. The mold wall is typically cooled to provide cooling of the metal within the casting cavity. The ingot 222 emerging from the lower end of the mold 216 in DC casting is externally solid but is still molten in its central core. To maintain the periphery of the ingot and to promote internal cooling and solidification of the ingot, a coolant such as water 224 is directly applied onto a surface 225 of the ingot 222 emerging from the mold 216. In this procedure, the water 224 is directed onto the ingot surface 225. Some of the water 224 flows downwardly over the ingot surface 225 and the remaining water turns into steam 226. As previously mentioned, the steam 226 generated by DC casting is traditionally vented to the environment.

[0021] As illustrated in FIG. 2, a steam condensation system 206 is provided for processing of the steam 226. In the embodiment illustrated in FIG. 2, the steam condensation system 206 includes one or more nozzles or sprayers 228. The sprayers 228 are configured to spray water 230 into the casting pit for interaction with the steam 226, which in turn causes condensation of the steam 226 as recycled water (represented by arrows 232). In some embodiments, the sprayers 228 may spray the water 230 in various forms. In one non-limiting example, the sprayers 228 optionally spray the water 240 as fine droplets, although in other embodiments,

the sprayers 228 may introduce the water 230 into the casting pit for interaction with the steam 226 as desired. The sprayers 228 may be various types of nozzles as desired and may introduce the water 230 in various spray patterns as desired. As two non-limiting examples, the sprayers 228 may be nozzles that introduce the water 230 in a flat spray pattern, a hollow cone spray pattern, a full cone spray pattern, and/or other patterns as desired.

[0022] In addition to being various types of nozzles as desired, the number and location of the sprayers 228 should not be considered limiting as the steam condensation system 206 may include any number of sprayers 228 at various locations as desired. In certain embodiments, one or more of a type of nozzle, a location of the nozzle, and a number of nozzles may be controlled to control a rate and/or an amount of condensation of the steam 226. Additionally or alternatively, other control parameters of the sprayers 228 may be controlled for controlling the rate and/or amount of condensation of the steam 226, including but not limited to a pressure of the water 230, a flow rate of the water 230 to the sprayers 228, a temperature of the water 230 being dispensed, combinations thereof, and/or other control parameters as desired. The control parameters also may be controlled and/or changed during the casting process as the conditions of steam generation change. As a non-limiting example, a casting process may start out with low water flow, move to high water flow, and then have a reduced water flow during the casting process.

[0023] As mentioned, the water 230 dispensed by the sprayers 228 in turn causes condensation of the steam 226 into recycled water 232 (e.g., in liquid form). The water 232 may be collected using various devices, mechanisms, or techniques as desired, including but not limited to various collecting tanks 234, drains, suction devices, etc. as desired. The collected recycled water 232 optionally may be returned to the cooling system 204 such that the recycled water 232 may be re-cooled (if needed) and/or otherwise treated as desired. Such water 232 may then be supplied to the DC casting system 214 for cooling of the ingot 222 and/or for use by the sprayers 228. As mentioned, by condensing the steam 226 generated by the metal processing (e.g., DC casting), the system is able to re-use the recycled water 232 for subsequent cooling, thereby providing cost and resource savings.

[0024] FIG. 3 illustrates another example of a steam condensation system 306 for a metal processing system according to embodiments. In one non-limiting example, the steam condensation system 306 may be used with the DC casting system 214 in place of or in addition to the steam condensation system 206. In the embodiment of FIG. 3, the steam

condensation system 306 includes a conduit 336, and the steam 226 is condensed into recycled water within the conduit 336.

[0025] In certain embodiments, and as illustrated in FIG. 3, the conduit 336 includes one or more inlets 338. In some embodiments, the conduit 336 may be elongated between opposing ends 342, 344, and the one or more inlets 338 may be provided on a side wall 346 between the ends 342, 344. As represented by arrows 348, the steam 226 may enter the conduit 336 via the one or more inlets 338. The conduit 336 further includes one or more fluid outlets 356 for discharging the recycled water 232 after the steam 226 has been condensed within the conduit 336.

[0026] The steam condensation system 306 includes one or more devices or mechanisms for condensing the steam 226 within an internal region 352 of the conduit 336.

[0027] In some embodiments, and as illustrated in FIG. 3, the steam condensation system 306 includes one or more of the sprayers 228 for spraying the water 230 onto the steam 226 within the internal region 352. In certain embodiments, the sprayers 228 are within an internal region 352 of the conduit 336; however, in other embodiments, the sprayers 228 need not be within the internal region 352, and the sprayers 228 may direct the water 230 into the internal region 352. The number, type, and location of the sprayers 228 within and/or relative to the conduit 336 should not be considered limiting.

[0028] In some embodiments, the sprayers 228 and/or nozzles may be controlled such that the water 230 is directed in various directions relative to steam and/or air flow. In such embodiments, the sprayers 228 may further be utilized to assist in controlling the direction of steam and/or air flow. As non-limiting examples, the sprayers 228 and/or nozzles may be controlled such that the water 230 is directed (e.g., in droplet form or otherwise desired) parallel to steam and/or air flow, at a non-zero angle relative to steam and/or air flow, in a cross-flow direction relative to the steam and/or air flow, combinations thereof, and/or as otherwise desired. In certain embodiments, the angle or orientation of the sprayers 228 and/or nozzles may be adjustable such that the angle of water 230 from the sprayers 228 and/or nozzles (and thus the ability to control steam and/or air flow) is adjustable as desired. Such control may be achieved automatically (e.g., using a controller (processor and/or memory) communicatively coupled to the sprayers 228 and/or other actuator as desired) and/or by the operator.

[0029] Additionally or alternatively, the steam condensation system 306 optionally includes one or more chiller conduits 354 within the internal region 352. A coolant such as chilled water may be directed through the chiller conduit 354 for reducing a temperature within the internal region 352, thereby causing condensation of the steam 226. As another non-limiting example, a chilled gas such as but not limited to chilled air may be used as the coolant. Other devices, materials, and/or mechanisms within the internal region 352 for condensing the steam 226 may be utilized as desired.

[0030] Similar to the steam condensation system 206, after the steam 226 has been condensed to the recycled water 232 by the steam condensation system 306, the recycled water 232 optionally may be provided to a cooling system before being used as part of cooling during metal processing.

[0031] In some embodiments, one or more suction devices, such as air movers 350, optionally may be included with the conduit 336 for generating a suction force that draws the steam 226 into the conduit 336. As non-limiting examples, the air mover 350 may be a blower or fan that pulls air and the steam 226 into the conduit 336. In the embodiment illustrated, the steam condensation system 306 includes two air movers 350 provided at the opposing ends 342, 344 of the conduit 336. However, in other embodiments, the steam condensation system 306 may include any number of air movers as desired, including omitting air movers 350, a single air mover 350, or more than two air movers 350. The one or more air movers 350 may be provided at any suitable location.

[0032] FIG. 4 illustrates another example of a steam condensation system 406 for a metal processing system according to embodiments. Similar to the steam condensation system 306, the steam condensation system 406 includes a conduit 436. Steam 226 may be directed into the conduit 436 (represented by arrow 458) where the steam 226 is condensed into recycled water. In some embodiments, similar to the steam condensation system 306, the steam condensation system 406 may include the one or more air movers 350 for generating a suction force that draws the steam 226 into the conduit 436.

[0033] Compared to the steam condensation system 306 with the internal cooling devices or mechanisms for condensing the steam, the steam condensation system 406 includes one or more cooling devices or mechanisms on an external surface 460 of the conduit 436 for cooling the temperature of the conduit 436. The external cooling devices or mechanisms may be various suitable devices or mechanisms as desired.

[0034] Referring to FIG. 4, in some embodiments, process gas lines or conduit 462 for the metal processing system may be provided on the external surface 460 for cooling of the conduit 436. In certain embodiments, because process gases may be provided at lower temperatures, the conduit 462 may have a reduced temperature, and as such, placing the conduit 462 in contact with the conduit 436 may provide cooling to the conduit 436. The process gas lines 462 may be various process gas lines as desired and may depend on the particular metal processing system. Non-limiting examples of process gas lines 462 may be one or more of an argon gas line, a nitrogen gas line, a carbon dioxide gas line, a chlorine gas line, combinations thereof, and/or other processing gas lines 462 as desired.

[0035] Additionally or alternatively to the process gas lines 462, the conduit 436 may include one or more heat exchanger fins 464 along the conduit 436. In some embodiments, the heat exchanger fins 464 may be circular fins on the conduit 436 and optionally may be provided along the length of the conduit 436. However, in other embodiments, the heat exchanger fins 464 may have other shapes or profiles as desired, and the heat exchanger fins 464 may be provided along the conduit 436 as desired. In other embodiments, other devices or mechanisms suitable of externally cooling the conduit 436 may be used as desired.

[0036] The external cooling devices of the steam condensation system 406 cool the conduit 436, thereby reducing the temperature within the internal region of the conduit 436. Such reduction in temperature may cause the steam 226 to condense within the conduit as recycled water. The steam 226 condensed into recycled water optionally may be held in a storage tank 434 before being directed to a cooling system or as otherwise desired (represented by arrow 466).

[0037] While the steam condensation systems 206, 306, 406 are illustrated separately, in various embodiments, two or more condensation systems may be employed with a metal processing system. As a non-limiting example and referring to FIG. 2, the DC casting system 214 may utilize both the steam condensation system 206 and the steam condensation 306 and/or may utilize all of the steam condensation systems 206, 306, 406. Various other combinations or sub-combinations of steam condensation systems may be utilized as desired. Moreover, in other embodiments, other steam condensation systems may be utilized in addition to or in place of the steam condensation systems 206, 306, 406.

[0038] Referring back to FIG. 1, a method of processing a metal substrate with the metal processing system 100 having the steam condensation system 106 includes providing water to

the metal processing station 102 for a cooling process. In one non-limiting example, providing water to the metal processing station 102 may include providing water to the DC casting system 214 and cooling the metal ingot 222 emerging from the mold 216 by directing the water onto the metal ingot 222.

[0039] The method includes condensing steam generated by the cooling process into recycled water using the steam condensation system 106. In some embodiments, condensing the steam may include spraying water into the steam. In certain embodiments, condensing the steam may include drawing the steam into a conduit, and condensing the steam using an internal cooling device and/or an external cooling device. Non-limiting examples of internal cooling devices may include sprayers and/or a chiller conduit(s), and non-limiting examples of external cooling devices may include processing gas lines and/or heat exchanger fins.

[0040] In certain embodiments, the method optionally includes providing the recycled water from the steam condensation system 106 to the cooling system 104. The method optionally includes re-cooling and/or otherwise treating the recycled water with the cooling system 104 or using another system as desired. The method includes providing the recycled water from the cooling system 104 to the metal processing station 102 for the cooling process.

[0041] A collection of exemplary embodiments are provided below, including at least some explicitly enumerated as "Illustrations" 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.

[0042] Illustration 1. A DC casting system for casting a metal ingot, the DC casting system comprising a steam condensation system for condensing steam generated during a DC casting process.

[0043] Illustration 2. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a plurality of sprayers configured to spray water inside a casting pit of the DC casting system.

[0044] Illustration 3. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the plurality of sprayers comprise a plurality of nozzles.

[0045] Illustration 4. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the plurality of sprayers are configured to control a direction of steam flow and/or air flow by spraying the water inside the casting pit.

[0046] Illustration 5. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the plurality of sprayers are adjustable such that the direction of steam flow and/or air flow is adjustable by spraying the water inside the casting pit.

[0047] Illustration 6. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises: a conduit comprising at least one inlet and at least one outlet and configured to receive the steam; a suction device configured to generate a suction force for pulling the steam through the at least one inlet into the conduit; and at least one sprayer within the conduit for spraying water within the conduit.

[0048] Illustration 7. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the conduit comprises a first end, a second end, and a side wall extending from the first end to the second end, wherein the suction device is provided on the first end, and wherein the at least one inlet and the at least one outlet are provided on the side wall of the conduit.

[0049] Illustration 8. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the suction device is a first suction device, and wherein the steam condensation system further comprises a second suction device on the second end of the conduit for pulling the steam into the conduit.

[0050] Illustration 9. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a conduit for receiving the steam and a cooling device on an external surface of the conduit for cooling the conduit.

[0051] Illustration 10. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device comprises at least one of a processing gas line for the DC casting process or a plurality of heat exchanger fins.

[0052] Illustration 11. A DC casting system for casting a metal ingot, the DC casting system comprising a cooling system configured to at least partially cool the metal ingot during a DC

casting process by directing water from a coolant supply onto the metal ingot, the cooling system further comprising a steam condensation system for condensing steam generated during a DC casting process.

[0053] Illustration 12. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system is configured to condense steam generated by the cooling of the metal ingot as recycled water and provide the recycled water to the coolant supply.

[0054] Illustration 13. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a sprayer configured to spray water for condensing the steam.

[0055] Illustration 14. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system further comprises a conduit and a suction device for pulling steam into the conduit, and wherein the sprayer is within the conduit.

[0056] Illustration 15. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a conduit for receiving the steam and a cooling device for causing condensation of the steam into recycled water.

[0057] Illustration 16. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device is at least one sprayer within the conduit, the at least one sprayer configured to spray water for condensing the steam into recycled water.

[0058] Illustration 17. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device is on an external surface of the conduit and is configured to cool the conduit.

[0059] Illustration 18. The DC casting system of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device comprises at least one of a processing gas line for the DC casting process or a plurality of heat exchanger fins.

[0060] Illustration 19. A method of DC casting a metal ingot, the method comprising: cooling the metal ingot emerging from a mold by directing water from a coolant supply onto

the metal ingot; condensing steam generated by the cooling of the metal ingot as recycled water; and providing the recycled water to the coolant supply.

[0061] Illustration 20. The method of any preceding or subsequent illustrations or combination of illustrations, wherein condensing the steam comprises spraying water into the steam.

[0062] Illustration 21. The method of any preceding or subsequent illustrations or combination of illustrations, wherein condensing the steam comprises directing the steam into a conduit and condensing the steam within the conduit using a cooling device.

[0063] Illustration 22. The method of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device comprises a sprayer within the conduit, and wherein condensing the steam comprises spraying water into the steam within the conduit.

[0064] Illustration 23. The method of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device is on an external surface of the conduit, and wherein condensing the steam comprises cooling the conduit using the cooling device.

[0065] Illustration 24. The method of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device comprises at least one of a processing gas line for the DC casting process or a plurality of heat exchanger fins.

[0066] Illustration 25. A metal processing system for processing a metal substrate, the metal processing system comprising a steam condensation system for condensing steam generated during metal processing of the metal substrate.

[0067] Illustration 26. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the metal processing system comprises a casting system for producing a metal ingot from a molten metal.

[0068] Illustration 27. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the casting system is a direct chill (DC) casting system.

[0069] Illustration 28. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, further comprising a cooling system for dispensing water onto the metal substrate during metal processing, wherein the steam

condensation system is configured to condense the steam as recycled water and return the recycled water to the cooling system.

[0070] Illustration 29. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a plurality of sprayers configured to spray water in a steam-generating area of the metal processing system.

[0071] Illustration 30. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises: a conduit comprising at least one inlet and at least one outlet and configured to receive the steam; a suction device configured to generate a suction force for pulling the steam through the at least one inlet into the conduit; and at least one sprayer within the conduit for spraying water within the conduit.

[0072] Illustration 31. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system comprises a conduit for receiving the steam and a cooling device on an external surface of the conduit for cooling the conduit.

[0073] Illustration 32. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the cooling device comprises at least one of a processing gas line for the DC casting process or a plurality of heat exchanger fins.

[0074] Illustration 33. A metal processing system for processing a metal substrate, the metal processing system comprising a steam condensation system for directing a flow of steam generated during metal processing of the metal substrate by spraying water relative to a direction of the flow of the steam.

[0075] Illustration 34. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the metal processing system is a direct chill (DC) casting system.

[0076] Illustration 25. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system is configured to spray water parallel to the direction of the flow of the steam or in a cross-direction relative to the direction of the flow of the steam.

[0077] Illustration 36. The metal processing system of any preceding or subsequent illustrations or combination of illustrations, wherein the steam condensation system is adjustable such that the direction of water sprayed by the steam condensation system is adjustable relative to the direction of the flow of the steam.

[0078] The subject matter of embodiments is described herein 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,” “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. In the figures and the description, like numerals are intended to represent like elements. As used herein, the meaning of “a,” “an,” and “the” includes singular and plural references unless the context clearly dictates otherwise.

[0079] 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 may 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 direct chill (DC) casting system for casting a metal ingot, the DC casting system comprising a steam condensation system for condensing steam generated during a DC casting process as recycled water.

2. The DC casting system of claim 1, wherein the steam condensation system comprises a plurality of sprayers configured to spray water inside a casting pit of the DC casting system.

3. The DC casting system of claim 2, wherein the plurality of sprayers comprise a plurality of nozzles.

4. The DC casting system of claim 2, wherein the plurality of sprayers are configured to control a direction of steam flow and/or air flow by spraying the water inside the casting pit.

5. The DC casting system of claim 4, wherein the plurality of sprayers are adjustable such that the direction of steam flow and/or air flow is adjustable by spraying the water inside the casting pit.

6. The DC casting system of claim 1, wherein the steam condensation system comprises:

a conduit comprising at least one inlet and at least one outlet and configured to receive the steam;

a suction device configured to generate a suction force for pulling the steam through the at least one inlet into the conduit; and

at least one sprayer within the conduit for spraying water within the conduit.

7. The DC casting system of claim 6, wherein the conduit comprises a first end, a second end, and a side wall extending from the first end to the second end, wherein the suction device is provided at the first end, and wherein the at least one inlet and the at least one outlet are provided on the side wall of the conduit.

8. The DC casting system of claim 1, wherein the steam condensation system comprises a conduit for receiving the steam and a cooling device on an external surface of the conduit for cooling the conduit.

9. The DC casting system of claim 8, wherein the cooling device comprises at least one of a processing gas line for the DC casting process or a plurality of heat exchanger fins.

10. The DC casting system of claim 1, further comprising means for directing the recycled water back to the DC casting process and/or to other processing steps for the metal ingot.

11. A method of direct chill (DC) casting a metal ingot, the method comprising:

cooling the metal ingot emerging from a mold by directing water from a coolant supply onto the metal ingot;

condensing steam generated by the cooling of the metal ingot as recycled water; and

providing the recycled water to the coolant supply.

12. The method of claim 11, wherein condensing the steam comprises spraying water into the steam.

13. The method of claim 11, wherein condensing the steam comprises directing the steam into a conduit and condensing the steam within the conduit using a cooling device.

14. The method of claim 13, wherein the cooling device comprises at least one of:

a sprayer within the conduit, and wherein condensing the steam comprises spraying water into the steam within the conduit; or

a cooling device is on an external surface of the conduit, and wherein condensing the steam comprises cooling the conduit using the cooling device.

15. A metal processing system for processing a metal substrate, the metal processing system comprising a steam condensation system for directing a flow of steam generated

during metal processing of the metal substrate by spraying water relative to a direction of the flow of the steam.

16. The metal processing system of claim 15, wherein the metal processing system is a direct chill (DC) casting system for producing a metal ingot from a molten metal.

17. The metal processing system of claim 15, wherein the steam condensation system is configured to spray water parallel to the direction of the flow of the steam or in a cross-direction relative to the direction of the flow of the steam.

18. The metal processing system of claim 15, wherein the steam condensation system is adjustable such that the direction of water sprayed by the steam condensation system is adjustable relative to the direction of the flow of the steam.

19. The metal processing system of claim 15, wherein the steam condensation system is further configured to condense steam generated during metal processing of the metal substrate.

20. The metal processing system of claim 15, wherein the steam condensation system comprises a plurality of sprayers configured to spray water in a steam-generating area of the metal processing system.

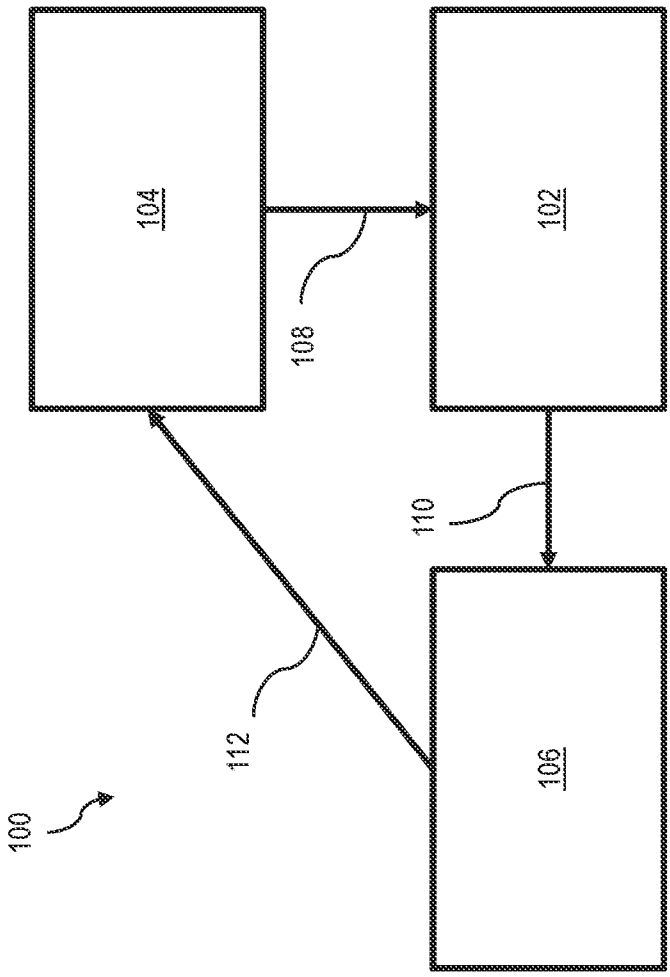


FIG. 1

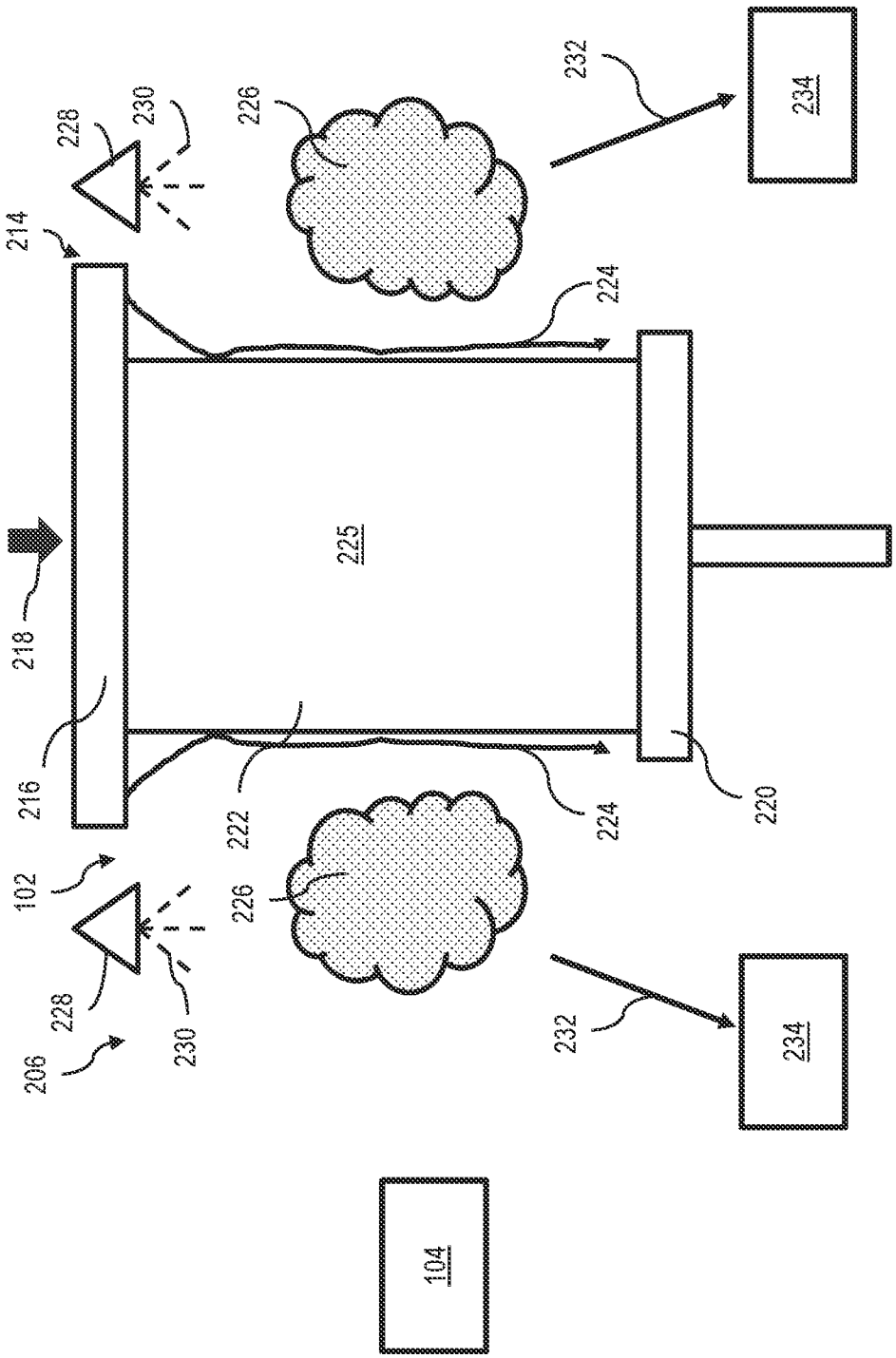


FIG. 2

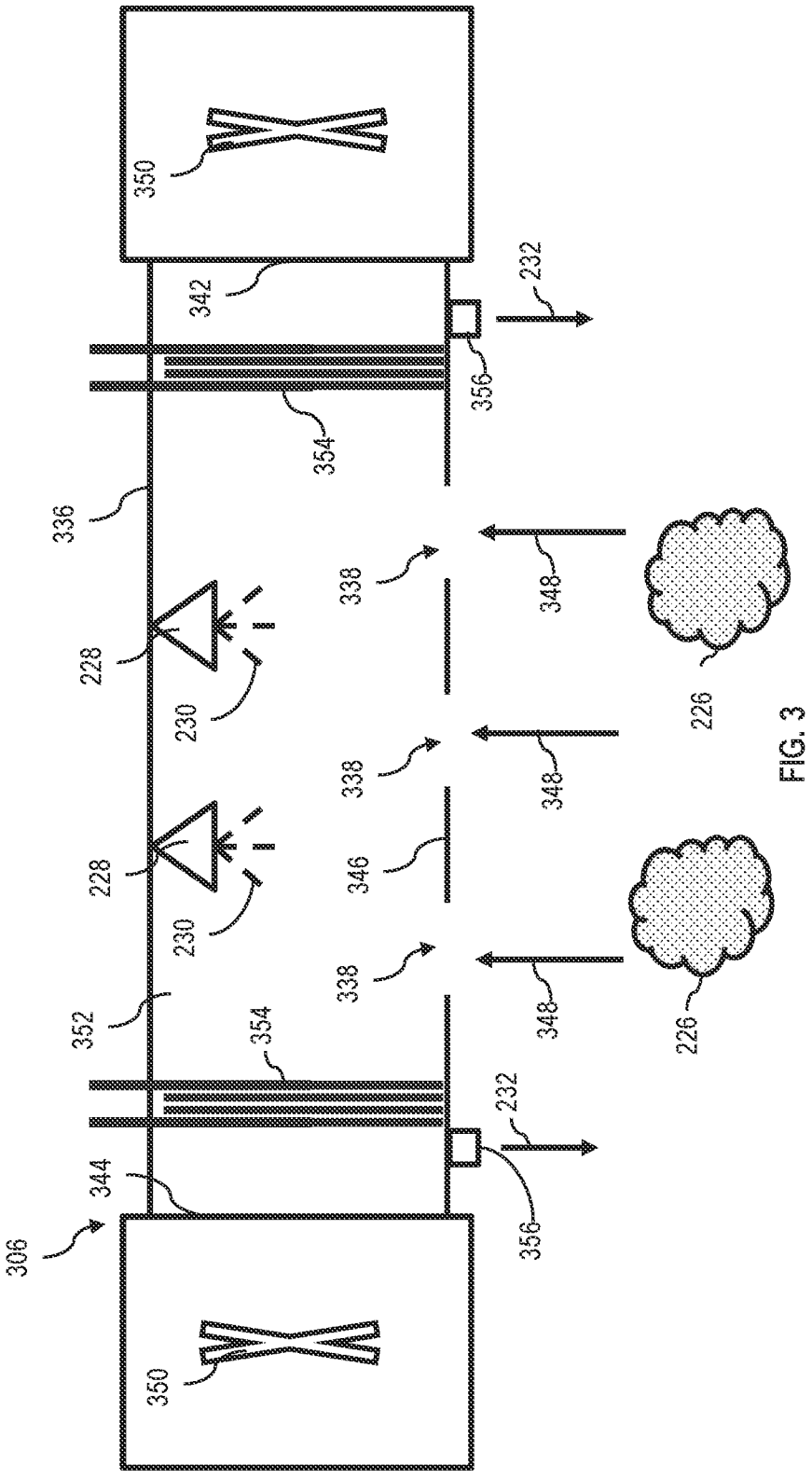


FIG. 3

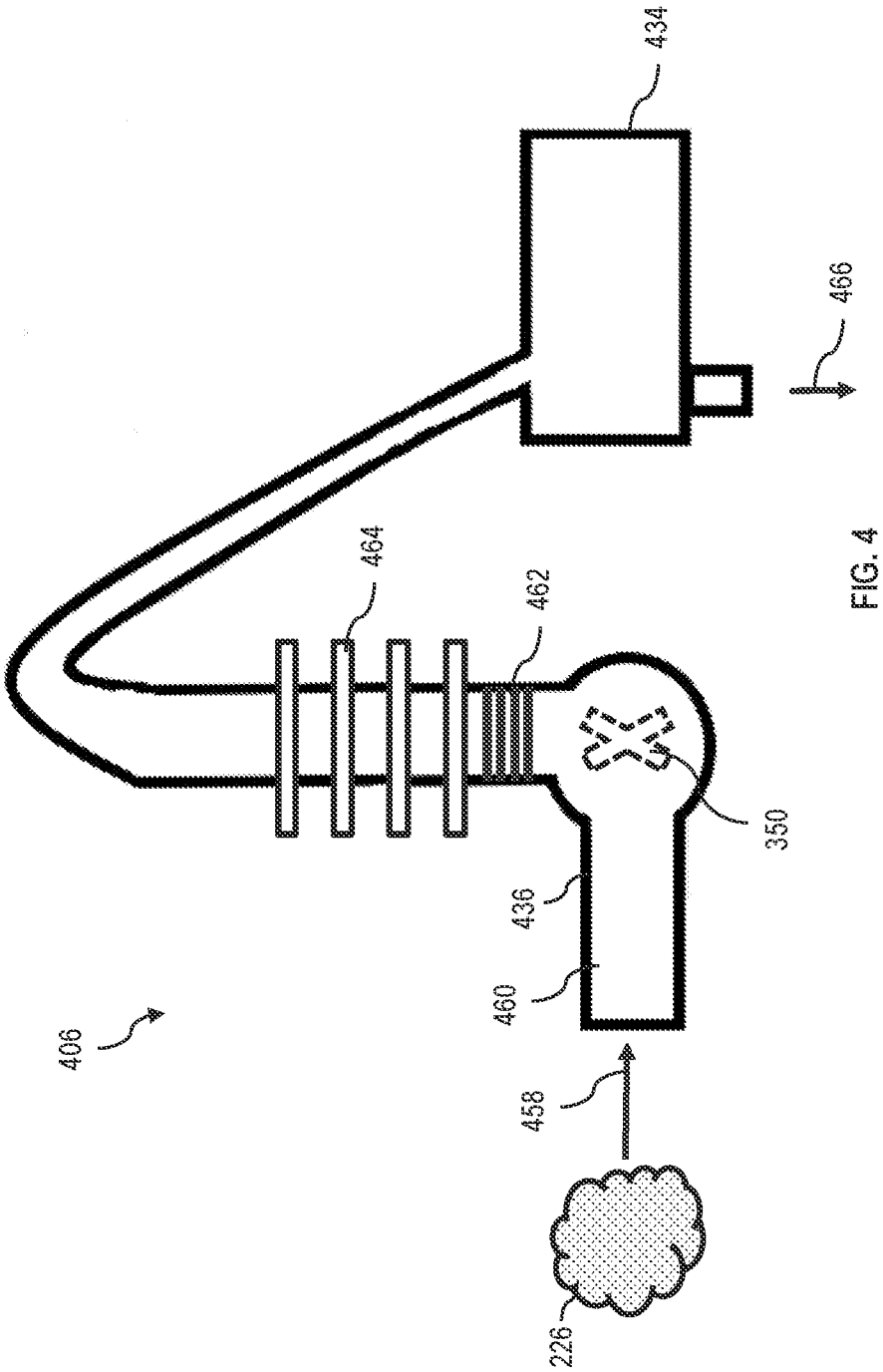


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/067743

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22D7/06 B22D11/04 B22D11/049 B22D11/055 B22D11/06 B22D11/124
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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	claim 1; figure 5 column 2; lines 51-55	11-14
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A	paragraphs [0001], [0029]	1-14,16
X	RU 2 739 358 C2 (STULOV VYACHESLAV VIKTOROVICH [RU]) 23 December 2020 (2020-12-23)	15,17-20
A	paragraph [0018]; claim 1; figure 1	1-14,16
X	CN 110 586 888 A (WISDRI ENGINEERING & RES INCORPORATION LIMITED) 20 December 2019 (2019-12-20) paragraph [0021]; claim 1; figure 1	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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"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	Date of mailing of the international search report
15 August 2023	22/08/2023

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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