Title: SYSTEMS AND METHODS OF COOLING BLAST FURNACES

Abstract: Systems and methods provide a cooling device for a blast furnace that may prevent an excessive amount of coolant from entering the blast furnace and may be easily installed in a conventional blast furnace. Systems and methods may provide a cooling device for a blast furnace that may prevent an excessive amount of coolant from entering the blast furnace and may be simple and cost effective to manufacture.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
SYSTEMS AND METHODS OF COOLING BLAST FURNACES

BACKGROUND

1. Related Technical Fields

   [0001] Related fields include systems and methods for cooling blast furnaces. Related fields include cooling plates, cooling staves, cigar coolers, and tuyeres.

2. Related Art

   [0002] Conventional blast furnaces cool the blast furnace with shell sprays, cooling plates, or more recently, cooling staves. Conventional cooling plates may be arranged in the tuyere breast, bosh, and/or stack of a blast furnace. The cooling plates may be inserted through an opening in the shell of the furnace and may be interposed between a refractory lining. The cooling plates have cavities that provide passages. Coolant, such as, for example, water at an elevated pressure is pumped through the passages in order to cool the cooling plates. The cooled plates thus cool the refractory lining.

   [0003] Conventional cooling staves are arranged within a blast furnace and are arranged substantially parallel to a steel shell of the blast furnace. The cooling staves typically cover the majority of the inner surface of the steel shell of the blast furnace. Refractory lining may be disposed on or around the surface of the stave. Staves also have cavities that provide passages. The passages are attached to one or more pipes that extend from the furnace shell side of the stave and penetrate the steel shell. Coolant, such as, for example, water at an elevated pressure is pumped through the pipes and passages in order to cool the stave. The cooled stave thus cools the refractory lining.

   [0004] U.S. Patent 4,154,175 to Gritsuk et al. (hereinafter "Gritsuk") discloses a plate cooler (stave style) for a blast furnace including a number of closed pipes containing coolant. The stave is arranged on the inside of a blast furnace wall either during construction of the blast furnace or during non-operational repairs. The stave cooler is made of at least two different materials and includes sealed pipes containing coolant. Each of the pipes within the plate cooler requires an internal partition in order to operate effectively. The sealed pipes transfer heat to a separate cooling chamber that is outside of the furnace shell.

   [0005] U.S. Patent 4,245,572 to Sharp (hereinafter "Sharp") discloses a cooling plate to be installed within a furnace wall (plate style). The cooling plate includes transversely disposed heat pipes. The heat pipes are sealed and contain a coolant. The cooling plate also includes a large cooling chamber containing cooling fluid. The heat pipes
transfer heat from a furnace side of the pipes to a cooling chamber side of the pipes. The chamber containing cooling fluid is within the shell of the furnace and is connected to an external coolant source.

SUMMARY

[0006] Within a blast furnace, the refractory lining, burden materials, and the cooling plates and/or staves may be subject to extreme mechanical wear, high temperatures, gas channeling, and other occurrences that may erode and/or damage the refractory lining and cooling plates and/or staves. Frequently, such damage to the cooling plates and/or staves can result in rupture of the plates and/or staves. If the internal passages are ruptured, large volumes of cooling water may be discharged into the furnace, especially if the passages are fed by an external source of coolant.

[0007] Uncontrolled coolant entering the blast furnace may cause operating problems and may damage the lining of the blast furnace. The damage may be a loss of refractory lining exposing the steel shell to excessive temperatures. Because the shell is typically both a pressure containing vessel and a structural support, it may be highly stressed. Thus, over heating the shell may result in buckling and/or rupture of the shell. The coolant may damage the lining locally or at any portion of the furnace below the leak. Uncontrolled coolant entering the blast furnace may cause molten material in the lower region of the furnace to solidify. When uncontrolled coolant enters the blast furnace, the blast furnace may be rendered inoperable until the damage is repaired. Such repair may be expensive, time consuming, and/or production inhibiting.

[0008] The stave cooler of Gritsk attempts to alleviate the problem of excessive amounts of coolant entering the furnace by separating the coolant in the stave, from the external coolant. However, the stave cooler of Gritsk is complex. For example, it includes a plurality of materials. The pipes in Gritsk rely on evaporative cooling. Thus, the pipes require a complex split design. Furthermore, the stave cooler of Gritsk is not configured to be installed in a conventional blast furnace that uses conventional cooling plates.

Accordingly, the stave coolers of Gritsk must be installed in a new furnace during its construction. Alternatively, at least the shell and a large portion of the lining of an existing furnace would have to be redesigned and replaced in order to retrofit a conventional furnace with the stave cooler of Gritsk. Such a retrofitting would require shutting the furnace down for an extended period (non-production time). Thus, a retrofit may be extremely costly due to the significant redesign and replacement of components and extended non-production time.
The plate cooler of Sharp also separates the coolant in the pipes within the cooling plate from an external coolant. In Sharp, the coolant is sealed within the pipes primarily to allow the pipes to move relative to the cooling plate in order to adjust cooling amounts within the plate. Furthermore, the external coolant in Sharp enters at least a chamber of the plate that is within the furnace shell. Thus, if that chamber is ruptured, an excessive amount of coolant may still enter the furnace. The pipes in Sharp are complex and contain a wick that significantly complicates the design and increases costs.

In light of at least the foregoing, it is beneficial to provide a cooling device for a blast furnace that may prevent an excessive amount of coolant from entering the blast furnace and may be easily installed in a conventional blast furnace. It is beneficial to provide a cooling device for a blast furnace that may prevent an excessive amount of coolant from entering the blast furnace and may be simple and cost effective to manufacture.

It is also beneficial to provide a method for replacing a cooling device in a blast furnace. The method may include replacing a conventional cooling device in a blast furnace with a cooling device for a blast furnace that may prevent an excessive amount of coolant from entering the blast furnace and may be easily installed in a conventional blast furnace.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Exemplary implementations will be described with reference to the following drawings, wherein:

- Fig. 1 shows an exemplary blast furnace;
- Fig. 2 shows an exemplary cooling plate installed in a blast furnace;
- Fig. 3 shows a the exemplary cooling plate of Fig. 2 from line A-A' to the furnace end of the exemplary cooling plate;
- Fig. 4 shows an exemplary cooling stave installed in a blast furnace;
- Fig. 5 shows an exemplary cooling stave;
- Fig. 6 shows an exemplary cooling stave that may be retrofit into a plate-type blast furnace;
- Fig. 7 shows an exemplary "cigar-type" cooler; and
- Figs. 8(A) - 8(C) show an exemplary tuyere including heat pipes.

**DETAILED DESCRIPTION OF EXEMPLARY IMPLEMENTATIONS**

Blast furnaces may be used to convert iron bearing raw materials into a form that can be easily transformed into steel. A blast furnace is typically a large refractory lined
steel vessel in which pellets and/or sinter, coke, and flux materials may be charged into the furnace top. High temperature air at high pressure may be blown into the bottom of the furnace. Molten iron and slag accumulate at the bottom of the furnace and may be removed periodically. Fig. 1 shows an exemplary blast furnace.

[0022] As shown in Fig. 1, the lower portion of the furnace is called the hearth. The steel jacket surrounding the hearth is vertical or slightly conical. The jacket may be lined with refractory material (e.g., carbon, graphite, silicon carbide, and/or ceramics) and may be cooled with staves or external shell sprays. The hearth bottom may be lined with refractory material. One or more iron notches may be located on or above the hearth floor. The iron notches permit iron and or slag to be removed from the furnace.

[0023] A portion above the hearth is called the tuyere breast. In the tuyere breast the steel jacket may have large holes through which the tuyeres and/or tuyere coolers may be inserted. The tuyere breast may include refractory material adjacent to the steel wall with cooling plates, staves or cooling panels to cool the refractory material. Above the tuyere breast is the bosh. The bosh may taper out to the widest part of the furnace and may be lined with refractory. The bosh may also utilize spray cooling, cooling plates, or staves.

[0024] Above the bosh is the stack. The stack includes a long, sometimes tapering, shell lined with refractory material. The refractory material is typically cooled by cooling plates and/or staves. The top of the furnace is typically cylindrical and is referred to as the stockline section. Typically, this area is not cooled and may use refractory and/or cast or fabricated metal materials to protect the steel walls from heat and abrasion.

[0025] Common types of blast furnaces in operation today utilize conventional cooling plates. As described above, these conventional plates are inserted through corresponding holes in the shell of the furnace and are connected to an external coolant source. This type of conventional furnace is the most numerous type in part because the conventional cooling plate was the preferred method of cooling a blast furnace when the majority of the furnaces were built. Furthermore, the conventional plates (when they have not ruptured causing extreme damage) may be replaced without a significant burden on production. Thus, these conventional furnaces have remained substantially in production for much of their lives. As discussed above, the shutting down of a furnace for maintenance or upgrading may be cost prohibitive. Thus, these conventional furnaces remain in operation.

[0026] However, because conventional plates are prone to catastrophic failure (i.e., allowing a substantial amount of coolant into the furnace) it is beneficial to provide a cooling
plate that may be installed in the existing openings in a conventional furnace and that prevents a substantial amount of coolant from entering the furnace if the plate ruptures.

[0027] Figs. 2 and 3 show an exemplary plate that may be installed in the existing openings 270 in a conventional furnace and that prevent a substantial amount of coolant from entering the furnace if the plate ruptures. Fig. 2 shows the exemplary cooling plate installed in a furnace and Fig. 3 is a cut away view of the same exemplary cooling plate.

[0028] As shown in Fig. 2, the cooling plate 200 may be installed in the shell 260 (e.g., a steel shell) of a blast furnace. The shell 260 may be lined with refractory lining 250. The cooling plate 200 may contain a heat pipe 202 that contains an amount of coolant. The coolant may be for example, any liquid and/or gas that is capable of transferring heat from a region of the cooling plate 200 within the furnace, to an end of the cooling plate 200 outside of the furnace. The cooling plate 200 may be configured to be easily inserted into the furnace shell 260 through an existing hole 270 without substantial modification to the shell 260 and/or refractory lining 250.

[0029] The end of the heat pipe 202 that is outside of the furnace may be configured to interact with a heat sink 210. The heat sink 210 may be for example, a separate amount of coolant that is circulated outside of the furnace, an evaporative cooling system, and/or any other system or method of cooling the heat pipe 202 that transfers heat from the heat pipe 202 to the heat sink 210. Because the coolant within the heat pipe 202 is sealed within the heat pipe 202, only the small, fixed amount of coolant that is within the heat pipe 202 will enter the furnace should the cooling plate 200 rupture. Thus, substantial damage to the furnace, extensive repairs, and/or long periods of non-production may be avoided.

[0030] It should be appreciated that the term "heat pipe" as used herein is not intended to describe any particular structure other than one or more sealed passages containing a fixed amount of coolant. The heat pipes 202 are capable of transferring heat with or without using evaporative cooling and with or without the use of additional structures such as a partition or a wick. The heat pipes 202 may absorb the heat of the furnace and/or refractory material 250 in a portion of the heat pipe 202 substantially in a vicinity of the furnace and/or refractory material 250 and transfer at least a portion of that absorbed heat to the heat sink 210 in a portion of the heat pipe 202 substantially outside of the furnace.

[0031] As shown in Fig. 3, the cooling plate 200 may include one or more heat pipes 202, the heat pipes 202 may be arranged substantially parallel to one another with one end towards the interior of the furnace and the other end towards the exterior of the furnace.
However, any configuration may be used in which heat may be transferred by the heat pipe 202 from a portion of the heat pipe 202 inside the furnace to a portion of the heat pipe 202 outside the furnace. Furthermore, one or more heat pipes 202 may intersect or contact one another and/or share coolant.

[0032] The cooling plate 200 may be made from a single material and at least a portion of the heat pipes 202 may be passages formed within the material. Thus, the cooling plates 200 may be simple and cost effective to manufacture.

[0033] Although many of the conventional blast furnaces operating today are configured to use conventional cooling plates, many conventional blast furnaces operating today are configured to use conventional cooling staves.

[0034] Figs. 4 and 5 show an exemplary cooling stave that may be installed in a conventional furnace configured to use staves and that may prevent a substantial amount of coolant from entering the furnace if the plate ruptures. Fig. 4 shows the exemplary cooling stave installed in a furnace and Fig. 5 is another view of the exemplary cooling stave.

[0035] As shown in Fig. 4, the cooling stave 400 may be installed in the steel shell 260 of a blast furnace. The cooling stave 400 may contain a heat pipe 402 that contains an amount of coolant. The coolant may be for example, any liquid and/or gas that is capable of transferring heat from a portion of the cooling stave 400 within the furnace, to one or more portions of the cooling stave 400 outside of the furnace. Furthermore, the heat pipe 402 may include a reservoir 450 that contains an amount of coolant.

[0036] The heat pipe 402 may form a circular circuit of coolant that operates as, for example, a thermosiphon. As the coolant in the heat pipe 402 is heated on the inside of the furnace, the coolant density changes (e.g., becomes less). As the warm or hot coolant is cooled outside the furnace, the density increases. Due to gravity, the more dense (cooler) coolant outside the furnace sinks to the lower part of the pipe. This forces the less dense coolant to the top of the stave where it is cooled. This cycle may perpetuate as long as there is a differential in temperature.

[0037] As shown in Fig. 4, in order to cool the coolant outside of the furnace, the heat pipe 402 may interact with another heat pipe 412. That heat pipe 412 may interact with the heat sink 210. Thus, heat may be transferred from heat pipe 402 to heat pipe 412 and then to the heat sink 210. Because each heat pipe 402, 412, may be sealed and contain a separate amount of coolant; the coolant within the furnace (e.g., within heat pipe 402) may be sufficiently separated from both the coolant in heat pipe 412 and any coolant associated with
the heat sink 210. Only the small, fixed amount of coolant that is within the heat pipe 402 will enter the furnace should the cooling stave 400 rupture. Thus, substantial damage to the furnace, extensive repairs, and/or long periods of non-production may be avoided.

[0038] The cooling stave 400 may be configured to be installed in the furnace shell 260 through an existing hole or holes 470 without substantial modification to the shell. However, substantially more work is required for installing a cooling stave (conventional or otherwise). For instance, the stave may not be simply inserted through the existing holes 470 from the outside of the furnace, but must be inserted from the inside of the furnace. Such an installation may require the removal and/or reinstallation of a portion of the refractory lining 250. Such an installation may also require a longer non-production period compared to the installation of, for example, cooling plate 200. However, no additional work or non-production time is required than would otherwise be necessary for replacing a conventional cooling stave with another conventional cooling stave.

[0039] As described above, the heat sink 210 may be for example, a separate amount of coolant that is circulated outside of the furnace, an evaporative cooling system, and/or any other system or method of cooling the heat pipe 402 that transfers heat from the heat pipe 402 to the heat sink 210.

[0040] It should be appreciated that although Fig. 4 shows two separate heat pipes 402, 412, the heat pipe 402 may directly interact with the heat sink 210. Because the coolant within the heat pipe 402 is sealed within the heat pipe 402, only the small, fixed amount of coolant that is within the heat pipe 402 will enter the furnace should the cooling stave 400 rupture. Thus, substantial damage to the furnace, extensive repairs, and/or long periods of non-production may be avoided. Furthermore, it should be appreciated that the heat pipe 402, either used alone or in conjunction with other heat pipes 412 need not form a circuit. Rather, each of separate sealed ends extending from the shell 260 via holes 470 may separately interact with and transfer heat to the heat sink 210.

[0041] As shown in Fig. 5, the cooling stave 400 may include one or more heat pipes 402, the heat pipes 402 may be arranged substantially parallel to one another with at least a portion facing the interior of the furnace and at least one end outside of the furnace. As discussed above, although Fig. 4 shows that a portion of the circuit formed by heat pipe(s) 402 is outside of the furnace and communicating with the heat sink 210, only one portion of the heat pipe(s) 402 may communicate with the heat sink 210 and the heat pipe(s) 402 need not form a circuit. Furthermore, any configuration of heat pipes 402 may be used in which
heat may be transferred by the heat pipe 402 from a portion of the heat pipe 402 inside the furnace to a portion of the heat pipe 402 outside the furnace. One or more heat pipes 402 may intersect or contact one another and/or share coolant.

[0042] The cooling stave 400 may be made from a single material and at least a portion of the heat pipes 402 may be passages formed within the material. Thus, the cooling stave 400 may be simple and cost effective to manufacture.

[0043] Fig. 6 shows a cooling stave 600 adapted to be retrofit into a blast furnace shell originally designed to utilize conventional cooling plates. As discussed above, when a conventional plate-cooler type furnace is upgraded to a conventional stave-type blast furnace, the entire shell of the furnace may be redesigned and/or replaced. As shown in Fig. 6, the stave is configured such that at least some of the heat pipes 402 that extend from the stave 600 may extend through the existing holes 270 in the shell that were originally intended for conventional cooling plates. If necessary, additional holes 610 may be drilled in the shell to accommodate additional heat pipes 402. This cooling stave 600 maintains all of the advantages of the cooling stave 400 described above (including the disclosed variations). However, this cooling stave 600 achieves the added benefit of using the conventional plate cooler-type shell to incorporate the more modern stave cooling system without the requirement of a costly and time consuming shell change.

[0044] Frequently, during the normal operation of a blast furnace, a particular portion of, for example, the refractory material 250 and/or shell 260 in any of, for example, the tuyere breast, bosh, and/or stack may become damaged or worn. Since heat is usually a contributing factor to damage and/or increased wear in a blast furnace, one practice for slowing the damage or wear of that portion of the furnace may include installation of a "cigar-type" cooler. Fig. 7 shows an exemplary cigar-type cooler installed in a furnace.

[0045] As shown in Fig. 7, the cigar cooler 700 may be installed in the shell 260 of a blast furnace. However, instead of being installed in existing holes, a hole 770 may be drilled in the vicinity of the portion of the furnace that is damaged or experiencing greater than normal wear. As discussed above, the shell 260 may be lined with refractory lining 250. The cigar cooler 700 may contain one or more a heat pipes 702 that contain a fixed amount of coolant. The coolant may be, for example, any liquid and/or gas that is capable of transferring heat from an end of the cigar cooler 700 within the furnace, to and end of the cigar cooler 700 outside of the furnace. The cigar cooler 700 may be configured to be easily
inserted into the furnace shell 260 through the drilled hole 770 without any other substantial modification to the shell 260 and/or refractory lining 250.

[0046] The end of the heat pipe 702 that is outside of the furnace may be configured to interact with a heat sink 210. According to this example, the heat sink 210 may need to be moved into a vicinity of the cigar cooler 700, depending on where the hole 770 was drilled. Again, the heat sink may be for example, a separate amount of coolant that is circulated outside of the furnace, and evaporative cooling system, and/or any other system or method of cooling the heat pipe 702 that transfers heat from the heat pipe 702 to the heat sink 210. Because, the coolant within the heat pipe 702 is sealed within the heat pipe 702, only the small, fixed amount of coolant that is within the heat pipe 702 will enter the furnace should the cigar cooler 700 rupture. Thus, substantial damage to the furnace, extensive repairs, and/or long periods of non-production may be avoided.

[0047] By virtue of being installed in a drilled hole 770, the cigar cooler 700 may be installed in a vicinity of the furnace that is damaged and/or experiencing greater than normal wear. Accordingly, a temperature in that area may be reduced and the damage and/or increased wear may be inhibited. Because the exemplary cigar cooler 700 may be installed through a drilled hole 770, it may be shaped to fit within that hole, for example, it may be substantially cylindrical (circular or otherwise), or any other shape capable of being installed in a drilled hole. Furthermore, due to its shape, the cigar cooler 700 may include only a single heat pipe 702.

[0048] However, the cigar cooler 700 may include one or more heat pipes 702, the heat pipes 702 may be arranged substantially parallel to one another with at least a portion facing the interior of the furnace and at least one end outside of the furnace. Furthermore, any configuration of heat pipes 702 may be used that allows the cigar cooler 700 to fit within the drilled hole 770 and allows heat to be transferred by the heat pipe 702 from a portion of the heat pipe 702 inside the furnace to a portion of the heat pipe 702 outside the furnace. Furthermore, one or more heat pipes 702 may intersect or contact one another and/or share coolant.

[0049] The cigar cooler 700 may be made from a single or composite material and at least a portion of the heat pipe 702 may be a passage formed within the material. Thus, the cigar cooler 700 may be simple and cost effective to manufacture.

[0050] It should be appreciated that Figs. 2 and 7 only show a representative amount of the refractory material 250. Depending on, for example, the design, composition, age, and
rate of wear of the refractory material 250, there may be more or less refractory material 250 and it may be configured differently (e.g., an amount may be include between the exemplary cooling stave 400 and the furnace shell 260).

[0051] It should be appreciated that although the heat sink 210 is shown relatively close to the outside of the furnace shell, the heat sink may be any distance form the outside of the furnace as long as one or more heat pipes are capable of transferring heat within the furnace to the heat sink. In some cases it may be beneficial to have the heat sink 210 a substantial distance from the shell 260 to insure that no coolant associated with the heat sink may enter the shell 260 if a portion of the shell 260, plate coolers 200, stave coolers 400, 600, and cigar coolers 700, including the variants thereof, become damaged.

[0052] It should be appreciated that the above-described plate coolers 200, stave coolers 400, 600, and cigar coolers 700, including the variants thereof, may be utilized throughout the blast furnace including, for example, in the tuyere breast, bosh, stack, substantially in a vicinity of the iron notches, and/or any other area that may be susceptible to heat damage within a blast furnace. The above-described plate coolers 200, stave coolers 400, 600, and cigar coolers 700, including the variants thereof, may be particularly advantageous when used in an area substantially in a vicinity of the iron notches. When a large amount of coolant comes in contact with molten iron, the result can be explosive. Thus, if a conventional plate cooler or stave cooler were to rupture in the vicinity of the iron notches (containing molten iron) the coolant may contact the molten iron. A resulting explosion could cause significant damage to the furnace.

[0053] For example, Figs. 8(A) - 8(C) shows an exemplary tuyere 800 for use in cooling tuyeres. As discussed above, in the tuyere breast, the steel jacket may have large holes (tuyeres) in which the tuyere coolers may be inserted. During operation of the blast furnace, air is forced through the tuyeres to facilitate combustion. As a result, the tuyeres, tuyere coolers and any refractory lining around the tuyeres are subject to extreme heat.

[0054] As shown in Figs. 8(A) - 8(C), the tuyere 800, itself may include heat pipes 802. The heat pipes 802 may be configured and operate in a similar manner as discussed above. However, the tuyere 800 may be formed in a substantially conical shape, having a substantially conical cylindrical opening through which air may be forced into the furnace. Specifically, according to the example in Figs. 8(A) - 8(C), the tuyere 800 may be in the form of a substantially annular circular conical frustum. However, the tuyere 800 may take any shape having a hollow portion allowing air into the blast furnace. The heat pipes 802 may be
configured in any manner along the length of the tuyere 800 such that heat absorbed by an end of the heat pipes 802 inside the blast furnace may transfer the absorbed heat to an end of the heat pipes 802 outside of the blast furnace. At the end outside of the blast furnace, the heat may be transferred to a heat sink.

[0055] The tuyere 800 may be configured to be easily inserted into the tuyere breast through an existing tuyere opening without substantial modification to the furnace shell and/or refractory lining. However, any configuration may be used in which heat may be transferred by the heat pipe 202 from a portion of the heat pipe 202 inside the furnace to a portion of the heat pipe 202 outside the furnace. Furthermore, one or more heat pipes 202 may intersect or contact one another and/or share coolant.

[0056] By utilizing the above-described plate coolers 200, stave coolers 400, 600, cigar coolers 700, and tuyeres 800, including the variants thereof, substantially in a vicinity of the iron notches, the amount of coolant that may enter the furnace may be limited only to that coolant within the heat pipe(s) 202, 402, 702. Thus, by reducing the amount of coolant that may enter the furnace, the chances of an explosion due to coolant contacting the molten iron may be reduced as well.

[0057] According to the above-described examples, the majority of conventional blast furnaces may be upgraded to include cooling plates and/or cooling staves that may prevent a substantial amount of coolant from entering the furnace if a cooling plate and/or cooling stave ruptures. Furthermore, the upgrade may be undertaken with substantially the same resource expenditure, time expenditure, and/or non-production time that would otherwise be necessary to replace the conventional cooling plates and/or staves with more conventional cooling plates and/or staves.

[0058] According to the above-described examples, the cooling plates, cooling staves, cigar coolers, and or tuyeres may be made of a single material and at least a portion of the heat pipes therein may be a passage formed within the material. Thus, the cooling plates, cooling staves, cigar coolers, and/or tuyeres may be simple and cost effective to manufacture.

[0059] According to the above-described examples, if a certain portion of the blast furnace is damaged or experiencing greater than average wear, holes may be drilled and cigar coolers may be inserted to reduce the temperature in that area. The cigar cooler may prevent a substantial amount of coolant from entering the furnace if the cigar cooler ruptures.

[0060] While various features of this invention have been described in conjunction with the examples outlined above, various alternatives, modifications, variations, and/or
improvements of those features may be possible. Accordingly, the various examples, as set forth above, are intended to be illustrative. Various changes may be made without departing from the broad spirit and scope of underlying principles.
WHAT IS CLAIMED IS:

1. A device for exchanging heat between an inside of a blast furnace and an outside of the blast furnace, comprising:
   a body configured to be at least partially inserted into an opening in the blast furnace; and
   at least one cavity disposed within the body, each of the at least one cavities extending from substantially one end of the body to substantially an opposite end of the body, each of the at least one cavities capable of containing coolant;
   wherein the body is configured to transfer heat between a coolant contained within each of the at least one cavities and a heat sink outside of the blast furnace, and when the body is inserted into the opening of the blast furnace and each of the at least one cavities contains the coolant:
   the one end of the body is exposed to heat generated by the blast furnace and the opposite end of the body is exposed to the outside of the blast furnace;
   heat is absorbed by the coolant in a portion of the cavity in the vicinity of the one end of the body and is transferred to the coolant in a portion of the cavity in the vicinity of the opposite end of the body;
   the heat in the portion of the cavity in the vicinity of the opposite end of the body is transferred from the coolant, through the body, to the heat sink; and
   the body forms a barrier between the coolant and the heat sink such that substantially none of the coolant within each of the at least one cavities is in direct contact with the heat sink.

2. The device of claim 1, wherein the body is configured to be at least partially inserted into an existing opening in the blast furnace without substantial modification to the existing opening.

3. The device of claim 1, wherein the body is at least partially copper.

4. The device of claim 1, wherein the body is in the form of a plate cooler.

5. The device of claim 1, wherein the body is in the form of a cooling stave.

6. The device of claim 1, wherein the body is in the form of a cigar cooler.

7. The device of claim 1, wherein the body is configured to be inserted in an existing hole in a vicinity of an iron notches portion of the blast furnace.

8. The device of claim 1, wherein the body is configured to be inserted in an existing hole in a vicinity of a bosh portion of the blast furnace.
9. The device of claim 1, wherein the body is configured to be inserted in an existing hole in a vicinity of a stack portion of the blast furnace.

10. The device of claim 1, wherein the body is configured to be inserted in an existing hole in a vicinity of a tuyere breast portion of a blast furnace.

11. The device of claim 10, wherein the body is a substantially annular circular conical frustum.

12. A method of replacing a cooling device within a blast furnace, comprising: removing the cooling device from the blast furnace; and inserting the cooling device of claim 1 into an opening in the blast furnace previously occupied by the removed cooling device.

13. The method of claim 12, further comprising: avoiding substantial modification to a shell or a refractory lining of the blast furnace.

14. A method of cooling a blast furnace, comprising: at least partially inserting a body into an opening in the blast furnace, at least one cavity disposed within the body, each of the at least one cavities extending from substantially one end of the body to substantially an opposite end of the body, each of the at least one cavities containing coolant, the body being configured to transfer heat between the coolant contained within each of the at least one cavities and a heat sink outside of the blast furnace;

   exposing the one end of the body to heat generated by the blast furnace;
   exposing the opposite end of the body to the outside of the blast furnace;
   absorbing, with the coolant, heat in a portion of the cavity in the vicinity of the one end of the body;

   transferring the absorbed heat to the coolant in a portion of the cavity in the vicinity of the opposite end of the body; and
   transferring the heat in the portion of the cavity in the vicinity of the opposite end of the body from the coolant, through the body, to the heat sink;

   wherein the body forms a barrier between the coolant and the heat sink such that substantially none of the coolant within each of the at least one cavities is in direct contact with the heat sink.

15. The method of claim 14, wherein at least partially inserting the body into the opening in the blast furnace comprises, inserting the body into an existing opening in the blast furnace without substantial modification to the existing opening.
16. The method of claim 14, wherein at least partially inserting the body into the opening in the blast furnace comprises inserting the body in an existing hole in a vicinity of an iron notches portion of the blast furnace.

17. The method of claim 14, wherein at least partially inserting the body into the opening in the blast furnace comprises inserting the body in an existing hole in a vicinity of a bosh portion of the blast furnace.

18. The method of claim 14, wherein at least partially inserting the body into the opening in the blast furnace comprises inserting the body in an existing hole in a vicinity of a stack portion of the blast furnace.

19. The method of claim 14, wherein at least partially inserting the body into the opening in the blast furnace comprises inserting the body in an existing hole in a vicinity of a tuyere breast portion of the blast furnace.