A method and system for generating a production sequence for the control of resources and production for metal castings of a manufacturing plant. The system employs a transport system to transfer the castings between a series of processing stations, which could include heat treatment, quenching, decorating, demolding, cleaning, machining, inspection, storage, etc., served by the transport system. A series of guided vehicles moving along the transport carry the castings between the processing stations. Each guided vehicle includes an identifier monitored by a controller to direct the castings to the next required processing station according to a predetermined production sequence for the castings thereon.
METHODS AND SYSTEM FOR MANUFACTURING CASTINGS UTILIZING AN AUTOMATED FLEXIBLE MANUFACTURING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present patent application is a formalization of previously filed, co-pending U.S. provisional patent application Ser. No. 60/813,938, filed Jun. 15, 2006. This patent application claims the benefit of the filing date of the cited provisional patent application according to the statutes and rules governing provisional patent applications, particularly 35 USC § 119(e)(1) and 37 CFR §§ 1.78(a)(4) and (a)(5). The specification and drawings of the provisional patent application are specifically incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Traditionally, in conventional processes for forming metal castings, a mold, such as a metal die or sand mold having an interior chamber with the exterior features of a desired casting defined therein, is filled with a molten metal. A sand core that defines interior features of the castings is received and positioned within the mold to form the interior detail of the casting as the molten metal solidifies about the core. After the molten metal of the castings has solidified, the castings are generally removed from a treatment furnace(s) for heat treatment of the castings, removal of sand from the sand cores and/or molds, and other processing as required. The heat treatment process conditions the metal or metal alloys of the castings to achieve the desired physical characteristics of the castings as needed for a given application.

[0003] In a conventional heat treatment system, a series of castings can be placed within a basket and passed along a roller hearth or similar conveying mechanism through one or more heating chambers for a solution heat treatment. Additionally, as the castings move along the chambers of the heat treating furnace, the sand cores or molds of the castings also can be broken down as their binder materials are combusted, such that the castings can be de-cored and their molds broken down and removed, with the sand falling beneath the baskets and conveying mechanism for collection. After the castings have been heat treated, they can be removed from the heat treatment unit or furnace and directed to a quench station or tank.

[0004] However, during the transfer of the castings from the pouring station to the heat treatment station, and especially if the castings are allowed to sit for any appreciable amount of time, the castings may be exposed to the ambient environment of the foundry or metal processing facility. As a result, the castings tend to rapidly cool down from a molten or semi-molten temperature. While some cooling of the castings is necessary to allow the castings to solidify, the more the temperature of the castings drops, and the longer the castings remain below a process critical temperature (also referred to in some applications as the “process critical temperature”) of the castings, the more time is required to heat treat the castings.

[0005] For example, as illustrated in FIG. 1, it has been found that for certain types of metals, for every minute of time that the castings drop below its process control temperature, more than one minute, and in most cases at least about 3-4 minutes or more, of extra heat treatment time will be required to achieve the desired solution heat treatment results in the castings. Thus, even dropping below the process control temperature for the metal of the castings for as few as 10 minutes may require at least about 40 minutes of additional heat treatment time to achieve the desired physical properties. As a consequence, therefore, castings typically are heat treated for 2 to 6 hours, in some cases longer, to ensure the desired heat treatment effects are achieved in all the castings of a batch or series. This results in greater utilization of energy and, therefore, greater heat treatment costs.

[0006] Accordingly, it can be seen that a need exists for a system and method of heat treating castings that addresses the foregoing and other related and unrelated problems in the art.

SUMMARY OF THE INVENTION

[0007] Briefly described, the present invention generally relates to a casting processing system for enabling the pouring, forming, heat treating, cleaning, aging, quenching, and further processing of castings formed from metal and/or metal alloys at enhanced rates and efficiency, and with greater flexibility and control of movement of the castings between various processing stations, as compared with conventional casting processes in which castings are processed in batches along a substantially uniform path through heat treatment, quenching, etc. The castings are formed at a pouring station at which a molten metal such as aluminum, iron, or a metal alloy, is poured into a mold or die, such as a permanent metal mold, semi-permanent mold, or a sand mold. A transfer mechanism then typically will transfer the castings to a series of guided vehicles, each generally including a series of racks and/or baskets defining compartments in which the castings are received for transport into and through a heat treatment station and/or other processing stations, according to a pre-programmed processing sequence or schedule for each casting or set of castings on the guided vehicles. During this transition from the pouring station to one or more downstream processing stations, the molten metal of the castings generally is permitted to cool to an extent sufficient to form the castings.

[0008] The guided vehicles generally are carried along their predetermined processing paths through the various casting processing stations in a vertically hanging arrangement supported on a transport system, typically comprising an overhead gantry or monorail conveyor, or other, similar type of conveying mechanism, with the racks thereof being stacked vertically in one or more rows mounted on a vertical support structure. Each of the guided vehicles generally will include an identifier, which can include a bar code, alphanumeric tag, or other readable identifier that can be attached to each of the racks or along the vertical supports of the guided vehicles. Alternatively, the identifiers also can include infrared or RF transceivers or tags, or other sensors that provide a signal to various receivers or other reader mechanisms mounted along the processing paths for the castings.

[0009] A system control monitors and automatically directs each of the guided vehicles along a predetermined/pre-programmed processing sequence or path for the cast-
ings of each guided vehicle through the required processing stations for that particular set of castings based upon the detection or reading of the identifiers of the guided vehicles. For example, a first casting or set of castings can be transported from the pouring station to a heat treatment station and thereafter transferred to an aging or quench station, while a second casting or set of castings can be transferred first to trimming and/or mold removal stations prior to heat treatment and quenching, or simply can be directed straight to quenching and then aging, depending upon the desired properties for the casting.

[0010] The overhead transport system further generally will include an elongated track having a series of pathways or segments, and a series of switches or junction points at which the guided vehicles can be diverted into the various processing stations according to their pre-programmed processing sequences. The transport system segments or pathways can extend through the various processing stations themselves, or can simply stop at the various processing stations, whereupon a transfer mechanism can transfer the castings directly into the processing stations, such as a heat treatment unit, etc., for processing. Thereafter, the castings can then be reloaded into a basket or rack of the guided vehicle at the downstream end of the processing station.

[0011] The transport system also generally includes a drive system for conveying the guided vehicles along their path of travel. This drive system can be a constant drive, utilizing a substantially constantly moving chain or belt, with each guided vehicle including a carrier that is detachably engageable therewith to facilitate the transfer of the automatic guided vehicles to different lines or segments of the transport system track, so as to be transferable into and through the different processing stations, as needed. Alternatively, the transport system can include an electrified rail or other, similar drive, and with the guided vehicles including drive motors for driving the guided vehicles along the rails of the transport system.

[0012] Various features, objects and advantages of the present invention will become apparent to those skilled in the art upon a review of the following detailed description, when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a graphical representation of a heat treatment cycle illustrating the increase in heat treatment time required for each minute of time the temperature of the casting falls below its process control temperature.

[0014] FIG. 2A is a schematic illustration of one exemplary embodiment of a casting processing system according to various aspects of the present invention.

[0015] FIG. 2B is a plan view illustrating the transfer of the castings from the transport system to a processing station.

[0016] FIG. 3 is an end view illustrating the transport of castings contained with a guided vehicle being conveyed through a processing station such as a heat treatment unit.

[0017] FIGS. 4A-4B are side elevational views illustrating an exemplary embodiment of an automatic guided vehicle according to the principles of the present invention.

[0018] FIG. 5A is an end view illustrating the passage of a guided vehicle through a processing station, being supported by the monorail system on the outside of the processing station.

[0019] FIG. 5B is an end view illustrating the passage of a guided vehicle through a processing station, being supported by a conveying system mounted within the inner chamber of the processing station.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring now in greater detail to the drawings in which like numerals refer to like parts throughout the several views, FIGS. 2A-2B schematically illustrate one exemplary embodiment of an integrated metal casting processing facility or system 5 including a series of casting processing stations, such as a pouring station 10, transfer/loading station 11, mold removal 12, trimming station 13, heat treatment station 14, a quench station 16, and cleaning and aging stations 17 and 18, for processing a series of castings C according to pre-programmed processing sequences or paths for such castings. Other, different processing stations, such as for machining, inspection, storage, and the like, also can be included in this casting processing system as will be understood by those skilled in the art. The present invention is directed to a system for controlling the movement of such castings between the pouring station and the various downstream casting processing stations 12-18 as needed to treat the castings to achieve desired physical properties thereof, to enhance the flexibility and efficiency of manufacture of such castings by maintaining and controlling their movement between the processing stations needed to treat or process the castings to achieve desired physical properties, therefore, according to the programmed processing sequences for each casting or set of castings.

[0021] Metal casting processes generally are known to those skilled in the art and a traditional casting process will be described only briefly for reference purposes. It will be understood by those skilled in the art, however, that the present invention can be used in any type of casting process, including metal casting processes for forming aluminum, iron, steel, and/or other types of metal and metal alloy castings. The present invention thus is not and should not be limited solely for use with a particular casting process or a particular type or types of metals or metal alloys.

[0022] As generally illustrated in FIG. 2A, a molten metal or metallic alloy M typically is poured into a die or mold 19 at the pouring or casting station 10 for forming a casting C, such as a cylinder head, engine block, or other, similar cast part. A casting core 21, generally formed from sand and a binder such as a phenolic resin or other known binder materials, can be received or placed within the mold 19 to create hollow cavities and/or casting details or core prints within the casting. Each of the molds alternatively can be a permanent mold or die, typically formed from a metal such as steel, cast iron, or other materials as is known in the art. Such molds also may have a clam-shell style design for ease of opening and removal of the casting therefrom. Alternatively still, the molds can be “precision sand mold” type molds and/or “green sand molds”, which generally are formed from a sand material such as silica sand or zircon sand mixed with a binder such as a phenolic resin or other binder as is known in the art, similar to the materials forming the sand casting cores 21. The molds further may be semi-permanent sand molds, which typically have an outer mold wall formed from sand and a binder material, a metal such as steel, or a combination of both types of material.
Additionally, the molds may be provided with one or more riser openings (not shown) to serve as reservoirs for molten metal. These reservoirs supply extra metal to fill the voids formed by shrinkage as the metal cools and passes from the liquid to the solid state. When the cast article is removed from its mold, the solidified metal in these openings can remain attached to the casting as a projection or “riser” (not shown). These risers generally are non-functional and are subsequently removed, typically by mechanical means, such as in trimming station 13 as needed or desired.

It will be understood that the term “mold” will be used hereafter to refer generally to all types of molds and/or dies as discussed above, including permanent or metal dies, semi-permanent and precision sand mold types, and other metal casting molds, except where a particular type mold is indicated. It further will be understood that in the various embodiments discussed below, unless a particular type of mold and/or heat treatment process is indicated, the present invention can be used for heat treating castings that have been removed from their permanent molds, or that remain within a sand mold for the combined heat treatment and sand mold break-down, removal, and sand reclamation.

A heating source or element, such as a heated air blower, gas-fired heater mechanism, electric heater mechanism, fluidized bed, or any combination thereof also may be provided adjacent the pouring station 10 for preheating the molds. Typically, the molds can be preheated to a desired temperature depending upon the metal or alloy used to form the castings. For example, for aluminum, the mold may be preheated to a temperature of from about 400°F to about 600°F. The varying preheating temperatures required for preheating the various metallic alloys and other metals for forming castings are well known to those skilled in the art and can include a wide range of temperatures above and below from about 400°F to about 600°F. Additionally, some mold types require lower processing temperatures to prevent mold deterioration during pouring and solidification. In such cases, and where the metal processing temperature should be higher, a suitable metal temperature control method, such as induction heating, also may be employed.

Alternatively, the molds may be provided with internal heating sources or elements for heating the molds. For example, when a casting is formed in a permanent type metal die, the die may include one or more cavities or passages formed adjacent the casting and in which a heated medium such as a thermal oil is received and/or circulated through the dies for heating the dies. Thereafter, thermal oils or other suitable media may be introduced or circulated through the dies, with the oil being of a lower temperature, for example, from about 250°F to about 300°F, to cool the casting and cause the casting to solidify. A high temperature thermal oil, for example, heated to from about 500°F to about 550°F, then may be introduced and/or circulated through the die to arrest cooling and raise the temperature of the casting back to a soak temperature for heat treating. The pre-heating of the die and/or introduction of heated media into the die may be used to initiate heat treatment of the casting. Further, preheating helps maintain the metal of the casting at or near a heat treatment temperature to minimize heat loss as the molten metal is poured into the die, solidified, and transferred to a subsequent processing station for heat treatment. If additionally desired, the casting also may be moved through a radiant chamber or zone to arrest or minimize cooling of the casting prior to its movement into a desired casting processing station.

As indicated in FIG. 2A, each of the molds 19 generally can include side walls 22, an upper wall or top 23, and a lower wall or bottom 24, which collectively define an internal cavity 26 in which the molten metal M is received and formed into the casting C. A pour opening 27 generally is formed in the upper wall or top of each mold and communicates with the internal cavity for passage of the molten metal through and into the internal cavity 26 of each mold. As also indicated in FIG. 2A, the pouring station 10 generally includes a ladle or similar mechanism 28 for pouring the molten metal M into the molds 19. The pouring station 10 further can include a conveyor, carousel, or similar conveying mechanism, that moves one or more molds from a pouring or casting position, where the molten metal is poured into the molds, to a transfer point or position at or within the transfer/loading station 11. Thereafter, the castings can be removed from their molds and transferred, or transferred while remaining in their molds, by a robotic arm or other similar transfer mechanism or manipulator, such as shown at 29 in FIG. 2B, to a transport system 40 for conveyance to the downstream processing stations or chambers thereof as indicated at 12-14 in FIG. 2A. Prior to and/or during such transfer, the molten metal is allowed to cool to a desired extent or temperature within the molds as needed for the metal to solidify into the castings. The castings then are transported to one or more of the downstream processing stations for further processing such as, for example, heat treatment, as illustrated in FIGS. 2A-3.

It further has been discovered that, as the metal of the casting is cooled down below its solidification temperature, it reaches a temperature or range of temperatures referred to herein as the “process control temperature” or “process critical temperature,” below which the time required to both raise the castings to their solution heat treatment temperature and perform the heat treatment thereof is significantly increased. It will be understood by those skilled in the art that the process control temperature for the castings being processed by the present invention will vary depending upon the particular metal and/or metal alloys being used for the castings, the size and shape of the castings, and numerous other factors.

In one aspect, the process control temperature may be from about 380°F-480°F to upwards of about 600°F. and as low as about 250°F-325°F. for castings made from aluminum or aluminum/copper alloys or similar metals. In another aspect, the process control temperature maybe from about 800°F to about 1300°F. for some iron or iron alloys. The process control temperature further generally is below the solution heat treatment temperature for most aluminum/copper alloys, which typically is from about 40°F-472°F to about 495°F. While particular examples are provided herein, it will be understood that the process control temperature will vary depending upon the particular metal and/or metal alloys being used for the castings, the size and shape of the castings, and numerous other factors.

When the metal of the castings is within the desired process control temperature range, the casting typically will be cooled sufficiently to solidify as desired. For example, depending on the alloy formation or metal composition of...
the castings, castings made from aluminum alloys generally will need to cool to about 460°C-425°C or lower, to enable sufficient solidification so that the castings can be gripped and manipulated, i.e., removed from their molds/dies and/or transferred to the vertical heat treatment unit or line. This solidification temperature will be understood as varying and can be determined as understood by those skilled in the art based on the formulation of the metal being cast. However, if the metal of the casting is permitted to cool below its process control temperature, it has been found that the time that the casting will need to be exposed to heat treatment at the desired heat treatment temperature for the metal of the casting will be increased by more than one minute, and possibly for at least about three-four additional minutes or more, for each minute that the metal of the casting is cooled below the process control temperature, for example, from about 475°C to about 495°C for aluminum/copper alloys, or from about 510°C to about 570°C for aluminum/magnesium alloys. Thus, if the castings cool below their process control temperature for even a short time, the time required to heat treat the castings properly and completely as needed to achieve the desired physical properties for the casting may be increased significantly.

[0031] In addition, it should be recognized that in a batch processing system, where several castings are processed through the heat treatment station in a single batch, the heat treatment time for the entire batch of castings generally is based on the heat treatment time required for the casting(s) with the lowest temperature in the batch. As a result, if one of the castings in the batch being processed has cooled to a temperature below its process control temperature, for example, for about ten minutes, the entire batch typically will need to be heat treated, for example, for at least an additional forty minutes to ensure that all of the castings are heat treated properly and completely.

[0032] Various aspects of the present invention therefore, are directed to an integrated processing facility or system 5 (FIG. 2A-2B) and methods of processing metal castings, wherein the castings are moved and/or transitioned (within or from the molds) from the pouring station 10 to and through a predetermined/programmed series of processing stations, i.e., trimming, heat treatment, and then quenching or heat treatment quenching, cleaning and aging, while arresting cooling of the molten metal prior to heat treatment thereof at a temperature at or above the process control temperature of the metal, but below or equal to the desired heat treatment temperatures thereof to allow the castings to solidify. Accordingly, various aspects of the present invention include a system control 35 for monitoring both the location and/or movement of the castings along the transport system and the temperature of the castings during such transport to ensure that the castings are maintained substantially at or above the process control temperature. Still further, the system control can be linked to and in control of the various processing stations so as to control not only the movement and dwell time of the casting through the processing stations, but also the operation of these processing stations (e.g., the heat treatment temperature of the heat treatment station, the application of fluid media for cleaning, and/or trimming, etc.).

[0033] Additionally, thermocouples or other similar temperature sensing devices 36 (FIG. 2A) can be placed on or adjacent the castings, such as at spaced locations along the path of travel of the castings from the pouring station 10 to the heat treatment station 12 so as to provide substantially continuous monitoring of the temperature of the castings. Alternatively, periodic monitoring of the castings at intervals determined to be sufficiently frequent, may be used. Such sensing devices may be in communication with the system control 35 that can be linked to and in control of one or more heat sources positioned at desired or predetermined locations along the path(s) of travel of the castings C from the pouring station 10 to the trimming, mold removal, and/or heat treatment stations 12-14. One or more heat sources also can be positioned on or adjacent the robot or transfer mechanism 29 (FIG. 2B) of the transfer/loading station 11 and along the transport system 40 for applying heat to the castings during transfer of the castings to the heat treatment station or a chamber thereof.

[0034] The temperature measuring or sensing device(s) and the operation of the heat source(s) upstream from the heat treatment station can be controlled or coordinated to substantially arrest cooling of the castings and apply heat as needed to maintain the temperature of the castings substantially at or above the process control temperature for the metal of the castings. It also will be understood that the temperature of the castings can be measured at one particular location on or within the castings, can be an average temperature calculated by measuring the temperature at a plurality of locations on or within the castings or may be measured in any other manner as needed or desired for a particular application. Thus, for example, the temperature of the castings may be measured at multiple locations on or in the casting, and an overall temperature value may be calculated or determined to be the lowest temperature detected, the highest temperature detected, the median temperature detected, an average of the detected temperatures, or any combination or variation thereof.

[0035] As indicated in FIGS. 3-5B, the transport system 40 for the integrated casting processing facility 5 typically will comprise an overhead gantry or monorail system 41 including a guide track 42 along which a series of guided vehicles 43 are supported for transport of the castings C along various casting processing pathways according to their predetermined programmed casting processing sequences to perform various processing operations therein to achieve the desired metallurgical properties of the castings. This monorail or other conveying system typically will be designed to accommodate maximum payload ranges of up to four-five tons, which can be conveyed at speeds upwards of 250-300 feet per minute. In some applications, greater maximum payloads may be designed into the system as needed or required, while the processing speeds further can be varied (i.e., increased or decreased) as needed to accommodate the efficient transfer and processing of the different type castings being processed.

[0036] As indicated in FIG. 2A-2B, the guide track 42 of the monorail system 41 typically includes a series of spur lines, segments or pathways 44 that diverge or branch off from each other at a series of junction points 46 (FIG. 2A) generally located at or adjacent the upstream or downstream ends of the processing stations 12-18. According to the principles of the present invention, the system control 35 for the casting processing system 5 will monitor the guided vehicles 43 (FIG. 2B) as they approach the junction points 46 of the transport system 40 and will direct the guided
vehicles 44 to a next processing station according to the programmed processing sequence for the castings or sets of castings contained thereon. The guide track 42 of the monorail system can include a constant driven chain system such as, for example, a ski lift type system, utilizing a series of driven chains or belts 47 (FIG. 4B) that are constantly moving along their respective portions of the guide track, or a walking beam type system for moving the guided vehicles therealong. Alternatively, the guide track further can be formed from a metal material through which an electric current is conducted to help drive each of the guided vehicles 43 along the guide track.

[0037] With such a constant driven chain type drive system, the guided vehicles can be releasably mounted thereto so as to be engagable and disengagable from the drive chain for transfer of the vehicles between various segments or pathways of the guide track. In such an embodiment, the monorail system further will generally include a drive mechanism such as an electric motor, battery pack, and one or more drive gears for driving the belt, chains or walking beams of the guide track segments. Alternatively, in the embodiment of the guide track for the monorail system that includes a conductive rail along which an electric current is passed, the guided vehicles generally will include an inducitive type drive mechanism that is driven therealong by the current passing through the rail of the guide track. For example, such a conductive rail conveyance system can include a Siemens Dematic or "RoboLoop™ system or other, similar system as known in the art that generally can be laid out in straight lines and with curved sections that typically will be modular for each expansion or reconfiguration based upon changing needs within the casting processing facility or system.

[0038] As indicated in FIGS. 3-5B, each of the guided vehicles 43 generally includes an elongated, vertically extending support section 50 that is attached to and supported from the guide track 42 of the transport system 40 by carrier 51. As shown in FIG. 4A, the carrier 51 can include a series of rollers or drive wheels 52 and a carrier base 53 on which the vertical support section 50 can be detachably mounted. The drive wheels are adapted to engage and roll along the guide track 42 of the transport system 40. In addition, the carrier base 53 can also have a drive motor or other, similar drive mechanism 54 for driving the drive wheels 52 to convey the carrier base on support section 50 along their desired path or travel. Still further, as indicated in FIG. 4B, for systems where the monorail 41 of the transport system 40 includes a driven chain or belt 47, the carrier 51 (FIG. 4A-4B) can include a locking clamp 55 adapted to releasably engage and disengage the carrier from a downwardly extending locking projection or arm 56 attached to the drive chain 47. A locking lever or arm 57 typically is mounted to the carrier 51 in a position projecting forwardly therefrom and can be engaged so as to cause the clamping sections 55A/55B of the locking clamp 55 to be pivoted into engagement with a locking projection 56 of the drive chain 47 and/or disengage from the locking projection for transfer of the guided vehicle 43 to another section in the pathway 44 of the guide track 42.

[0039] As further illustrated in FIGS. 4A and 4B, the vertical support section 50 of each guided vehicle 43 generally includes one or more support racks 60 having one or more compartments or baskets 61 that project outwardly from the central support section 50, and are adapted to receive a series of castings C therein. The guided vehicles 43 further will include one or more identifiers 62 mounted or applied to one or more of the support racks 60, as indicated at FIG. 4A, or at one or more desired points along the central support section 50 of each guided vehicle 43. Each of the identifiers designates and coordinates a casting or series of castings contained within one or more racks/baskets of each guided vehicle with a pre-programmed processing sequence for such casting(s), e.g., with a desired sequence of processing stations 12-18 (FIG. 2A) and steps needed to achieve the desired physical properties for such casting(s).

[0040] The identifiers can include visual identifiers such as bar codes, reflective tags, or alphanumeric identifiers applied to or formed on the racks or the central support section of each guided vehicle, which visual identifiers can be read by optical sensors or detectors 63 (FIG. 4B), such as alphanumeric scanners, photoelectric detectors, or other, similar detectors. Typically, one or more detectors will be mounted at selected locations along the path of travel of the guided vehicles, for example, upstream from the junction points along the guide track. The detectors generally will be mounted to positions adapted to read the identifiers on the guided vehicle and/or racks/baskets thereof. Alternatively, the identifiers can include infrared or RF tags, or other wireless transmitters or transceivers that emit wireless signals that can be monitored by the detectors 63 as the guided vehicles pass thereby.

[0041] As the identifiers are detected or read by the detectors 63, the detectors will send a signal indicative of the position of such monitored/detected guided vehicles, and thus the castings supported thereon, to the system control 35 (FIG. 2A) for purposes of tracking the progress of the casting through the processing system 5 of the present invention. In response, the system control can thereafter automatically direct the guided vehicles to a next desired processing station (i.e., heat treatment, trimming, or quenching, etc.) according to the pre-programmed processing sequence for a particular casting or batch of castings contained on such a guided vehicle. As a result, the entire guided vehicle, and thus the entire set or batch of castings supported thereon, can be transferred or redirected to a next desired processing station according to its preprogrammed processing sequence.

[0042] In another example embodiment, the racks/baskets containing the individual castings or batches of castings contained within the various support racks 60 or the baskets 61 of each of the guided vehicles can be hand off or transferred directly into a next desired processing station as needed. For example, the racks 60 themselves can be removably mounted to each of the central support sections of the guided vehicles 45 and thus can be detached and fed directly into a processing station, such as the heat treatment station 14 (FIG. 2A). Additionally, the baskets or the castings contained therein can be transferred to another guided vehicle or simply dumped or otherwise transferred to another conveyance mechanism, such as a basket or rack of another guided vehicle for transfer to the next processing station for such castings.

[0043] Accordingly, each guided vehicle or basket/rack thereof will be provided with its own unique identifier associated therewith to enable precise tracking and control
of the movement of the casting(s) received thereon throughout the casting processing system/facility. This will further enable enhanced flexibility and efficiency in the various processing of the castings by automatically transferring the castings to the processing stations as required for the processing of the castings to achieve the desired or necessary physical characteristics thereof.

[0044] As further illustrated in FIGS. 3 and 5A-5B, after being transferred or directed to a next desired processing station, the guided vehicles 43 can be conveyed through such a processing station, for example, the heat treatment station 14, while remaining connected to and transported by the overhead monorail system 41 as indicated in FIGS. 3 and 5A. Alternatively, the guided vehicles can be transferred to separate, stand-alone transport systems, such as indicated at 70 in FIG. 5B, for transport of the guided vehicles through such processing stations. Still further, the castings also can be unloaded into other types of conveying mechanisms, such as into baskets of a roller hearth, for movement through the processing stations.

[0045] In operation of the casting processing system 5 (FIG. 2A), after the molten metal M or metallic alloy has been poured into a series of the molds or dies and has at least partially solidified to a degree where the resultant formed castings C will not deform, the molds or dies with the castings therein generally are removed from the pouring station by a transfer mechanism. The castings/molds are initially transferred to the transport/loading station 11 where they are placed on a rack or basket of a guided vehicle of a transport system 40, such as an overhead gantry or monorail conveyor 41, for conveyance of the castings in series or in batches to various ones of the processing stations according to the pre-programmed processing sequence or instructions for a particular casting or set of castings.

[0046] Each guided vehicle, or each rack/basket of each guided vehicle, generally will have an identifier 62 already applied thereto prior to being loaded with the castings. Once a particular casting or set of castings has been loaded on the racks/baskets, a detector reads the identifier associated therewith and notifies the system control that the casting or set of castings just released from the pouring station has been loaded on a guided vehicle or a particular rack having that identifier. The system control will then match the programmed processing sequence for that detected casting or batch of castings with that identifier for tracking through the facility.

[0047] After the castings have been loaded into the racks of the guided vehicles 43 (FIG. 2B), a scanner or tracking system is used to track individual castings/molds and/or sets thereof and their location in the rack. The movement of each of the guided vehicles of the monorail system also can be recorded, tracked, and controlled by the system control. The rack system of each guided vehicle also may have numerous identified locations, thereby allowing a single guided vehicle to carry numerous castings or components that will be directed to a variety of different processing stations. The system control monitors the status of each of the guided vehicles and/or racks thereof and is programmed with the sequence(s) for moving the castings into and through predetermined ones of the processing station for the casting or components. Once the system control determines the position and necessary pathway for processing the castings or components, it directs their guided vehicles to carry them to their necessary processing station(s) according to their programmed processing sequence(s).

[0048] The system control additionally monitors all the processing stations as the castings are moved into and out of required processing stations. If the castings have an exterior mold or interior cores, the system control initially may direct the guided vehicles therefore to a pulse wave demolding or decorating station where at least a portion of the mold and/or core may be removed or separated from the casting. An example of such demolding and decorating that can be utilized with the present invention is illustrated in U.S. Pat. No. 6,622,775, the disclosure of which is also incorporated herein in its entirety by this reference. The molds and cores may be removed by physically impinging with a fluid or by sound, or the casting may be physically shaken or vibrated to break up the sand core and remove the sand.

[0049] An alternative processing path or sequence can include directing the castings to the trimming station for the removal or unblocking of orifices before the demolding station. For instance, the “trimming” system may be used to penetrate and cut the blockages from the openings of the castings using external pressure. Various other types of mechanical methods including punching or trimming devices as known in the art may be used, including a laser, a water jet, a physical or mechanical cutter, such as a milling machine, drill or boring device, a saw device, or a punch press system with piercing/upsetting dies to cut or otherwise physically penetrate the blockage. Still further, such a trimming system may be controlled by the system control to employ variable pressure, volume and/or temperature of the fluids, for example water, air, thermal oils, sand or other particulate media, etc., to cut or trim the blockage and expose the core according to the programmed processing sequence for the castings. The trimming means may also be used to remove the feed gates and/or risers which are formed during the forming of the castings. The trimming and/or demolding processes may be started and/or completed while the temperature of the castings is maintained at or above the “Process Critical Temperature” to aid in the decreasing of the actual heat treatment time period for heat treating the castings.

[0050] After substantial decoring and demolding, the system control generally will direct the guided vehicles with the castings therein to a next programmed processing station, such as solution heat treatment station 14 (FIG. 2A) to strengthen or harden the casting or to relieve internal stresses, or to quenching, cleaning, etc. During heat treatment, the cast alloy or metal is heated to a suitable temperature, held at that temperature long enough to allow a certain constituent to enter into solid solution, and then cooled rapidly to hold that constituent in solution. The heat treatment station generally includes a heat treatment furnace, typically a gas fired furnace or heated by a commonly allowable means, and generally includes a series of treatment zones or chambers for heat treating each casting and removal and reclaimation of the sand material of the sand cores. Such heat treatment zones may include various types of heating environments such as conduction, oxidation, and convection zones or other commercially viable systems known in the art, such as using
heated air flow. The number of treatment zones also may vary as needed or required for a particular application to remove the sand cores.

[0051] The residence or dwell time of the castings within the heat treatment station, or each zone thereof, generally will be a function of the time needed for heat treating the castings to a desired level, and can be controlled by the system control according to the programmed processing sequence for each batch of castings associated with that particular identifier to achieve the desired heat treatment properties. It is also possible to partially age the castings within the heat treatment station if desired. The heat treatment station also can be designed so that the gantry or monorail conveyor 41 will be able to convey the castings through the heat treatment station without requiring unloading or transfer of the guided vehicles to a separate conveying mechanism, as indicated in FIG. 5A. Alternatively, as indicated in FIG. 5B, the racks of the guided vehicles, or simply the castings therein, can be transferred to a separate conveying or transport system 70 contained within the heat treatment or other processing station, with the racks and/or castings thereafter being loaded on a downstream guided vehicle for transport to another processing station.

[0052] Examples of a heat treatment furnace or system in which heat treatment of castings is carried out in conjunction with the removal of the sand cores from the castings, and potentially the reclamation of the sand from the sand cores of the castings, are provided in U.S. Pat. Nos. 5,294,094, 5,565,046; and 5,738,162, the disclosures of which are incorporated herein in their entireties by this reference. A further example of equipment for the heat treatment of metal castings and in-furnace mold and sand core removal and sand reclamation that can be utilized with the present invention is illustrated in U.S. Pat. No. 6,217,317, the disclosure of which is also incorporated herein in its entirety by this reference.

[0053] According to one aspect of the present invention illustrated in FIG. 2A, after the heat treatment is complete, each casting can be transferred from the heat treatment station to a next station, such as a cleaning station via controlled movement of their guided vehicles by the system control, or can be individually loaded into the cleaning station by a robot or other automated loading means. For cleaning, the castings will be placed into a chamber having nozzles positioned around the periphery of the casting. One or more nozzles may be positioned in direct alignment with the open orifices. Additionally, one or more nozzles may be inserted into the open orifices. The nozzles then direct an air, water, oil or other media jet at the orifices to assist with removal of the cores. During the cleaning process, some areas of the castings may be slightly quenched; however, any temperature change is likely minimal. After the cleaning process is complete, the castings may then be transferred to an aging oven.

[0054] According to yet another aspect of the present invention depicted in FIG. 2A, the castings may be transferred to a quenching station after heat treatment or after cleaning. The quenching process provides a high volume/pressure of fluid media (water, air, steam, oil, etc.) to the castings via the cleared orifices or otherwise. The quenching process may utilize a quench tank or reservoir filled with a cooling fluid, such as water or other known media material, in which each casting or batch of castings are immersed for cooling and quenching. The quench tank or reservoir generally is designed to accommodate various sizes and types of castings being formed, the specific heat of the metal or metal alloy, and the temperatures to which each casting has been heated. The quench time and temperature generally are controlled to achieve the desired resulting mechanical and physical properties of the castings. For example, the system control can control the quench time and temperature of the quench media applied according to the programmed processing sequence for each identified casting or group of castings. In some instances, the quench station may be maintained at about 120°F to about 200°F. As above, the casting may then be transferred to an aging oven immediately or at a later time dependent by the required process for the specific component.

[0055] Often, the quenching media accumulates traces of sand from the castings. The sand then re-deposits on the castings. To further remove any traces of sand on or in the castings, the castings may be transferred to a cleaning station. As described above, the cleaning process subjects the castings to a variable volume, pressure and temperature of a media stream of air, water, oil, or steam. Where air is used to clean the castings, the cleaning process may further quench the castings. After cleaning the castings, the castings may then be placed into an aging oven if desired. Both the cleaning and or quenching station will be designed so that the guided vehicles will be able to convey the castings through the stationing without any type of unloading or load mechanism. A further example of quenching and cleaning can be utilized with the present invention is illustrated in U.S. Pat. No. 6,910,522 the disclosure of which is also incorporated herein in its entirety by this reference. After cleaning and quenching, the system control can then monitor and direct each guided vehicle to deliver the castings therein to a machining, inspection or storage station where further necessary processing according to the programmed processing sequence therefore can be completed.

[0056] Throughout the manufacturing process the system control commands and controls movement of the guided vehicles to each of their assigned processing stations or tasks, such as presenting a casting to a particular processing/machining station, removing the casting from each such processing station, and conveying casting(s) between required processing stations, etc. Each identifier of each guided vehicle also can include a processor or controller including an infrared or RF transceiver or other wireless communication device for communicating with the main system control located remotely from the monorail system, so as to actively send positional and status information from each guided vehicle to the main system control and receiving task commands from the main system control on a regular timely interval.

[0057] Additionally, the guided vehicles also may be adapted to simply deliver individual basket type of carriers to and from the various processing stations, as well as be directed to transport waste materials or finished castings back to a designated area. According to yet another aspect of the present invention depicted in, the rack system or baskets of the guided vehicles can incorporate saddles or locating pins to assure proper orientation of the casting or components during the processing station procedures.
The present invention is directed to a system for lowering the overall cost, labor, energy for the manufacturing of castings by removing direct human contact and using flexible manufacturing principles. Since only minimal human contact is required, human errors and safety concerns will be lowered or eliminated making the process more efficient and safer. Flexible manufacturing also allows a manufacturing facility to produce different product lines or components during identical time periods without modifying the manufacturing stations. A logic computer program can be created for the system control to adjust or maintain different processing times for the various different castings or components by modifying their delivery to the required station by the guided vehicles; thereby increasing the overall efficiency of facility. For an example, if the castings have a shorter or longer required heat treatment processing requirement, then the system controller would adjust the delivery time of the guided vehicle(s) for the relevant castings/components to the heat treatment station and the dwell time within the station to assure optional efficiency for that particular station. Furthermore additional queuing or thermal arresting chambers also may be required or utilized on a spur portion of the gantry or monorail line to assure efficiency at the processing stations. Utilizing an adaptive flexible and “just-in-time system” will allow the manufacturer to produce a variety of different components at the identical time and minimize storage and stock inventory.

It will be readily understood by those persons skilled in the art that, in view of the above detailed description of the invention, the present invention is susceptible of broad utility and application. Many adaptations of the present invention other than those herein described, as well as many variations, modifications, and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the above detailed description thereof, without departing from the substance or scope of the present invention. Additionally, while the present invention is described herein in detail in relation to specific aspects, it is to be understood that this detailed description is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the present invention. The detailed description set forth herein is not intended nor to be construed to limit the present invention or otherwise to exclude any such other embodiments, adaptations, variations, modifications, and equivalent arrangements of the present invention, the present invention being limited solely by the claims appended hereto and the equivalents thereof.

What is claimed:

1. A system for processing castings, comprising:
   a pouring station for pouring molten metal into a mold to form the castings;
   a series of processing stations downstream from said pouring station, including at least one of a heat treatment station, quench station, aging station, and a cleaning station; and
   a transport system adapted to receive the castings from said pouring station and direct the castings to one or more of said processing stations according to a programmed processing sequence for the castings, said transport system comprising:
      a conveying mechanism;
      a series of guided vehicles, each including an identifier referencing said processing sequence for at least one casting received thereon.

2. The system of claim 1 and wherein said identifier referencing said processing sequence for at least one casting received thereon.

3. The system of claim 2 and wherein said wireless communication device comprises an RF transmitter.

4. The system of claim 1 and wherein each guided vehicle comprises a carrier having at least one rack for receiving at least one casting therein.

5. The system of claim 1 and wherein said conveying mechanism of said transport system comprises an overhead monorail conveyor adapted to receive said guided vehicles thereon.

6. The system of claim 5 and wherein said monorail conveyor further comprises a guide track along which said guided vehicles are moved and extending between said processing stations, said guide track having a series of junction points at which said guided vehicles can be redirected to selected ones of said processing stations according to said processing sequence for the at least one casting within each of said guided vehicles.

7. The system of claim 1 and wherein said transport system comprises a guide track having a series of track segments extending through each of said processing stations adapted to receive and direct selected ones of said guided vehicles through said processing stations.

8. The system of claim 1 and further comprising a system control adapted to monitor said identifiers of said guided vehicles and direct said guided vehicles between each of said processing stations according to said processing sequence for the at least one casting within each of said guided vehicles.

9. A method of manufacturing a series of metal castings, comprising:
   pouring molten metal into a series of molds;
   solidifying the molten metal sufficiently to form the castings;
   loading the castings on a series of guided vehicles of a transport system;
   monitoring and identifying at least one set of castings on each of the guided vehicles, and directing each guided vehicle through one or more processing stations according to a predetermined processing sequence for the castings loaded on each guided vehicle.

10. The method of claim 9 and further comprising directing a series of guided vehicles through a heat treatment station and heat treating the castings.

11. The method of claim 10 and further comprising moving the guided vehicles through a trimming station prior to heat treating the castings.

12. The method of claim 9 and further comprising placing the guided vehicles on a conveying mechanism for conveying the guided vehicles with the castings thereon to selected processing stations according to the predetermined processing sequence for the castings.
13. The method of claim 9 and wherein monitoring and identifying at least one set of castings on each of the guided vehicles comprises monitoring an identifier of each guided vehicle with a system control, and in response, directing each guided vehicle along a transport system through one or more selected ones of the processing stations according to the predetermined processing sequence for the castings on the guide vehicle associated with the monitored identifier.

14. The method of claim 9 and wherein monitoring and identifying at least one set of castings on each of the guided vehicles comprises detecting an identifier for the set of castings, and in response, transferring the set of castings into a selected processing station according to the processing sequence for the castings associated with the monitored identifier.