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(54) **METHOD AND APPARATUS FOR SIMPLIFIED PRODUCTION OF HEAT TREATABLE ALUMINUM ALLOY CASTINGS WITH ARTIFICIAL SELF-AGING**

VERFAHREN UND VORRICHTUNG ZUR VEREINFACHTEN HERSTELLUNG VON
WÄRMEBEHANDELBAREN ALUMINIUMLEGIERUNGSGUSSTEILEN MIT KÜNSTLICHER
SELBSTALTERUNG

PROCEDE ET APPAREIL DE FABRICATION SIMPLIFIEE DE PIECES MOULEES EN ALLIAGE
D'ALUMINIUM APTES AU TRAITEMENT THERMIQUE A AUTOVIEILLISSEMENT ARTIFICIEL

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method and apparatus for making aluminum alloy castings, wherein the heat-treatment processes of the prior art are simplified, by actually eliminating some traditional steps and equipment. The invention is applicable for example in the production of cylinder heads, motor blocks and the like, for automotive engines. The invention provides many advantages over the prior art heat-treatments, with an increased productivity of the casting plants, and lower capital and operation costs as well. The invention is particularly useful for producing aluminum alloys of the 3xx. x series of the classification of the Aluminum Association (AA), especially for T6 and T7 properties.

[0002] This invention is broadly applicable to the production of any aluminum alloy casting which in the past has derived meaningful benefit from quenching and artificial aging in an aging furnace. The invention eliminates the need for an aging furnace, while retaining the benefits thereof. This improvement has been styled herein as artificial self-aging (to distinguish from natural aging at ambient temperatures and from prior art artificial aging, which requires an aging furnace).

[0003] This invention is broadly-applicable to the production of any aluminium alloy casting of the type having significant precipitation hardening with meaningful benefit from "solution" heat treating and aging.

BACKGROUND ART

[0004] For a good background discussion and definitions of "heat treatable aluminum alloy castings", "artificial aging" (see also "precipitation hardening"), "quenching", "solution heat treatment", "casting series 3xx. x", and "T6 & T7 tempers" see the ASM Handbook series; particularly Volume 4 (1991), entitled "Heat Treating" (especially pages 841-879; see p. 841 for "heat treatable", p. 851 et seq. for "quenching" and p. 859 for "age hardening") and Volume 2 (1990), entitled "Properties and Selection: Nonferrous Alloys and Special Purpose Materials", (especially pages 15-41; see p. 39 for "heat treatable", p. 40 for "artificial aging") both being tenth editions, and also Volume 15 (1988), entitled "Casting" ninth edition (specially pages 757-761, see pp. 760-1 for "quenching" and "aging"); all published by ASM International.

[0005] In the production of cast parts made of aluminum alloys it has always been thought in the past to be necessary for many such castings (especially with a T6 or T7 temper) to undergo an elaborate heat-treating process in order to impart to the cast parts the necessary mechanical properties (like hardness and tensile strength required for the demanding working uses of said parts).

[0006] It is known that the degree of hardness and other mechanical properties of the cast parts depend on the

thermal history of the cast parts after having been cast in the mold. The Aluminum Association (AA) has classified the most used aluminum alloys and the several standard heat treatments used in the industry. Examples of such standard heat-treatments those denominated T6 and T7, which designate a standard set of mechanical properties developed by certain castings of primarily silicon-copper-aluminum alloys.

[0007] The automotive industry throughout the world demands very strict quality standards. Casting plants making aluminum motor parts must therefore be able to produce cast parts which consistently comply with the minimum levels of mechanical properties specified for each part. Since quality is a must, the casting plants follow those procedures and processes which are well tested and have proven reliable for many years. The production process currently followed in the industry comprises filling a mold with liquid aluminum alloy, cooling the cast part in the mold in order to obtain a solidified casting, extracting the casting from the mold, and allowing the cast part to cool-down naturally to ambient temperatures, and then subjecting batches of such cooled castings to the aforementioned "solution" heat-treating process. One way to reduce the heat load in the solution heat treatment furnace, has been to remove the sand cores and riser portions of the castings after natural cooling and before the "solution" heat treatment. The heat treating of the prior art comprises heating the preferably trimmed castings in a furnace to temperatures above about 470°C (typically in the range between 480°C and 495°C) for a certain period of time, usually in the range between at least 2 to 7 hours. This treatment is performed in order to bring back into solid solution the copper and/or other alloying elements that give the castings their hardness. It is known that, while the casting metal is in the molten state, the alloying elements are in solution in the aluminum substrate. During the cooling process, particularly if the cooling is carried out at a slow rate, there is a tendency for the different elements to become segregated. Therefore, traditionally the casting is re-heated in a "solution" heat treatment furnace for several hours, and only then is quenched, i.e. rapidly cooled down by a fluid quench from a temperature for example about 480°C to around 85°C, so that the solid solution is preserved (before segregation can occur). Such post solution-treatment quench cooling may commonly be continued in a manner sufficient to bring the castings down to any of a number of different temperatures and at different rates according to the final properties of the alloy to be emphasized.

[0008] This quenching step produces a supersaturated solid solution that causes the alloy to harden naturally as time passes. Finally, in order to accelerate and improve this age hardening, the quenched castings are maintained at temperatures of about 200°C in an "aging" furnace for about 2 or more hours. The time spent in the "aging" furnace at elevated artificial aging temperatures brings the alloy to at least a partial coherency in its struc-

ture giving the required hardness and strength properties.

[0009] U.S. patent No. 5,788,784 to Koppenhoefer et al. discloses a process for heat-treating light metal castings that requires "a solution heat treatment furnace 2, an adjoining quenching device 3, as well as an aging furnace 4", all particularly for cylinder heads of piston engines. In the 5,788,784 process, after solidifying and removing the casting from the mold, said castings unconventionally are not naturally cooled, yet are still solution heat treated (claiming the advantage of using the residual heat of the casting present at the approximate 530°C temperature of such treatment). Thereafter, the castings are quenched with an air/water mixture down to 130°C to 160°C, and then aged in a furnace at approximately 170°C to 210°C (thus taking advantage of some relatively minor residual heat carryover into the aging furnace), and are then finally cooled to room temperature after, for example, four hours of furnace aging. The castings are individually quenched with a mist-type fine mixture of air and water, which is "nozzle sprayed on all sides" of the casting.

[0010] Koppenhoefer asserts a number of advantages by reason of quenching the castings with an air-water spray, for example that a uniform and low-distortion cooling is achieved, that the adhering core sand is not wetted at the elevated quenching temperatures and can be collected clean and reused after regeneration, and that the residual heat of the casting remaining at 130° to 160°C can be used to aid in the subsequent furnace aging step (by not cooling down the casting too much and leaving some heat in said casting). Quenching the casting by directing the sprayed water on all sides of the casting suggests that most of the residual heat is lost, with that amount retained being mainly in the inner portion of the casting. This also suggests that a large temperature gradient would have to be maintained between the interior and the surface of the casting in order for the amount of retained residual heat carried over into the aging step to be meaningful. Such large differentials in temperature across the casting (particularly the end product portion thereof) is one of the problems to be avoided while quenching a piece in order to avoid stresses and achieve the T6 or T7 properties and also to avoid spheroidization of the alloying elements.

[0011] U.S. patent No. 5,112,412 to Plata et al. teaches a process for cooling large cast billets of aluminum after a temperature homogenization (re-heat) annealing step. Annealing is a softening process for aluminum (just the opposite of the strengthening and hardening heat treatment of the present invention), and this Plata patent is silent on how the cooling is to be done to accomplish a particular result (mainly mentioning only that it be "in accordance with the alloy composition" and describing how the "automated and controlled manner of spraying can be adjusted to different shaped billets, as they may differ from the usual round shape"). This patent first describes cooling the annealed billet with a spray on all sides. This

decreases the temperature at the surface of said billet, while the center portion (inaccessible to the spray) necessarily cools more slowly and thus initially remains at a relatively higher temperature. The billet leaves the spray and is allowed to equalize its internal and external temperatures in an insulated chamber. In another embodiment, Plata et al describes a process modification in the case of a so-called (but otherwise unidentified) "hard" alloy to continue spraying until the billet has achieved an equalized temperature. An example of this temperature is given as "310 C.-350 C. in AlMgSi alloys" (a range above most age hardening but typical of softening annealing). The teaching includes the possibility of varying the intensity of the continuous spray, but only for the purpose of achieving a "better balanced heat flow" and a temperature zone "preferably distributed homogeneously during cooling so that no or only minimal deformations, stresses or cracks form". For example, the patent states that circular billets are sprayed evenly, but a rectangular billet may be sprayed with different intensity along its periphery. This difference in spray intensity is to achieve uniformity of cooling during the quench (just the opposite of subjecting the casting to a significant differential or complete absence of quench cooling of a specific waste portion of the casting in order to maintain such portion at a significantly higher temperature during the quench of the work portion (and much less to identify such a waste portion which is accessible to the spray, but is not to be so spray cooled). Thus, even though one of the embodiments discloses a spray process involving a difference in the temperature between certain portions of the billet which later reach an equalized temperature, there is no disclosure of differential quenching of selected portions of the casting to promote rather than minimize an initial significant heat differential between selected different portions of the casting (particularly with the division being between equally exposed waste and workpiece portions). Furthermore, Plata et al. teaches a process of cooling the surfaces of the workpiece (billet) on all sides, while the inner portion of the workpiece remains hot. If this process is applied to the workpiece portion of the castings for cylinder heads or blocks for engines, it will cause a different distribution of the alloying elements and thus it will fail to achieve the objects of the present invention (which provides a quenching step to produce uniform properties such as those obtained with a T6 treatment, all with accelerated aging but without the need for an aging furnace). In applicant's casting, the unquenched portion is an existing waste portion that is put to a useful interim purpose but whose ultimate alloy and physical properties are irrelevant Engine castings, if made by the Plata process would be rejected.

[0012] One or more of the present inventors' recent U.S. patent, No. 5,922,147 (to Valtierra et al.), mentioned above, discloses an improved heat-treating method whereby the castings are quenched immediately after having been extracted from the mold, thus eliminating "solution" heat treatment and avoiding the need for a so-

lution heat treatment furnace; while nevertheless producing castings with similar properties to those that undergo the traditional solution heating step. The 5,922,147 patent process provides a casting plant with greatly improved productivity and significant savings in capital and operational costs. This patent, however, does not teach or suggest a method capable of eliminating also the aging furnace.

SUMMARY OF THE INVENTION

[0013] According to a first aspect of the invention, there is provided a method of quenching and artificially aging an aluminum alloy casting having a riser portion and a workpiece portion, said method comprising: selectively quench cooling the workpiece portion of the casting while maintaining the riser portion at a relatively higher temperature; initiating the quench when the casting is at elevated temperatures with its alloying elements in solid solution; proceeding with the quench to cool the workpiece portion sufficiently rapidly to inhibit precipitation of the alloy elements and thereby to maintain such elements in supersaturated solution within the aluminum matrix, discontinuing the quench when the workpiece portion is cooled to a temperature which is at or below the range for artificial aging; artificially aging said workpiece portion within a range of temperatures and over an effective time period appropriate for such aging of the aluminium alloy casting workpiece primarily by means of residual heat flowing from the relatively hotter riser portion.

[0014] According to a second aspect of the invention, there is provided the use of an apparatus for quenching and artificially aging a hot aluminum alloy casting (20) having a riser portion (24) and a workpiece portion (22), the apparatus comprising:

- a quench unit (10);
- an aging unit;
- transfer means (16), arranged to move at least one casting (20) successively through said units, the transfer means arranged to position such casting (20) in said quench unit (10) in an oriented position; and
- cooling means (30) for quenching the casting, wherein the use of the apparatus comprises rapidly and selectively quenching the workpiece portion (22) of the casting (20) in said oriented position, largely to the exclusion of the riser portion (24), which riser portion (24) will thus initially remain at a relatively higher temperature.

[0015] Embodiments of the present invention can improve one or more of the present inventors' aforementioned 5,922,147 patent by simplifying even further the overall heat-treatment of the castings, although broadly it can be applied separately. These embodiments of the invention can dispense with the aging furnace, in addition to preferably also dispensing with the solution furnace.

Therefore, the invention is able to provide a method and apparatus for producing the casting in a considerably shorter time, with less capital, and lower production costs, while maintaining and even improving on required mechanical properties of the castings.

[0016] Preferred embodiments of the present invention use a selectively directed spray quench in a manner which can eliminate expensive equipment and reduce significantly the overall production time. The castings are preferably so quenched promptly after demolding in accordance with one or more of the present inventors' own recent patent (US Patent No. 5,922,147) to obtain the properties of a conventional "solution" heat treatment (such as the properties required by a T6 temper) but without the usual "solution" heat treatment in a furnace.

[0017] Furthermore, Koppenhoefer (US Patent No. 5,788,784) discussed above, does not teach or suggest the present inventors' invention of selectively quenching only the end product portion of the casting in order to use eventually the unquenched retained residual heat from the sprue and from any other temporarily retained waste portion of the casting (including sand cores) in order to enable aging of said casting without need for an aging furnace. In contrast, the Koppenhoefer teaches decoring the resin bonded sand cores from the castings by being "pyrolytically destroyed" during solution heat treatment and further removed during quenching, all prior to aging.

[0018] It is another advantage obtainable with embodiments of the present invention to provide method and use of apparatus for producing aluminium alloy castings having similar mechanical properties as those produced by the prior art methods while avoiding the necessity of an aging furnace, and preferably also of a solution heat furnace.

[0019] It is a further advantage obtainable with embodiments of the invention to increase the productivity of a casting plant and to reduce its capital costs and its operating costs significantly.

[0020] Other advantages obtainable with embodiments of the invention will be evident to those skilled in the art or will be pointed out hereafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] To enable a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:-

Figure 1 is a graph showing the different casting temperature paths followed over time during the heat treatment according to the conventional prior art, according to one or more of the present inventors' most recent prior art process (shown in U.S. Patent 5,922,147 to Valtierra et al.); and in one embodiment according to the method of the present invention with respect to the workpiece portion and also to the riser portion;

Figure 2 is a schematic side elevational view of a preferred embodiment according to the method of the present invention illustrating a series of stations making up the quench portion of a casting production line, showing some castings (each comprised of both the workpiece portion and the riser portion) and spray nozzles used for quenching only the workpiece portion oriented uppermost; and

Figure 3 is a schematic frontal view of the embodiment shown in Figure 2, showing the nozzles directing the spray or mist selectively onto the workpiece portion of the casting.

DETAILED DESCRIPTION

[0022] In order to better describe the invention, the present inventors specifically identify the two major parts of the casting as a riser portion (the riser portion being that portion which is subsequently removed and discarded) and a workpiece portion (the workpiece portion being the portion used for the end product). A "riser" is a reservoir of liquid metal used to largely compensate for shrinkage of a casting as it cools in its mold. The term "riser" also commonly has the meaning used in this application, namely the solidified metal portion of the casting remaining in the reservoir after the casting is cooled. "Riser portion" is intended to include at least the riser and additionally in its broader sense can include other similar waste attachments such as sprue, runners, gates, etc. formed as part of the original casting. When the casting is demolded from the typical water-cooled mold, the workpiece commonly has a temperature of about 400°C and the riser one of about 500°C. The invention achieves its advantages by a selective quench of only the workpiece portion to surface temperatures preferably in the range from above about 100°C to about 130°C, at a rate sufficient to achieve a supersaturated solution of the hardening element (typically copper) in the aluminum alloy of the workpiece at the atomic level. Preferably, to perform this selective quench, spray nozzles are set to direct the water spray or mist on the workpiece and minimize any impingement on the riser. This workpiece-directed quench permits the riser (subjected only to natural or at most a minimized indirect cooling) to maintain a significantly higher temperature typically above about at least 300°C to 350°C during the workpiece quenching step. Thereafter, when the quenching is finished, the residual heat in the sprue portion is used as a heat reservoir to slightly re-heat the workpiece and maintain it (by conductive phenomena) in the artificial aging temperature range of between 140°C and 250°C, and preferably about 180°C to about 220°C, for an adequate time period, to thus achieve the desired properties for the workpiece. The invention dispenses with the need to supply furnace heat for re-heating and maintaining the whole casting in the artificial aging temperature range and simplifies the casting plant by thus rendering the aging furnace unnecessary. The final quench temperature should not be so

low that the residual heat from the riser is too little to maintain the workpiece in the required aging temperature range for the necessary length of time. Also, if the workpiece surface temperature is maintained high enough above the boiling point of the spray liquid (typically water) throughout the quench, then liquid overflow onto the riser can be more easily minimized or avoided altogether and the latent heat of can be utilized and concentrated on the workpiece. A copious flow of a fine water mist is especially effective, since the mist particles evaporate immediately and there is no liquid wetting of the hot workpiece surface that can flow over onto the riser.

[0023] It has been found that the existing riser mass as dictated by ordinary foundry practice is sufficient to achieve this result (i.e. provides an adequate heat reservoir for the artificial age hardening without need for an aging furnace); however, it would be within the scope of this invention to increase the mass as needed for the desired inventive result.

[0024] Even though the temperature of the workpiece and the riser greatly depends on the mass and the surface area of both portions, the quenching temperature can be regulated to achieve the advantages of the invention at different temperature paths. Also the aging position of the casting plant can be insulated to prolong the artificial aging step at elevated temperatures for a more extended time period as may be needed (or even make use of a heat exchanger to take advantage of other residual or excess heat sources that may be available elsewhere in the casting plant system), all as an aid to avoid the need for the added expense of an aging furnace.

[0025] The invention is herein described as applied to the production of cylinder heads for automotive motors using generally silicon-based aluminum alloys of the AA 3xx.x series, having T6 and T7 properties (such as particularly A319), but it will be evident to those skilled in the art, that the invention can in its broader aspects be also applied to other metal alloys and to the heat-treating of other castings.

[0026] Figure 1 is a graph showing the different temperature paths vs. time of various castings; with the prior art processes in dotted lines and embodiments of the present invention in continuous lines. Nowadays, the most common practice of the prior art (shown in the graph by the thinner dotted line) includes, after demolding, the steps of subjecting the casting to: natural cooling, reheating and maintaining in a solution heat furnace, quenching, and reheating and maintaining in an aging furnace. Another illustrated prior art temperature path (shown by the bold dotted line) is the heat treatment disclosed in one or more of the present inventors' very recent U.S. Patent 5,922,147 (wherein the solution treatment is omitted entirely, with the quenching of the casting occurring without natural cooling after demolding, and preferably immediately).

[0027] Also shown in the graph in Figure 1, are the casting temperature paths of the workpiece portion and of the riser portion according to the method of the present

invention (shown in respective continuous lines). As it can be seen, there is a selective quenching of the workpiece portion of the casting. At the same time, the riser remains essentially unquenched, with any cooling typically occurring only naturally and at a much lower rate; so that when the quenched workpiece has a temperature of about 120°C, the riser still has a temperature about 350°C. At about that point, before the quench reaches ambient temperature, the quenching step is stopped and the casting (riser and workpiece together) is allowed to homogenize its temperature with the workpiece being mainly in the range of from about 160°C to about 220°C (initially towards the high end of the range, preferably). This essentially duplicates the conventional temperature profile of a casting maintained in an aging furnace after the quenching step, while surprisingly eliminating the need for any aging furnace. This is possible, because there is sufficient mass in the riser to function as an adequate reservoir of heat available for a sufficient duration to achieve complete aging.

[0028] Figure 2 schematically shows a preferred embodiment of the apparatus used for the quenching step in accordance with the invention. Immediately after demolding, the casting 20, broadly comprising riser 24 and the workpiece 22, is placed on a conveyor 16 by means of a feeding robot 12. The conveyor 16 has structural supports 18 (such as rollers) located through the quenching unit 10. Also provided in the quenching unit 10 are an air header 26 and a water header 28, both being connected to spray nozzles 30. Spray nozzle 30 projects a water spray or an air driven mist 32 that is directed to impinge mainly on the workpiece portion 22 of the casting 20 positioned on the conveyor 16. Since rapid cooling rates are quite important to achieve the desired properties in the workpieces 22, and the nozzles 30 in this embodiment are in a fixed position within the quenching unit 10, the conveyor 16 is operated discontinuously in order to transport castings 20 from one quenching station 33 to the next in a step-wise mode (over a distance 34). After the castings 20 have traveled along the length of the conveyor 16 within the quenching unit 10, the residence time needed for quenching the workpieces 22 to the desired temperatures is completed. Finally, a withdrawing robot 14 transports the quenched castings to a place to be aged artificially at still elevated temperatures over an extended time utilizing the reservoir of heat remaining in the riser 24. In order to improve the quenching operation of the quenching unit 10, a fan 13 can be supplied to extract the vapor produced by the evaporation of the sprayed water while quenching the workpieces 22 of castings 20.

[0029] Figure 3 shows an end view of the quenching unit 10. The same elements bear the same reference numerals of Figure 2. Additionally shown is an air supply 25 for air header 26, preferably at high pressure in order to achieve a better water spray or mist. Liquid supply 27 feeds header 28, which can handle water or any other suitable liquid cooling medium.

[0030] Even though the process described on figures 2 and 3 teaches a quenching unit for processing castings 20 in a step-wise mode and with the riser 24 oriented as the base of the casting 20, it will be evident to those skilled in the art that the quenching unit 10 of the invention could be operated continuously preferably with moving headers and spray nozzles or in a batch processing system as well. Another change that can be performed to the embodiments of the invention without departing from its scope comprises locating the spray nozzles below the castings thus directing the spray 32 upwardly. In this case, the sprue portion 24 of the castings 20 would be positioned above the workpiece 22.

[0031] As previously indicated, the invention in its broader aspects can be applicable to other aluminum alloys and heat treating processes wherein the aging furnace step is normally used, including those prior art systems still using a conventional solution heat treatment with a subsequent quenching step.

Claims

1. A method of quenching and artificially aging an aluminum alloy casting (20) having a riser portion (24) and a workpiece portion (22), said method comprising:

selectively quench cooling the workpiece portion (22) of the casting while maintaining the riser portion (24) at a relatively higher temperature; initiating the quench when the casting (20) is at elevated temperatures with its alloying elements in solid solution;

proceeding with the quench to cool the workpiece portion (22) sufficiently rapidly to inhibit precipitation of the alloy elements and thereby to maintain such elements in supersaturated solution within the aluminum matrix,

discontinuing the quench when the workpiece portion (22) is cooled to a temperature which is at or below the range for artificial aging;

artificially aging said workpiece portion (22) within a range of temperatures and over an effective time period appropriate for such aging of the aluminum alloy casting workpiece primarily by means of residual heat flowing from the relatively hotter riser portion (24).

2. A method according to claim 1, wherein the artificial aging of said workpiece portion is carried out without actively heating the overall casting (20).

3. A method according to claims 1 or 2, wherein the mass, shape and the cross-sectional area of attachment of the riser portion (24) relative to the workpiece portion (22) and the temperature differential therebetween are chosen to be sufficient to maintain the

workpiece portion (22) within the temperature and time period ranges required for the artificial aging.

4. A method according to any one of the preceding claims, wherein said selective quench cooling is performed by spraying a quenching fluid (32) on the surfaces of said workpiece portion (22).
5. A method according to any one of the preceding claims, wherein said quenching fluid (32) is water.
6. A method according to any one of the preceding claims, wherein said quench is by a water mist.
7. A method according to any one of the preceding claims, wherein said quench is initiated when the casting (22) is at a temperature above about 350°C.
8. A method according to any one of the preceding claims, wherein said quench is less than five minutes in duration.
9. A method according to any one of the preceding claims, wherein said quench is discontinued when the workpiece portion (22) reaches a temperature on the order of 100°C to 130°C, while the riser portion (24) remains above 300°C.
10. A method according to any one of the preceding claims, wherein said quench is discontinued when the workpiece portion (22) reaches about 130°C.
11. A method according to any one of claims 1 to 9, wherein said quench is discontinued when the workpiece portion (22) reaches about 120°C.
12. A method according to any one of the preceding claims, wherein said artificial aging of the workpiece portion (22) is at a temperature between 140°C and 250°C.
13. A method according to any one of the preceding claims, wherein said artificial aging of the workpiece portion (22) is at a temperature between 180°C to 220°C.
14. A method according to any one of the preceding claims, wherein said artificial aging is for a period of time from two to five hours.
15. A method according to any one of the preceding claims, wherein said workpiece portion (22) is decored after the artificial aging.
16. A method according to any one of the preceding claims, wherein said casting (20) is insulated during artificial aging to prolong the duration of the artificial aging process without adding heat to the casting

(20).

17. A method according to any one of the preceding claims, wherein a heat treatable aluminum alloy having properties, including hardness and strength, which are improved by precipitation hardening through aging.
18. A method according to any one of the preceding claims, wherein said casting (20) is formed from an aluminum alloy of the 3xx.x series according to the Aluminum Association (AA) classification having Al, Si, & Cu or Mg as the principal casting constituents, with properties at least equal to a T6 or T7 temper.
19. A method according to claim 18, wherein said casting (20) is made from an A319 aluminum alloy with up to a 5% copper content.
20. A method according to any one of the preceding claims, further comprising:
 - solidifying and extracting the casting (20) from its mold while said casting is at a temperature above 400°C;
 - heating said castings (20) in a solution furnace to solution heat treating temperatures for a time period from about 2 to 7 hours.
21. A method according to claim 20, wherein said heating of said castings (20) in a solution furnace is to a range of solution heat treatment temperatures from about between 480°C and 495°C.
22. A method according to claim 20 or 21, further comprising naturally cooling the casting (20) after extraction from its mold and before solution heat treating said castings.
23. A method of producing a workpiece, comprising the steps of:
 - performing the method of any of claims 1 to 22;
 - and
 - removing the riser portion from the casting, to produce said workpiece.
24. A method according to claim 23, wherein the workpiece is a cylinder head for an automotive engine.
25. Use of an apparatus for quenching and artificially aging a hot aluminum alloy casting (20) having a riser portion (24) and a workpiece portion (22), the apparatus comprising:
 - a quench unit (10);
 - an aging unit;
 - transfer means (16), arranged to move at least

one casting (20) successively through said units, the transfer means arranged to position such casting (20) in said quench unit (10) in an oriented position; and

- cooling means (30) for quenching the casting, wherein the use of the apparatus comprises rapidly and selectively quenching the workpiece portion (22) of the casting (20) in said oriented position, largely to the exclusion of the riser portion (24), which riser portion (24) will thus initially remain at a relatively higher temperature.

26. Use of an apparatus according to claim 25, wherein said units are part of a continuous processing line; said quench unit (10) is a spray containment housing; said cooling means (30) is at least one liquid quench sprayer directed to impinge directly on essentially only the workpiece portion (22) of the casting presented to it by the transfer means (16) in the oriented position.

27. Use of an apparatus according to claims 25 or 26, wherein said aging unit is an insulated tunnel housing.

28. Use of an apparatus according to any one of claims 25 to 27, wherein said aging unit is not re-heated by means of a furnace.

29. Use of an apparatus according to any one of claims 25 to 28, wherein said cooling means (30) has a plurality of liquid quench sprayers spaced apart along the processing line, each impinging directly on essentially only the workpiece portion (22) of the castings (20) successively presented to it by the transfer means (16) in the oriented position so as to achieve quench cooling of the workpiece portion (22).

30. Use of an apparatus according to any one of claims 25 to 29, wherein said aging unit is heated only by residual heat including from a heat exchanger.

Patentansprüche

1. Ein Verfahren zum Abschrecken und Warmauslagern eines Aluminiumlegierungsgusses (20), der einen erhöhten Abschnitt (24) und einen Werkstückabschnitt (22) aufweist, wobei das Verfahren umfasst:

selektives Abschrecken des Werkstückabschnitts (22) des Gusses unter Beibehaltung einer relativ höheren Temperatur des erhöhten Abschnitts (24);

Einleiten des Abschreckens, wenn der Guss (20) eine erhöhte Temperatur hat, mit seinen Legierungselementen als Mischkristalle vorlie-

gend;

Fortsetzen des Abschreckens, um den Werkstückabschnitt (22) ausreichend schnell zur Unterdrückung der Ausscheidung von Legierungselementen abzukühlen und **dadurch** diese Elemente in übersättigter Lösung in der Aluminiummatrix zu halten;

Abbrechen des Abschreckens wenn der Werkstückabschnitt (22) auf eine Temperatur heruntergekühlt ist, die im oder unter dem Bereich zum Warmauslagern liegt;

Warmauslagern des Werkstücks (22) in einem Bereich von Temperaturen und über eine effektive Zeitspanne, so bemessen, dass das Warmauslagern des Aluminiumlegierungsgusswerkstücks vorwiegend durch Abfließen von Restwärme des relativ heißeren erhöhten Abschnitts (24) stattfindet.

2. Verfahren nach Anspruch 1, wobei das Warmauslagern des Werkstückabschnitts ohne aktives Erhitzen des gesamten Gusses (20) ausgeführt wird.

3. Verfahren nach Anspruch 1 oder 2, wobei die Masse, Form und die Querschnittsfläche der Anbindung des erhöhten Abschnitts (24) relativ zum Werkstückabschnitt (22) und die dazwischen liegende Temperaturdifferenz ausreichend gewählt sind, um den Werkstückabschnitt (22) in den Bereichen von Temperaturen und Zeitspannen zu halten, die zum Warmauslagern notwendig sind.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abkühlen durch selektives Abschrecken über das Ansprühen der Oberfläche des Werkstückabschnitts (22) mit einem Abschreckfluid (32) erfolgt.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschreckfluid (32) Wasser ist.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschrecken über Wasserdampf stattfindet.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschrecken eingeleitet wird, wenn der Guss (22) ungefähr eine Temperatur über 350°C aufweist.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschrecken eine Dauer von unter 5 Minuten beträgt.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschrecken abgebrochen wird, wenn der Werkstückabschnitt (22) eine Temperatur im Bereich von 100°C bis 130°C erreicht, während

der erhöhte Abschnitt weiterhin über 300°C aufweist.

10. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Abschrecken abgebrochen wird, wenn der Werkstückabschnitt (22) ungefähr 130°C erreicht. 5
11. Verfahren nach einem der Ansprüche 1 bis 9, wobei das Abschrecken abgebrochen wird, wenn der Werkstückabschnitt (22) in etwa 120°C erreicht. 10
12. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Warmauslagern des Werkstückabschnitts (22) bei einer Temperatur zwischen 140°C und 250°C stattfindet. 15
13. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Warmauslagern des Werkstückabschnitts (22) bei einer Temperatur zwischen 180°C und 220°C stattfindet. 20
14. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Warmauslagern in einer Zeitspanne zwischen zwei und fünf Stunden stattfindet. 25
15. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Werkstückabschnitt (22) nach dem Warmauslagern entkernt wird. 30
16. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Guss (20) während des Warmauslagerns isoliert ist, um die Dauer des Warmauslagerns ohne Zuführen von Wärme zum Guss (20) zu verlängern. 35
17. Verfahren nach einem der vorhergehenden Ansprüche, wobei eine mit Wärme behandelbare Aluminiumlegierung Eigenschaften besitzt, einschließlich Härte und Festigkeit, die durch Ausscheidungshärten verbessert werden. 40
18. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Guss (20) aus einer Aluminiumlegierung der 3xx.x Reihe nach der Klassifizierung der Aluminum Association (AA) erstellt wird, der Al, Si, & Cu oder Mg als Gushauptbestandteile aufweist, mit den Härtegraden T6 oder T7 entsprechenden Eigenschaften. 45
19. Verfahren nach Anspruch 18, wobei der Guss (20) aus einer A319 Aluminiumlegierung mit bis zu 5% Kupfergehalt hergestellt wird. 50
20. Verfahren nach einem der vorhergehenden Ansprüche, weiterhin umfassend: 55

Erstarren und Herausnahme des Gusses (20) aus seiner Form während die Temperatur des

Gusses über 400°C beträgt; Aufheizen der Güsse (20) in einem Lösungsglühofen auf eine Lösungswärmebehandlungstemperatur über eine Zeitspanne von ungefähr 2 bis 7 Stunden.

21. Verfahren nach Anspruch 20, wobei das Aufheizen der Güsse (20) in einem Lösungsglühofen auf einen Bereich von Lösungswärmebehandlungstemperaturen zwischen ungefähr 480°C bis 495°C erfolgt.
22. Verfahren nach Anspruch 20 oder 21, das weiterhin ein natürliches Abkühlen des Gusses (20) nach der Entnahme aus seiner Form und vor der Lösungswärmebehandlung der Güsse umfasst.
23. Verfahren zum Herstellen eines Werkstücks, die Schritte umfassend:

Durchführen des Verfahrens nach einem der Ansprüche 1 bis 22;
und
Entfernen des erhöhten Abschnitts des Gusses, um das Werkstück herzustellen.
24. Verfahren nach Anspruch 23, wobei das Werkstück ein Zylinderkopf für einen Automotormotor ist.
25. Verwendung einer Vorrichtung zum Abschrecken und Warmauslagern eines erhitzten Aluminiumlegierungsgusses (20), der einen erhöhten Abschnitt (24) und einen Werkstückabschnitt (22) aufweist, die Vorrichtung umfassend:
 - eine Abschreckeinheit (10);
 - eine Auslagerungseinheit;
 - Transportmittel (16), angeordnet, um zumindest einen Guss (20) nacheinander durch die Einheiten zu bewegen, wobei die Transportmittel derart angeordnet sind, um den Guss (20) in der Abschreckeinheit (10) in einer ausgerichteten Lage zu positionieren; und
 - Mittel zum Kühlen (30) zum Abschrecken des Gusses,

wobei die Verwendung der Vorrichtung das schnelle und selektive Abschrecken des Werkstückabschnitts (22) des Gusses (20) in der ausgerichteten Lage umfasst, hauptsächlich unter Ausschluss des erhöhten Abschnitts (24), dessen erhöhter Abschnitt (24) deswegen ursprünglich eine relativ höhere Temperatur beibehalten wird.
26. Verwendung einer Vorrichtung nach Anspruch 25, wobei die Einheiten Teil einer kontinuierlichen Fertigungslinie sind; die Abschreckeinheit (10) eine abgeschlossene Sprühkammer ist; die Mittel zum Kühlen (30) mindestens einen Abschreckungs-Flüssigkeits-Sprüher aufweisen, der ausgerichtet ist, um im

Wesentlichen direkt auf den Werkstückabschnitt (22) des Gusses einzuwirken, der durch die Transportmittel (16) in der ausgerichteten Lage zugeführt wird.

27. Verwendung einer Vorrichtung nach Anspruch 25 oder 26, wobei die Auslagerungseinheit eine isolierte Tunnelkammer ist.
28. Verwendung einer Vorrichtung nach einem der Ansprüche 25 bis 27, wobei die Auslagerungseinheit nicht erneut über einen Ofen erhitzt wird.
29. Verwendung einer Vorrichtung nach einem der Ansprüche 25 bis 28, wobei die Mittel zur Kühlung (30) eine Mehrzahl von in Abständen entlang der Fertigungslinie angeordneten Abschreck-Flüssigkeits-Sprühern aufweisen, wobei jeder im Wesentlichen direkt auf den Werkstückabschnitt (22) der Güsse (20) einwirkt, die nacheinander durch die Transportmittel (16) in der ausgerichteten Lage zugeführt werden, um das Abschrecken des Werkstückabschnitts (22) zu erreichen.
30. Verwendung einer Vorrichtung nach einem der Ansprüche 25 bis 29, wobei die Auslagerungseinheit nur über Restwärme, einschließlich der eines Wärmetauschers, erhitzt wird.

Revendications

1. Procédé de trempe et de vieillissement artificiel d'une pièce (20) en alliage d'aluminium ayant une partie de masselotte (24) et une partie de pièce d'usinage (22), ledit procédé comprenant :

le refroidissement sélectif par trempage de la partie de pièce d'usinage (22) de la pièce tout en maintenant la partie de masselotte (24) à une température relativement plus élevée ;
l'initiation du trempage lorsque la pièce (20) est à des températures élevées avec ses éléments d'alliage en solution solide ;
la poursuite du trempage pour refroidir la partie de pièce d'usinage (22) suffisamment rapidement pour inhiber une précipitation des éléments d'alliage et pour ainsi maintenir de tels éléments en solution supersaturée au sein de la matrice d'aluminium ;
l'interruption du trempage lorsque la partie de pièce d'usinage (22) est refroidie à une température qui est dans ou en-dessous de la plage pour un vieillissement artificiel ;
le vieillissement artificiel de ladite partie de pièce d'usinage (22) dans une plage de températures et sur une période de temps effective appropriée pour un tel vieillissement de la pièce d'usinage

de la pièce en alliage d'aluminium essentiellement au moyen d'une chaleur résiduelle provenant de la partie de masselotte (24) relativement plus chaude.

2. Procédé selon la revendication 1, dans lequel le vieillissement artificiel de ladite partie de pièce d'usinage est effectué sans chauffage actif de la pièce (20) en général.
3. Procédé selon la revendication 1 ou 2, dans lequel la masse, la forme et la superficie de la section transversale de fixation de la partie de masselotte (24) par rapport à la partie de pièce d'usinage (22) et le différentiel de température entre celles-ci sont choisis de façon à être suffisants pour maintenir la partie de pièce d'usinage (22) dans les plages de température et de période de temps requises pour le vieillissement artificiel.
4. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit refroidissement sélectif par trempage est effectué par pulvérisation d'un fluide de trempage (32) sur les surfaces de ladite partie de pièce d'usinage (22).
5. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit fluide de trempage (32) est l'eau.
6. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit trempage est effectué par un brouillard d'eau.
7. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit trempage est initié lorsque la pièce (22) est à une température supérieure à environ 350°C.
8. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit trempage est inférieur à cinq minutes en durée.
9. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit trempage est interrompu lorsque la partie de pièce d'usinage (22) atteint une température de l'ordre de 100°C à 130°C, tandis que la partie de masselotte (24) reste au-dessus de 300°C.
10. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit trempage est interrompu lorsque la partie de pièce d'usinage (22) atteint environ 130°C.
11. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel ledit trempage est interrompu lorsque la partie de pièce d'usinage (22) atteint environ

- 120°C.
12. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit vieillissement artificiel de la partie de pièce d'usinage (22) est effectué à une température entre 140°C et 250°C. 5
13. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit vieillissement artificiel de la partie de pièce d'usinage (22) est effectué à une température entre 180°C et 220°C. 10
14. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit vieillissement artificiel est effectué sur une période de temps de deux à cinq heures. 15
15. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite partie de pièce d'usinage (22) est débourrée après le vieillissement artificiel. 20
16. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite pièce (20) est isolée pendant le vieillissement artificiel pour prolonger la durée du processus de vieillissement artificiel sans ajouter de chaleur à la pièce (20). 25
17. Procédé selon l'une quelconque des revendications précédentes, dans lequel un alliage d'aluminium traitable à la chaleur ayant des propriétés, incluant une dureté et une résistance, qui sont améliorées par un durcissement par précipitation par l'intermédiaire d'un vieillissement. 30
18. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite pièce (20) est formée à partir d'un alliage d'aluminium de la série 3xx.x selon la classification de l'Aluminum Association (AA) ayant Al, Si, & Cu ou Mg comme les constituants principaux de la pièce, avec des propriétés au moins égales à une trempe T6 ou T7. 35
19. Procédé selon la revendication 18, dans lequel ladite pièce (20) est fabriquée à partir d'un alliage d'aluminium A319 avec une teneur en cuivre de jusqu'à 5%. 40
20. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre : 45
- la solidification et l'extraction de la pièce (20) de son moule tandis que ladite pièce est à une température supérieure à 400°C ;
- le chauffage desdites pièces (20) dans un four de traitement en solution à des températures de traitement thermique en solution pendant une période de temps d'environ 2 à 7 heures. 55
21. Procédé selon la revendication 20, dans lequel ledit chauffage desdites pièces (20) dans un four de traitement en solution est effectué dans une plage de températures de traitement thermique en solution d'environ entre 480°C et 495°C.
22. Procédé selon la revendication 20 ou 21, comprenant en outre le refroidissement naturel de la pièce (20) après extraction de son moule et avant le traitement thermique en solution desdites pièces.
23. Procédé de production d'une pièce d'usinage, comprenant les étapes de :
- mise en oeuvre du procédé selon l'une quelconque des revendications 1 à 22 ; et
- enlèvement de la partie de masselotte de la pièce, pour produire ladite pièce d'usinage.
24. Procédé selon la revendication 23, dans lequel la pièce d'usinage est une culasse pour un moteur d'automobile.
25. Utilisation d'un appareil pour tremper et vieillir artificiellement une pièce (20) chaude en alliage d'aluminium ayant une partie de masselotte (24) et une partie de pièce d'usinage (22), l'appareil comprenant :
- une unité de trempage (10) ;
 - une unité de vieillissement ;
 - un moyen de transfert (16), agencé de façon à déplacer au moins une pièce (20) successivement à travers lesdites unités, le moyen de transfert agencé pour positionner une telle pièce (20) dans ladite unité de trempage (10) dans une position orientée ; et
 - un moyen de refroidissement (30) pour tremper la pièce,
- dans laquelle l'utilisation de l'appareil comprend le trempage rapide et sélectif de la partie de pièce d'usinage (22) de la pièce (20) dans ladite position orientée, largement à l'exclusion de la partie de masselotte (24), laquelle partie de masselotte (24) restera ainsi initialement à une température relativement plus élevée.
26. Utilisation d'un appareil selon la revendication 25, dans laquelle lesdites unités font partie d'une ligne de traitement continu ; ladite unité de trempage (10) est un logement de confinement pour pulvérisation ; ledit moyen de refroidissement (30) est au moins un pulvérisateur de liquide de trempe dirigé de façon à venir frapper directement essentiellement uniquement la partie de pièce d'usinage (22) de la pièce qui lui est présentée par le moyen de transfert (16) dans la position orientée.
27. Utilisation d'un appareil selon la revendication 25 ou

26, dans laquelle ladite unité de vieillissement est un logement en tunnel isolé.

- 28.** Utilisation d'un appareil selon l'une quelconque des revendications 25 à 27, dans laquelle ladite unité de vieillissement n'est pas réchauffée au moyen d'un four. 5
- 29.** Utilisation d'un appareil selon l'une quelconque des revendications 25 à 28, dans laquelle ledit moyen de refroidissement (30) a une pluralité de pulvérisateurs de liquide de trempe espacés le long de la ligne de traitement, chacun venant frapper directement essentiellement uniquement la partie de pièce d'usinage (22) de la pièce (20) qui lui est successivement présentée par le moyen de transfert (16) dans la position orientée de façon à réaliser le refroidissement par trempage de la partie de pièce d'usinage (22). 10 15
- 30.** Utilisation d'un appareil selon l'une quelconque des revendications 25 à 29, dans laquelle ladite unité de vieillissement n'est chauffée que par une chaleur résiduelle, incluant celle provenant d'un échangeur de chaleur. 20

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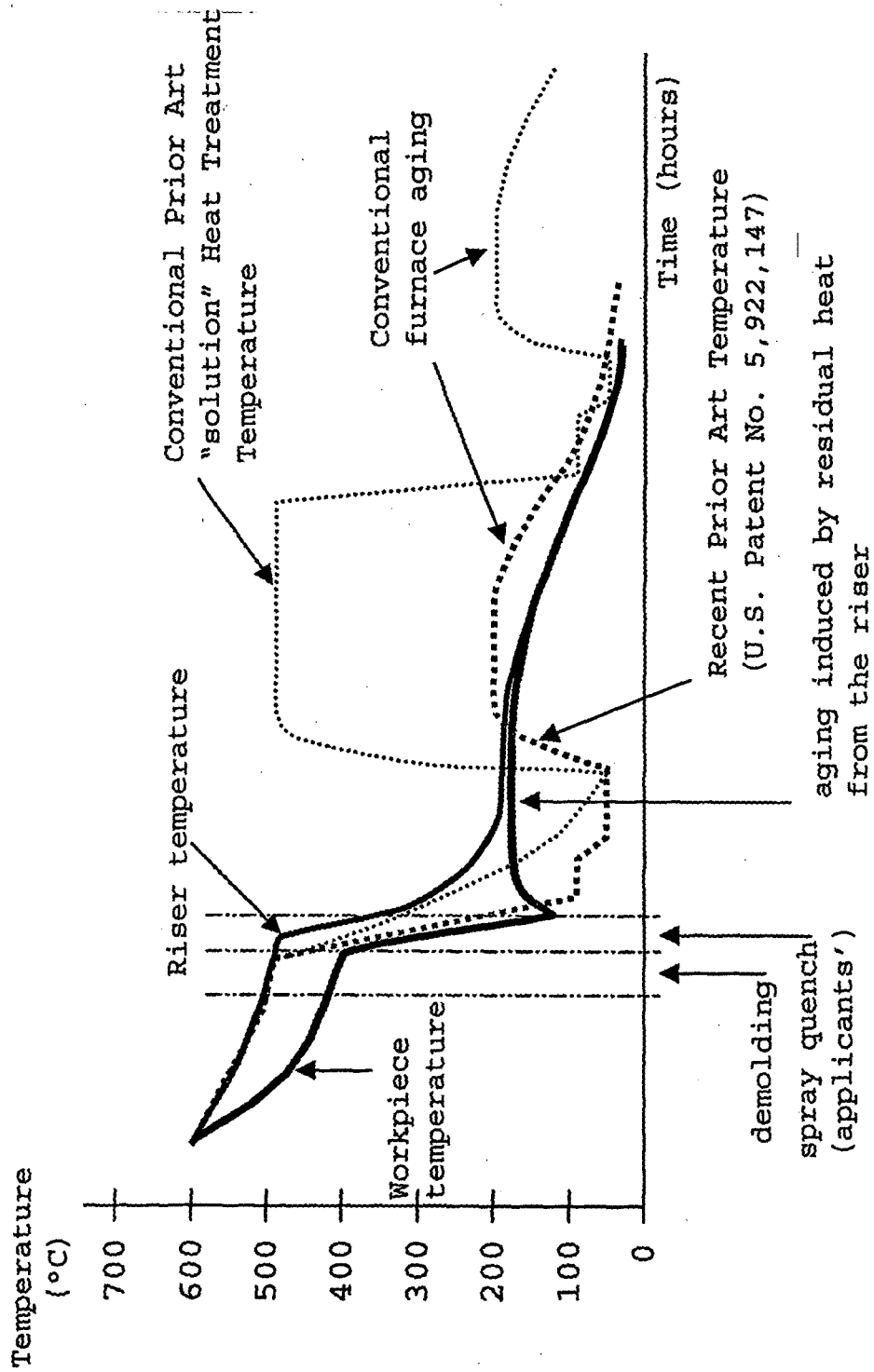


FIG. 1

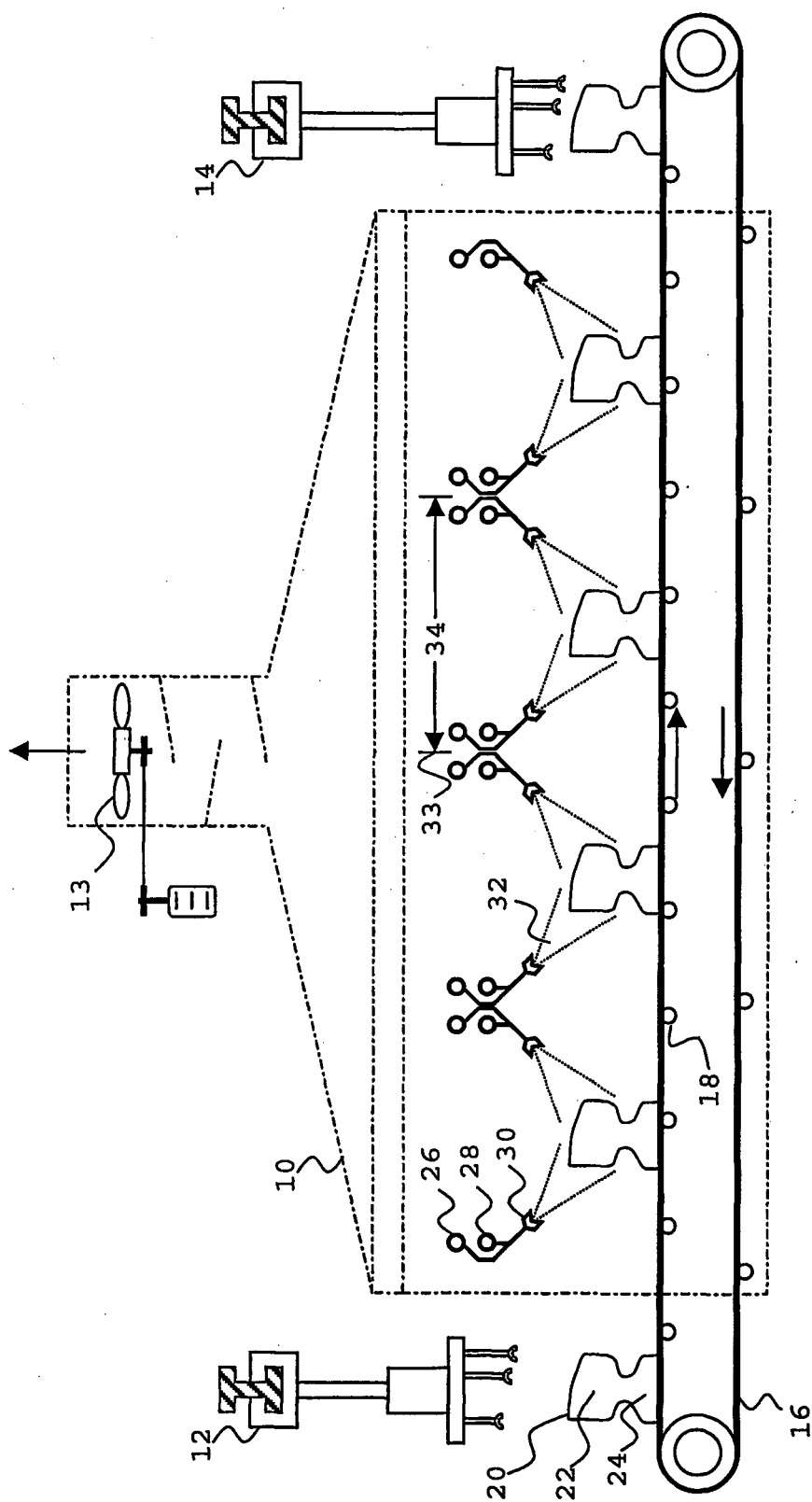


FIG. 2

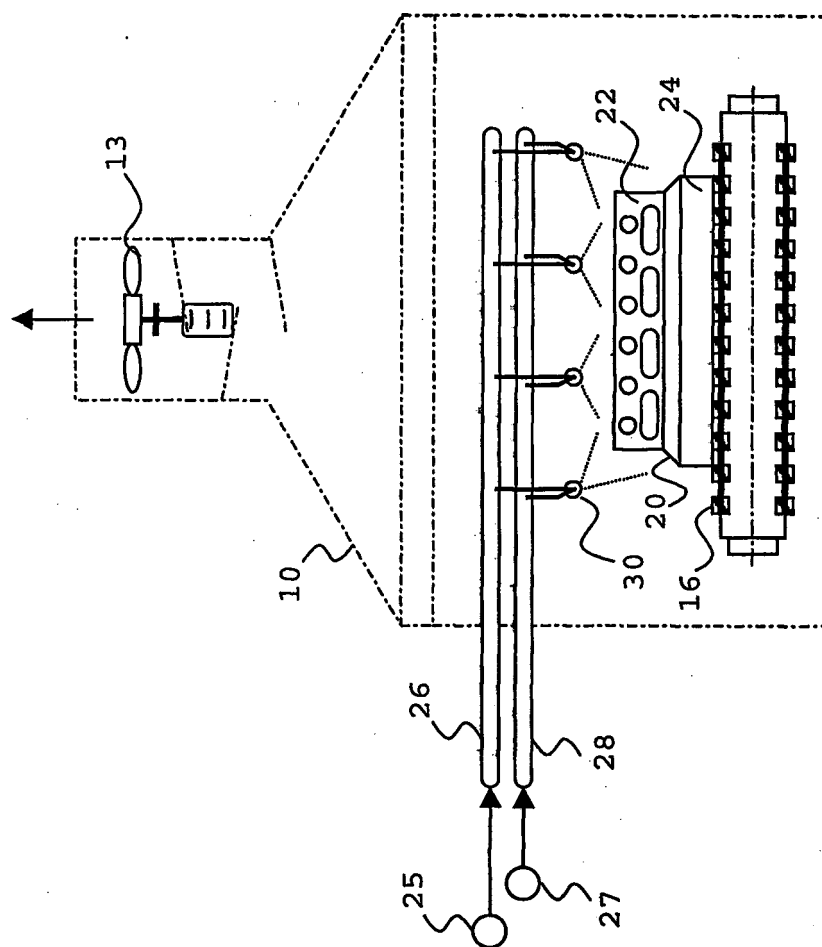


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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