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(54) **Method and apparatus for heat treating material**

Verfahren und Vorrichtung zum Wärmebehandeln von Werkstücken

Procédé et dispositif pour le traitement thermique de pièces

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Description

Background of Invention

[0001] This invention relates to a method and an apparatus for heat treating a material. Specifically, the present invention relates to a method and apparatus for fluid impingement quenching a forging.

[0002] Conventional quenching techniques include bath quenching and fan quenching. The bath quenching process immerses a forging within a container of oil. The oil acts as a heat sink to cool the forging. The process typically agitates the oil to increase the rate of heat transfer.

[0003] The oil bath quenching process has numerous drawbacks. The first drawback relates to the handling of the oil. Oil handling must follow specific procedures for environmental and safety concerns.

[0004] The second drawback relates to the waste stream. The used oil must enter the waste stream properly. Environmental and safety concerns demand the proper entry of the used oil into the waste stream.

[0005] The third drawback relates to predictability. Oil bath quenching is not a fully controllable process. For instance, the oil bath quenching process lacks the ability to control local heat transfer rates precisely. Generally speaking, oil bath quenching produces an arbitrary heat transfer coefficient of between approximately 70 and 140 BTU/hr ft² ° F (397 and 795 W/m²°C) uniformly across the forging.

[0006] The final drawback relates to residual stress. Oil bath quenching tends to produce high residual stress values due to the arbitrary heat transfer coefficient. Such values can produce cracking and distortion of the forging.

[0007] The second conventional quenching technique is fan quenching. The fan quenching process uses forced convection to cool a forging. One or more fans propel air against the forging to increase the rate of heat transfer. While avoiding the environmental issues encountered with oil bath quenching, the fan quenching process does have several drawbacks. Notably, the fan quenching process may not create the heat transfer rates needed to produce the desired material properties in high temperature aerospace alloy forgings. Second, the fan quenching process also lacks the ability to control the heat transfer rates locally at various locations on the forging.

[0008] New high temperature aerospace alloys have placed greater demands on the quenching process. These new alloys require a high lower limit of the cooling rate during quenching to achieve metallurgical requirements (e.g. tensile strength). As a result, fan quenching is no longer an option for these new high temperature aerospace alloys.

[0009] These new high temperature aerospace alloys also demand that the quenching process control the upper limit of the cooling rate so as to avoid the formation of cracks in the forging. As a result, oil bath quenching

is no longer an option for these new high temperature aerospace alloys.

[0010] In other words, the quenching process must remain within a limited range of cooling rate values to produce the desired material qualities in the forging. Unfortunately, conventional quenching techniques do not appear to achieve these goals satisfactorily for certain applications, such as these new high temperature aerospace alloys.

10 [0011] US 5 452 882 over which the independent claims are characterised, discloses a device for quenching a heated work piece using a stream of cooling gas.

[0012] United States Statutory Invention Registration H 777 discloses a method of gas jet impingement quenching of metal workpieces.

Summary of Invention

[0013] It is an object of the present invention in a preferred embodiment at least to provide an improved quenching method and apparatus.

[0014] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that reduces environmental concerns.

25 [0015] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that produces less scrap during quenching caused by cracking and distortion.

[0016] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that produces less scrap during subsequent manufacturing operations caused by residual stress effects.

35 [0017] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that consumes less raw material.

[0018] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that is controllable.

40 [0019] It is a further object of the present invention in a preferred embodiment at least to provide a quenching technique that can keep cooling rate values within a limited range.

45 [0020] From a first aspect, the present invention provides a method of quenching a material as claimed in claim 1.

[0021] From a yet further aspect, the present invention provides an apparatus for quenching a material as claimed in claim 18.

Brief Description of Drawings

55 [0022] Other uses and advantages of the present invention will become apparent to those skilled in the art upon reference to the specification and the drawings, in which:

Figure 1 is an exploded, perspective view of one em-

bodiment of the quenching apparatus of the present invention;

Figure 2 is a cross-sectional view of the quenching apparatus taken along line II-II in Figure 1;

Figure 3 is a plan view of one component of the quenching apparatus shown in Figure 1;

Figure 4 is a detailed view of a portion of the component shown in Figure 3;

Figure 5 is a cross-sectional view of the component taken along line V-V in Figure 4;

Figure 6 is an elevational view of a second component of the quenching apparatus shown in Figure 1; and

Figure 7 is an elevational view of a section of the quenching apparatus shown in Figure 1 with a forging placed therein.

Detailed Description

[0023] Figure 1 displays an exploded perspective view of one embodiment of a quenching apparatus 100. The quenching apparatus 100 can receive an annular forging F (only partially shown in the figure), such as a turbine disk or an air seal. Although accommodating an annular shape, the apparatus could heat treat any shape of forging F.

[0024] Similarly, the apparatus 100 could quench a forging made from any material. The preferred material, however, is a high temperature aerospace alloy. Generally speaking, such material must have adequate performance characteristics, such as tensile strength, creep resistance, oxidation resistance, and corrosion resistance, at high temperatures. Course grained nickel alloys are especially prone to quench cracking due to a ductility trough at the upper temperatures (e.g. 1800-2100° F) (982-1149°C) of the quenching process. Examples of high temperature aerospace materials include nickel alloys such as IN100, IN1100, IN718, Waspaloy and IN625.

[0025] To achieve these characteristics, the aforementioned alloys demand precise control of the quenching process. Precise control is necessary to avoid cracking of the forging during quenching and to avoid residual stress effects during subsequent manufacturing operations on the forging. Typically, most forgings that exhibit cracks during quenching are considered scrap.

[0026] The quenching apparatus 100 preferably can provide impingement cooling to all surfaces of the forging F. The apparatus 100 includes a first cooling section 101, a second cooling section 103 and a central cooling section 105. Each section will now be described in further detail.

[0027] Figure 3 displays the first cooling section 101. The first cooling section 101 preferably corresponds to a bottom of the forging F. The first cooling section 101 includes one or more supports 107 arranged around the apparatus 100. Although the figure displays three, the present invention could use any suitable number of supports 107.

[0028] The supports 107 have recesses in which a plurality of concentric pipes 109 can reside. Although the figures show five, the present invention could utilize any number of pipes 109. The number of pipes 109 depends upon the geometry of the forging F. A larger forging F requires more pipes 109.

[0029] A plurality of spacers 111 secure to the supports 107 with conventional fasteners. The spacers 111 serve to retain the pipes 109 to the supports 107. Although the figures show each spacer 111 retaining multiple pipes 109, the spacer 111 could retain only one pipe. This would allow the individual adjustment of pipes 109 without disturbing the other pipes 109. Another important function of the spacers will be discussed below.

[0030] As seen in Figure 2, the top of the forging F could have a different shape than the bottom of the forging F. Accordingly, the second cooling section 103 may not mirror the shape of the first cooling section 101. Rather, the second cooling section 103 preferably conforms to the top of the forging F.

[0031] Similar to the first cooling section 101, the second cooling section 103 includes one or more supports 115, concentric pipes 117 and spacers 119. When fastened to the supports 115, the spacers 119 secure the pipes 117 to the supports 115. The supports 107, 115 and the spacers 111, 119 could be made from any material suitable to the demands of the quenching process.

[0032] For versatility, the apparatus 100 should accommodate forgings F of various shapes. For every forging F, the cooling sections 101, 103 should generally conform to the specific shape. This could be accomplished with conventional techniques. For example, the apparatus could utilize supports 107, 115 specific to each forging shape.

[0033] Alternatively, the same supports 107, 115 could be used for every forging F. To accommodate different shapes, the universal supports should include features (not shown) to allow selective positioning of each of the pipes 109, 117. In one possible arrangement, the universal supports could have height adjustable platforms upon which the pipes 109, 117 rest. The platforms could use a threaded shaft to adjust height.

[0034] In addition, either of the supports 107, 115 could be sized and shaped to allow an outermost pipe 109, 117 to surround the outer diameter of the forging F. This arrangement allows the apparatus 100 to quench the outer diameter of the forging F. Not all forgings F, however, require quenching at the outer diameter. As an example, forgings F with thin sections at the outer diameter typically do not require quenching.

[0035] Figures 4 and 5 display one of the pipes 109.

The pipe 109 is annular to provide axisymmetric cooling to the annular forging F. The pipes 109 can be made from any suitable material, such as tooling steel (e.g. AMS5042, AMS5062, AISI4340), stainless steel (AISI310, AISI316, 17-4HP), copper and brass. As an example, the pipes 109 could have an inner diameter of between approximately 0.7" and 1.3" (18 and 33 mm) and have a suitable thickness. The specific values will depend upon the demands of the quenching process.

[0036] The pipes 109, 117 each have an inlet (not shown) attached to a fluid source 127 using conventional techniques. The source 127 could use conventional valves (not shown) to control fluid flow to each pipe 109, 117. The valves could either be manually or computer-controlled. The benefits of having such control will become clear below.

[0037] The pipes 109, 117 have an arrangement of openings 131 therein. Preferably, the openings are regularly arranged around the pipes 109, 117 to provide axisymmetric cooling to the forging F. However, non-symmetric arrangements are possible. As seen in Figure 5, The openings 131 spin an angle α of between approximately 25° and 270° of the circumference of the pipe 109, 117. Preferably, the angle α is approximately 90° .

[0038] The openings 131 in the pipes 109, 117 define outlet nozzles for the fluid to exit the cooling sections 101, 103. The fluid propels from the openings 131 to cool the forging F. The openings 131 could have either sharp edges or smooth edges in order to provide a desired nozzle configuration. Specific geometric aspects of the openings 131 will be discussed in detail below.

[0039] Figure 6 displays the central cooling section 105. The central cooling section 105 preferably resides within the inner bore of the forging F. As with the outer diameter, the inner diameter of the forging F may not require quenching. Forgings F with thin sections at the inner diameter typically do not require quenching.

[0040] Similar to the pipes 109, 117, the central cooling section 105 is a pipe that includes an inlet 133 attached to the fluid source 127 using conventional techniques. The central cooling section 105 also includes a plurality of openings 135 at an outlet end. The size and shape of the central cooling section 105 depends upon the geometry of the forging F.

[0041] Assembly of the apparatus 100 proceeds as follows. The assembled first cooling section 101 receives the forging F. Specifically, the forging F rests on the spacers 111. Then, the second cooling section 103 is placed over the forging F. Likewise, the spacers 119 rest on the forging F. Next, the central cooling section 105 is placed inside the central bore of the annular forging F. The central cooling section 105 preferably rests on the supports 107 of the first cooling section 101, and is spaced from the forging F by abutting the distal ends of the spacers 111. Other arrangements, however, are possible. The apparatus 100 is now ready to begin the quenching operation.

[0042] The apparatus could utilize any suitable fluid,

such as a gas, to quench the forging F. Preferably, the present invention uses air. The source 127 could have a diameter of between approximately 2.5" and 3.5" (63 and 89 mm). The source 127 could also supply approximately 12 lb/sec (19595 kg/hr) of ambient (e.g. $65-95^\circ\text{F}$ ($18.3-35^\circ\text{C}$)) air to the apparatus 100 at a pressure of between approximately 45 and 75 psig (310 kPa and 517 kPa). Again, the specific values will depend upon the demands of the quenching process.

[0043] Generally speaking, one goal of the present invention is to control the cooling rate of the forging F precisely. This precise control allows the use of impingement cooling on the forging F. Impingement cooling is a subset of forced convection cooling that produces significantly higher heat transfer coefficients than the remainder of the forced convection regime. For example, conventional forced air convection can achieve heat transfer coefficients of approximately 50 BTU/hr $\text{ft}^2\ ^\circ\text{F}$ ($284\text{ W/m}^2\text{C}$) with typical equipment. Impingement cooling, on the other hand, can achieve heat transfer coefficients up to approximately 300 BTU/hr $\text{ft}^2\ ^\circ\text{F}$ ($1703\text{ W/m}^2\text{C}$).

[0044] Figure 7 provides the spatial relationship between the pipes 109, 117 and the forging F. Although displaying the first and second cooling sections 101, 103, the spatial relationships shown in this figure are also applicable to the central cooling section 105. As seen in the figure, the spacers 111 provide a gap between the forging F and the pipes 109, 117.

[0045] The openings 131 in the pipe preferably have a diameter d adequate to propel a sufficient amount of fluid against the forging F to perform the quenching process. As an example, the diameter d of the openings 131 could be between approximately 0.55" and 0.75" (14 and 19 mm). At this diameter d, preferably between approximately 0.002 lb/sec (3.26 kg/hr) and 0.01 lb/sec (16.32 kg/hr) of fluid flows through each opening 131 at a velocity of between approximately 200 ft/sec (61ms^{-1}) and 1000 ft/sec (305ms^{-1}).

[0046] The gaps formed between the pipes 109, 117 and the forging F created by the spacers 111 are an essential aspect of the present invention. The spacers 111 define a distance Z between the pipes 109, 117 and the forging F. The distance to diameter ratio (Z/d) should range between approximately 1.0 and 6.0.

[0047] A circumferential spacing X exists between adjacent openings 131 in the pipes 109, 117. The circumferential spacing of the openings 131 ensures adequate fluid flow to the forging F to achieve the desired cooling rate. The circumferential arrangement of the apertures 131 also ensures axisymmetric cooling of the forging F. The circumferential spacing to diameter ratio (X/d) should be between approximately 0.0 and 24.0.

[0048] Finally, a radial spacing Y exists between adjacent openings 131 in the pipes 109. Similarly, the radial spacing of the openings 131 ensures adequate fluid flow to the forging F to achieve the desired cooling rate. The radial spacing to diameter ratio (Y/d) should be between approximately 0.0 and 26.0.

[0049] Using these parameters, the present invention can treat all sections of the forging using impingement cooling. Impingement cooling is preferred because of the combined effect of increased turbulence and increased jet arrival velocity significantly increases the heat transfer coefficient of the apparatus 100.

[0050] By varying the aforementioned parameters within the suitable ranges, the present invention can achieve another goal of the present invention - to reduce any differential between the cooling rates of different areas of the forging F. Ideally, the present invention seeks to equalize the cooling rates across all areas of the forging.

[0051] The present invention reduces temperature gradients within the forging F by providing more impingement cooling to one area of the forging F compared to another area of the forging F. In terms of heat transfer, the volume of an object equates to thermal mass and the surface area of the object equates to cooling capacity. Objects exhibiting a low surface area to volume ratio cannot transfer heat as readily as objects with higher surface area to volume ratios.

[0052] The present invention seeks to increase the heat transfer of areas of the forging F that exhibit low surface area to volume ratios. Practically speaking, the present invention provides more cooling to surfaces of the forging F located adjacent larger volumetric sections than surfaces of the forging F located adjacent smaller volumetric sections.

[0053] The present invention can locally adjust impingement cooling by varying any of the aforementioned characteristics. For example, one can selectively adjust cooling to desired areas of the forging F by adjusting the diameters of the pipes 109, 117, by adjusting the diameter of the openings 131, by adjusting the size of the spacer 111 or by adjusting the density of the openings 131 (*i.e.* adjust spacing distances X or Y) during the system design stage. During operation of the apparatus 100, one can selectively adjust the cooling to desired areas of the forging F by adjusting pressure in each pipe 109, 117, 133. The aforementioned valves on the supply 127 could be used to adjust pressure. Any other technique to adjust pressure could also be used.

[0054] The present invention could leave these characteristics static during the quenching process. In other words, the apparatus 100 could keep the selected pressures in the pipes 109, 117, 133 constant throughout the entire temperature range of the quenching process. Alternatively, the present invention could dynamically adjust the pressures in the pipes 109, 117, 133 during the quenching process. For example, the apparatus 100 could operate at a desired pressure until the course grain nickel alloy forging F exits the temperature range of the ductility trough (*e.g.* 1800-2100° F (982-1149°C)). Thereafter, the apparatus could operate at a reduced pressure for the remainder of the quenching process. Other variations are also possible.

[0055] The present invention can produce heat trans-

fer coefficients greater than those created by oil bath quenching (*e.g.* 70-140 BTU/hr ft² ° F (397-795 W/m²°C)) or fan quenching (*e.g.* 50 BTU/hr ft² ° F (284 W/m² °C)). The present invention can produce a heat transfer coefficient of approximately 300 BTU/hr ft² ° F (1703 W/m²°C).

[0056] Despite the higher heat transfer coefficient, the quenched products that the present invention produces exhibit lower residual stress values than those products created by oil bath quenching. The arbitrary cooling rate of oil bath quenching produces high residual stress values. The present invention, on the other hand, achieves lower residual stress values because of the ability to differentially cool the forging F (*i.e.* control the temperature gradients across the forging). Note that reference to the residual stress values produced by fan quenching is not appropriate because fan quenching cannot meet the cooling requirements needed to quench high temperature aerospace alloys.

[0057] The present invention has been described in connection with the preferred embodiments of the various figures. It is to be understood that other similar embodiments may be used or modifications and additions may be made to the described embodiment for performing the same function of the present invention without deviating therefrom. Therefore, the present invention should not be limited to any single embodiment, but rather construed in breadth and scope in accordance with the recitation of the appended claims.

Claims

1. A method of quenching a material, comprising the steps of:

providing a material having a first section and a second section;
providing a source of cooling fluid, said source of cooling fluid having a plurality of fluid outlets (131) spaced from said material; and
propelling said fluid from said outlets (131) against said first section so as to impingement cool said first section so as to increase a cooling rate of said first section relative to a cooling rate of said second section; **characterised by:**

providing a series of annular pipes (109, 117) arranged about an axis;
providing said outlets (131) in said series of pipes (109, 117); and
supporting said pipes (109, 117) such as to be offset from one another along said axis.

2. The method as recited in claim 1 wherein the material is a forging.

3. The method as recited in claim 1 or 2, wherein said

fluid comprises a gas.

4. The method as recited in any preceding claim, wherein said propelling step generally minimizes a gradient between a temperature of said first section and a temperature of said second section. 5
5. The method as recited in any preceding claim, wherein the propelling step remains constant during quenching. 10
6. The method as recited in any of claims 1 to 4, wherein the propelling step varies during quenching.
7. The method as recited in claim 6, wherein the propelling step varies by adjusting a pressure of said fluid. 15
8. The method as recited in any preceding claim, wherein said outlet (131) has a diameter (d) and is positioned a distance (Z) from the material, and Z/d is between approximately 1.0 and 6.0. 20
9. The method as recited in any preceding claim, wherein said outlet comprises a plurality of outlets (131) each having a diameter (d), adjacent outlets having a spacing (s) therebetween, and s/d is less than approximately 26.0. 25
10. The method as recited in claim 9, wherein said spacing is a circumferential spacing (X) and X/d is less than approximately 26.0. 30
11. The method as recited in claim 9, wherein said spacing is a radial spacing (Y) and Y/d is less than approximately 24.0. 35
12. The method as recited in any preceding claim, wherein said annular pipes (109; 117) are concentric. 40
13. The method as recited in any preceding claim wherein said material is spaced from said pipes (109;117) by spacers (111) engaging said pipes (109; 117) 45
14. The method as recited in claim 13 wherein said spacers (111) serve to retain the pipes (109; 117) to their support (107; 115).
15. The method as recited in any preceding claim wherein respective sets of annular pipes (109; 117) are provided above and below said material, said material being supported between said sets of pipes (109; 117). 50
16. The method as recited in any preceding claim wherein further cooling fluid is impinged against said material from a further outlet pipe (105) arranged along

said axis.

17. An apparatus (100) for quenching a material, the material having a first section and a second section, said apparatus comprising: 5

a support (107) for receiving the material; and
a plurality of outlets (131) adjacent said support for impinging a fluid against the first section of the material, so that a cooling rate of the first section increases relative to a cooling rate of the second section; **characterised in that** it comprises:

a plurality of annular pipes (109; 117) comprising said outlets (131) arranged adjacent said first section of material and arranged about an axis; and
a support (107; 115) for supporting said pipes (109; 117) offset from one another along the said axis.
18. The apparatus as recited in claim 17, wherein said outlet (131) has a diameter (d) and is positioned a distance (Z) from the material placed in said support, and Z/d is between approximately 1.0 and 6.0.
19. The apparatus as recited in claim 17 or 18, wherein said outlet comprises a plurality of outlets (131) each having a diameter (d), adjacent outlets having a spacing (s) therebetween, and s/d is less than approximately 26.0.
20. The apparatus as recited in claim 19, wherein said spacing is a circumferential spacing (X) and X/d is less than approximately 26.0.
21. The apparatus as recited in claim 19 or 20, wherein said spacing is a radial spacing (Y) and Y/d is less than approximately 24.0.
22. The apparatus as recited in any of claims 17 to 21 further comprising spacers (111) engaging said pipes (109; 117) for spacing said material from said pipes (109;117). 45
23. The apparatus as recited in claim 22 wherein said spacers (111) serve to retain the pipes (109; 117) to their support (107; 115).
24. The apparatus as recited in any of claims 17 to 23 wherein respective sets of annular pipes (109; 117) are provided above and below said material, said material being supported between said sets of pipes (109; 117). 55
25. The apparatus as recited in any of claims 17 to 23 further comprising a central cooling section (105) for

impinging cooling fluid outwardly against said material from said axis.

26. The apparatus as recited in any of claims 17 to 25 wherein said annular pipes (109;117) are concentric about said axis.

Patentansprüche

1. Verfahren zum Abkühlen eines Materials, das folgende Schritte aufweist:

Bereitstellen eines Materials, das einen ersten Bereich und einen zweiten Bereich aufweist; Bereitstellen einer Kühlfluidquelle, wobei die Kühlfluidquelle eine Mehrzahl von Fluidauslässen (131) aufweist, die von dem Material beabstandet sind; und

Vorantreiben des Fluids von den Auslässen (131) gegen den ersten Bereich, um eine Aufprallkühlung des ersten Bereichs vorzunehmen und dadurch eine Kühlrate des ersten Bereichs relativ zu einer Kühlrate des zweiten Bereichs zu steigern;

gekennzeichnet durch:

Bereitstellen einer Serie von ringförmigen Rohren (109, 117), die um eine Achse herum angeordnet sind; Bereitstellen der Auslässe (131) in der Serie von Rohren (109, 117); und Abstützen der Rohre (109, 117) derart, dass sie entlang der Achse voneinander versetzt sind.

2. Verfahren nach Anspruch 1, wobei es sich bei dem Material um ein Schmiedeteil handelt.
3. Verfahren nach Anspruch 1 oder 2, wobei das Fluid ein Gas aufweist.
4. Verfahren nach einem der vorausgehenden Ansprüche, wobei der Vorantreib-Schritt ein Gefälle zwischen einer Temperatur des ersten Bereichs und einer Temperatur des zweiten Bereichs allgemein minimiert.
5. Verfahren nach einem der vorausgehenden Ansprüche, wobei der Vorantreib-Schritt während des Abkühlvorgangs konstant bleibt.
6. Verfahren nach einem der Ansprüche 1 bis 4, wobei der Vorantreib-Schritt während des Abkühlvorgangs variiert.

7. Verfahren nach Anspruch 6, wobei der Vorantreib-Schritt unter Einstellen eines Drucks des Fluids variiert.

8. Verfahren nach einem der vorausgehenden Ansprüche, wobei der Auslass (131) einen Durchmesser (d) aufweist und in einer Distanz (Z) von dem Material angeordnet ist und wobei Z/d im Bereich von ca. 1,0 bis 6,0 liegt.

9. Verfahren nach einem der vorausgehenden Ansprüche, wobei der Auslass eine Mehrzahl von Auslässen (131) aufweist, von denen jeder einen Durchmesser (d) hat, wobei einander benachbarte Auslässe eine gegenseitige Beabstandung (s) aufweisen und wobei s/d geringer ist als ca. 26,0.

10. Verfahren nach Anspruch 9, wobei es sich bei der Beabstandung um eine umfangmäßige Beabstandung (X) handelt und X/d geringer ist als ca. 26,0.

11. Verfahren nach Anspruch 9, wobei es sich bei der Beabstandung um eine radiale Beabstandung (Y) handelt und Y/d geringer ist als ca. 24,0.

12. Verfahren nach einem der vorausgehenden Ansprüche, wobei die ringförmigen Rohre (109; 117) konzentrisch sind.

13. Verfahren nach einem der vorausgehenden Ansprüche, wobei das Material von den Rohren (109; 117) durch Abstandselemente (111) beabstandet ist, die mit den Rohren (109; 117) zusammenwirken.

14. Verfahren nach Anspruch 13, wobei die Abstandselemente (111) zum Festhalten der Rohre (109; 117) an ihrer Abstützeinrichtung (107; 115) dienen.

15. Verfahren nach einem der vorausgehenden Ansprüche, wobei jeweilige Sätze von ringförmigen Rohren (109; 117) über und unter dem Material vorgesehen werden und das Material zwischen den Sätzen von Rohren (109; 117) abgestützt wird.

16. Verfahren nach einem der vorausgehenden Ansprüche, wobei man weiteres Kühlfluid auf das Material von einem weiteren Austrittsrohr (105) auftreffen lässt, das entlang der Achse angeordnet ist.

17. Vorrichtung (100) zum Abkühlen eines Materials, wobei das Material einen ersten Bereich und einen zweiten Bereich hat und wobei die Vorrichtung folgendes aufweist:

eine Abstützeinrichtung (107) zum Aufnehmen des Materials; und
eine Mehrzahl von Auslässen (131), die der Abstützeinrichtung benachbart sind, um ein Fluid auf den ersten Bereich des Materials auftreffen zu lassen, so dass eine Kühlrate des ersten Bereichs relativ zu einer Kühlrate des zweiten Bereichs zunimmt;

dadurch gekennzeichnet, dass sie Folgendes aufweist:

eine Mehrzahl von ringförmigen Rohren (109; 117), die die Auslässe (131) aufweisen, die dem ersten Bereich des Materials benachbart angeordnet sind, und um eine Achse angeordnet sind; und
eine Abstützeinrichtung (107; 115) zum Abstützen der Rohre (109; 117) in einer entlang der Achse voneinander versetzten Weise.

18. Vorrichtung nach Anspruch 17, wobei der Auslass (131) einen Durchmesser (d) aufweist und in einer Distanz (Z) von dem in der Abstützeinrichtung platzierten Material angeordnet ist und wobei Z/d im Bereich von ca. 1,0 bis 6,0 liegt.
19. Vorrichtung nach Anspruch 17 oder 18, wobei der Auslass eine Mehrzahl von Auslässen (131) aufweist, von denen jeder einen Durchmesser (d) hat, wobei einander benachbarte Auslässe eine gegenseitige Beabstandung (s) aufweisen und wobei s/d geringer ist als ca. 26,0.
20. Vorrichtung nach Anspruch 19, wobei es sich bei der Beabstandung um eine umfangmäßige Beabstandung (X) handelt und X/d geringer ist als ca. 26,0.
21. Vorrichtung nach Anspruch 19 oder 20, wobei es sich bei der Beabstandung um eine radiale Beabstandung (Y) handelt und Y/d geringer ist als ca. 24,0.
22. Vorrichtung nach einem der Ansprüche 17 bis 21, weiterhin mit Abstandselementen (111), die mit den Rohren (109; 117) zusammenwirken, um das Material im Abstand von den Rohren (109; 117) zu halten.
23. Vorrichtung nach Anspruch 22, wobei die Abstandselemente (111) zum Festhalten der Rohre (109; 117) an ihrer Abstützeinrichtung (107; 115) dienen.

24. Vorrichtung nach einem der Ansprüche 17 bis 23, wobei jeweilige Sätze von ringförmigen Rohren (109; 117) über und unter dem Material vorgesehen sind und das Material zwischen den Sätzen von Rohren (109; 117) abgestützt ist.

25. Vorrichtung nach einem der Ansprüche 17 bis 23, weiterhin mit einem zentralen Kühlbereich (105) zum Auftreffen-Lassen von Kühlfluid auf das Material ausgehend von der Achse in Richtung nach außen.
26. Vorrichtung nach einem der Ansprüche 17 bis 25, wobei die ringförmigen Rohre (109; 117) konzentrisch um die Achse sind.

Revendications

1. Procédé de trempe d'un matériau, comportant les étapes consistant à :

mettre à disposition un matériau présentant un premier tronçon et un deuxième tronçon ;
mettre à disposition une source de fluide de refroidissement, ladite source de fluide de refroidissement étant dotée d'une pluralité de sorties (131) de fluide espacées par rapport audit matériau ; et
propulser ledit fluide à partir desdites sorties (131) contre ledit premier tronçon de façon à refroidir par impact ledit premier tronçon, de façon à augmenter une vitesse de refroidissement dudit premier tronçon par rapport à une vitesse de refroidissement dudit deuxième tronçon ; **caractérisé par** les étapes consistant à :

mettre en place une série de tuyaux annulaires (109, 117) disposés autour d'un axe ;
mettre en place lesdites sorties (131) dans ladite série de tuyaux (109, 117) ; et
supporter lesdits tuyaux (109, 117) de telle façon qu'ils soient décalés les uns par rapport aux autres le long dudit axe.

2. Procédé selon la revendication 1, le matériau étant une pièce forgée.
3. Procédé selon la revendication 1 ou 2, ledit fluide comportant un gaz.
4. Procédé selon l'une quelconque des revendications précédentes, ladite étape de propulsion minimisant généralement un gradient entre une température dudit premier tronçon et une température dudit deuxième tronçon.
5. Procédé selon l'une quelconque des revendications précédentes, l'étape de propulsion demeurant cons-

- tante au cours de la trempe.
6. Procédé selon l'une quelconque des revendications 1 à 4, l'étape de propulsion variant au cours de la trempe. 5
 7. Procédé selon la revendication 6, l'étape de propulsion variant par réglage d'une pression dudit fluide.
 8. Procédé selon l'une quelconque des revendications précédentes, ladite sortie (131) présentant un diamètre (d) et étant positionnée à une distance (Z) du matériau, et Z/d se situant entre environ 1,0 et 6,0. 10
 9. Procédé selon l'une quelconque des revendications précédentes, ladite sortie comportant une pluralité de sorties (131), chacune présentant un diamètre (d), les sorties adjacentes présentant un espacement (s) entre elles, et s/d étant inférieur à environ 26,0. 15
 10. Procédé selon la revendication 9, ledit espacement étant un espacement circonférentiel (X) et X/d étant inférieur à environ 26,0. 20
 11. Procédé selon la revendication 9, ledit espacement étant un espacement radial (Y) et Y/d étant inférieur à environ 24,0. 25
 12. Procédé selon l'une quelconque des revendications précédentes, lesdits tuyaux annulaires (109, 117) étant concentriques. 30
 13. Procédé selon l'une quelconque des revendications précédentes, ledit matériau étant espacé par rapport auxdits tuyaux (109, 117) par des entretoises (111) interagissant avec lesdits tuyaux (109, 117). 35
 14. Procédé selon la revendication 13, lesdites entretoises (111) servant à maintenir les tuyaux (109, 117) sur leur support (107, 115). 40
 15. Procédé selon l'une quelconque des revendications précédentes, des ensembles respectifs de tuyaux annulaires (109, 117) étant mis en place au-dessus et au-dessous dudit matériau, ledit matériau étant supporté entre lesdits ensembles de tuyaux (109, 117). 45
 16. Procédé selon l'une quelconque des revendications précédentes, du fluide de refroidissement supplémentaire étant projeté contre ledit matériau à partir d'un tuyau (105) de sortie supplémentaire disposé le long dudit axe. 50
 17. Appareil (100) de trempe d'un matériau, le matériau présentant un premier tronçon et un deuxième tronçon, ledit appareil comportant :
 - un support (107) destiné à recevoir le matériau ;
 - et
 - une pluralité de sorties (131) adjacentes audit support destinées à projeter un fluide contre le premier tronçon du matériau, de telle sorte qu'une vitesse de refroidissement du premier tronçon augmente par rapport à une vitesse de refroidissement du deuxième tronçon ; **caractérisé en ce qu'il** comporte :
 - une pluralité de tuyaux annulaires (109, 117) comportant lesdites sorties (131) disposées au voisinage dudit premier tronçon du matériau et disposées autour d'un axe ;
 - et
 - un support (107, 115) destiné à supporter lesdits tuyaux (109, 117) décalés les uns par rapport aux autres le long dudit axe.
 18. Appareil selon la revendication 17, ladite sortie (131) présentant un diamètre (d) et étant positionnée à une distance (Z) du matériau placé dans ledit support, et Z/d se situant entre environ 1,0 et 6,0. 20
 19. Appareil selon la revendication 17 ou 18, ladite sortie comportant une pluralité de sorties (131), chacune présentant un diamètre (d), les sorties adjacentes présentant un espacement (s) entre elles, et s/d étant inférieur à environ 26,0. 25
 20. Appareil selon la revendication 19, ledit espacement étant un espacement circonférentiel (X) et X/d étant inférieur à environ 26,0. 30
 21. Appareil selon la revendication 19 ou 20, ledit espacement étant un espacement radial (Y) et Y/d étant inférieur à environ 24,0. 35
 22. Appareil selon l'une quelconque des revendications 17 à 21, comportant en outre des entretoises (111) interagissant avec lesdits tuyaux (109, 117) afin d'espacer ledit matériau par rapport auxdits tuyaux (109, 117). 40
 23. Appareil selon la revendication 22, lesdites entretoises (111) servant à maintenir les tuyaux (109, 117) sur leur support (107, 115). 45
 24. Appareil selon l'une quelconque des revendications 17 à 23, des ensembles respectifs de tuyaux annulaires (109, 117) étant mis en place au-dessus et au-dessous dudit matériau, ledit matériau étant supporté entre lesdits ensembles de tuyaux (109, 117). 50
 25. Appareil selon l'une quelconque des revendications 17 à 23, comportant en outre un tronçon central (105) de refroidissement destiné à projeter du fluide de refroidissement vers l'extérieur contre ledit matériau 55

à partir dudit axe.

- 26.** Appareil selon l'une quelconque des revendications 17 à 25, lesdits tuyaux annulaires (109, 117) étant concentriques autour dudit axe.

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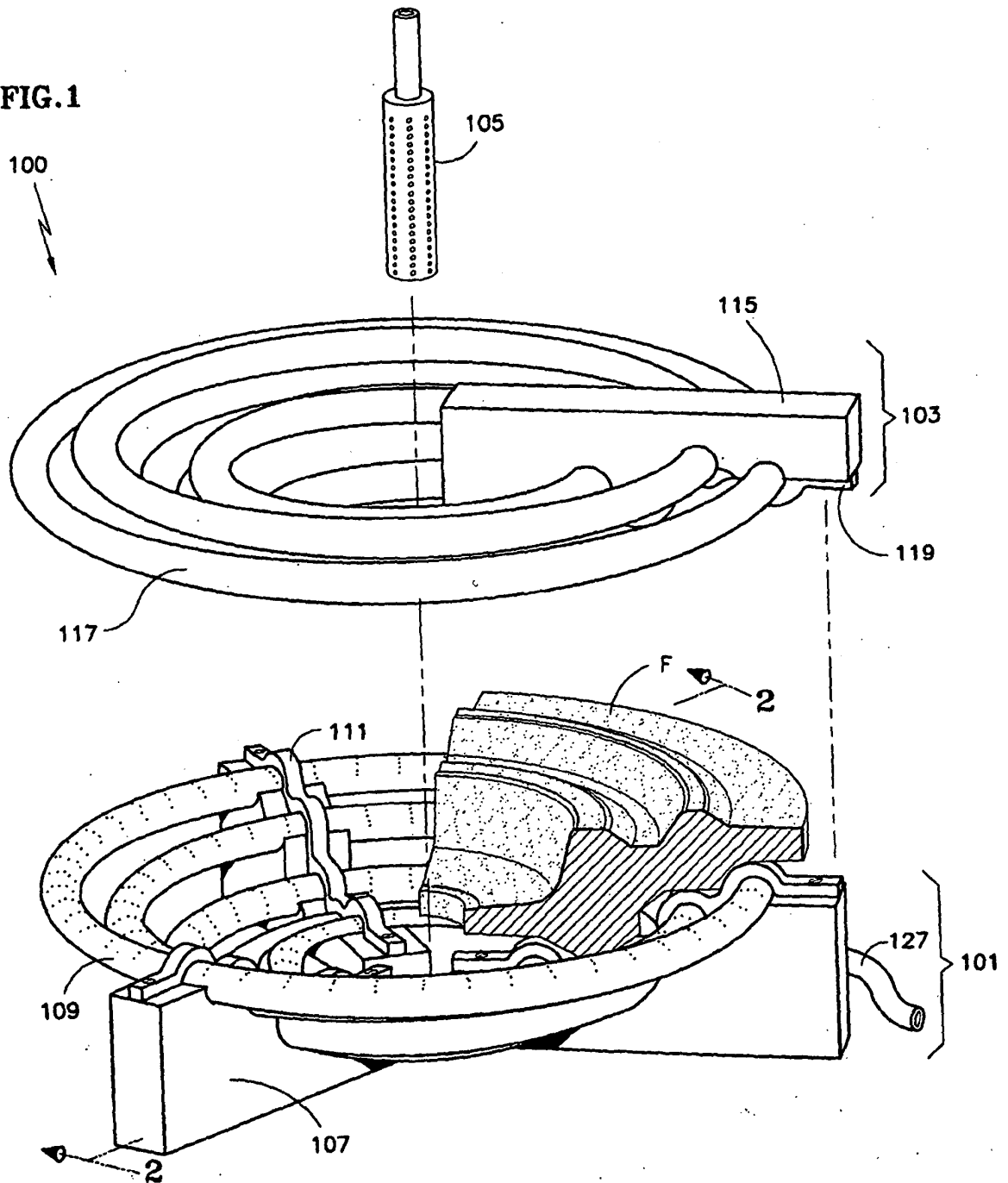
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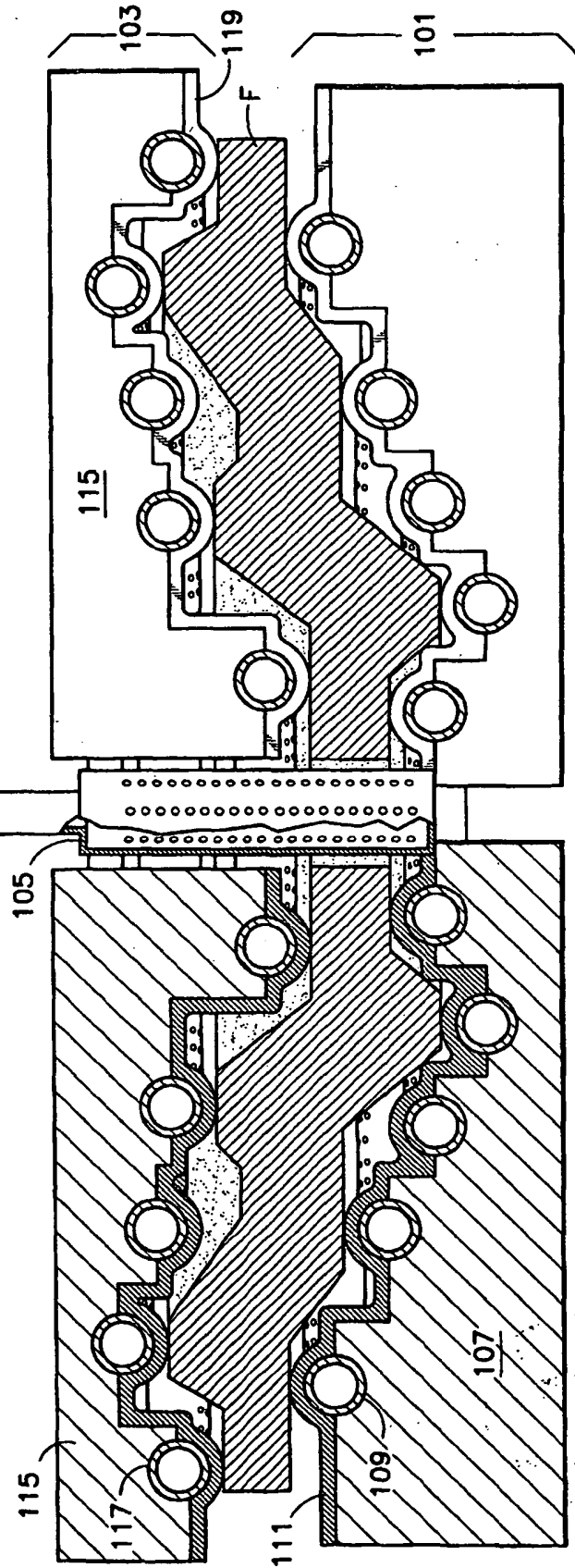
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FIG. 1



100

FIG.2



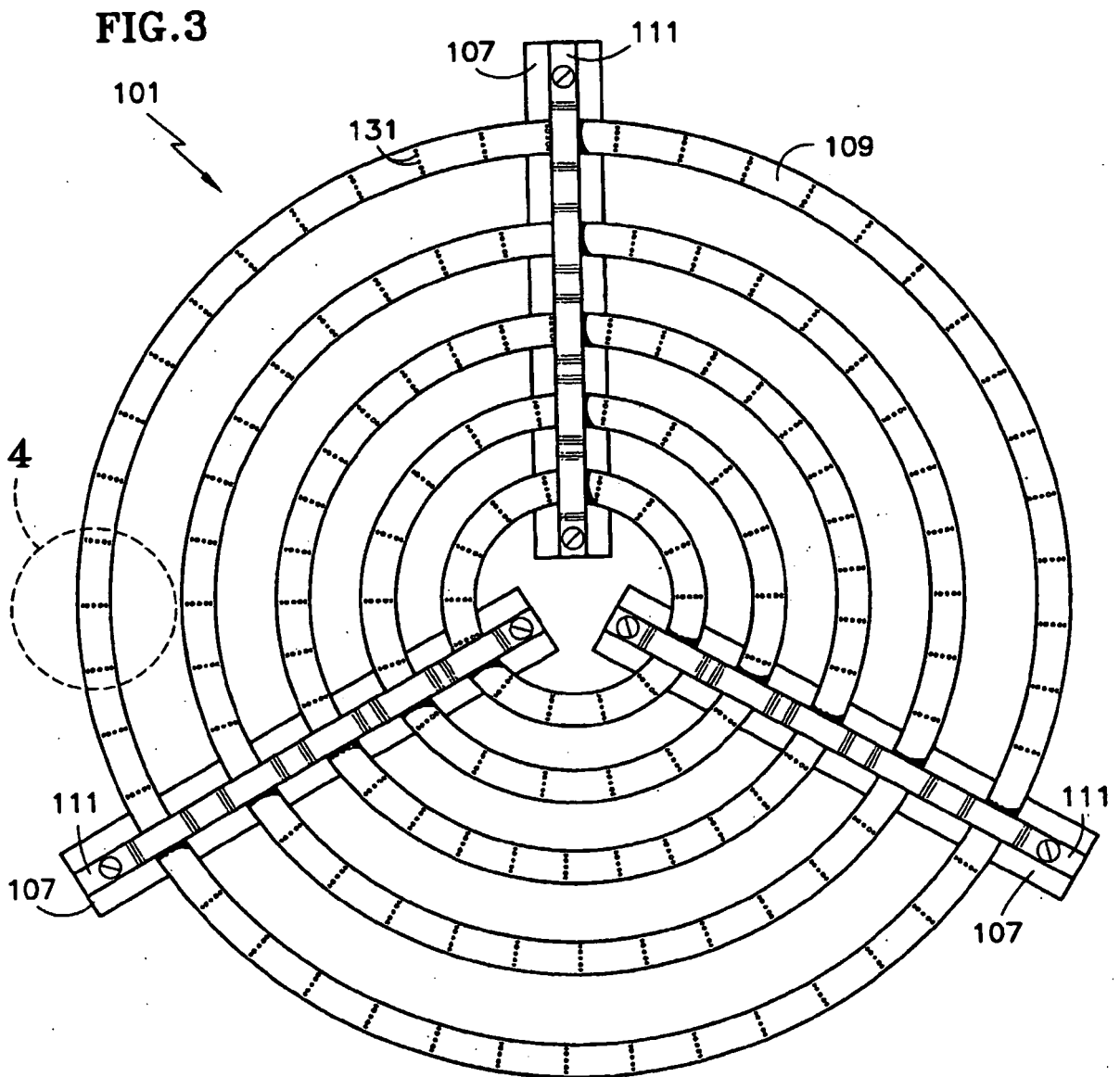


FIG.4

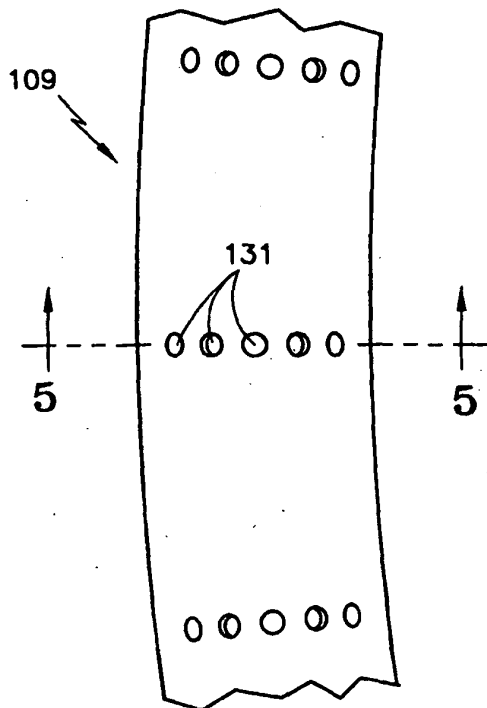


FIG.5

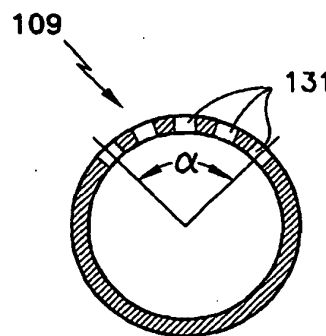


FIG.6

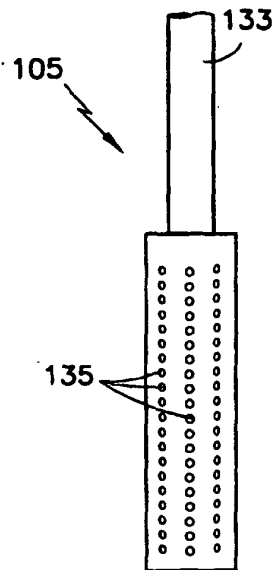
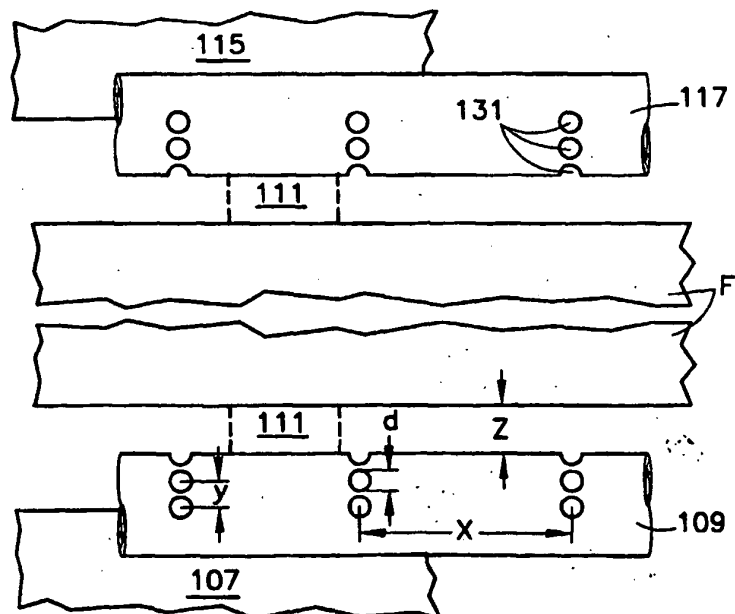


FIG.7



REFERENCES CITED IN THE DESCRIPTION

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