(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 729 079 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.12.2006 Bulletin 2006/49

(51) Int Cl.:
F28F 1/36 *(2006.01)* ***F22B 37/10*** *(2006.01)*
F22D 1/08 *(2006.01)*

(21) Application number: **05011585.6**

(22) Date of filing: **30.05.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR LV MK YU

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(54) Method for producing a heat exchange unit for a recovery steam generator, a heat exchange unit, a recovery steam generator and a tube for a heat exchange unit

(57) A method for producing a heat exchange unit (22) for a recovery steam generator (20) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), said segmented finning (26) being obtained by winding in a spiral and welding a metallic strip having a substantially trapezium-shaped cross section around said tubes (24), on said metallic strip a series of transversal cuts being made, which have a predetermined pitch and extend from a side edge of the strip, corresponding to the shorter base of the trapezium, for a predetermined depth, said strip being welded to said tubes (24) along the opposite side edge, corresponding to the longer base of the trapezium.

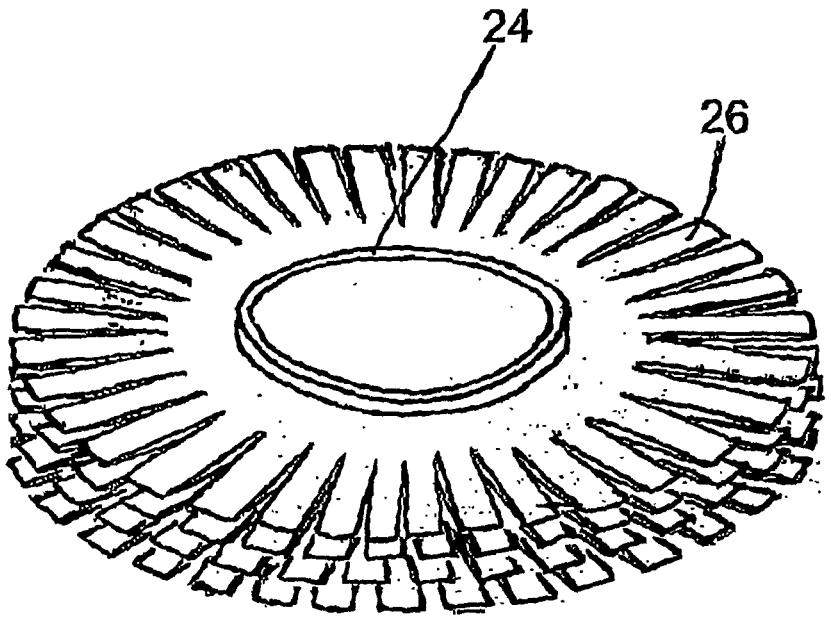

Fig.3

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Description

Field of application

[0001] The present invention, in its most general aspect, refers to a method for producing a recovery steam generator (which is also indicated with the acronym RSG - Recovery Steam Generator or HRSG Heat Recovery Steam Generator), particularly but not exclusively intended for a use in thermoelectric plants of the so-called combined gas/steam cycle type.

[0002] More specifically, this invention concerns a method for the production of a heat exchange unit for a steam generator of the aforementioned type and comprising a tube bundle equipped with so-called segmented finning.

[0003] The present invention also refers to a recovery steam generator produced with said method, as well as to a tube bundle heat exchange unit and to a tube equipped with segmented finning suitable for being included in said recovery steam generator.

[0004] In the rest of the description reference shall be made, only as a non-limiting example, to the technological field relative to combined gas/steam cycle thermoelectric plants, i.e. plants in which two technological cycles are provided, one carried out by air and natural gas (gas cycle) and the other carried out by water and steam (steam cycle), both intended to produce electrical energy with high yield (typically greater than 55%).

Prior Art

[0005] It is known that the gas cycle of a combined cycle thermoelectric plant of the type considered essentially comprises a compressor, a combustion chamber, a gas turbine and an alternator. The compressor takes in air from the atmosphere taking it to a predetermined high pressure; the air thus compressed is introduced into the combustion chamber together with a fuel, generally consisting of natural gas; the mixture that forms is ignited and the high pressure and high temperature gases produced are made to expand in the gas turbine that moves the alternator, which generates electrical energy.

[0006] The steam cycle of the aforementioned thermoelectric plant, on the other hand, comprises a steam generator, a steam turbine and a further alternator. A heat exchange unit of said steam generator, essentially consisting of a tube bundle, is placed in a heat exchange relationship with the hot gases discharged by the gas turbine of the aforementioned gas cycle, with a consequent great and quick heating of the water and generation of steam in a liquid-gas separation chamber of the steam generator itself. The steam thus produced is sent to the steam turbine that makes the respective alternator operate to generate electrical energy.

[0007] A steam generator used in the aforementioned way is called a heat recovery steam generator precisely because to generate steam the heat of the hot gases (at about 600°C) discharged by the gas turbine is "exploited".

[0008] In modern combined cycles the steam is preferably produced at different pressure levels in order to be able to optimize the energy recovery.

[0009] In particular, the most widely used plant configuration for high-power embodiments provides three pressure levels (high, medium and low) plus a superheating of the medium pressure steam returning from the steam turbine, i.e. of the so-called cold steam.

[0010] As known, the recovery steam generator, for each pressure level, takes care of three well-defined heat exchange operations:

- preheating of liquid water coming from a feed pump or from a condensate extraction pump, carried out in a section of the heat exchange unit known as economizer or preheater;
- evaporation of the water for the generation of saturated steam, carried out in a section of the heat exchange unit known as evaporator;
- superheating of the steam, carried out in a section of the heat exchange unit known as superheater.

[0011] The sections of the heat exchange unit that take care of the three aforementioned operations essentially consist of finned tube bundles.

[0012] In particular, in this technological field, it has become common practice to use tubes equipped with so-called segmented finning, obtained from a metal strip having a substantially rectangular cross section, mainly made from carbon steel (with the exception of part of the superheating sections, where stainless steel is used), said strip being wound in a spiral around said tubes and at the same time being welded to them along one of the side edges of the strip. As an example, for tubes with a diameter typically between 38 and 51 mm, a strip with rectangular cross section with a width of 19 mm and thickness of 1-1.2 mm can be used and the pitch of the spiral winding can be about 4 mm.

[0013] Such finnings radially jut from the tubes and are segmented since, before carrying out the winding in a spiral of the strip on the tubes, on the metallic strip itself a series of transversal cuts are made, which have a predetermined pitch (for example 4-5 mm) and which extend from the same side edge of the strip for a predetermined depth (for example 13 mm), obtaining a segmented metallic strip. More specifically, such transversal cuts are perpendicular to the longitudinal direction of the strip.

[0014] In this way, in the subsequent spiral winding operative step of the strip on the tubes - where the side edge of the strip without transversal cuts is what is welded to the tubes -, the outer "segmented" parts of the finnings (i.e. the "segments" of the finnings that are defined by the series of transversal cuts) are not subjected to internal traction tensions, since they are free to open one with

respect to the others.

[0015] Although advantageous from various points of view, the known technique for producing a heat exchange unit for a recovery steam generator has recognized drawbacks, the main one of which is that the segmented finnings thus made represent a considerable component of the overall weight of the heat exchange unit of the steam generator (for example, in a recovery steam generator downstream of a 250 MW gas turbine the weight of the finnings represents about 60% of the weight of all of the parts under pressure of the heat exchange unit, i.e. 1200 t out of 2000 t), and consequently the finnings have a considerable impact upon the overall cost of the heat exchange unit.

[0016] Another drawback is the fact that the efficiency of the gas turbine of a combined cycle thermoelectric plant that comprises the aforementioned recovery steam generator is significantly penalized by the hindrance to the flow of the fumes (discharge gases of the gas turbine) which is created with the type of segmented finnings described above, i.e. in other words a significant counterpressure at the turbine is generated.

Summary of the invention

[0017] The technical problem underlying the present invention is that of devising and providing a method for producing a heat exchange unit for a recovery steam generator of the type considered in which, with the same heat exchange efficiency, the heat exchange unit has a considerably reduced overall weight with respect to what has been possible up to now with the prior art and in which, in the case of a combined cycle thermoelectric plant, the resistance to the flow of discharge gases of the gas turbine is simultaneously limited.

[0018] This problem is solved, according to the present invention, by a method for producing a heat exchange unit for a recovery steam generator comprising a tube bundle each tube of which is equipped with segmented finning jutting radially from said tubes, said segmented finning being obtained by winding in a spiral and welding a metallic strip having a substantially trapezium-shaped cross section around said tubes, on said metallic strip a series of transversal cuts being made, which have a predetermined pitch and extend from a side edge of the strip, corresponding to the shorter base of the trapezium, for a predetermined depth, said strip being welded to said tubes along the opposite side edge, corresponding to the longer base of the trapezium.

[0019] In this way, with the same heat exchange efficiency, it is possible to reduce the weight of the segmented finning of the aforementioned heat exchange unit of the steam generator by 20-30%, with respect to the heat exchange unit used in the prior art.

[0020] Moreover, given the lesser hindrance to the flow of the fumes offered by the finning thus configured, it is possible to reduce - with the same free section of fume passage, i.e. with the same air-pressure drop at fume side - the pitch between the tubes of the heat exchange unit or to decrease the pitch of the spiral winding of the finning, further increasing the heat exchange efficiency.

[0021] Further characteristics and advantages of the method for producing a heat exchange unit for a recovery steam generator according to the present invention shall become clearer from the following description of a preferred embodiment thereof, provided for indicating and not limiting purposes with reference to the attached drawings.

Brief description of the drawings

[0022]

Figure 1 represents a block diagram of a method for producing a heat exchange unit for a recovery steam generator, according to the present invention.

Figure 2 schematically represents a elevation view of a recovery steam generator produced according to the method represented in figure 1.

Figure 3 schematically represents an enlarged perspective view of a detail of the recovery steam generator of figure 2, illustrating a finned tube.

Figure 4 schematically represents a elevation view, in radial section and enlarged, of a detail of the finned tube of figure 3, illustrating a finning profile.

Figure 5 represents a block diagram of a variant embodiment of the method for producing a heat exchange unit for a recovery steam generator, according to the present invention.

Figure 6 schematically represents a elevation view, in radial section, of a finning profile of a finned tube included in the recovery steam generator produced according to the method represented in figure 5.

Detailed description of a preferred embodiment

[0023] With initial reference to figure 1, the method for producing a heat exchange unit 22 for a recovery steam generator 20 according to the _present invention comprises an operative step 10 of making tubes 24 equipped with finning 26 and an operative assembly step 18 of the tubes 24 thus made to form a tube bundle 24, constituting said heat exchange unit 22, which forms part of said recovery steam generator 20.

[0024] In particular, the operative step 10 of making tubes 24 equipped with finning 26 comprises a succession of steps (blocks 12, 14 and 16 of figure 1), i.e. each tube 24 equipped with finning 26 is produced following the steps of:

- drawing a metallic strip having a substantially rec-

tangular cross section (block 12), obtaining a metallic strip having a substantially trapezium-shaped cross section, the longer and shorter bases of the trapezium corresponding to two side edges of the strip (alternatively, it is possible to obtain a metallic strip having a substantially trapezium-shaped cross section by drawing a metallic strip having, initially, a circular cross section);

- on the metallic strip having a substantially trapezium-shaped cross section making a series of transversal cuts (block 14), which have a predetermined pitch, extend from the side edge corresponding to the shorter base of the trapezium for a predetermined depth and are open on that side edge, obtaining a segmented metallic strip;

- winding said segmented metallic strip in a spiral around said tube 24, at the same time welding it to said tube 24 along the side edge corresponding to the longer base of the trapezium (block 16), obtaining a segmented finning 26, jutting radially from said tube 24 and having a substantially trapezium-shaped radial section, tapered towards the outside.

[0025] In the same way as the prior art, the "segmented" outer parts of the finning 26 are not subjected to internal traction tensions, since they are free to open out one with respect to the others. Preferably, said transversal cuts are perpendicular to the longitudinal direction of the metallic strip.

[0026] We would like to point out that, in the present patent application, with the term "substantially trapezium-shaped" we mean to include, as well as rectangular, isosceles and scalene trapezia, also the limit case of a triangle, i.e. we mean to include all shapes that, starting from a base end, are tapered towards an end opposite the base end itself.

[0027] Preferably, the substantially trapezium-shaped radial section is in the form of an isosceles trapezium or an isosceles triangle.

[0028] As an example, for tubes 24 with an outer diameter of 51 mm, it has been found that advantageously a finning 26 that is, in cross section, an isosceles trapezium with longer base 1.2 mm, shorter base 0.4 mm and height 19 mm, have a heat exchange substantially equivalent to a finning that is, in cross section, a rectangle with a width of 19 mm and thickness of 1 mm, having the same pitch of the spiral winding of the finning on the tube. Moreover, the pitch of the series of transversal cuts and their depth can be of analogous value to that used in the prior art (for example, 5 mm in pitch and 13 mm in depth).

[0029] In a variant embodiment of the method of the present invention, an inversion of the operative steps corresponding to blocks 12 and 14 of figure 1 can be provided, i.e, each tube 24 equipped with finning 26 is produced following the steps of:

- on the metallic strip having a substantially rectangle-shaped cross section making a series of transversal cuts, which have a predetermined pitch, extend from a side edge of the strip and are open on that side edge, obtaining a segmented metallic strip;

- drawing said segmented metallic strip, obtaining a metallic strip having a substantially trapezium-shaped cross section, the longer and shorter bases of the trapezium corresponding to the two side edges of the strip;

- winding said metallic strip having a substantially trapezium-shaped cross section in a spiral around said tube 24, at the same time welding it to said tube 24 along the side edge corresponding to the longer base of the trapezium, obtaining the segmented finning 26.

[0030] In the present invention, the verb "to draw" includes any hot or cold mechanical processing, with or without chip removal, suitable for modifying the shape of the starting cross section of the metallic strip. For example, such mechanical processing can take place through the passage of the strip through drawing matrices or mill rollers.

[0031] In general, the method for producing a heat exchange unit 22 for a recovery steam generator 20 according to the present invention does not depend upon the processing used to make said metallic strip having a substantially trapezium-shaped cross section, for example from a metallic strip having a substantially rectangle-shaped cross section or having a circular cross section.

[0032] With reference to figures 2, 3 and 4, a steam generator 20 is shown, including a heat exchange unit 22 made with the method of the present invention.

[0033] The heat exchange unit 22 comprises a tube bundle 24, each tube of which is equipped with segmented finning 26.

[0034] The segmented finning 26 juts radially from said tube and have a substantially trapezium-shaped radial section, tapered towards the outside.

[0035] Preferably, as stated above, the substantially trapezium-shaped radial section is in the form of an isosceles trapezium, which can be seen in figure 4, or of an isosceles triangle.

[0036] With reference to figure 5, a variant embodiment of the method for producing a heat exchange unit for a recovery steam generator according to the present invention is shown. Also in this case, the method comprises an operative step of making tubes 124 equipped with finning 126, globally indicated with 110, and an operative assembly step 18 of the tubes thus made to form a tube bundle 124, constituting said heat exchange unit, which forms part of said recovery steam generator.

[0037] In particular, the operative step 110 of making tubes 124 equipped with finning 126 comprises a succession of steps (blocks 112, 114, 115 and 116 of figure

5), i.e. each tube 124 equipped with finning 126 is produced following the steps of:

- drawing a metallic strip having a substantially rectangular cross section (block 112), obtaining a metallic strip having a cross section that is tapered at the two side edges of the strip (alternatively, it is possible to obtain a metallic strip having a cross section that is tapered at the two side edges of the strip by drawing a metallic strip having, initially, a circular cross section);

- on the metallic strip having a tapered cross section making two series of transversal cuts (block 114), each of which has a predetermined pitch, extends from a respective side edge of the strip for a predetermined depth, and is open on the respective side edge, obtaining a double-segmented metallic strip;

- longitudinally bending said double-segmented metallic strip substantially at its middle zone (block 115), obtaining a bent metallic strip having a substantially U-shaped cross section;

- winding said bent metallic strip in a spiral around said tube 124, at the same time welding it to said tube 124 along the base of the "U" (block 116), obtaining a finning 126 segmented on a double row, each row jutting radially from said tube 124 and having a radial section that is tapered towards the outside, as illustrated in figure 6.

[0038] Alternatively, the longitudinal bending step of the segmented metallic strip can precede the step of making the two series of longitudinal cuts on the two wings of the "U" that has been formed.

[0039] From the previous description it can clearly be seen that the method for producing a heat exchange unit for a recovery steam generator according to the invention solves the technical problem and gives numerous advantages the first of which lies in the fact that the overall weight of the heat exchange unit thus produced is unusually low with respect to what has been possible up to now with the prior art. In particular, at the design stage of the heat exchange unit 22, it is possible to select the trapezium-shaped cross section of the finning that is satisfactory in terms of heat exchange efficiency and weight.

[0040] Another advantage is that, in a combined gas/steam cycle thermoelectric plant, the air-pressure drop of the hot gases discharged from the gas turbine that cross the heat exchange unit of the recovery steam generator according to the invention, and which meet the tube bundle in a direction substantially perpendicular to the axis of the tubes themselves, is less than the prior art.

[0041] For such a reason, with the same air-pressure drop of the hot gases in the recovery steam generator according to the invention and in the generator according to the prior art, the pitch of the spiral winding of the finning according to the invention on the tube can be reduced with respect to the pitch used in the prior art.

[0042] Of course, a man skilled in the art can make numerous modifications and variants to the method for producing a heat exchange unit for a recovery steam generator described above in order to satisfy contingent and specific requirements, all of which are in any case covered by the scope of protection of the present invention as defined by the following claims.

Claims

1. Method for producing a heat exchange unit (22) for a recovery steam generator (20) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), said segmented finning (26) being obtained by winding in a spiral and welding a metallic strip having a substantially trapezium-shaped cross section around said tubes (24), on said metallic strip a series of transversal cuts being made, which have a predetermined pitch and extend from a side edge of the strip, corresponding to the shorter base of the trapezium, for a predetermined depth, said strip being welded to said tubes (24) along the opposite side edge, corresponding to the longer base of the trapezium.

2. Method for producing a heat exchange unit (22) for a recovery steam generator (20) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), each tube (24) equipped with finning (26) being produced following the steps of:

   - drawing a metallic strip having a substantially rectangular cross section, obtaining a metallic strip having a substantially trapezium-shaped cross section, the longer and shorter bases of the trapezium corresponding to the two side edges of the strip;
   - on the metallic strip having a substantially trapezium-shaped cross section making a series of transversal cuts, which have a predetermined pitch and extend from the side edge corresponding to the shorter base of the trapezium for a predetermined depth, obtaining a segmented metallic strip;
   - winding said segmented metallic strip in a spiral around said tube (24), at the same time welding it to said tube (24) along the side edge corresponding to the longer base of the trapezium, obtaining said segmented finning (26), having a substantially trapezium-shaped radial section, tapered towards the outside.

3. Method according to claim 2, **characterized in that**

said step of drawing a metallic strip having a substantially rectangular cross section is replaced by the step of:

- drawing a metallic strip having a circular cross section, obtaining a metallic strip having a substantially trapezium-shaped cross section.

4. Method for producing a heat exchange unit (22) for a recovery steam generator (20) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), each tube (24) equipped with finning (26) being produced following the steps of:

- on the metallic strip having a substantially rectangle-shaped cross section making a series of transversal cuts, which have a predetermined pitch and extend from a side edge of the strip, obtaining a segmented metallic strip;-drawing said segmented metallic strip, obtaining a metallic strip having a substantially trapezium-shaped cross section, the longer and shorter bases of the trapezium corresponding to the two side edges of the strip;
- winding said metallic strip having a substantially trapezium-shaped cross section in a spiral around said tube (24), at the same time welding it to said tube (24) along the side edge corresponding to the longer base of the trapezium, obtaining said segmented finning (26), having a substantially trapezium-shaped radial section, tapered towards the outside.

5. Method according to claim 1, 2, 3, or 4, **characterized in that** said substantially trapezium-shaped radial section is in the form of an isosceles trapezium or an isosceles triangle.

6. Heat exchange unit (22) for a recovery steam generator (20) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), said segmented finning (26) having a substantially trapezium-shaped radial section, tapered towards the outside.

7. Recovery steam generator (20) including a heat exchange unit (22) comprising a tube bundle (24) each tube of which is equipped with segmented finning (26) jutting radially from said tubes (24), said segmented finning (26) having a substantially trapezium-shaped radial section, tapered towards the outside.

8. Tube (24) for a heat exchange unit (22) of a recovery steam generator (20) and equipped with segmented finning (26) jutting radially, said segmented finning (26) having a substantially trapezium-shaped radial section, tapered towards the outside.

9. Tube for a heat exchange unit (22) of a recovery steam generator (20) and equipped with finning jutting radially from it, said finning being made by winding a metallic strip having a substantially trapezium-shaped cross section in a spiral on said tube, so that said finning have a substantially trapezium-shaped radial section, tapered towards the outside.

10. Method for producing a heat exchange unit for a recovery steam generator comprising a tube bundle (124) each tube of which is equipped with finning (126), each tube (124) equipped with finning (126) being produced following the steps of:

- drawing a metallic strip having a substantially rectangular cross section, obtaining a metallic strip having a cross section that is tapered at the two side edges of the strip;
- on the metallic strip having a tapered cross section making two series of transversal cuts, each of which has a predetermined pitch and extends from a respective side edge of the strip for a predetermined depth, obtaining a double-segmented metallic strip;
- longitudinally bending said double-segmented metallic strip substantially at its middle zone, obtaining a bent metallic strip having a substantially U-shaped cross section;
- winding said bent metallic strip in a spiral around said tube (124), at the same time welding it to said tube (124) along the base of the "U", obtaining said finning (126) that is segmented on a double row, each row jutting radially from said tube (124) and having a radial section that is tapered towards the outside.

11. Tube (124) for a heat exchange unit for a recovery steam generator and equipped with finning (126) that is segmented on a double row, each row jutting radially from said tube (124) and having a radial section that is tapered towards the outside.

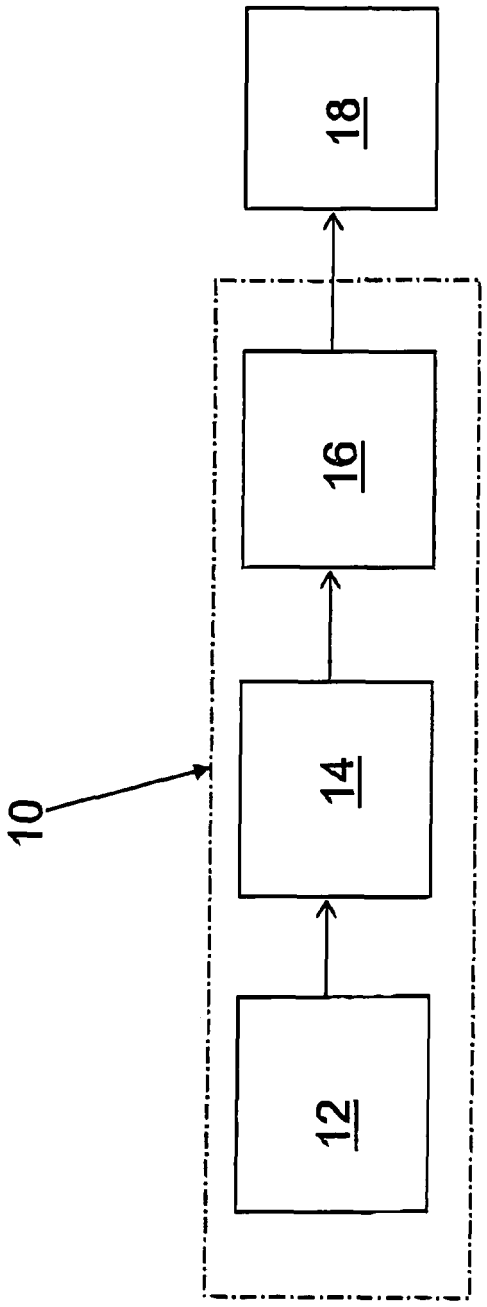


Fig.1

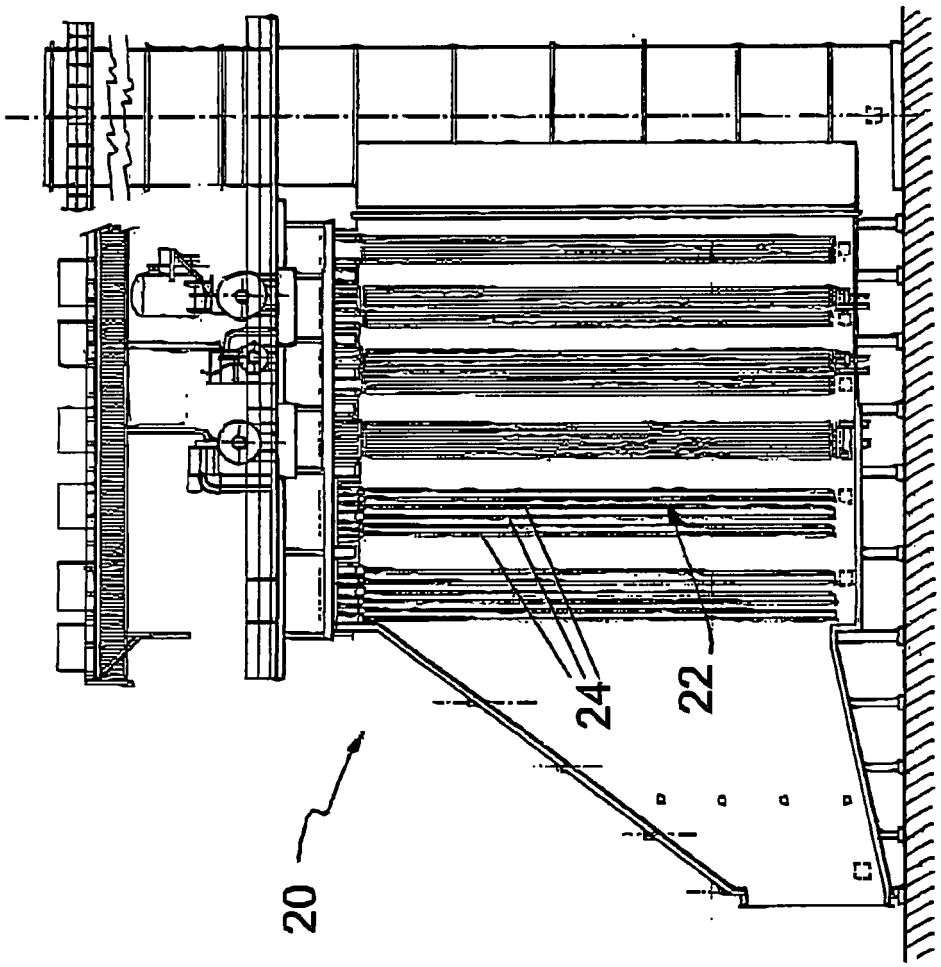


Fig.2

Fig.4

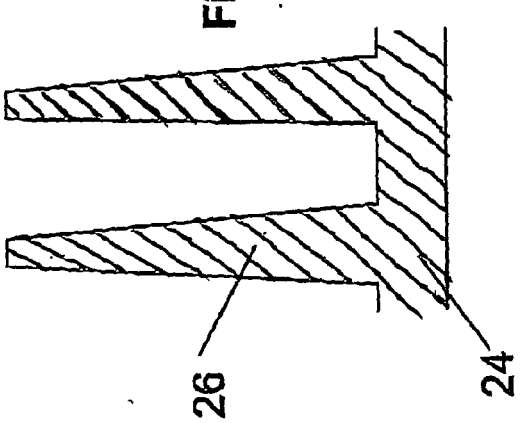
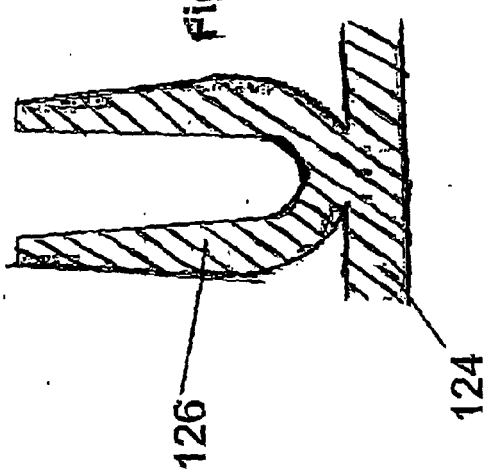


Fig.6



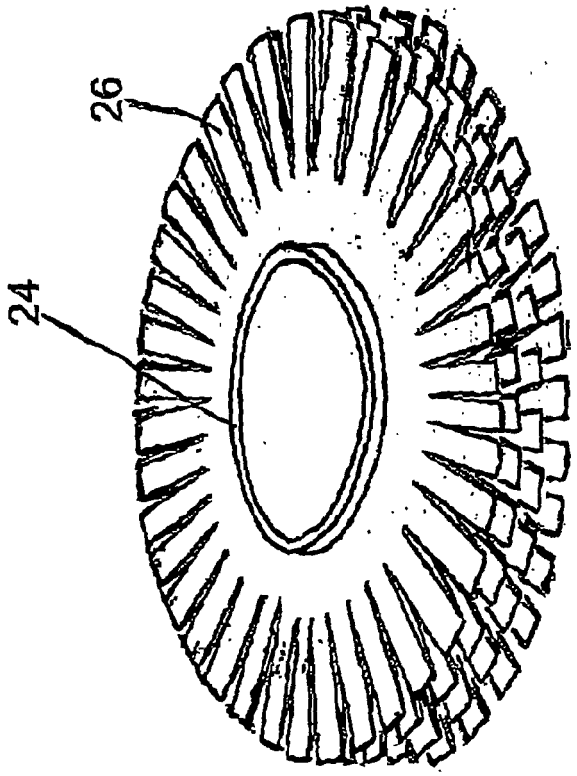


Fig.3

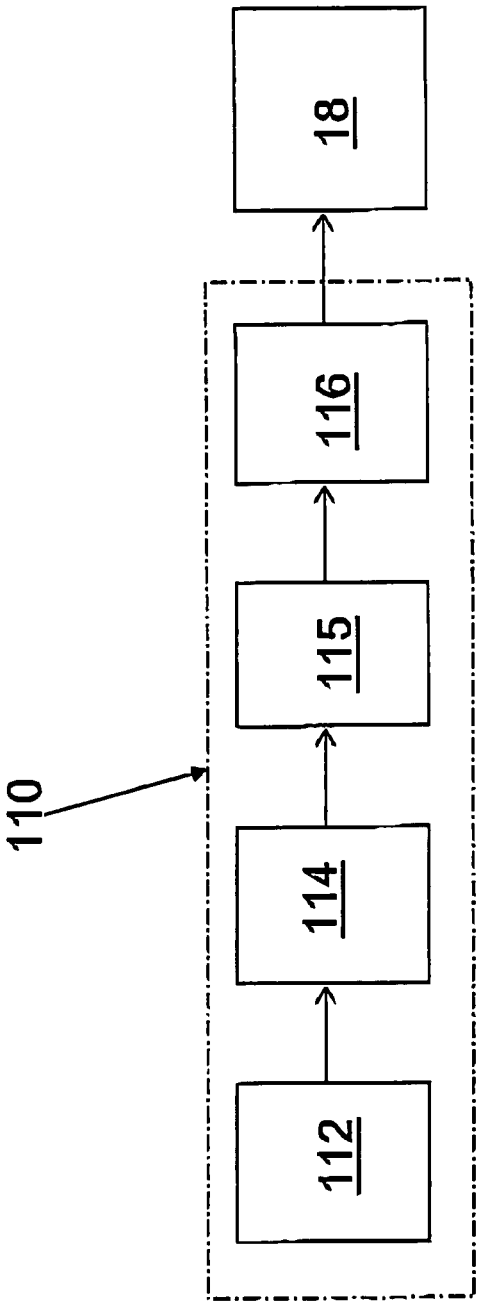


Fig.5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 01 1585

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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X	US 2002/074114 A1 (FIJAS DAVID F) 20 June 2002 (2002-06-20)	1-9	
Y	* paragraph [0016] - paragraph [0020]; figures 2,4,5 * * abstract *	10,11	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 October 2005	Zerf, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 01 1585

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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