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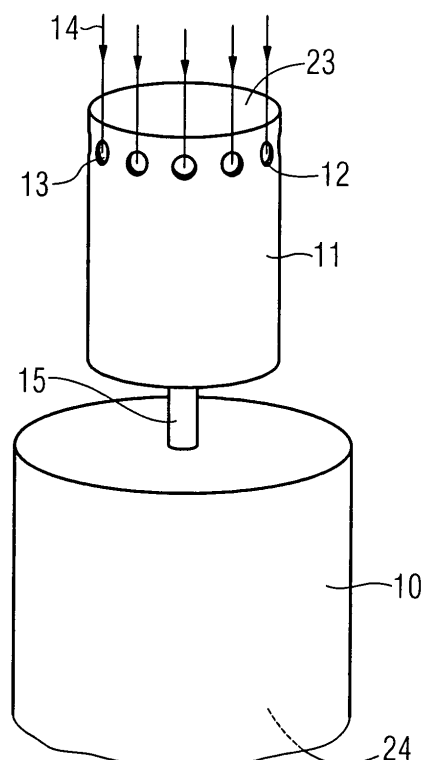
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(54) **Device and method for damping thermoacoustic oscillations in a combustion chamber**

(57) The invention relates to a Helmholtz resonator (11), which has a resonating volume in connection with the combustion chamber volume via a connective opening (15). The device has the unique characteristic that an adjustable flow (14,20) of cooling air can be introduced into the resonating volume and connective opening (15). As opposed to other approaches for tuning a Helmholtz resonator (11), the present invention allows for the first time the resonance frequency of the Helmholtz resonator (11) to be adjusted by a dynamic flow (14,25) of cooling air. A method for damping thermoacoustic oscillations in a combustion chamber is also given, wherein a flow (14,25) of cooling air is adjusted in order to modify the resonator characteristics of the Helmholtz resonator (11) fluidically connected to the combustion chamber (20).

FIG 2



Description

Field of the Invention

[0001] The present invention relates to the field combustion chambers, particularly gas turbine combustion chambers. The invention comprises a device and method for reducing thermoacoustic oscillations in gas turbine combustion chambers. The invention relates more specifically to a Helmholtz resonator, which has a resonating volume in connection with the combustion chamber volume.

Background of the Invention

[0002] Thermoacoustic oscillations occur in combustion chambers due to the interference between thermal and acoustic fluctuations. Such combustion chamber instabilities can result in acoustic pressure oscillations with high amplitudes (more than 160 dB) and at low frequencies (hundreds of Hertz in gas turbines). Such oscillations might also increase pollutant formation (i.e. NO_x) due to inhomogeneous temperature distributions inside the combustion chamber. Furthermore, oscillations of this nature give rise to severe mechanical stresses, which cause damage and reduce the life span of the combustion chamber.

[0003] Helmholtz resonators have often been employed as a means of damping such thermoacoustic oscillations in combustion chambers. In general, a Helmholtz resonator consists of a hollow air space which communicates with a volume of air outside the resonator volume via an elongated connective opening. An air plug present in the connective opening forms the mass that resonates by being driven by the spring force formed by the air enclosed in the hollow resonator air space. The resonant frequency of the Helmholtz resonator depends on the cross-sectional area of the connective opening (S), on the volume (V) of the hollow air space and on the length (L) of the air plug formed in the connective opening. The resonant frequency (f) of the Helmholtz resonator is given by the equation;

$$F = (c/2\pi)\sqrt{S/VL}$$

[0004] When Helmholtz resonators are driven by acoustic energy at the resonant frequency, the resonators will absorb a maximum amount of incoming acoustic energy. However, because they are tuned systems, the absorption decreases rapidly as the frequency of the incoming acoustic energy varies substantially from the resonant frequency. Therefore, the principle limitation of Helmholtz resonators is that they attenuate sound energy efficiently only within a narrow frequency range centred at their tuned resonant frequency.

[0005] Several techniques have been developed in order to provide a Helmholtz resonator with variable res-

onant frequencies. US 2002/0000343 A1 discloses a Helmholtz resonator containing a closed air space connected to a gas turbine combustion chamber. The disclosed apparatus is provided with a hollow body, the volume of which can be changed by adding or draining a fluid via a supply line, and which is arranged either within the Helmholtz resonator volume or adjacent to it in such a way that the resonance volume of the Helmholtz resonator changes when the volume of the hollow body changes.

[0006] EP 0 974 788 A1 teaches a Helmholtz resonator in connection with a combustion chamber. An injection nozzle is located within the resonating volume of the Helmholtz resonator and is directed towards the mouth of the opening connecting the resonating volume to the combustion chamber. A fine fluid spray is introduced into the connective opening, which effects the mass of the air plug within the connecting opening and therefore effects the resonance behaviour of the entire system.

[0007] DE 44 14 232 A1 teaches a Helmholtz resonator in connection with a combustion chamber. A heating element is located inside the resonating volume or directly outside, but in thermal connection with the resonator wall. By heating the air within the resonating volume, the air's density is reduced which results in a decrease in the resonant frequency of the Helmholtz resonator.

[0008] Helmholtz resonators have also been employed to reduce noise in internal combustion engines. DE 100 04 991 A1 discloses a Helmholtz resonator in connection with a motor engine via a long pipe in which at least two holes are located, which are at a distance from each other along the pipe. The two holes have covers which allow the cross-sections of the holes to be varied, which effects the resonance behaviour of the Helmholtz system.

Summary of the Invention

[0009] The present invention describes an apparatus and method for damping thermoacoustic oscillations as well as a combustor arrangement comprising this apparatus that enables continuous adaptation to frequencies of the vibrations to be damped even under the high pressure conditions which occur in gas turbines.

[0010] The device comprises a Helmholtz resonator, which consists of a hollow resonating volume which is in connection with a combustion chamber via a connective opening. The device has the unique characteristic that an adjustable flow of cooling air can be introduced into the resonating volume and connective opening. This is realised according to the invention by suitable means for adjusting a flow of cooling air into the resonator volume. As opposed to other approaches for tuning a Helmholtz resonator, the present invention allows for the first time the resonance frequency of the Helmholtz resonator to be adjusted by a dynamic flow of cool-

ing air.

[0011] The device of the present invention allows cooling air flow to be introduced into the resonator volume through at least one opening located on the resonator. A preferred embodiment of the invention allows the cross-sectional area of said opening to be adjusted so as to control the amount of cooling air flowing into the resonator volume.

[0012] A preferred embodiment of the device of the present invention comprises the introduction of cooling air into the resonator volume via several openings located on the resonator itself. The cross-sections of the openings are adjustable. In this way the openings can be completely closed, which therefore reduces the number of effective openings in the resonator.

[0013] The closing of the openings could for instance be achieved by having a Helmholtz resonator with a double wall structure, both walls having aligned openings. One of the walls could then be turned in order to alter the alignment of the through bores forming the openings in the walls. The openings could then be closed.

[0014] The number of openings in the resonator has been found to effect the resonating properties of the Helmholtz resonator. A homogeneous distribution of the number of openings advantageously effects the maximum airflow as well as the tuning sensitivity. As a particular advantage of this approach is that the supplied cooling air provides a double function of blocking hot gas from the combustion chamber entering the Helmholtz resonator, as well as achieving the desired tuning. Surprisingly, the interval of change in the mass flow is sufficiently small for a broad tuning range without reducing the cooling air mass flow below a limit for secure cooling or exceeding an acceptable amount of cooling air.

[0015] A further preferred embodiment of the device involves the supply of air to the resonator volume via an inlet pipe, the cross-sectional area of which can narrowed. This might be a choke-like mechanism or a valve or the like. The amount and pressure of the cooling air entering the resonator volume can thus be controlled.

[0016] Another preferred embodiment comprises a gas turbine combustion chamber incorporating the device of the present invention. Gas turbines are characterised by the release of large amounts of energy. Therefore, combustion instabilities could have particularly severe consequences. In particular heavy duty gas turbines such as those with a power production rate of more than 50 MW can suffer from such instabilities. Additionally, with such energy output rates cooling of the combustion chamber is of particular importance, therefore the cooling air supplied to the Helmholtz resonator provides a double function of blocking hot gas from the combustion chamber as well as achieving the desired tuning effect.

[0017] The present invention describes a method which comprises a Helmholtz resonator, which consists of a hollow resonating volume which is in connection

with a combustion chamber via a connective opening. The method comprises an adjustable flow of cooling air to be introduced into the resonating volume and connective opening. As opposed to other approaches for tuning a Helmholtz resonator, the method of the present invention allows for the first time the resonance frequency of the Helmholtz resonator to be adjusted by a dynamic flow of cooling air.

[0018] In a preferred embodiment the method comprises the detection of combustion instabilities so as to instantaneously adapt the mass flow of cooling air and therefore suppress the instability by dynamically adjusting the frequency of the Helmholtz resonator accordingly. This can viewed as an active instability control.

Brief Description of the Drawings

[0019] The novel features characteristic of the present invention are set forth and differentiated in the claims. The invention, together with further objects and advantages thereof, is more particularly described in conjunction with the accompanying drawings in which:

Figure 1 shows the general assembly of a gas turbine engine incorporating the use of the Helmholtz resonator of the present invention,

Figure 2 shows the Helmholtz resonator of the present invention in greater detail,

Figure 3 shows a preferred embodiment of the invention, and

Figure 4 shows a preferred embodiment of the invention.

Detailed Description of the Invention

[0020] Referring to the drawings in detail, wherein like numerals indicate like elements. Figure 1 shows a gas turbine 1 comprising a compressor 6, a combustion chamber 10 and turbine. During operation, air (arrow 2) enters the compressor 6, is compressed, and then compressed air 3 passes along conduit 7 into combustion chamber 10. Fuel (arrow 4) is introduced into the combustion chamber via an inlet (not shown) where it is mixed with the compressed air and the mixture burned. The resulting combustion gases (arrow 5) then pass along discharge line 8 into the turbine 9. As a result of the combustion process in combustion chamber 10 damaging thermoacoustic oscillations could occur. Thermoacoustic oscillations originate in the burner located inside the combustion chamber, and are particularly likely to occur in low NO_x emission premix burners. The thermoacoustic oscillations produce fluctuations in heat release, for instance by perturbing the fuel-air ratio or flame shape. Such combustion instabilities can in turn

generate more thermoacoustic oscillations which are reflected by the combustion chamber 10 inner walls and can then result in self-sustaining oscillations. In order to damp these thermoacoustic oscillations a Helmholtz resonator 11 is arranged on the surface of the combustion chamber 10. The hollow volume of the Helmholtz resonator is in connection with the inner volume of the combustion chamber 10 via an elongated connective opening 15.

[0021] Figure 2 schematically shows the preferred configuration of the Helmholtz resonator 11 of the present invention. The hollow volume 23 of the Helmholtz resonator 11 is in connection with the inner volume 24 of the combustion chamber 10 via an elongated connective opening 15. Equally spaced openings or holes 12 are arranged on the surface of the Helmholtz resonator 11. Cooling air flow 14, supplied from the compressor 6, is introduced into the hollow volume 23 of the Helmholtz resonator 11 via openings 12. The cross-sectional area of the openings 12 can be adjusted by covering the openings 12 with a cover mechanism 13. A variety of methods of covering the openings 12 or holes would be available to a person skilled in the art. By covering the openings 12 completely or even partially the amount of cooling air 14 flowing into the resonator volume 23 and the connective opening 15 can be controlled and therefore the present invention allows, for the first time, the resonance frequency of the Helmholtz resonator 11 to be adjusted by a dynamic flow 14 of cooling air. Furthermore, the use of cooling air 14 provides a double function of blocking hot gas from the combustion chamber 10 entering the Helmholtz resonator 11, as well as achieving the desired tuning of the resonance frequency.

[0022] Figure 3 shows a preferred embodiment of the invention illustrating how the variable cross-sectional area of the openings 12 might be achieved. Figure 3 shows a cut-away section of the Helmholtz resonator 11 of the present invention having a double wall structure with outer wall 16 and inner wall 17. Outer wall 16 has one or more homogeneously spaced openings 12A on its surface, while inner wall 17 also has one or more homogeneously spaced openings 12B on its surface. Openings 12A and 12B are aligned with each other. Outer wall 16 or inner wall 17 can be turned. In this way the alignment of the openings 12A and 12B would then be altered and the cross-section of the openings 12A, 12B would be changed or the openings 12A, 12B could be completely closed. The number of openings 12A, 12B in the resonator 11 has been found to effect the resonating properties of the Helmholtz resonator 11. The number of openings 12A, 12B advantageously effects the maximum air flow 14 through the resonator 11 as well as the tuning sensitivity.

[0023] Figure 3 also schematically depicts a possible arrangement for the active stability control mechanism as a closed loop process. A sensor 36 is in connection with the combustion chamber 10. The sensor 36 would

advantageously detect changes in pressure inside the combustion chamber 10 (not shown). The sensor 36 is connected to a control unit 34, which is in turn connected to an electric motor 32. When a pressure difference is detected, the electric motor 32 will turn a shaft 30, which is connected to wall 16 or 17 of the Helmholtz resonator 11, where said wall can be rotated around the axis of the shaft 30. Therefore the openings 12A, 12B in the Helmholtz resonator 11 will be opened or closed in such a way as to adapt the resonant frequency of the Helmholtz resonator 11 and thus damp the thermoacoustic oscillations appearing in the combustion chamber 10 (see fig. 2). By having numerous openings 12A, 12B in the Helmholtz resonator 11, the motor 32 must only turn the shaft 30 through a small angle for there to be a significant change in the effective cross-section of the openings 12A, 12B, therefore the system can react quickly and efficiently to adapt the resonant frequency of the Helmholtz resonator 11 and therefore damp the oscillations appearing in the combustion chamber 10.

[0024] Figure 4 also shows a preferred embodiment of the invention having a valve mechanism 18 which enables the pressure and the amount of cooling air flow 20 flowing into the openings 12 in the Helmholtz resonator 11, to be directly controlled. The mechanism depicted by 18 could also be a choke-like mechanism. The cooling air flow 20 passes along a pipe 19 in which the air encounters the choke mechanism or valve, the air then passes into a cavity 21 which contains the Helmholtz resonator 11. The cavity 21 occurs between an outer wall 22 and the wall of the Helmholtz resonator 11. The valve 18 could also be connected to a closed loop active stability control mechanism, whereby a pressure sensor 36 would detect changes in the combustion chamber 10 and relay the detection data to a control unit 34 which in turn could suitably adapt the valve position so as to change the pressure and amount of the airflow 20 passing through the openings 12.

Claims

1. A device for damping thermoacoustic oscillations in a combustion chamber (10), comprising a Helmholtz resonator (11), which has a resonating volume (23) which is in connection with the combustion chamber (10) comprising means for adjusting a flow (14, 20) of cooling air into the resonator volume.
2. A device according to claim 1, wherein cooling air (14, 20) is introducable into the resonator volume (23) through an opening (12, 12A, 12B) located on the resonator (11) and whereby the cross-section of said opening (12, 12A, 12B) is adjustable so as to control the amount of cooling air (14, 20) flowing into the resonator volume (23).

3. A device according to claim 1, wherein cooling (14,20) air is introducable into the resonator volume (23) through several openings (12A,12B) located on the resonator and whereby the cross-section of said openings (12A,12B) is adjustable so that the openings (12A,12B) can be completely closed in order to alter the number of effective openings. 5
4. A device according to claim 1, wherein cooling air is suppliable to the resonator volume (23) by an inlet pipe (19), which cross-section can be narrowed in order to control the amount and pressure of cooling air (20) entering the resonator volume (23). 10
5. A gas turbine combustion chamber (10) comprising a device according to one of the preceding claims. 15
6. A gas turbine combustion chamber (10) according to claim 5 which is an annular combustion chamber. 20
7. A method for damping thermoacoustic oscillations in a combustion chamber (10), comprising a Helmholtz Resonator (11) with a resonator volume (23) being in connection with the combustion chamber (10), whereby 25
a flow (14,20) of cooling air into the resonator volume (23) is adjusted.
8. A method according to claim 7 whereby the flow (14,20) of cooling air into the resonator volume (23) is adjusted so as to control the resonating frequency of the Helmholtz resonator (11) over a wide band of frequencies. 30
9. A the method according to claim 7 being performed in a gas turbine combustion chamber (10). 35
10. A method according to claim 7 comprising an active instability control, particularly as a closed loop process. 40

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FIG 1

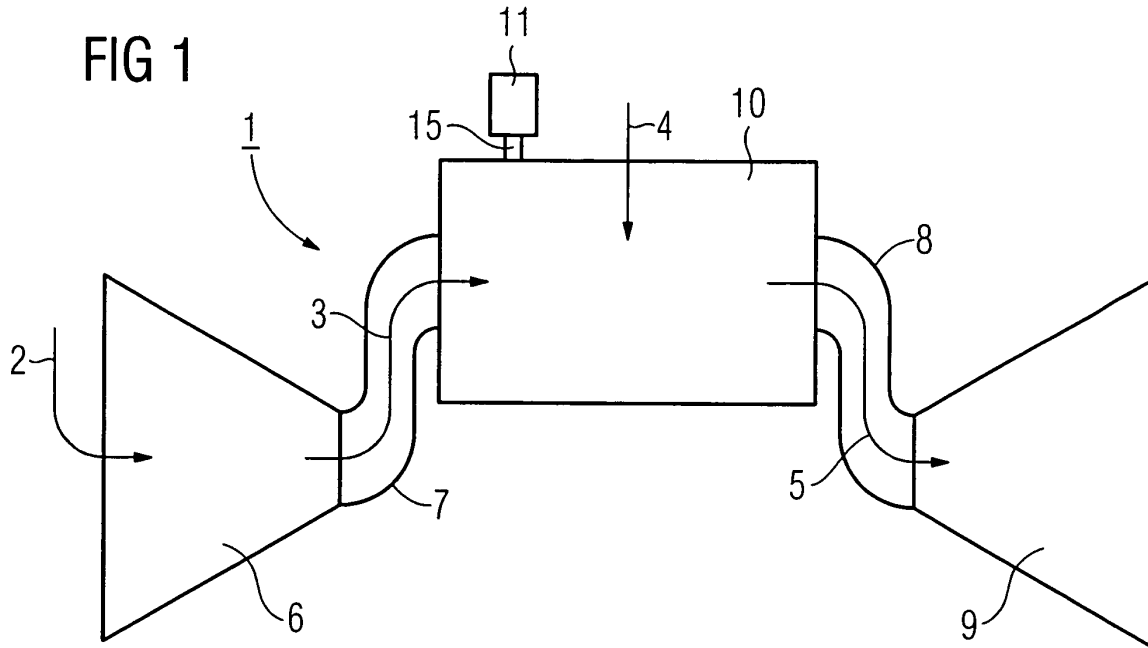


FIG 2

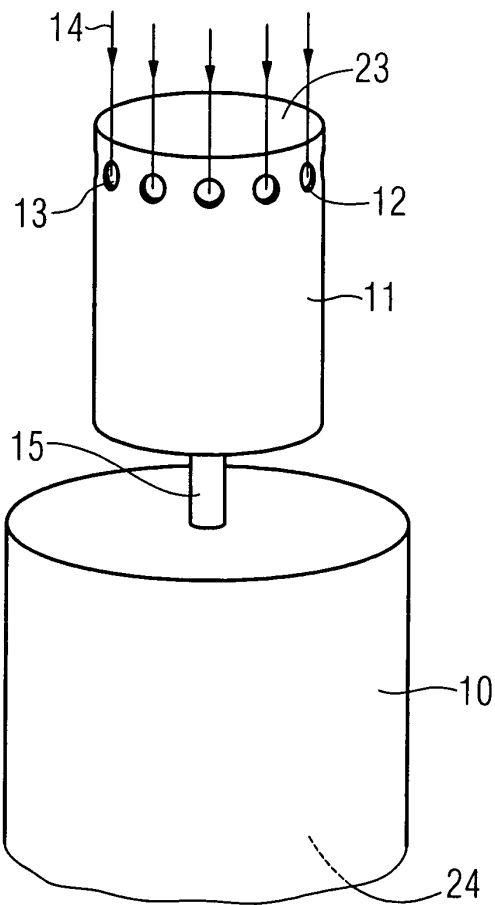


FIG 3

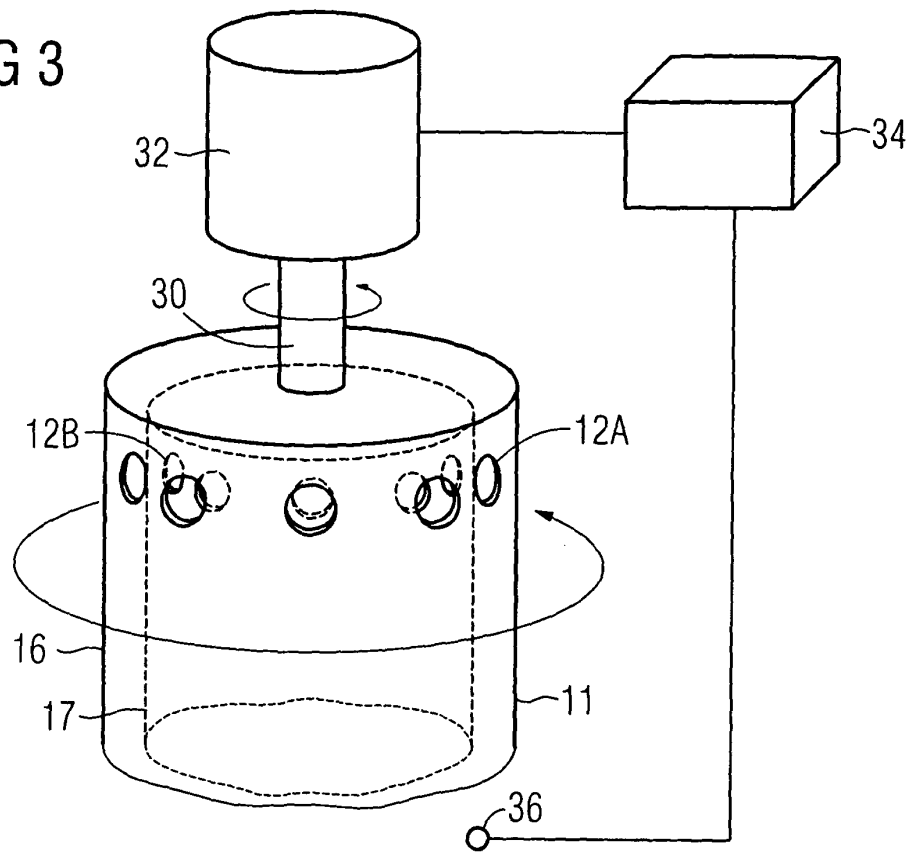
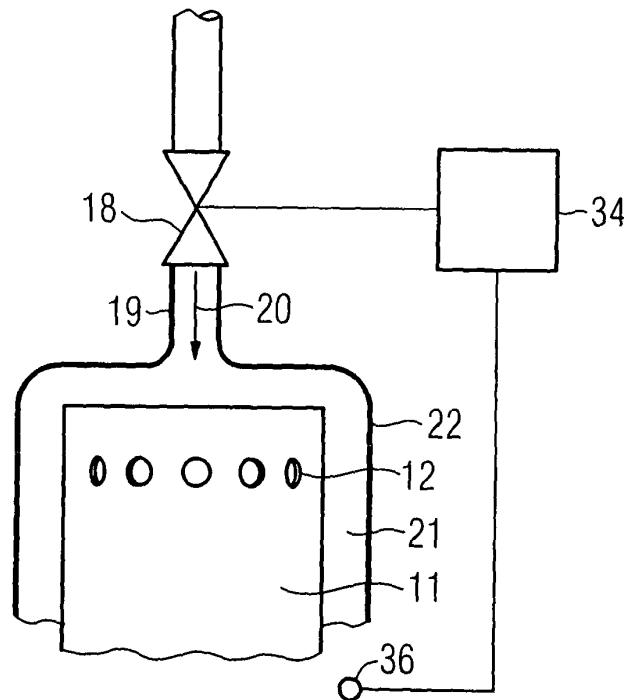


FIG 4





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 1240

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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 15 June 2004	Examiner Coquau, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document 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 L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P4/C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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