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

(11) EP 2 821 593 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.01.2015 Bulletin 2015/02

(51) Int Cl.:
F01D 5/28 *(2006.01)* ***F01D 11/22*** *(2006.01)*

(21) Application number: **13175099.4**

(22) Date of filing: **04.07.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(72) Inventors:
- **Schwestka, Peter**
  67133 Maxdorf (DE)
- **Zolkiewicz, David Maximilian**
  5408 Ennetbaden (CH)
- **Gafner, Silvia**
  5723 Teufenthal (CH)

(71) Applicant: **ALSTOM Technology Ltd**
5400 Baden (CH)

(54) Method and apparatus for controlling a steam turbine axial clearance

(57) The invention relates to a method and an arrangement for aligning an inner casing (40) of a steam turbine (10) that has an inner casing (40) that is adjustably mounted on the foundation (60) by means of an adjustable mounting (42) that enable axial adjustment of inner casing (40) relative to the rotor (30). During operation of the steam turbine (10) the axial clearance between the inner casing (40) and rotor (30) is measured and then the axial clearance between the rotor and the inner casing (40) is adjusted.

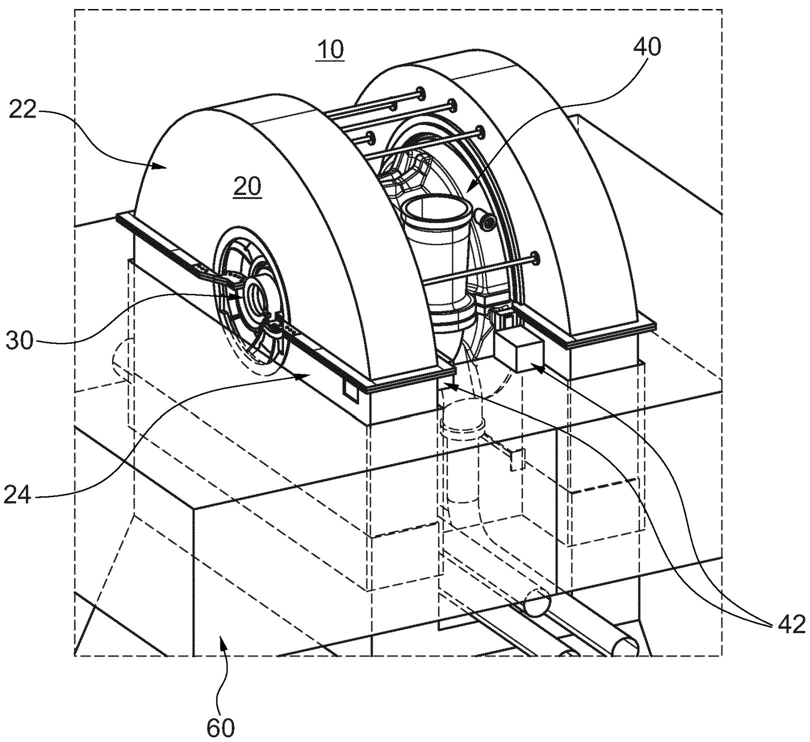

Fig. 1

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present disclosure relates to the control of the axial clearance between rotor blades and inner casing blades of a steam turbine.

BACKGROUND INFORMATION

[0002] The outer shell of a steam turbine low-pressure section is generally called the exhaust hood. The primary function of an exhaust hood is to divert the steam from the last stage blade of an inner shell to the condenser with minimal pressure loss. Usually the lower half of the exhaust hood supports an inner casing of the steam turbine while the upper exhaust hood typically is a cover that guides steam to the lower half of the hood. The rotor itself is independent from the exhaust hood and supported on bearing pedestals next to the exhaust hood. The hood for large double-flow low-pressure steam turbines is of substantial size and weight and so is usually assembled only in the field. In some steam turbines, the inner casing of the steam turbine has an encompassing exhaust hood having a vertical split that extends along opposite sides and ends of the turbine. As the rotor and the inner casing are fixed by the fact that the exhaust hood acts as a support for the inner casing, large axial clearance between blades of the rotor and the inner casing must be tolerated to take into account thermal expansion and contraction, as the steam turbine changes to different loads from standby to an operating state.

[0003] Larger axial clearances between blades and rotors may result in an excessive amount of steam passing between blade shrouds and the inner casing thereby reducing the efficiency of the turbine. This is, however, preferably to the contrary where contact is made between blade elements and the inner casing as such contact may result in damage to the components. The problems caused by large axial clearances can in part be addressed through measurement. For example, U.S. Pat. No.4876505A discusses measuring the clearance between a plurality of turbine blade shroud segments using proximity sensors discussed in U.S. Pat. No. 4,644,270. This allows an operator to take action if a critical clearance condition occurs. Other than the discussed measurement means, other known blade tip clearance measurement methods used in gas turbines maybe adapted for use in steam turbines. Such measurement methods include fibre optic laser Doppler distance sensors, as discussed in Thorsten Pfister et al, "Fiber optic laser Doppler distance sensor for in-situ tip clearance and vibration monitoring of turbo machines" 14th Int Symposium on applications of Laser techniques to Fluid Mechanics Lisbon, Portugal, 07-10 July, 2008, as well as other sensors such as capacitive probes, inductive probes, optical measurement systems based on triangulation, optical coherence tomograph and time-of-flight measurements. While these solutions provide a means of alerting an operator to the approach to a potentially undesirable condition, the corrective action, which typically may result in change in load, typically requires the steam turbine to be operated away from a desired operating point.

[0004] The convention arrangement of the lower exhaust hood supporting the inner casing can further lead to misalignment of the steam path rotor parts and in the end resulting in bearing tilt. This may further invariably lead to an undesirable change in blade/inner casing clearances. U.S Pat No. 8,403.638B2 discusses a solution to this problem that involves supporting the inner casing directly by a foundation. U.S Pat Appl. No. 20120282089 provides another similar solution that involves supporting the inner casing directly on an external foundation at a mounting location below the longitudinal. Both these solution, however, only provide partial solutions to the problem of excessive clearance between blades and the inner casing.

SUMMARY

[0005] Provided is a method and apparatus for aligning an inner casing of a steam turbine with rotating blades during operation of the steam turbine. The method is intended to provide a solution to the problem how to minimise performance losses of a steam turbine due to inner casing / blade clearance.

[0006] This problem is addressed by means of the subject matter of the independent claims. Advantageous embodiments are given in the dependent claims.

[0007] An aspect provides a method for aligning an inner casing of a steam turbine with a rotor operation of the steam turbine. This aspect include first providing a steam turbine that has a lower hood connected directly to the condenser and without a fixation to the foundation, a rotor adjustably mounted on the bearing and an inner casing mounted on a foundation by an adjustable mounting that is axial adjustably wherein the inner casing, which encases a portion of the rotor, is adjustably mounted on the foundation by means of an adjustable mounting that enables axial adjust of the inner casing relative to the rotor. The aspect further includes measuring an axial clearance between the inner casing and the rotor and then adjusting the mounting of the inner casing and the inner casing based on the measured axial clearance.

[0008] In a further aspect wherein rotor has a plurality of rotating blades extending therefrom and the measuring of axial clearance includes measuring a clearance between the inner casing and one of the rotating blades.

[0009] In a further aspect measuring of axial clearance includes measurement a clearance between the inner casing and a rotating blade including by optical sensing means.

[0010] Another aspect comprises a double-flow steam turbine that has a foundation, a lower hood mounted to the condenser and without a fixation to the foundation, a rotor adjustably mounted on the bearing, a plurality of blades extending from rotor and an inner casing with one or more axial adjustably mountings between the inner casing and a foundation. In this aspect the inner casing encases the plurality of blades and is further partially encased by the lower hood while the mountings of the inner casing and the rotor are configured and arranged to independently adjust the mounting of the inner casing and the rotor respectively. The aspect further includes a sensor for measuring an axial clearance between the inner casing and the rotor and a controller that is configured to adjust, by means of the adjustable mountings, the mounting of the inner casing, based on the sensor. The steam turbine may have four adjustable mounts or further have the adjustable mountings arranged in a convex quadrilateral formation to enhance the adjustment.

[0011] It is a further object of the invention to overcome or at least ameliorate the disadvantages and shortcomings of the prior art or provide a useful alternative.

[0012] Other aspects and advantages of the present disclosure will become apparent from the following description, taken in connection with the accompanying drawings which by way of example illustrate exemplary embodiments of the present invention

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] By way of example, an embodiment of the present disclosure is described more fully hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a schematic a double flow steam turbine to which an exemplary embodiment of the disclosure has been applied;

Figure 2 is a sectional view in Fig 1 which an upper hood section of the steam turbine has been removed to show inner casing supports; and

Figure 3 is an expanded schematic view of an inner casing support of the steam turbine of Figs 1 and 2.

DETAILED DESCRIPTION

[0014] Exemplary embodiments of the present disclosure are now described with references to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the disclosure. However, the present disclosure may be practiced without these specific details, and is not limited to the exemplary embodiment disclosed herein.

[0015] Fig. 1 shows an exemplary steam turbine 10 of double-flow type, to which an exemplary embodiment may be applied. The steam turbine 10 is directly fixed to a condenser (not shown). and has a hood 20 comprising an upper hood 22 and a lower hood 24. An inner casing 40 encases the rotor 30 while the hood 20 at least partially encases the inner casing 40 thus enabling the inner casing 40 it be independently mounted on the foundation 60 by means of an adjustable mounting 42.

[0016] In the exemplary embodiment shown in Fig. 1 the upper hood 22 and the lower hood 24 are defined primary by a longitudinal split line at which the two hood 20 sections can be joined with stubs. In an alternate, not shown exemplary embodiment, the upper hood 22 and the lower hood 24 are formed as a single piece. In this arrangement the upper hood 22 and the lower hood 24 are defined by the relative position with the foundation 60, wherein the lower hood 24 is located towards or within, either partially or totally, the foundation 60.

[0017] The foundation itself may take any form known in the art and thus may be a concrete structure comprising one or multiple parts, or else be a welded or otherwise formed structure.

[0018] As shown in Fig. 1 the hood 20 at least partially encases the inner casing and in so doing performs the function of an outer casing. The inner casing 40, which is at least partially encased by the hood 20, is adjustably mounted on a foundation 60 independently of the mounting of the lower hood 24. The configuration of the mounting and the fact that the mounting is independent of the mounting of the lower hood 24 and rotor 30 enables the axial alignment of the inner casing 40 to be adjusted independently of the axial alignment of the rotor 30.

[0019] As shown in Fig. 2 the inner casing 40 encases the rotor 30 so as to form an elongated cavity between the inner casing 40 and the rotor 30. Therein, extending from the rotor 30 towards the inner casing 40 are blades (not shown) of the type known in the field of steam turbines. The gap formed between tips of the blades, distal from the rotor 30 and the inner casing 40 defines the axial clearance between the inner casing 40 and the rotor 30. In an exemplary embodiment, a sensor (not shown), is used to either measure or estimate this axial clearance as is known in the art. Such known sensors included optical sensing means.

[0020] As shown in Fig. 2 in an exemplary embodiment the inner casing has four adjustable mounts located in a convex quadrilateral formation, preferably arranged to form a trapezoid to provide precise axial alignment adjustment.

[0021] Fig. 3 shows an exemplary embodiment of one possible adjustable mounting 42 that is configured as that enable axial adjustment through two dimensional movements within the mounting. Although the inner casing is adjustably mounted, preferably with a plurality of adjustable mountings, each of the mounts may be configured with limited axial movement. The configuration of the adjustable mounting 42 shown in Fig. 3 is one such example. In addition, in exemplary embodiments with a plurality of mounts, as least some of the mounts may be configured to with constrained axial movement to differing degrees.

[0022] An exemplary method that may be applied to any of the aforementioned exemplary embodiments and variations thereof, includes measuring an axial clearance between the inner casing 40 and rotor 30, using known methods, while the steam turbine 10 is in operation, for example while rotor 30 is rotating at operating speed, and adjusting the adjustable mounting of the inner casing 40 based on the measured axial clearance while the steam turbine remains on line. The adjustment may either by manual adjustment, for example by a technician or else by automated means via, for example, by a controller.

[0023] Although the disclosure has been herein shown and described in what is conceived to be the most practical exemplary embodiment, it will be appreciated by those skilled in the art that the present disclosure can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the disclosure is indicated by the appended claims rather that the foregoing description and all changes that come within the meaning and range and equivalences thereof are intended to be embraced therein.

REFERENCE NUMBERS

[0024]

10	Steam Turbine
20	Hood
22	Upper hood
24	Lower hood
30	Rotor
40	Inner casing
42	Adjustable mounting
60	Foundation

Claims

1. A method for adjusting an axial clearance of a steam turbine (10) during operation of the steam turbine (10), including the steps of:

providing a steam turbine (10) having:

a rotor (30);
a foundation (60)
an inner casing (40) encasing a portion of the rotor (30) wherein the inner casing (40) is adjustably mounted on the foundation (60) by means of an adjustable mounting (42) that enables axial adjustment of inner casing (40) relative to the rotor (30);

measuring an axial clearance between the inner casing (40) and rotor (30); and
adjusting the adjustable mounting (42) based on the measured axial clearance thereby changing the axial clearance.

2. The method of claim 1 wherein the rotor (30) has a plurality of rotating blades extending therefrom and the measuring of axial clearance involves measuring between the inner casing (40) and one of the rotating blades.

3. The method of claim 1 wherein the measurement is by optical sensing means.

4. A double-flow steam turbine (10) comprising:

a foundation (60);
a rotor (30);
an inner casing (40) mounted on the foundation (60) with one or more axial adjustably mountings that enable enables axial adjustment of inner casing (40) relative to the rotor (30) ;
a sensor configured and arranged to measure an axial clearance between the inner casing (40) and the rotor (30); and
a controller configured to adjust, by means of the adjustable mounting (42), based on measurements from the sensor, the axial clearance.

5. The steam turbine (10) of claim 4 comprising four adjustable mounts (42).

6. The steam turbine (10) of claim 5 wherein the adjustable mountings (42) that are arranged in a convex quadrilateral formation.

7. The steam turbine (10) of any one of claims 4 to 6 further including a lower hood (24) that partially encasing the inner casing (40) thereby enabling the inner casing (40) to be found on the foundation (60).

8. The steam turbine of any one of claims 4 to 7 wherein the rotor (30) has a plurality of rotating blades extending therefrom wherein the axial clearance between the rotor (30) and the inner casing (40) is between one of the rotating blades and the inner casing (40).

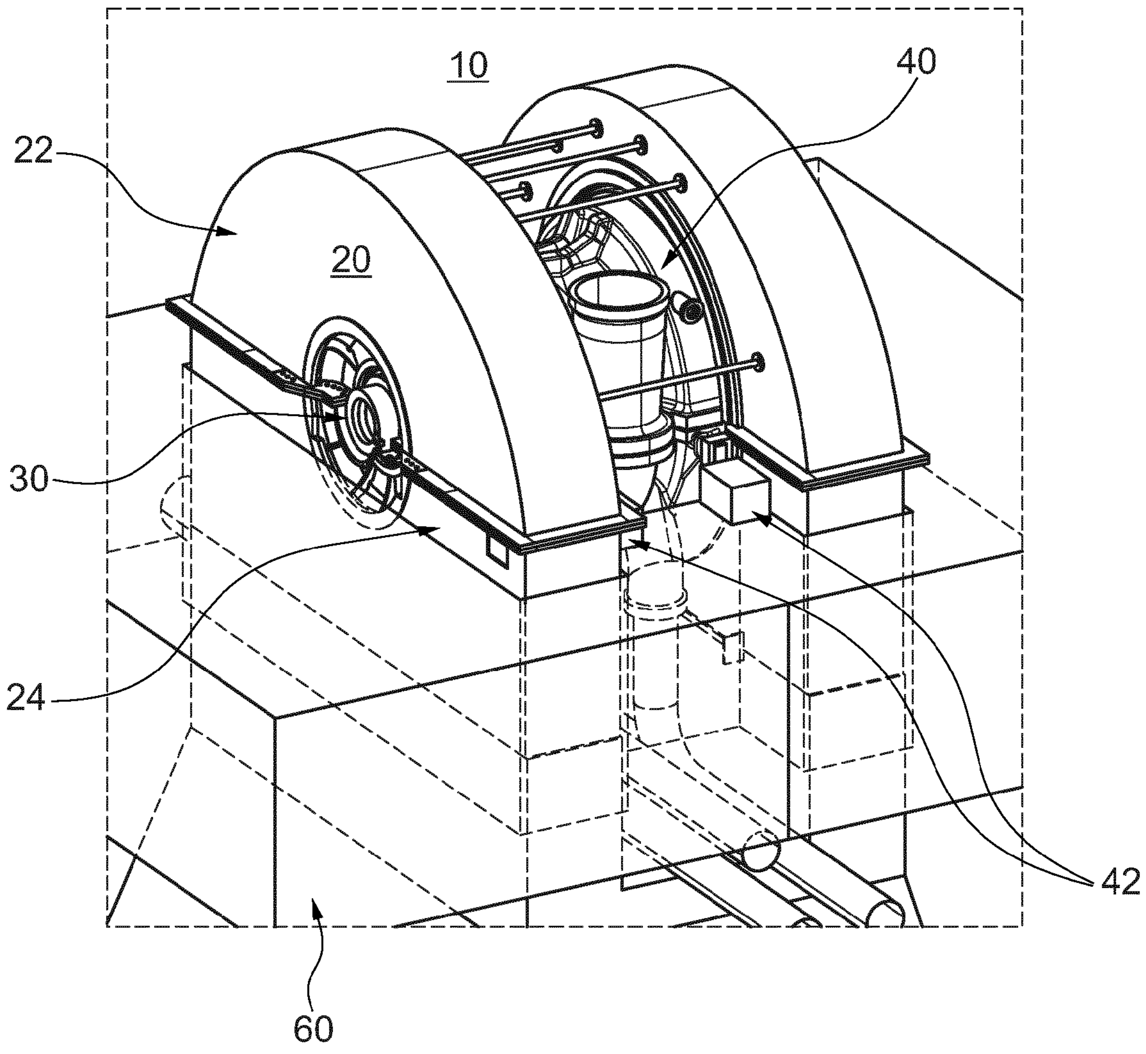

Fig. 1

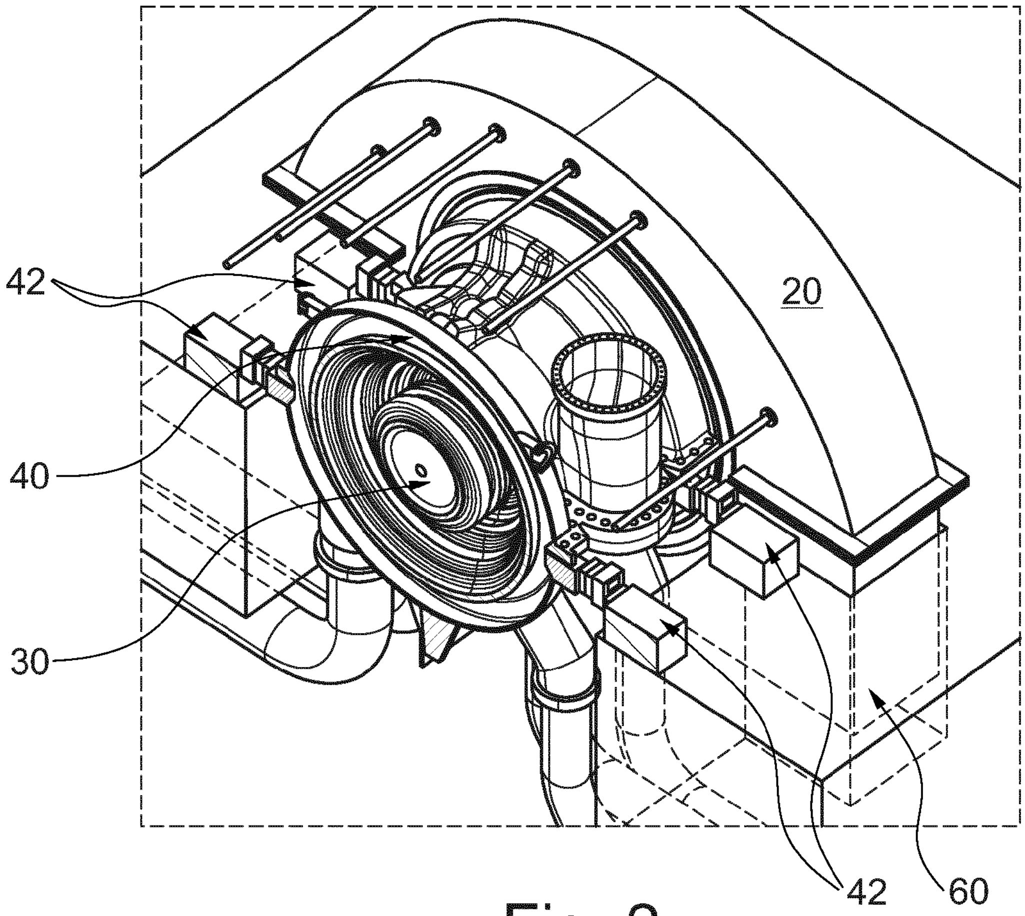

Fig. 2

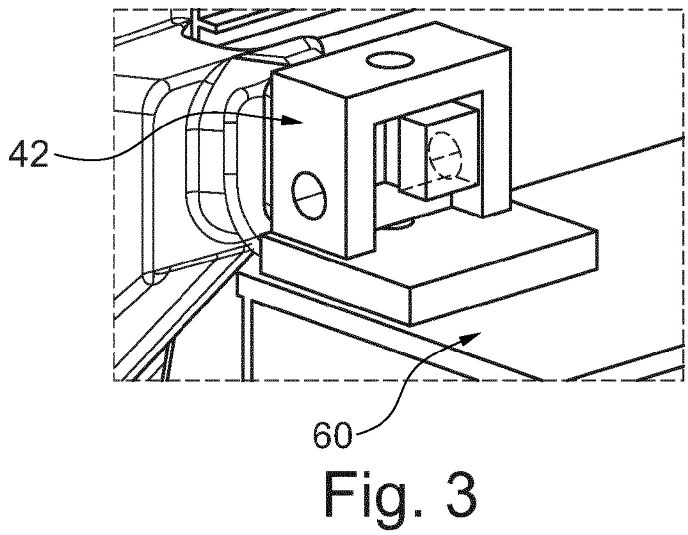

Fig. 3

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 13 17 5099

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 056 986 A (SILVESTRI JR GEORGE J [US] ET AL) 15 October 1991 (1991-10-15) * the whole document * -----	1-8	INV. F01D5/28 F01D11/22
X	US 2013/149117 A1 (HORI TAKUMI [JP] ET AL) 13 June 2013 (2013-06-13) * page 1, paragraph 2 - page 6, paragraph 129; figure 1 * -----	1-8	
X	FR 1 337 907 A (RATEAU SOC; CREUSOT FORGES ATELIERS) 20 September 1963 (1963-09-20) * page 1 - page 2; figures 1-3 * -----	1	
A	DE 196 29 933 C1 (SIEMENS AG [DE]) 4 September 1997 (1997-09-04) * column 1, line 1 - column 6, line 52; figures 1,2 * -----	1,4	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	7 November 2013	Rau, Guido

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

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 13 17 5099

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07-11-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5056986 A	15-10-1991	CA 2030463 A1	23-05-1991
		CN 1051961 A	05-06-1991
		ES 2026797 A6	01-05-1992
		IT 1244079 B	05-07-1994
		JP 2972323 B2	08-11-1999
		JP H03179107 A	05-08-1991
		US 5056986 A	15-10-1991
US 2013149117 A1	13-06-2013	CN 103210184 A	17-07-2013
		KR 20130036336 A	11-04-2013
		US 2013149117 A1	13-06-2013
		WO 2012132085 A1	04-10-2012
FR 1337907 A	20-09-1963	NONE	
DE 19629933 C1	04-09-1997	AT 206502 T	15-10-2001
		CN 1225705 A	11-08-1999
		DE 19629933 C1	04-09-1997
		EP 0914543 A1	12-05-1999
		ES 2165623 T3	16-03-2002
		JP 3898229 B2	28-03-2007
		JP 2001508146 A	19-06-2001
		PT 914543 E	28-03-2002
		RU 2185516 C2	20-07-2002
		WO 9804810 A1	05-02-1998

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader’s convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4876505 A **[0003]**
- US 4644270 A **[0003]**
- US 8403638B2 A **[0004]**
- US 20120282089 A **[0004]**