



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
31.12.2014 Bulletin 2015/01

(51) Int Cl.:
B22D 21/02 (2006.01) **B22D 27/04** (2006.01)
B22C 9/04 (2006.01)

(21) Application number: **13382238.7**

(22) Date of filing: **24.06.2013**

(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:
• **Vicario Markiegi, Iñaki**
48901 Barakaldo (Vizcaya) (ES)
• **Dominguez Barrios, Ignacio**
48901 Barakaldo (Vizcaya) (ES)

(71) Applicant: **Precicast Bilbao, S.A.**
48901 Barakaldo (Vizcaya) (ES)

(74) Representative: **Carvajal y Urquijo, Isabel et al**
Clarke, Modet & Co.
Suero de Quiñones, 34-36
28002 Madrid (ES)

(54) **Method for melting an alloy part**

(57) Method for melting an alloy part in a mold, into whose ceramic cup a mineral is added as said alloy part is cooled in air. The alloy may comprise Nickel, Cobalt

or Titanium and is preferably an alloy of Nickel and Cobalt. The Nickel and Cobalt alloy may comprise Hafnium, Chrome, Rhenium or Tungsten.

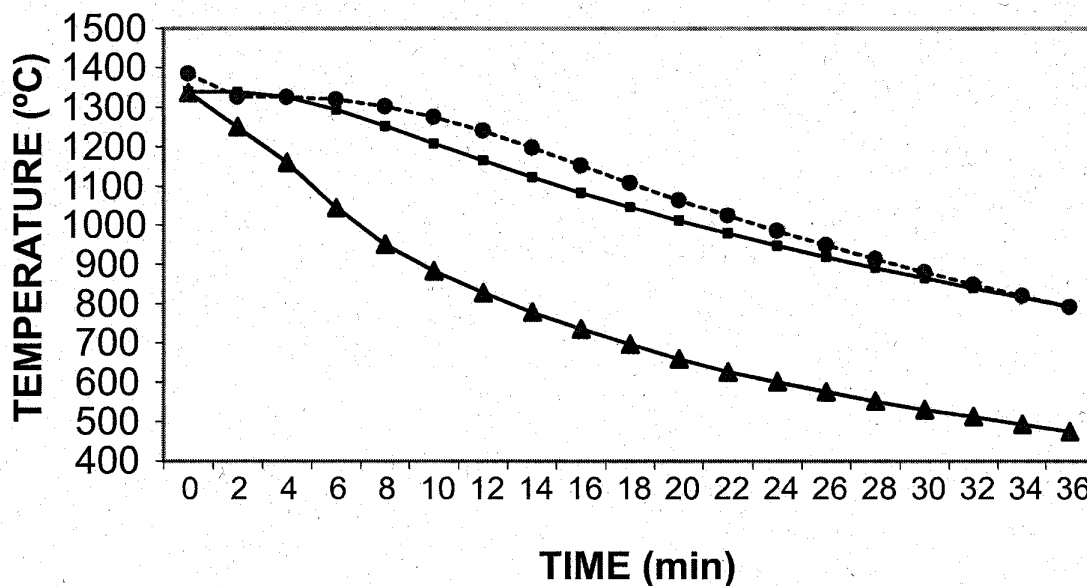


FIG. 1

Description

Field of the invention

[0001] The present invention refers to lost-wax melting methods (*investment casting*), a manufacturing technology for Nickel and Cobalt based superalloy parts, mainly intended for the aviation industry.

Background of the invention

[0002] Lost-wax (*investment casting*) melting methods are applied to the manufacture of Nickel and Cobalt based superalloy parts, mainly intended for the aviation industry. These methods entail various processes, amongst which the melting process is the fundamental core process, given that this is when the metal is melted and is introduced into the interior of the ceramic mold.

[0003] The melting process in turn entails five different consecutive stages: isolating the mold, preheating, vacuum melting, cooling or solidification, knock out the mold and cutting.

[0004] The mold isolation stage entails applying various layers of ceramic blanket on to the exterior of the ceramic mold. It serves to control and direct the various thermal gradients throughout the solidification stage. The position and number of isolation layers is determined by the arrangement and number of gates and sprues forming the part's supply system.

[0005] The isolation stage is basically designed in such a way that the part is firstly solidified, then the gates which supply it and finally, the main sprue and shell. Thus guaranteeing the part's metallurgical integrity, since the contraction it undergoes as it passes from a liquid to solid state is offset perfectly by the continuous input of molten metal.

[0006] The preheating stage is carried out in gas furnaces, within which the ceramic mold is introduced at a certain temperature and for a determined length of time. The main aim of this stage is to increase the temperature of the ceramic mold in order to reduce thermal shock with the metal that will be introduced into it later on.

[0007] The vacuum melting stage is carried out in vacuum furnaces, this type of furnace being necessary so the physicochemical properties of superalloys remain intact. The alloy is supplied in the form of cylindrical ingots, which are introduced into a ceramic container, referred to as the "liner", usually made of SiO₂. At the same time, this container is situated within another, larger container named the coil, which is responsible for creating a magnetic induction field through which the ingot is fused in the crucible or liner.

[0008] The temperature of the molten metal is one of the fundamental parameters at the fusion stage, which is why optical pyrometers are used. Furthermore, the pressure or vacuum level is another significant variable to be considered throughout the entire process, the vacuum furnace being therefore provided with various cham-

bers separated from one another and having watertight valves. These valves make it possible to introduce the preheated mold into the mold chamber at atmospheric pressure, bringing it to vacuum level, wherein the metal will be found in a molten state in the fusion chamber. The ingots are charged by means of the charging chambers whilst the temperature is measured by the pyrometer.

[0009] Once the metal has been melted and the mold preheated (ready to be extracted), it is introduced into the mold chamber of the vacuum furnace. Once in position, the molten metal flows into the mold interior automatically and the mold is extracted in order to carry out the next stage (cooling).

[0010] Once the mold has been extracted from the vacuum furnace, the cooling or solidification stage is initiated. Many cooling techniques exist in terms of the way in which the mold interacts with the exterior; the mold can therefore, be cooled in air, it may be cooled under a protective atmosphere or even in a vacuum.

[0011] The vast majority of smelters cool the mold by exposing it to air, adding a powdered substance known as "exothermic material" to the ceramic cup. The exothermic material is composed of SiO₂, Al, NO₃Na and Na₂SiF₆. This material is of a combustion nature in that it reacts with the still incandescent metal, triggering a strong reaction which releases a lot of heat.

[0012] When the mold has solidified completely, the removal from the mold and the cutting process can be carried out, wherein the ceramic surrounding the metal is removed. Once the ceramic is completely removed, the parts in the supply system are separated. Various cutting techniques are employed to facilitate this separation, depending on the shape to be cut. Plasma cutting is henceforth the most common technique, although abrasive disc cutting systems and high pressure water-jet cutters also exist.

[0013] The resulting supply system is recycled. In order to avoid quality problems, the ceramic cup that have been contaminated with the exothermic powder are cut at a certain distance using an abrasive disk and the contaminated material is recycled as scrap. The rest forms what is commonly referred to as a "revert" which, mixed with virgin Nickel, serves to manufacture the following master heat cast.

[0014] The problem posed by this technique is providing an alloy cooling or solidification method which does not contaminate said alloy.

[0015] The present invention proposes a solution to this technical problem. The "revert" material, which is recycled to manufacture the following master heat cast is not contaminated, thereby allowing a greater alloy recovery of approximately 1 kg of revert per mold, the alloy serving to generate the following master heat cast also being of higher quality owing to the fact that it does not contain any form of contaminant. Moreover, 6 minutes per manufactured mold, are saved, corresponding to the average time usually needed to cut the upper portion of the contaminated ceramic cup. In addition, since it does

not produce a combustion reaction, the melting operator is not exposed to dangerous elements such as toxic fumes, to the intense light given off when the exothermic reacts with the metal or to potential risks associated with handling a material as flammable as the exothermic. Furthermore, these fumes and suspended particle pollutants are prevented from being released into the atmosphere.

Description of the invention

[0016] One embodiment is a method for melting an alloy part in a mold, **characterized in that** when cooling or solidifying said alloy part by cooling it in air, Vermiculite is added to the ceramic cup of said mold (henceforth referred to as the method of the invention).

[0017] From here on in, Vermiculite shall be referred to as "the material of the invention".

[0018] In the method of the invention, directionality is ensured throughout the cooling stage, in turn guaranteeing the metallurgical quality of the part.

[0019] The material of the invention is made up of hydrated phyllosilicate and has the following formula: $(\text{Mg}, \text{Ca})_{0.7}(\text{Mg}, \text{Fe}, \text{Al})_{6.0}[(\text{Al}, \text{Si})_8\text{O}_{20}](\text{OH})_{4.8}\text{H}_2\text{O}$

[0020] The mineral is composed of 30% SiO_2 , 15% Al_2O_3 , 10% Fe_2O_3 , 25% MgO and very slight traces of other minerals.

[0021] The material of the invention does not produce combustion; in other words, it does not react with the molten metal.

[0022] Another embodiment is the method of the invention, wherein before said cooling in air stage, the following stages are carried out:

- (a) isolating said mold;
- (b) preheating said mold and;
- (c) the vacuum melting of said alloy part.

[0023] An additional embodiment is the method of the invention, wherein after said cooling in air stage, said alloy piece is removed from the mold and cut.

[0024] A further embodiment is the method of the invention, wherein said alloy comprises at least one metal from the Nickel, Cobalt and Titanium group.

[0025] A further additional embodiment is the method of the invention, wherein said alloy comprises Nickel and Cobalt. More specifically, said alloy comprising Nickel and Cobalt, comprises at least one of the metals selected from the Hafnium, Chrome, Rhenium and Tungsten group.

[0026] A further additional embodiment is the method of the invention, wherein said mold is a ceramic mold.

[0027] A further additional embodiment is the method of the invention, wherein the particles of the material of the invention are between 0.5 mm and 5 mm in size.

[0028] A further additional embodiment is the method of the invention, wherein on average, said particles are between 0.8 mm and 1.2 mm in size. More specifically, said average size is 1 mm.

[0029] The technical effect achieved by the method of the invention is that the alloy is not contaminated. The advantages of the method of the invention are summarized below:

- Increased use of revert material: since it does not produce any combustion at all, the alloy is not contaminated, resulting in greater alloy recovery which may be estimated at approximately 1 kg of revert per mold, since it is not necessary to cut the upper portion of the ceramic cup.
- Time reductions: since it is not necessary to cut the ceramic cup, approximately 6 minutes are saved per every mold manufactured, corresponding to the average time usually needed to make said cut.
- Clean revert: since there is no combustion, the alloy which serves to generate the following master heat cast does not contain any form of contaminant. In other words, a higher quality alloy is generated. However, the exothermic contaminates the alloy and the cut made in order to eliminate it is not always enough to completely eliminate said contamination.
- Health and safety at work: since it does not produce a combustion reaction, the operator is not exposed to dangerous elements such as toxic fumes, the intense light given off when the exothermic reacts with the metal or to potential risks associated with handling a material as flammable as the exothermic.
- Reduced emissions: fumes and suspended particle pollutants are prevented from being released into the atmosphere.

Brief description of the drawings

[0030]

Figure 1. Graph comparing temperature evolution in the mold with exothermic (circles), with the material of the invention (squares) and, when no additional substance is used (triangles).

Figure 2. Representing the first 8 minutes of Figure 1. The symbols correspond to those indicated in the description of Figure 1.

Figure 3. Graph comparing the simulated temperature of the part and the actual temperature of the ceramic cup, into the mold, with exothermic material and with the material of the invention. Data on the temperature simulation in the part with exothermic is represented as a continuous line with squares, the temperature simulation in the part with the material of the invention as a dotted line with squares, the actual temperature of the ceramic cup with the exothermic as a solid line with triangles and the actual temperature of the ceramic cup with the material of the invention as a dotted line.

Preferred modes of embodiment

Example 1. Validation trials

[0031] Measurements were taken using thermocouples in actual molds, whilst these measurements were compared with the simulation. The measuring point of the part's temperature was located right in the middle of an intersection plane, between one part and its gate.

[0032] Type S thermocouples with an alumina jacket were used in order to prevent them from deteriorating as measurements were being taken. The measurements were made once the mold had been placed, starting right from the moment when the exothermic was added (approximately 40 seconds after the mold had been taken out of the furnace). The measuring point was identical and was located 25 mm below the molten metal line.

[0033] The process simulation was carried out using Procast, a specific software on melting (Unigraphics NX 6, Visual-Mesh 8.0, Procast 2011.0, Rev 4.0, Visual-Viewer 8.0, number of elements 1699768, CPU calculation time: 26 hours).

[0034] The actual validation trials consisted in carrying out the melting process of 3 identical molds to which the exothermic, the material of the invention, or no material at all was applied for the cooling process.

[0035] The material of the invention added was very fine grade and in flake form. The average size of the particles was approximately 1 mm although there were particles measuring between 0.5 mm and 5 mm.

[0036] In the trials, the alloy INCO718 (11 kg) was used, the mold temperature was 1100 °C and the metal temperature was 1440 °C.

[0037] Mold 1 was cooled in air with the material of the invention. Mold 2 was cooled in air, without adding any compound. Mold 3 was cooled in air with exothermic.

[0038] Looking at the upper surface of mold 1, it was possible to see that once the alloy had solidified, the material of the invention did not melt and was in the same state as it had been when it was added to the molten alloy.

[0039] The results of the trials carried out showed that, despite an initial temperature increase in the exothermic, in comparison with the material of the invention, the cooling process is very similar in both materials, especially in the critical solidification zone located around the average liquid temperature of the Nickel based alloys (1325 °C).

[0040] Figures 1 and 2 show the average temperature evolution, measured with the thermocouples of the ceramic cup in the 3 cases set out above.

[0041] Results on the part's temperature evolution, obtained in the simulation, were analogous, therefore confirming that the part behaves very similarly throughout the solidification process in both the mold with the material of the invention and the mold with the exothermic. The gap between the part and the ceramic cup during the solidification process may be observed (the part is at a higher temperature) (Figure 3).

[0042] In the area in which the temperature difference of the ceramic cup is greater, its influence on the temperature of the part is less than 0.9 %. In other words, it scarcely interferes with the part temperature.

Claims

1. Method for melting an alloy part in a mold, **characterized in that** Vermiculite is added to the ceramic cup of said mold when cooling said alloy part in air.
2. Method according to claim 1, **characterized in that** before said cooling in air process, the following stages are carried out:
 - (a) isolating said mold;
 - (b) preheating said mold; and
 - (c) the vacuum melting of said alloy part.
3. Melting method according to one of the claims 1 or 2, **characterized in that** after said cooling in air process, said alloy part is removed from the mold and cut.
4. Process according to any of the claims 1 to 3, **characterized in that** said alloy comprises at least one metal selected from the Nickel, Cobalt and Titanium group.
5. Process according to any of the claims 1 to 4, **characterized in that** said alloy comprises Nickel and Cobalt.
6. Process according to claim 5, **characterized in that** said alloy comprises at least one of the metals selected from the Hafnium, Chrome, Rhenium and Tungsten group.
7. Process according to any of the claims 1 to 6, **characterized in that** said mold is a ceramic mold.
8. Process according to any one of the claims 1 to 7, **characterized in that** Vermiculite particles, sized between 0.5 mm and 5 mm, are added.
9. Process according to claim 8, **characterized in that** the average size of said particles is between 0.8 mm and 1.2 mm.
10. Process according to claim 9, **characterized in that** said average size is 1 mm.

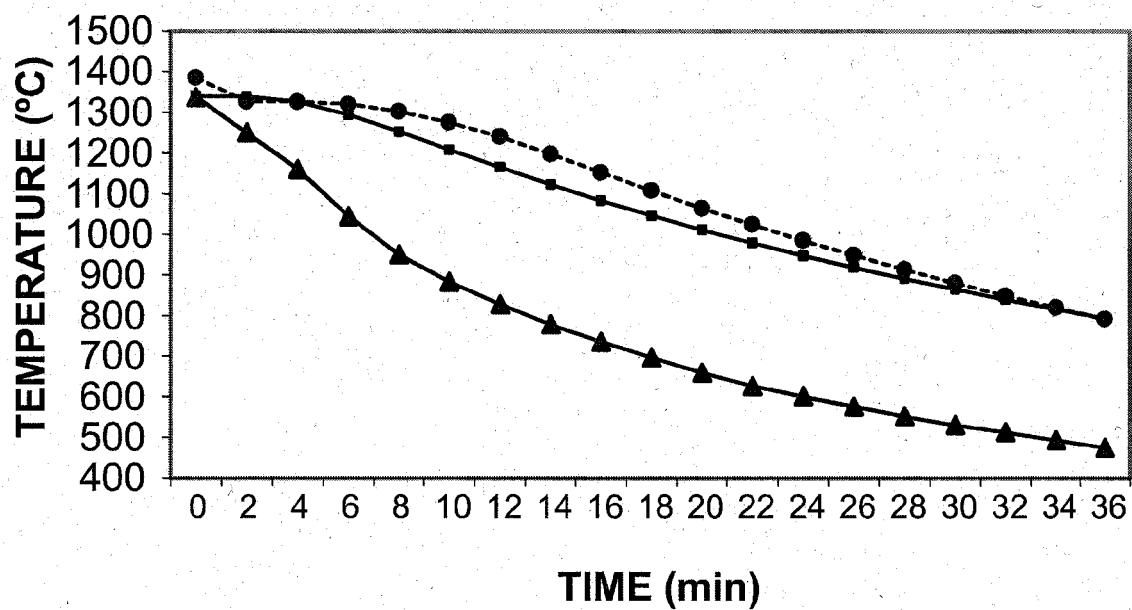


FIG. 1

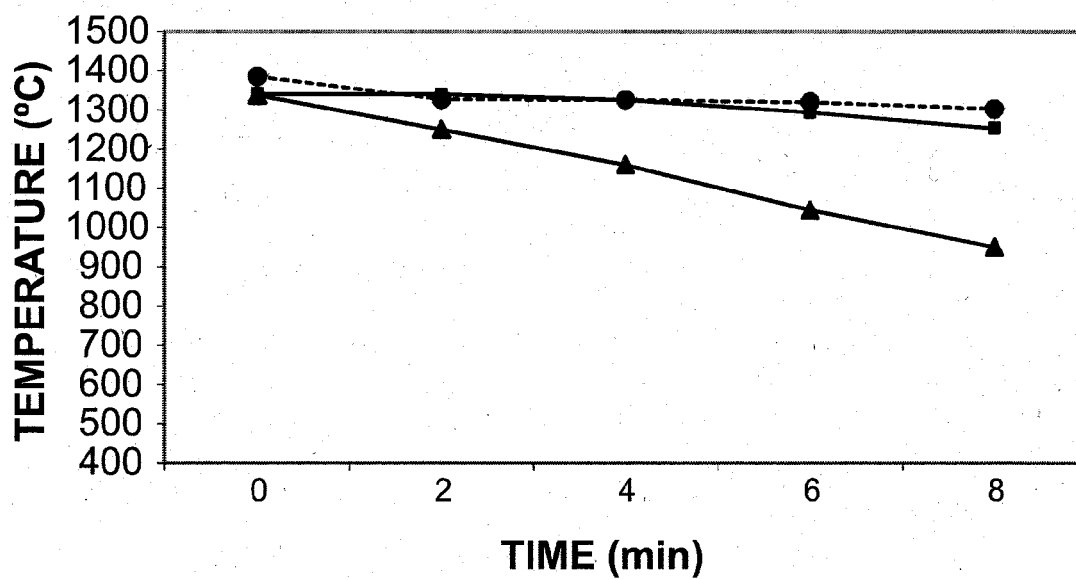


FIG. 2

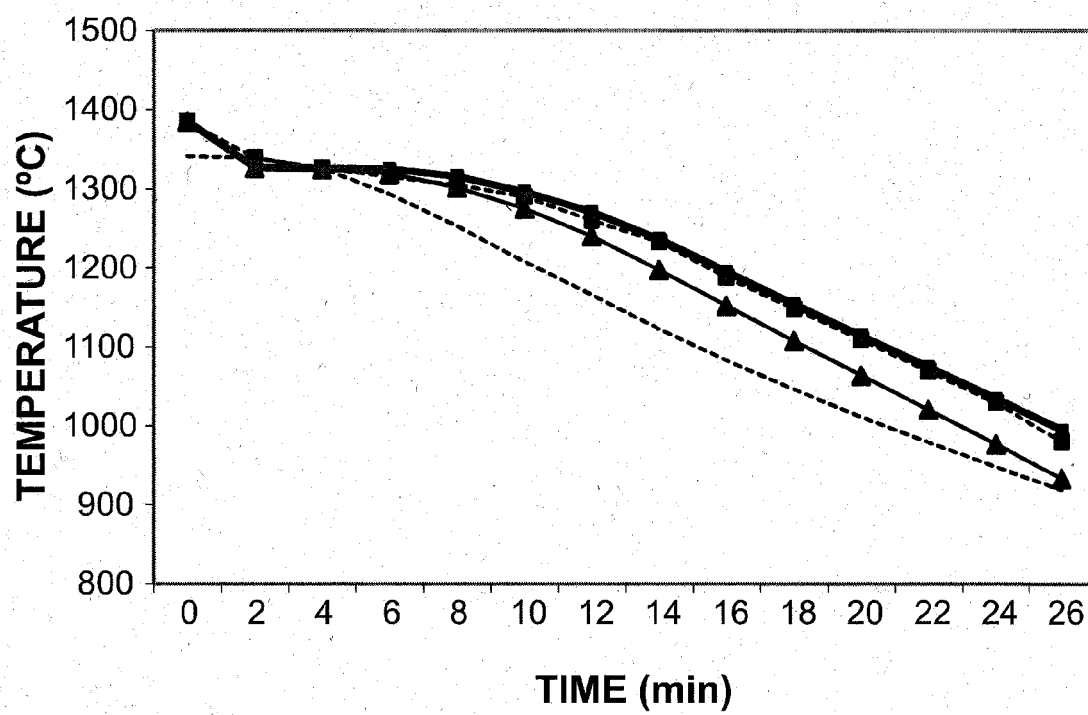


FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 13 38 2238

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	FR 2 186 309 A1 (KINGSCLIFFE SUPER REFRACTORIES [GB]) 11 January 1974 (1974-01-11) * example 7 *	1-10	INV. B22D21/02 B22D27/04 B22C9/04
X	FR 2 432 351 A1 (CREUSOT LOIRE CREUSOT LOIRE [FR]) 29 February 1980 (1980-02-29) * page 2, lines 1-12 *	1-10	
A	US 2002/124984 A1 (SODERSTROM MARK L [US] ET AL) 12 September 2002 (2002-09-12) * the whole document *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			B22D B22C
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 December 2013	Examiner Scheid, Michael
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			

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

EP 13 38 2238

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.

19-12-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2186309 A1	11-01-1974	BE 800345 A1	17-09-1973
		DE 2327251 A1	13-12-1973
		FR 2186309 A1	11-01-1974
		IT 988835 B	30-04-1975
		JP S4962325 A	17-06-1974
		LU 67666 A1	26-07-1973
		NL 7307599 A	04-12-1973

FR 2432351 A1	29-02-1980	FR 2432351 A1	29-02-1980
		JP S5522490 A	18-02-1980

US 2002124984 A1	12-09-2002	DE 10210681 A1	19-09-2002
		FR 2821773 A1	13-09-2002
		GB 2373204 A	18-09-2002
		JP 2002263789 A	17-09-2002
		US 2002124984 A1	12-09-2002
