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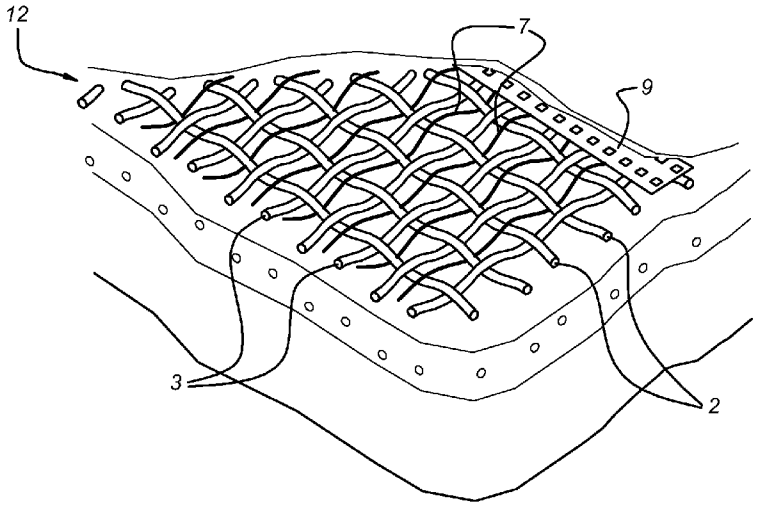
(54) **Title:** HEATED AERODYNAMIC PROFILE FOR COMPOSITE STRUCTURES



(57) **Abstract:** An aerodynamic profile (1) having walls built up from fibre reinforced polymer material. Near the outer surface of the wall electrical conductive elements (7) are provided such as metallic wires. More particular, stainless steel wires are present having a diameter between 5 and 70 micrometers. The wires (7) are connected to a voltage source for heating the related aerodynamic profile (1). According to the invention the wires (7) are included in a fibre reinforcement (2, 3) increasing the strength of a related profile. For example, it is possible that the electrically conductive elements (7) such as metallic wires are weft in a fibre reinforcement (2, 3). It is also possible to lay them parallel to reinforcement fibres (2, 3).

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Heated aerodynamic profile for composite structures

The present invention relates to an aerodynamic profile comprising a fibre reinforced polymer material, and electrically conductive elements.

Such an aerodynamic profile is known from US 6137083. In this specification a profile is disclosed having an outer layer, in which heat conductive elements, such as conductive fibres are present. These conductive fibres are carbon fibres forming part of a hybrid fabric or composite heating mat.

Such heating systems are used in aerodynamic profiles for example for de-icing/anti-icing. Critical spots on, for example, a wing can be heated for removal of ice or to prevent growing of ice on a wing. The presence of ice on a wing could seriously impair the function thereof, such as, for example, in an airplane.

After installation of a heating device, comprising rectangularly conductive elements, further maintenance of the system is not necessary and a simple functioning can be obtained.

US 4841124 discloses a heating system for a rotor blade of a helicopter. The heating wire is provided in a zig-zag pattern and this pattern is kept together through the use of temporary carrier threads. Such carrier threads can for example be solved with water after correct placement of the heating wires.

Application of electrically conductive elements is complicated in the prior art, which is the reason that the use of such elements is generally restricted.

The invention aims to remove this drawback.

According to the invention this aim is realised with the features of claim 1.

According to the invention the electrically conductive elements are part of a reinforcement layer giving required (main) strength to the structure of the aerodynamic

profile. In contrast to the prior art, the electrically conductive elements are no longer present as a separate item or layer but are integrated in the fibre reinforcement of the aerodynamic profile. This means that an additional manufacturing step is no longer necessary to include the electrically conductive elements. According to the invention the electrically conductive elements are already present in the related fibre reinforcement layer at the moment of impregnating with any kind of resin. This inclusion can comprise co-mingling, co-weaving and/or colaying with the fibre reinforcement. The fibre reinforcement providing the mechanical properties of said profile has to be distinguished from heating mats, which includes electrical conductive elements. Such a heating mat will always be used in combination with a separate reinforcement proper giving the required strength to the aerodynamic profile. The additional strength provided by such heating mat will be negligible relative to the strength of the fiber reinforcement giving the main strenght i.e. at least 50% of the required strength.

According to a preferred embodiment of the invention the electrical conductive element is a structural part of the fibre reinforcement. i.e. the electrically conductive elements adds to the mechanical properties of the fibre reinforcement and the aerodynamic profile containing the electrically conductive element. The fibre reinforcement providing the mechanical properties to the profile is always present in any profile subjected to considerable loads and surprisingly it has been found that the electrically conductive element according to the invention can simply be included therein during manufacturing thereof. Preferably the electrically conductive elements are fully integrated in the fibre reinforcement, i.e. present as a weft or the like in the other components of the reinforcement layer and cannot be simply removed therefrom. Preferably the electrically conductive element is integrated in the reinforcement through crossing further filaments of material providing the strength to fibre reinforcement. Such crossings are present at both sides (above and below) the related electrically conductive element to enclose such an element.

The electrically conductive elements can comprise any element known in the prior art such as carbon fibre but according to a preferred embodiment of the invention a metallic wire is used. More particular, stainless steel wire or titanium wire is used. The

diameter of such a wire is at least 5 μm and preferably smaller than 100 μm. More particular the length of such a fibre is at least 5 cm. By choosing the diameter and length of the wire, heat requirements can be met when the applied voltage is known. If a metallic wire is used, such a wire can be coated to provide electrical insulation.

Also a combination of metal and non-metal electrically conductive fibres can be used such as metal coated carbon fibres. Such a conductive fibre should generally have a high resistance to electro corrosion and have of course sufficient electrical resistance to provide heating. The material used for the electrically conductive elements should be chemically compatible with the used polymer material and adjacent fibre material. Generally, excessive differences between the thermal coefficient of the expansion between the electrically conductive elements and adjacent components are not preferable

Depending on the reinforcement used, the electrically conductive element can be provided. For example, it is possible to include the electrically conductive element through weft in the fibre reinforcement. An other possibility in case only uni-directionally fibres are used and the electrically conductive elements have to extend in the same direction, is to place those elements parallel to the uni-directional reinforcement fibres in the same layer.

According to a further embodiment of the invention, current collectors such as a mesh structure, are provided being in common for a number of preferably parallel extending electrically conductive elements.

According to a further preferred embodiment it is the reinforcement layer which is nearest to the outer surface of the related aerodynamic profile, which is provided with the electrically conductive elements. However, also other layers might be provided with electrically conductive elements. This depends on the application.

As indicated above, an application for the electrically conductive elements functioning to heat the related aerodynamic profile is de-icing/anti-icing in all kind of applications

such as aerospace application. Depending on the application, power supply can be applied as desired, continuously or interrupted.

However, it is also possible to use electrically conductive elements and more particular metallic wires for non-destructive examination of aerodynamic profiles. To that end, the related electrically conductive elements are heated by applying a voltage thereto. Subsequently the heat distribution over the aerodynamic profile is observed. This can be simply effected by an infrared camera. Surprisingly, it has been found that it is immediately clear where the electrical conductive properties of the aerodynamic profile change. If a reduction in heat development is observed, it might be concluded that there is also a mechanic failure such as a fault, which could mean that further investigation is necessary. This observation can even be effected during use of the related component.

It is also possible to simply measure the current absorbed by the electrically conductive elements and if a reduction is observed, it could be concluded that one or more of the elements have been damaged, which could possibly mean that also the related reinforcement layer has impaired mechanical properties.

The polymer material used in combination with the fibre reinforcement can be any polymer material known in the prior art. The same applies to the fibre reinforcement which can comprise e.g. glass, carbon or aramid fibres or combinations thereof.

The aerodynamic profile can be any profile known in the art, such as a wing of an airplane, rotor blade of a helicopter, or blade of a wind turbine.

The invention will be further elucidated referring to the enclosed drawing wherein:

Fig. 1 schematically shows an example of an aerodynamic profile;
Fig. 2 shows a cross section of II-II of fig. 1;
Fig. 3 shows a perspective view of the layer 12 of fig. 2;
Fig. 4 shows a reinforcement layer according to the invention; and
Fig. 5 schematically shows heat distribution over an aerodynamic profile.

In fig. 1 an aerodynamic profile is generally denoted with 1. A power supply 11 is schematically shown which connects to current collectors, which are discussed below, referring to fig. 3 and 4.

Fig. 2 shows cross section II-II of fig. 1 whilst fig. 3 shows a detail in perspective. It can be seen that the wall of the aerodynamic profile 1 comprises a number of reinforcement layers 12, 13, 14 and 15. In this example each layer comprises two perpendicular extended groups of fibres 2, 3, which are woven. However, it should be understood that the reinforcement can comprise any fibre reinforcement known in the prior art such as uni-directional fibres and a combination of cross layed fibres and uni-directional fibres.

According to the invention, in a reinforcement layer which increases the mechanical strength of the profile, a metallic wire is included. This is shown in fig. 2 and 3 as wire 7. However, it should be observed that the wire 7 can also comprise a non-metallic wire or a combination of a metallic material and non-metallic material. From fig. 3 it is clear that the wire is weft with other parts of the reinforcement layer. Such reinforcement layer can have a thickness of about 0.2-0.3 mm.

Fig. 3 shows top layer 12 of fig. 2. In the embodiment of fig. 2 and 3 only the top layer 12 is provided with a heating element comprising such metallic wires 7 in order to transfer heat as easily as possible to the outer surface of the profile.

From fig. 3 it is clear that a current collector 9 is provided connecting the several wires 7. This can be a thin metallic mesh structure or sheet material, such as aluminium or any other material which is compatible with wires 7 and having a low weight and a relatively small thickness and having high electrical conductivity.

The metallic wires in this embodiment preferably comprise stainless steel.

In fig. 4 an embodiment is shown wherein the reinforcement fibres 4 are uni-directional fibres. The heating wires 8 extend parallel thereto in between the fibres and are connected through current collector 10.

An application for the heating element according to the subject invention is de-icing/anti-icing. To that end the heating element is preferably placed as near as possible to the outer surface of the aerodynamic profile as shown in fig. 2 and 3.

An other application is the possibility of examination of the intactness of fibre reinforcement layers. To that end, the heating wires can be included on the critical points of the structure. If inspection is due, this can be effected by applying a voltage. Voltage drop or current can be observed to predict possible damage. If an infra-red picture is made of the related fibre reinforcement, it is immediately clear where interruption occurs. This is schematically shown in fig. 5. At the point of interruption it is likely that breakage or other mechanical damage has occurred to the wire, which could mean that also adjacent parts of the fibre structure is damaged. In that case, further examination is required.

Although the invention has been described above relating to a preferred embodiment, for a person skilled in the art, alternative embodiments will immediately be obvious and are within the range of the appended claims.

CLAIMS

1. Aerodynamic profile (1) comprising a fibre (2-4) reinforced polymer material, and electrically conductive elements (8), characterised in that, said fibre reinforcement comprises the fibre reinforcement to provide the mechanical properties of said profile and in that said electrically conductive elements are included in said fibre reinforcement.

2. Aerodynamic profile according to claim 1, wherein said electrically conductive elements are structural part of the fibre reinforcement.

3. Aerodynamic profile according to one of the preceding claims, wherein said electrically conductive elements comprise metal wires having a diameter of at least 5 μm and a length of at least 5 cm.

4. Aerodynamic profile according to one of the preceding claims, wherein said fibre reinforcement comprises parallel spaced metal wires.

5. Aerodynamic profile according to one of the preceding claims, wherein said fibre reinforcement comprises reinforcement fibres in a first direction and wherein said electrically conductive elements extend in a second different direction.

6. Aerodynamic profile according to claim 5, wherein said electrically conductive elements are weft with said non-conductive fibres.

7. Aerodynamic profile according to one of the preceding claims, comprising metallic current collectors (9, 10) being in common for several conductive elements.

8. Aerodynamic profile according to one of the preceding claims, wherein said conductive elements comprise stainless steel material.

9. Aerodynamic profile according to one of the preceding claims, wherein said conductive elements comprise titanium.

10. Aerodynamic profile according to one of the preceding claims, comprising an electrical power source (11) connected to said conductive elements for heating thereof.

11. Aerodynamic profile according to one of the preceding claims, comprising several reinforcement layers (12-15) in the thickness of the wall of said profile (1), wherein the conductive wires are provided in the reinforcement layer (12) nearest to the outer surface of said wall.

12. Aerodynamic profile according to one of the preceding claims comprising a wing profile.

13. Method for heating a fibre reinforced polymer material aerodynamic profile, comprising applying of a voltage to an electrically conductive component of the fibre reinforcement wherein said voltage is applied to metallic conductive elements in said fibre reinforcement.

14. Method according to claim 13, wherein said voltage is applied to current collectors connecting the extremities of said electrically conductive elements.

15. Method for de-icing/anti-icing an aerodynamic profile comprising heating according to one of the claims 12, 13.

16. Method for the examination of an aerodynamic profile comprising heating according to claim 12 or 13 and observing the heat distribution in said profile.

Fig 1

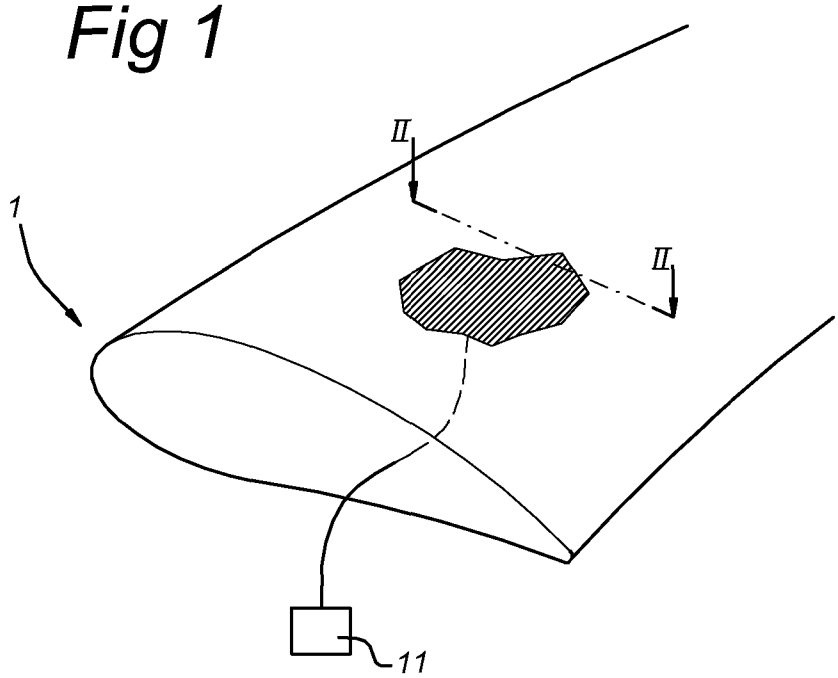


Fig 2

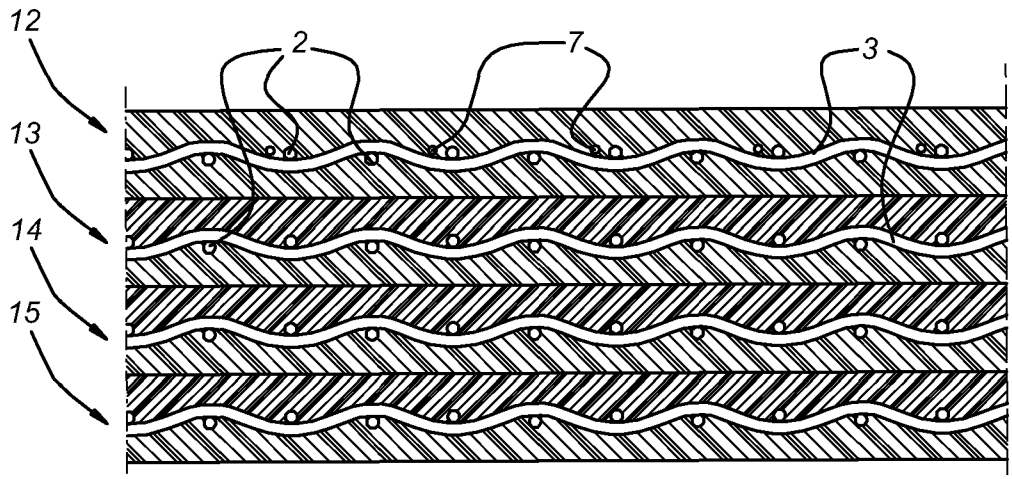


Fig 3

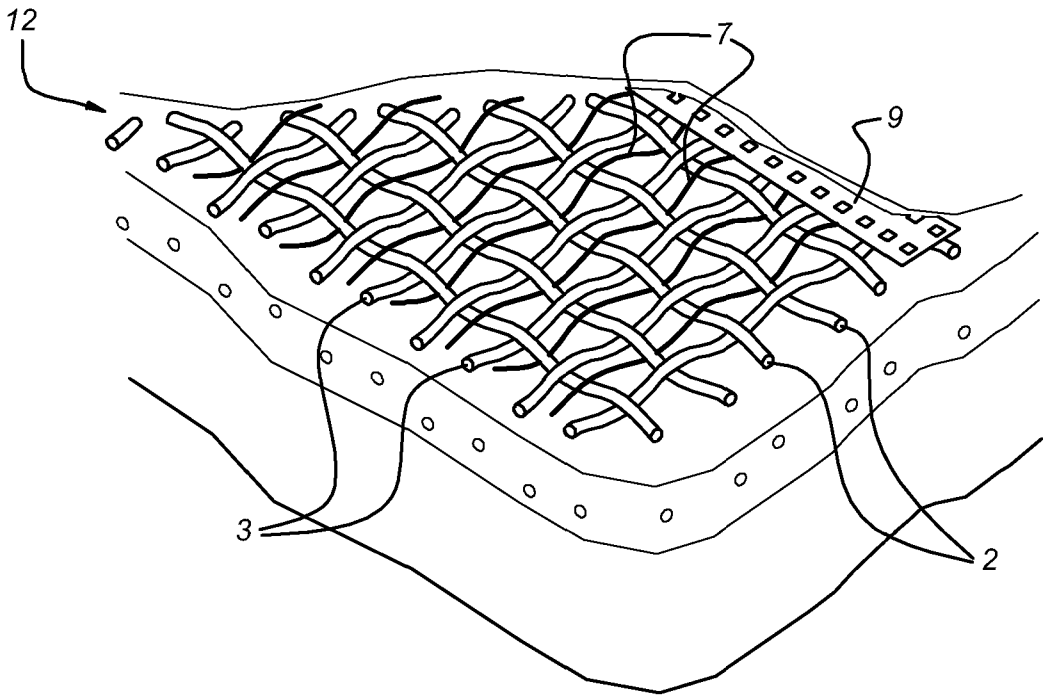


Fig 4

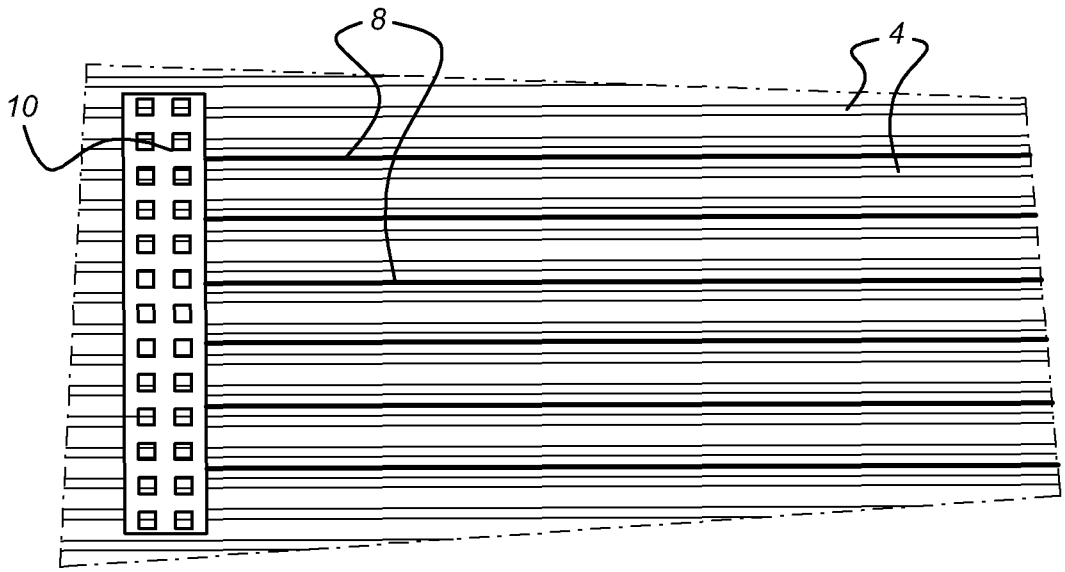
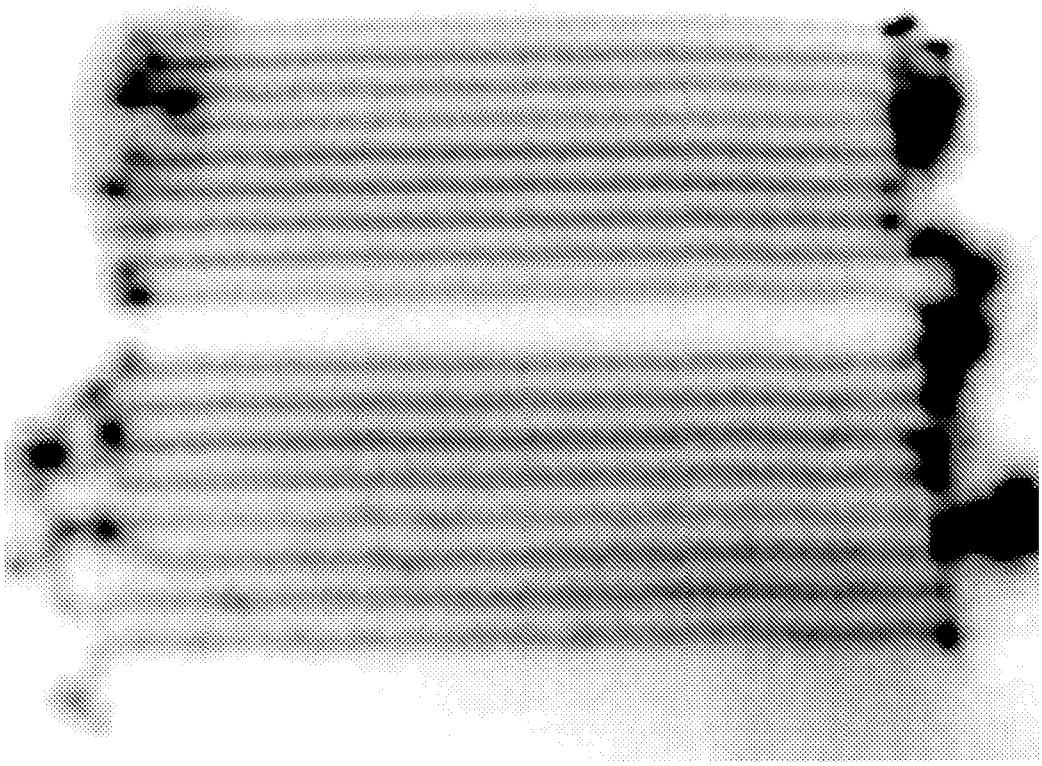


Fig 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2007/050223

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64D15/12 H05B3/34 H05B3/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B64D H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 6 137 083 A (BOST MICHEL [FR] ET AL) 24 October 2000 (2000-10-24) cited in the application abstract figures 5,6 column 2, line 27 - line 45 column 4, line 1 - line 12	1-7, 10-16 8,9
X	US 4 841 124 A (COX DECEASED DUNCAN B [US] ET AL) 20 June 1989 (1989-06-20) cited in the application figures 1C,3,4 column 5, line 47 - line 54 column 6, line 65 - column 7, line 1	1-7, 10-16

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 August 2007	17/08/2007

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2007/050223

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	page 3, line 7 - line 23 page 7, line 16 - line 25 page 8, line 20 - line 24 claims 10,11 figure 3	1-7, 10-16
A	US 3 218 436 A (EDWARDS JACK T ET AL) 16 November 1965 (1965-11-16) figures 2,4 column 2, line 31 - line 34 column 2, line 44 - line 47 column 2, line 67 - line 71	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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