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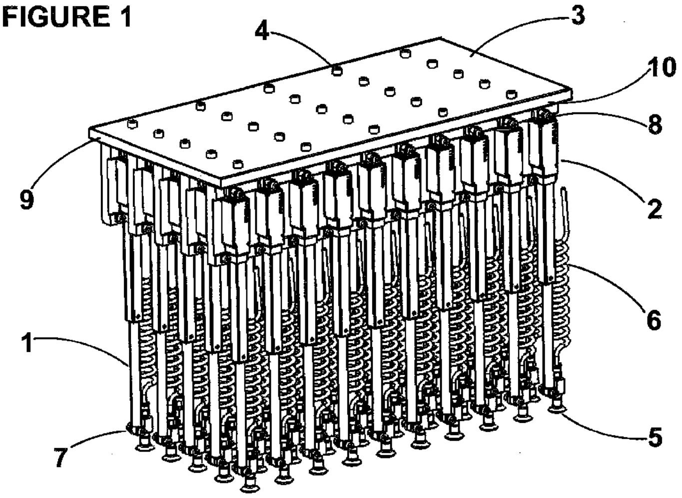
[Continued on next page]

(54) **Title**: IMPROVEMENTS TO ROBOTIC ARM END EFFECTORS AND THEIR USE IN THE PREPARATION AND APPLICATION OF PRODUCTION MATERIALS

FIGURE 1



(57) **Abstract**: A robot arm end effector has individually extending and retracting arm members 1 and 2 that are located to a plate 3 and fed air via a tube 6 and power is supplied to each actuator arm via 8, these arms are individually instructed to assign or morph themselves in an unlimited amount of continual combinations of certain positions via a computer programme software, each arm 1 and 2 having suction cups 5 and 15 or other tactile end portions affixed to their ends that directly touch and contact with a subject material 11 manipulating it in an unlimited number of ways that reduce or remove the need for human manual intervention, during material preparation and pre-tool or pre-mould insertion stages and is able to also push material into the mould or tool, and is therefore able to perform the work of several robot arms, with increased efficiency as a solo production.

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PATENT APPLICATION

OF

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FOR

IMPROVEMENTS TO ROBOTIC ARM END EFFECTORS AND THEIR USE IN THE PREPARATION AND APPLICATION OF PRODUCTION MATERIALS

Field of the Invention

The present invention relates to the use of robotic arm end effectors during the preparation of materials prior to or during the process of laying up and manufacture, including materials that require their shape to be manipulated in a multifarious way, such as composites including but not exclusively, composite or pre-impregnated sheet, carbon fibre, weave structured, wet fibre, dry fibre, thermoset and thermo plastics.

Background

The use of robot arms during preparation for or during manufacturing has been known for many years and has become an essential element for production and research areas of the global technology and related industries. In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment. Its usage varies and is dependent in its function and design by the very nature of the subject material to which it is directed or working on. The exacting nature of this device depends on the application of the robot. The robot arm is designed to be instructed or programmed to move in a finite pattern to repeat processes that provide a final result. If an item is to be manufactured it may take several stages and have to be passed through various numbers of robots to be completed. In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or end) of the robot. At this endpoint the tools are attached. In a wider sense, an end effector can be seen as the part of a robot that interacts with the work environment. This does not refer to the wheels of a mobile robot or the feet of a humanoid robot which are also not end effectors—they are part of the robot's mobility.

End effectors may consist of a gripper, vacuum cup or other type of tool. When referring to robotic prehension there are four general categories of robot end tools, these are as follows and are described here to offer an overview.

Impactive – jaws or claws which physically grasp by direct impact upon the object. Ingressive – pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fibre handling). Astrictive – suction forces applied to the objects surface (whether by vacuum, magneto- or electro adhesion). Contigutive – requiring direct contact for adhesion to take place (such as glue, surface tension or freezing).

They are based on different physical effects used to guarantee a stable grasping between a gripper and the object to be grasped. Industrial grippers can be mechanical, the most diffused in industry, but also based on suction or on the magnetic force.

Vacuum cups and electromagnets dominate the automotive field and in particular metal or composite sheet handling. Bernoulli grippers exploit the airflow between the gripper and the part that causes a lifting force which brings the gripper and part close each other (i.e. the Bernoulli's principle). Bernulli grippers are contactless gripper, namely the object remains confined in the force filed generated by the gripper without coming into direct contact with it. Bernoulli grippers are adopted in Photovoltaic cell handling in silicon wafer handling but also in textile or leather industry.

Other principles are less used at the macro scale (part size >5mm), but in the last ten years they demonstrated interesting applications in micro-handling. Some of them are ready of spreading out their original field. The other adopted principles are: Electrostatic grippers and van der Waals grippers based on electrostatic charges (i.e. van der Waals' force), capillary grippers and cryogenic grippers, based on liquid medium, and ultrasonic grippers and laser grippers, two contactless grasping principles.

Electrostatic grippers are based on charge difference between the gripper and the part (i.e. electrostatic force) often activated by the gripper itself, while van der Waals grippers are based on the low force (still electrostatic) due to the atomic attraction between the molecules of the gripper and those of the object. Capillary grippers use the surface tension of a liquid meniscus between the gripper and the part to center, align and grasp the part, cryogenic grippers freeze a small amount of liquid and the resulting ice guarantees the necessary force to lift and handle the object (this principle is used also in food handling and in textile grasping).

Even more complex are ultrasonic based grippers, where pressure standing waves are used to lift up a part and trap it at a certain level (example of levitation are both at the micro level, in screw and gasket handling, and at the macro scale, in solar cell or silicon wafer handling), and laser source that produces a pressure able to trap and move micro parts in a liquid medium (mainly cells). The laser grippers are known also as laser tweezers.

A particular category of friction/jaw gripper are the needle grippers: they are called intrusive grippers and exploits both friction and form closure as standard mechanical grippers.

The most known mechanical gripper can be of two, three or even five fingers.

The end effectors that can be used as tools serve various purposes, such as spot welding in an assembly, spray painting where uniformity of painting is necessary, and for other purposes where the working conditions are dangerous for human beings. Surgical robots have end effectors that are specifically manufactured for the purpose. A common form of robotic grasping is force closure.

Generally, the gripping mechanism is done by the grippers or mechanical fingers. Generally only two-finger grippers are used for industrial robots as they tend to be built for specific tasks and can therefore be less complex.

The fingers are also replaceable whether or not the gripper itself is replaced. There are two mechanisms of gripping the object in between the fingers (for the sake of simplicity, the following explanations consider only two finger grippers).

The shape of the gripping surface of the fingers can be chosen according to the shape of the objects that are to be manipulated. For example, if a robot is designed to lift a round object, the gripper surface shape can be a concave impression of it to make the grip efficient, or for a square shape the surface can be a plane.

Though there are numerous forces acting over the body that has been lifted by the robotic arm, the main force acting there is the frictional force. The gripping surface can be made of a soft material with high coefficient of friction so that the surface of the object is not damaged. The robotic gripper must withstand not only the weight of the object but also acceleration and the motion that is caused due to frequent movement of the object.

This present invention however revisits the astrictive method of suction cups or end tools assembled to a morphing end effector as a method of laying up of composites or other materials, with gripping or handling and moreover the ability to actually re-shape, form or manipulate the subject material directly to improve the preparation and manufacturing processes in any application instances.

The use of suction cups for moving or relocating items are known in manufacturing or other areas and it has also been cited that astriction has been derived with additional support to shape pliable or malleable materials in a basic change of form.

Therefore, attempts have already been cited wherein methods to use multiple suction on an end effector arrangement to alter material shapes.

An example of this is the disclosure within PCT/GB2014/051638 this shows a robot arm with an end effector that relies on having a flexible sheet with a myriad of air supplied apertures, to carry out the function of laying up or re-forming subject material. The apertures can provide a vacuum to the holes installed in the flexible sheets surface.

The sectionally linked flexible sheet can be moved and shaped using smaller robotic arms, governed by a single large positioning robotic arm that is controlled and programmed by a computer.

This however offers a restricted ability to contact with the subject material in a way that is sufficiently dexterous, detailed or infinite, to provide more detailed and diverse shaping. The large surface plane of the flexible sheet is limited to lending itself to more lateral subject materials such as sheet or larger sectional products. For example: A composite of some size that requires slight shaping or sheet of material for, as an example only, an aeroplane that has limited shape variations to its surface, for example, to curve a sheet.

Therefore its use for larger plies is stated and the posable flexible sheet reflects this in its design.

As with robotic end effectors that are already known this device attempt is aimed at a particular area of use, which is clearly stated as larger more basic manufactured or prepared sheeting or ply. The size of the contact area of this end effector is a large plane, as opposed to individually working contact points with cups or tools, of the disclosed advance herein.

This requirement for handling or laying up and shaping materials using only the end effector arms within industry is apparent but it is not fully addressed in the prior art, using the cited end effector can only have limited manufacturing or preparation results and some processes within industry are not benefitting fully from this. These processes include wet fibre, pre-impregnated (pre-preg) composites, dry fibre, thermoset and thermo plastics. For example pre-impregnated composite fibers often take the form of a weave and a matrix (such as an Epoxy Resin) is used to bond them together and to other components during manufacture. The matrix is only partially cured to allow easy handling; this is called B-Stage material and requires cold storage to prevent complete curing. B-Stage pre-preg is always stored in cooled areas since heat accelerates complete polymerization. Hence, composite structures built of pre-pregs will mostly require an oven or autoclave to cure.

There are several advantages and disadvantages of the B-Stage pre-preg process in comparison to the hot injection process. Pre-preg allows one to impregnate the fibers on a flat workable surface, or rather in an industrial process, and then later form the impregnated fibers to a shape which could prove to be problematic for the hot injection process. Pre-preg also allows one to impregnate a bulk amount of fiber and then store it in a cooled area for an extended period of time to cure later. Unfortunately the process can also be time consuming in comparison to the hot injection process and the added value for pre-preg preparation is at the stage of the material supplier. Therefore a composite material can require many hours of human manual labour to prepare and begin the formation of the subject. This is known and common when the building of certain articles such as motor vehicles is examined. General composite panels are produced by cutting numerous parts in either pre-impregnated composite fibres (impregnated with a matrix material such as epoxy) or dry composite fabrics. These parts then go through a lay-up process where the individual parts are carefully positioned within the form tool to ensure the correct overlaps, fibre direction and correct number of layers of fabric are achieved to ensure the correct function of the finished part. This lay-up must also be done while minimising the over-stretching of the individual cut fabric parts and preventing wrinkling. Both issues can have a detrimental effect on the function of the finished part, the direction of fibres, for example, are vital to the strength of the finished article, if they are not laid correctly the material may be weakened in that or other areas. The layering and positioning of these separate material sections is crucial to the overall final result and this is why it has always been a human manual procedure and infinite decisions can be made using close visual and physical senses.

Generally this process is a manual one and accounts for a significant percentage of the overall assembly process. Current systems lack the ability to sufficiently place the individual parts due to inabilities to take the flat cut pieces and place them in the required positions within the form tools. They are either fitted together in their flat form and then transferred to the tool or held over the tool in their flat form and pressed into shape when the two parts of the tool come together. Neither process can compete with the manual process in ensuring placement accuracy and deformation reduction.

The ability of the disclosed new end effector device is to automate this process by generating a basic pre-form of the flat materials to allow a more accurate placement into the tool while having the function to then 'drive' the pre-formed fabrics into the geometry of the tools by the use of formed grippers and linier motion control.

An alternative use comes from the ability of the end-effector to morph into different shapes which will allow a single robot and/or pick-and-place unit to service the loading/un-loading of multiple forming machines producing different parts. To create a part such as a car door takes a considerable amount of complex and skilled stages and specific variations of process that must be applied in a very concise way, method and order to achieve the desired end result.

Therefore currently the majority of the laying up and preparation relies on manual human endeavour, as the amounts and positioning of the materials are so important at this stage that the ability for an end effector to do this has not been possible.

The invention disclosed herein aims to provide an end effector solution to this need and provide a far more concise, controlled and dexterous ability to prepare and manipulate composite materials of varying types wherever the application is possible or suitable.

Prior Art

Accordingly patent applications have been filed to provide general solutions, including the following:

International patent ref: PCT/GB2014/051638 (Bristol University)

Discloses a robot arm with an end effector that relies on having a flexible sheet with a myriad of air supplied apertures, to carry out the function of laying up or re-forming subject material. The apertures can provide a vacuum to the holes installed in the flexible sheets surface.

The sectionally linked flexible sheet can be moved and shaped using smaller robotic arms, governed by a single large positioning robotic arm that is controlled and programmed by a computer.

Summary of the invention

According to the present invention there is provided a device that is attached to the receiving end of a suitable known robot arm member in the archetypal way and is able to enable improved handling, transportation and shape or form manipulation of suitable composites and materials. This is made possible by providing a myriad or selective number of suction cups or other direct manipulation end tools, wherein the end cup or tool area itself actually engages with the material surface changing the materials form or shape, as a legion of, normally, vertical mountings. This disclosed and improved end-effector is used for the handling, manipulation and initial forming of dry fabrics, pre-impregnated, pre-forms and moulded panels (predominantly in composites – to restrictive). The system operates by contacting flat plane components by the use of an actuator with a suction pad or gripper type holder. Once in place the actuators can be sequenced to lift the part up whilst forming an initial shape and once in the mould-tool 'drive' the material into position to aid with the forming process. The aim being better control of components to maximise material position. The system could also be used for the handling and manipulation of formed parts during the production cycle. The flexibility of the system would allow one tool to handle numerous parts and shape them or move them during a single process, instead of the current fixed and multiple robot production line systems.

Therefore, it can be stated that a single robot arm with this end effector attached may carry out a re-forming or pre-forming function on a subject material to a certain shape one or more times and place it in the desired next stage location, then re-align its actuator arms and therefore suckers or tools to then continue on to perform a separate task during the same production period, led by computer programming. It may then return to the aforementioned task and repeat as a continual, until instructed otherwise. This could provide a production or pre-production method of composite material manipulation and movement, using a single robot arm and end effector or at least a reduced number of robot arms.

The cup is provided to enable usage with a number of surface types and may vary to accommodate these. Each cup is located to the end of an individually actionable arm, which may be extended or curtailed in minute amounts at will. This antrorse action is governed by instructions being fed from a computer via a suitable programme. As the suction cup contacts with the composite material surface it provides a seal around its diameter, or similar, form or rubber which is further enhanced by the addition internally of a vacuum. The vacuum, in the known way, provides an inward directional of air under a pressure that pulls and holds the material surface closer in contact with the suction cup surface, or provides a 'sucking' action.

The material surface is therefore drawn to the suction cup and held in place, providing that the inward directional air flow vacuum remains. An outward directional air flow may also provide an effect on the material surface and may be used. The plurality of suction cups or end tools (example: Grippers or Needles) and extendable or retractable arms each append to an actuator arm, in the known method and this is in turn located and secured vertically in each case, moreover, to a horizontal housing platform, which may have a vacuum manifold or air supply arrangement, as seen in the enclosed Figures. The actuator arm, is conceived in the known way and provides automatic and electrically powered antrorse movement to the extending arm and therefore each cup or tool, in infinite amounts that can be pre-set and repeat or change in extension or retraction in anyway or amount, as a constant that can automatically be programmed to change mid process to adjust to another task and then return to its origin position thus. Should a number of these cup or tool arrangements from an appendage of extending arms and actuators be grouped as a legion, moreover in a vertical manner, from a horizontally provided housing plate, this will form the end effector.

As shown in Figure 1, for example, the multiple suction cups or tools, not shown, would begin in an aligned group. The computer programme would then provide specific positioning instructions for each of the individual arms and cups to extend or curtail or withdraw them in a grouped manner, that will later contact with the composite material and because of their positioning, alter the shape or form of the suitably pliable material due to the suction cups gripping and forcing the material, moving it into a new shape, as shown in Figures 2, 3 and 5.

This shape altering is enabled due to various reasons, these include the suction of the cup and its direct contact with the material surface, gripping the material and other neighbouring cups holding in a downward force against it, therefore the withdrawing suction cup and arm would intentionally 'move or bend' the area of the subject material, assisted by the holding or more static action of adjacent cup and arms. It is stated here that therefore, the position of each appendage arm and its affixed cup, or sometimes tool, is vital to the eventually formed shape of the materials and also the position and extended length of each arm and cup in relation to each other is also a crucial element to the amount of pressure or shaping force that is created between them on the surface, which in turn determines the effectiveness of material shape re-forming. If all arms therefore, where in a sucking action only it would lift the material as a single unit and this will provide the ability to lift and relocate the material to another position, possibly over a receiving mould. Should, for example, a number of the cups be sucking with the arm onto which the suction cup is attached being retracted by the actuator arm and other neighbouring arms are static and hold the material in a bedded manner, the area of the material that is being motioned would change shape.

The amount of shape that is changed and its very form and extent would depend on the amount of extension or retraction of each individual cup or tool and arm against the extent of the position and extension or retraction of the static or semi-static arms and their relationships with the others allocated within the end effector device.

This would also be possibly governed by a controlled and variable pressure of the air vacuum located within each cup and arm. More pressure to one set of cups grouped into a corner area of the material may provide a more dense and therefore suitable repositioning of the composite material in that area, when set against a slightly weaker or stronger air intake or directional vacuum of the remaining arms and cups in other areas of the group therein. Suction cups may also be allocated to the 'side' areas or at varying angles to the vertical arms as shown as 15 in Figure 5.

This would allow for the cups to render force to more undulated areas or locations upon the material that require an increased suction at that angle or location and position. The specific overlaps and material positioning can also be administered and delivered using this disclosed method of multiple direct contact suction cups of individual variable programmable automation positioning.

Due to the more exacting nature of the cups or tools and the way in which the moving arms and actuators can be programmed and controlled within minute degrees of measurement, it is possible that this end effector can lift and re-shape a large variety of composites of any suitably required material and holds major advantages with the handling of pre-impregnated or pre-formed variants. This includes the scope for sizing of the end effector and its size relation to the subject materials being quite unlimited. It is noted that there is little limitation to the size of the end effector and its components. They are governed only by the practical elements of allowing it to function. In application under known industrial circumstances the disclosed end effector arrangement is able to provide an automated way to provide a robotic solution to a manual operation and provide a basic pre-formation of the flat composite or other materials. This in turn will allow a more accurate placement into the receiving tool which is a part of the next stage of the production, while having the added advantage to be able to provide a function to then 'drive' the pre-formed fabrics into the internal geometry of the tools.

The reduction of the amount of robots needed to perform and execute the known and these new preparation processes are also provided herein, a possibility of a single robot being able to interchange between task types by morphing the shape of the end effector arms to suit each differing task is also apparent. The amount of suction cups per end effector and the way they are grouped or placed upon the horizontally provided housing plate.

Brief description of figures

Figures 1 show an example of the end effector in static state.

Figures 2 show an example of the end effector manipulating a subject material using its extended and retracted suction cups.

Figures 3 show an example of the end effector in relation to a robot arm.

Figures 4 show a close view of the end effector actuator, arms and suction cups in contact with the subject material.

Figures 5 show individual actuator, arms and suction cups shaping a subject material.

Figures 6 show a close sectional view or a reduced size variant of the end effector in use with a subject material.

Figures 7 show underside and plan views of two differently arranged end effectors.

Figures 8 show the varying lengths of the extended and curtailed suction cups.

Detailed description of figures

A typical embodiment of the invention is illustrated in Figure 1. This shows an extendable and retractable arm member **1**, as an operative and inclusive moving part of an actuator arm **2**. A myriad of these arm members and actuator arms are provided in and unlimited variation of collectives and infinitely variably spaced groups and forms, as desired.

These are each in turn housed or held inserted vertically in the preferred way to a horizontal locating plate **3** via an actuator locating point **4**, the locating plate **3** which may be horizontal but will vary in angle when in certain operative circumstance, has a suitable thickness **9** and **10** forming its supporting plane as shown in Figure 1, this locating plate **3** is the means to feed the collective of vertical arms with power and air and attach to a robot positioning arm.

Air **6** and **7** along with power **8** are supplied via linking apparatus as shown in the known way and provide the life for the animation of the moving elements of the solution.

To the extremity of the extendable and retractable arm member **1** is located a suction cup **5**, this may also be another desired tool that can interact with the subject material such as a gripper or needle device, not shown and is the part that contacts directly with the subject material upon use.

A collective of suctions cups **5** are presented, as shown in all figures and may pertain to any number and any desired arrangement into the locating plate **3** with differing groups of appendages containing **1, 2**, and **5** and spacing between them to suit different end result aims.

For example: should a more forced impact be required to form a 'squared' depression into a specific area of the subject material, then a more closely grouped application of cups **5** may be arranged to one area of the locating plate **3**, with other areas of the plate having a selection of more widely spaced cups **5**, or other suitable tool attachments, along with their collaborative components, **1, 2, 3, 4, 5, 6, 7** and **8**. This arrangement has no limitations and would be determined and arranged to suit each material production requirement.

The subject matter material **11**, as shown in Figure 2 has its shape and form altered by the resulting impact applied from the moving suction cups **5A** and **12**, being to pull or push the material depending on the particular delivery to the suction cup **5A** from the extendable and retractable arm members **1A** and actuator arm **2A**. The area of the material **11** to which the resulting impact is applied, depends on which cups **5A** move and where and when and to what extent they move and in which direction and their individually programmed degree of movement, as a combined process of unlimited varying settings. This results in upward and downward and possible other angles of movement including sideways or an obliquity effect of the material surface, a downward example is **14**, being administered by suction cup **13**, as shown in Figure 2.

An antrorse pulling and shaping of the material, being shown in the area of **12** and being administered by the upward pulling of the suction cups, as shown, is created by the vacuum within their collective embodiment in the known operative method.

An example of the end effector **K** in position to a robot arm **J** is shown in Figure **3**.

Subject matter **11C**, such as composite pre-impregnated material is manipulated by the moving force of the suction cups and their pushing and vacuum assisted pulling capabilities, as shown in Figure 4.

This action may also include or incorporate the positioning of sheet materials in a specific manner in preparation stage using the end effectors ability to select and re-locate items in a precise manner, the extent of this procedure and the amount to which is may be used would depend on individual human decisions based on the advice of a person with many years of experience providing a planning or selecting procedure that may run as a carefully chosen complete or derivative of the overall process and may then be translated into robotic arm instructions to be provided as a continual process that the robot arm and end effector can administer, this is changeable and adaptable at any given point and may be fully or partially altered as desired.

Multiple suction cups **16, 17, 18, 19, 20, 21, 22, 23, 24,** and **25** are shown in differing positions of motion in Figure 5, affecting the subject material due to their interrogation and manipulation of the material, a downward alteration of the materials shape shown as **11D**. The addition of side positioned suction cups **15**, may also be introduced to improve effective material shaping in other areas.

This is expanded upon in Figure 6, with the arrows again showing the directional shape change created following impact and contact with the moving vacuum cups.

The underside view 26 of the locating plate **3** is shown in Figure 7, with suction cups **5E**.

A plan view 27 of a differing and more spaced actuator arm and cup arrangement to the locating plate **3E** is shown also in Figure 7, with actuator arm positions shown **2E**.

Various positions of the suction cups **16F, 17F, 18F, 19F** and **20F** are shown as closer views 28 and 29 in Figure 8.

These include an example of a side located suction cup **20F**, as shown.

Claims

1. A robot arm end effector wherein individual extending and retracting arm members each have suction cups or other tactile end or side located portions that directly touch and contact with a subject material which requires reshaping, during but not exclusively the laying up process.

2. A robot arm end effector as claimed in claim 1 wherein tactile end portions and/ or sucker cups use pressure from administered mechanical force or vacuum air to anchor or impact to the surface of a subject material such as a composite or pre-impregnated sheet that requires some pre-mould or pre-tool shaping on an automated level to reduce or remove the need for extensive human manual intervention.

3. A robot arm end effector as claimed in claim 2 wherein shape manipulation of a subject material such as carbon fibre or other, is administered by the individual moving arm members that collectively form the end effector and their attached vertically derived contact devices, due to pulling or pushing in upward or downward trajectories, these materials onto which the end effector is to be used include wet fibre, pre-impregnated (pre-preg) composites, dry fibre, thermoset and thermo plastics.

4. A robot arm end effector wherein the need to manually apply and process pre-impregnated composite fibers in the form of a weave or similar variants during the laying up procedure and the requirement to have to manually handle bonding matrix solutions to strict temperature rules and time limits, is reduced or removed during material preparation pre-tool or mould insertion stages, at varying periods to the commencement or during the procedures, by the end effector automated process herein.

5. A robot arm end effector as claimed previously has individual moving arms that can be instructed by computer programme software, to each perform a solo extension or retraction of their arm and therefore the affixed end effector is thus used to press various required areas of a composite or similar sheet material into a mould or tool, to adapt the material into the shape of the mould interior.

6. A robot arm end effector is able to morph its collective of horizontal extending and retracting arms and therefore cups or similar manipulation end attachments, to change the individual lengths or each arm independently to perform a desired re-shaping of a sheet or similar material and may re-morph continually to perform different results on other sheets or similar materials.

7. A robot arm end effector as claimed in claim 8 wherein, the end effector is able to continually morph into different forms and arrangements to create varying dimensional shapes or lift and relocate materials and/or press them into a mould or tool during a manufacture or a material preparation process and thus one robot arm, to which the end effector is attached, is able to perform the work of several robot arms, at an increased rate of efficiency and as a solo production

Continues:

8. A robot arm end effector as claimed in all previous claims is a robot arm end effector and has individually extending and retracting arm members that are individually instructed to assign themselves to certain but infinite combinations of positions via a computer programme software as a continually changing variable, each arm having suction cups or other tactile end portions that directly touch and contact with a subject material which requires reshaping, the material to include but not exclusively composite or pre-impregnated sheet, carbon fibre, weave structured, wet fibre, dry fibre, thermoset and thermo plastics, that require some pre-mould or pre-tool shaping on an automated level to reduce the need for human manual intervention, to reduce or remove the requirement to manually handle bonding matrix solutions to strict temperature rules and time limits, during material preparation pre-tool or pre-mould insertion stages, at varying periods to the commencement or during the procedures, or press various required areas of a composite or similar sheet material into a mould or tool, to adapt the material into the shape of the mould interior, being able to morph its collective of horizontal extending and retracting arms and therefore cups or similar manipulation end attachments, to change the individual lengths or each arm, independently to perform a desired re-shaping of a sheet or similar material and may re-morph continually to perform different results on other sheet or similar materials, the end effector is able to continually morph into different forms and arrangements to create varying dimensional shapes or lift and relocate materials and/or press them into a mould or tool during a manufacture or a material preparation process and thus one robot arm, to which the end effector is attached, and is therefore able to perform the work of several robot arms, as a solo production.

AMENDED CLAIMS
received by the International Bureau on 21 November 2015 (21.11.2015)

Claims

1. A robot arm end effector wherein, individual extending and retracting arm members each have suction cups or other tactile end or side located portions that directly touch and contact with a subject material which requires reshaping, during but not exclusively the laying up process, these individual arm members impact and re-shape the material by their individual and grouped contact with it, which alters its shape and form due to their force and impact upon it, following programmed or controlled instruction upon them from a computer programme or other remote method.

2. A robot arm end effector as claimed in claim 1 wherein tactile end portions and/ or sucker cups use pressure from administered mechanical force or vacuum air to anchor or impact to the surface of a subject material such as a composite or pre-impregnated sheet that requires some pre-mould or pre-tool shaping on an automated level to reduce or remove the need for extensive human manual intervention.

3. A robot arm end effector as claimed in claim 2 wherein shape manipulation of a subject material such as carbon fibre or other, is administered by the individual moving arm members that collectively form the end effector and their attached vertically derived contact devices, due to pulling or pushing in upward or downward trajectories, these materials onto which the end effector is to be used include wet fibre, pre-impregnated (pre-preg) composites, dry fibre, thermoset and thermo plastics.

4. A robot arm end effector wherein the need to manually apply and process pre-impregnated composite fibers in the form of a weave or similar variants during the laying up procedure and the requirement to have to manually handle bonding matrix solutions to strict temperature rules and time limits, is reduced or removed during material preparation pre-tool or mould insertion stages, at varying periods to the commencement or during the procedures, by the end effector automated process herein.

5. A robot arm end effector as claimed previously has individual moving arms that can be instructed by computer programme software, to each perform a solo extension or retraction of their arm and therefore the affixed end effector is thus used to press various required areas of a composite or similar sheet material into a mould or tool, to adapt the material into the shape of the mould interior.

6. A robot arm end effector is able to morph its collective of horizontal extending and retracting arms and therefore cups or similar manipulation end attachments, to change the individual lengths or each arm independently to perform a desired re-shaping of a sheet or similar material and may re-morph continually to perform different results on other sheets or similar materials.

7. A robot arm end effector as claimed in claim 8 wherein, the end effector is able to continually morph into different forms and arrangements to create varying dimensional shapes or lift and relocate materials and/or press them into a mould or tool during a manufacture or a material preparation process and thus one robot arm, to which the end effector is attached, is able to perform the work of several robot arms, at an increased rate of efficiency and as a solo production

Continues:

8. A robot arm end effector as claimed in all previous claims is a robot arm end effector and has individually extending and retracting arm members that are individually instructed to assign themselves to certain but infinite combinations of positions via a computer programme software as a continually changing variable, each arm having suction cups or other tactile end portions that directly touch and contact with a subject material which requires reshaping, the material to include but not exclusively composite or pre-impregnated sheet, carbon fibre, weave structured, wet fibre, dry fibre, thermoset and thermo plastics, that require some pre-mould or pre-tool shaping on an automated level to reduce the need for human manual intervention, to reduce or remove the requirement to manually handle bonding matrix solutions to strict temperature rules and time limits, during material preparation pre-tool or pre-mould insertion stages, at varying periods to the commencement or during the procedures, or press various required areas of a composite or similar sheet material into a mould or tool, to adapt the material into the shape of the mould interior, being able to morph its collective of horizontal extending and retracting arms and therefore cups or similar manipulation end attachments, to change the individual lengths or each arm, independently to perform a desired re-shaping of a sheet or similar material and may re-morph continually to perform different results on other sheet or similar materials, the end effector is able to continually morph into different forms and arrangements to create varying dimensional shapes or lift and relocate materials and/or press them into a mould or tool during a manufacture or a material preparation process and thus one robot arm, to which the end effector is attached, and is therefore able to perform the work of several robot arms, as a solo production.

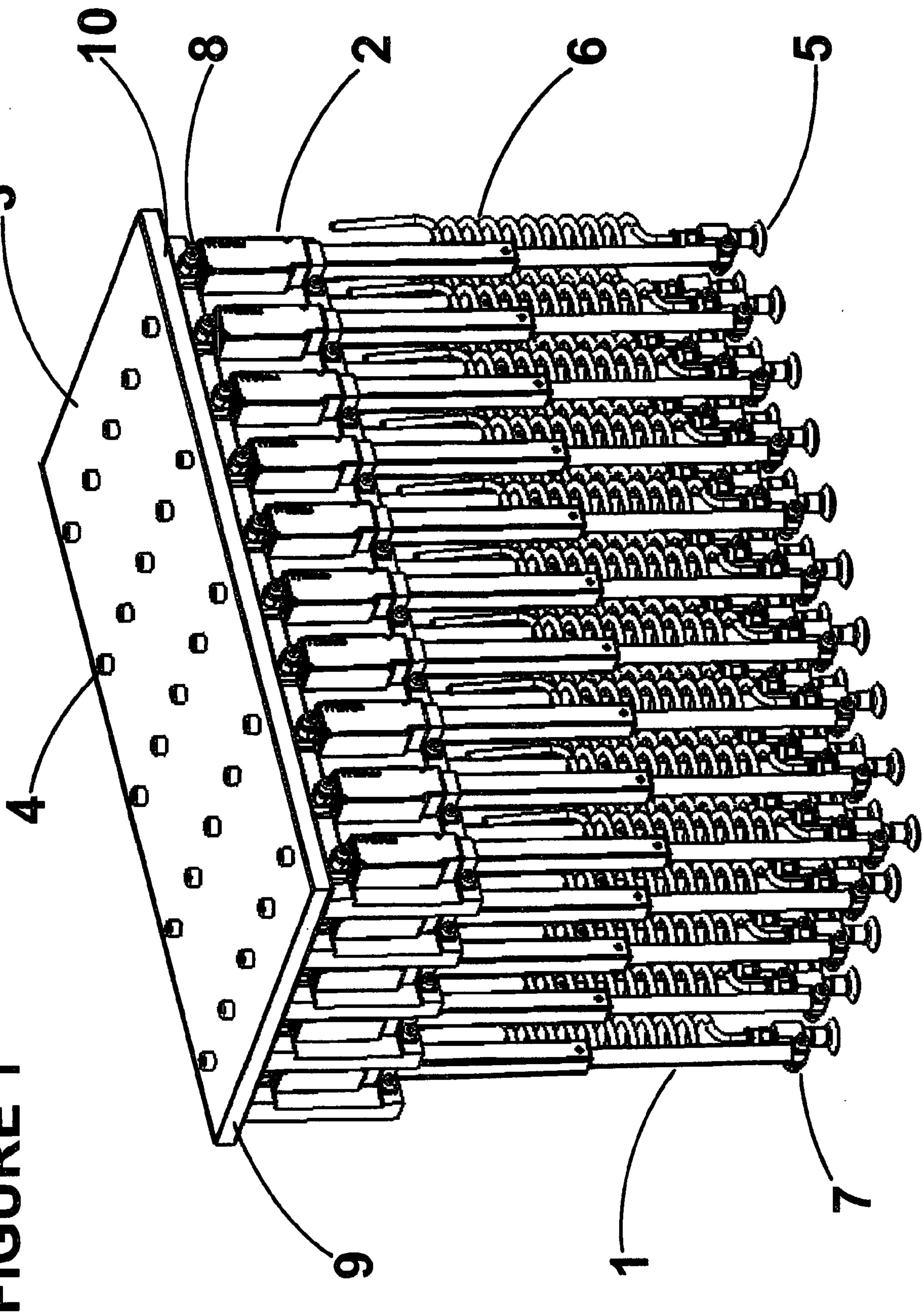


FIGURE 1

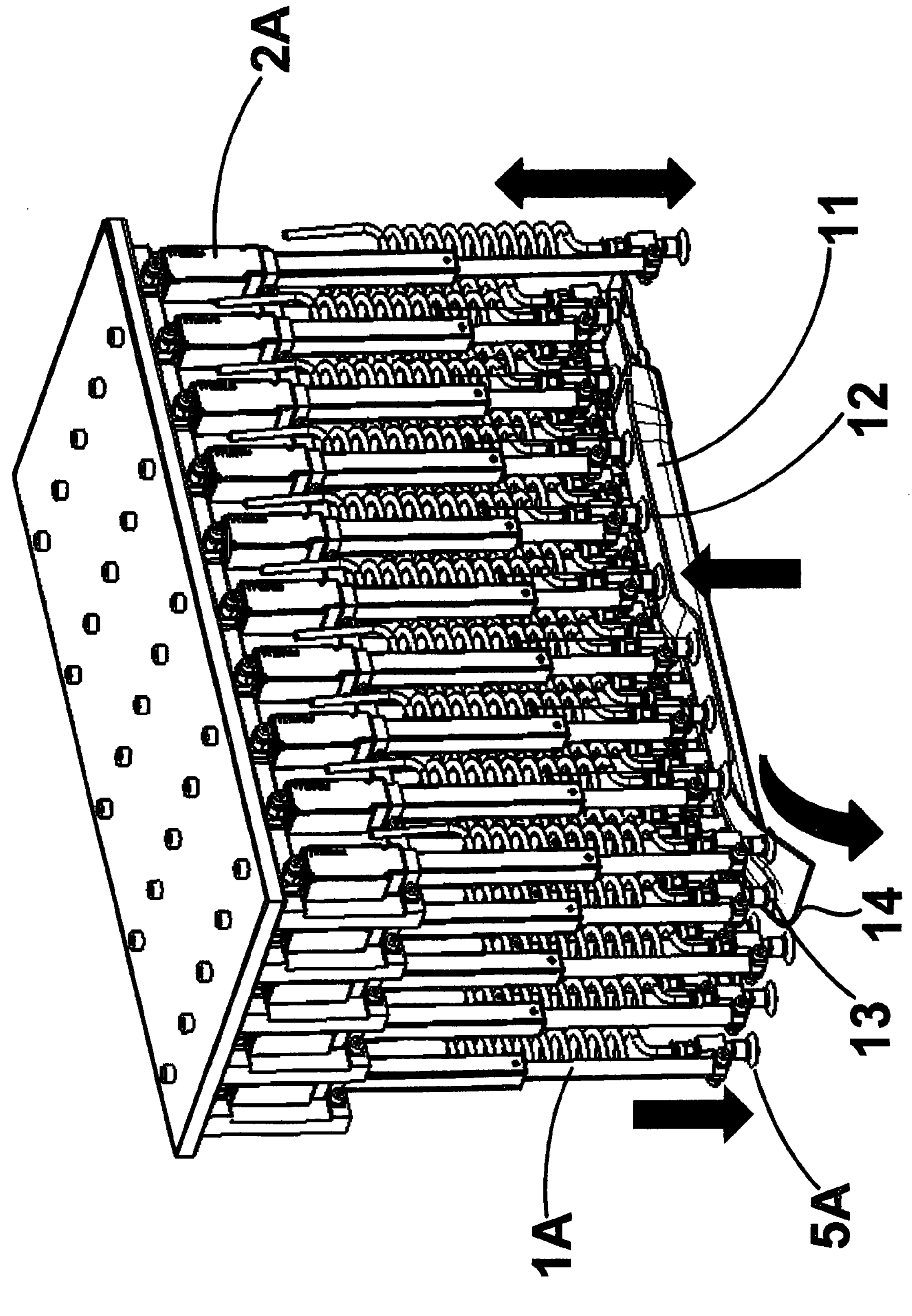


FIGURE 2

FIGURE 3

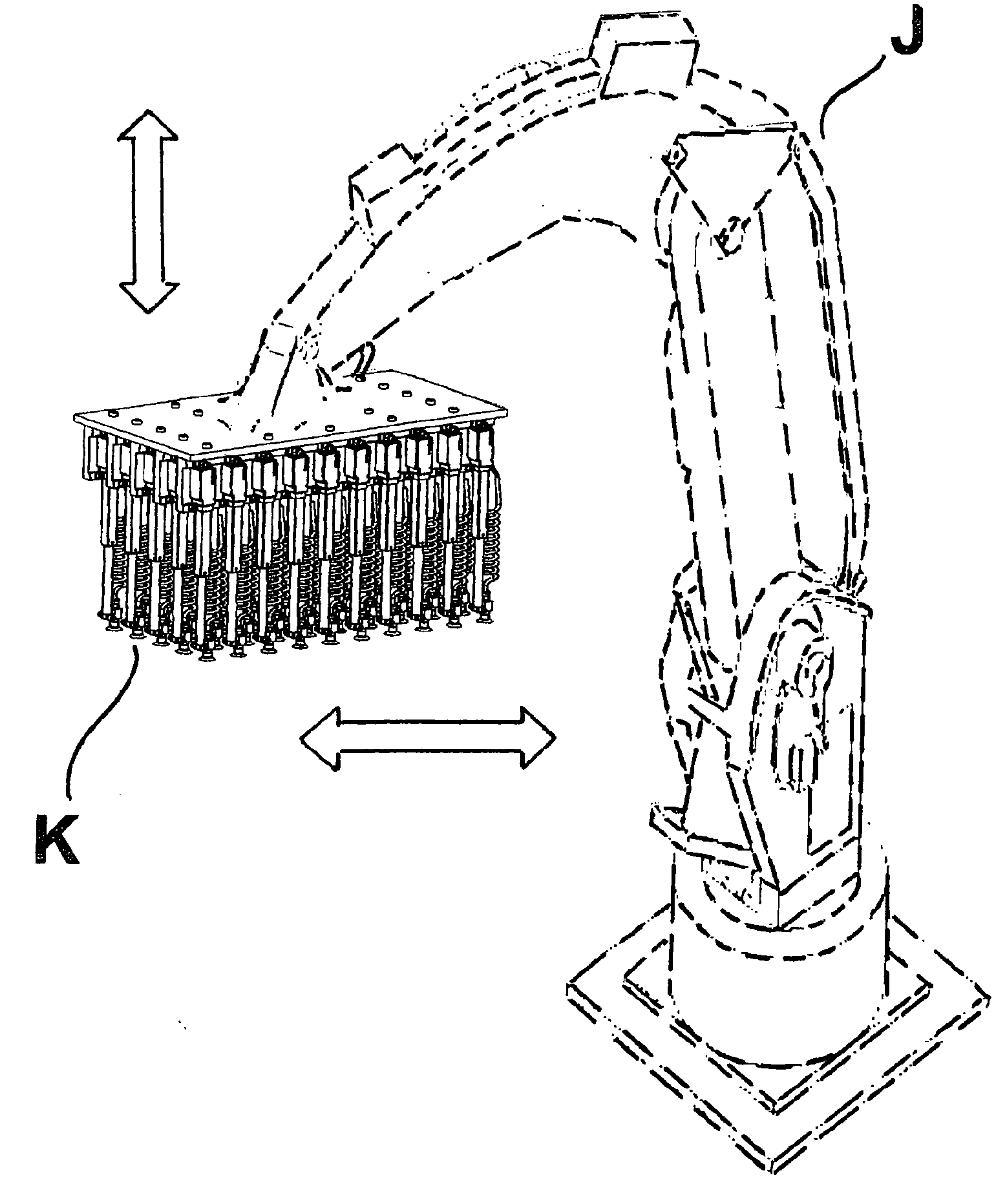
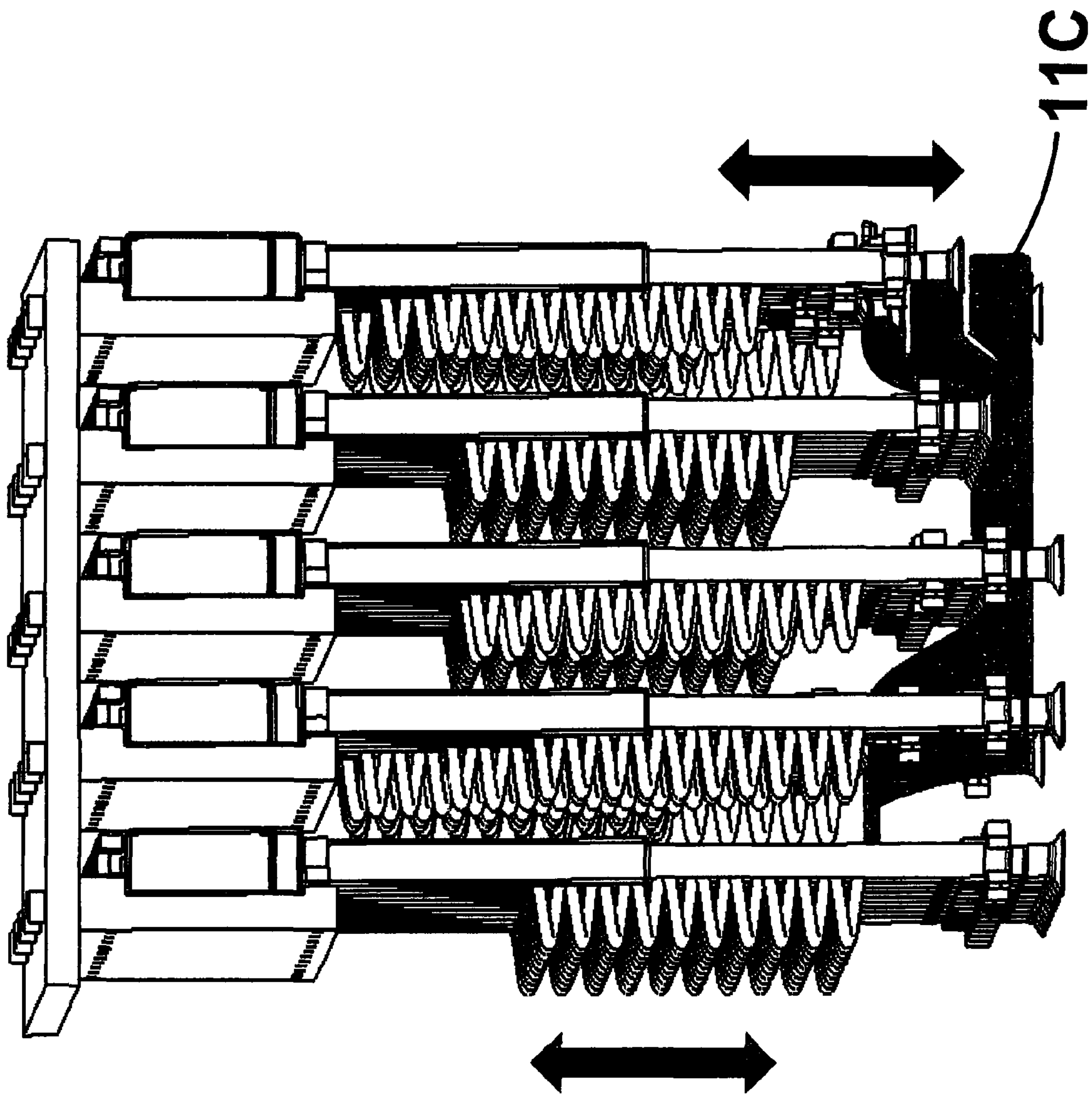


FIGURE 4



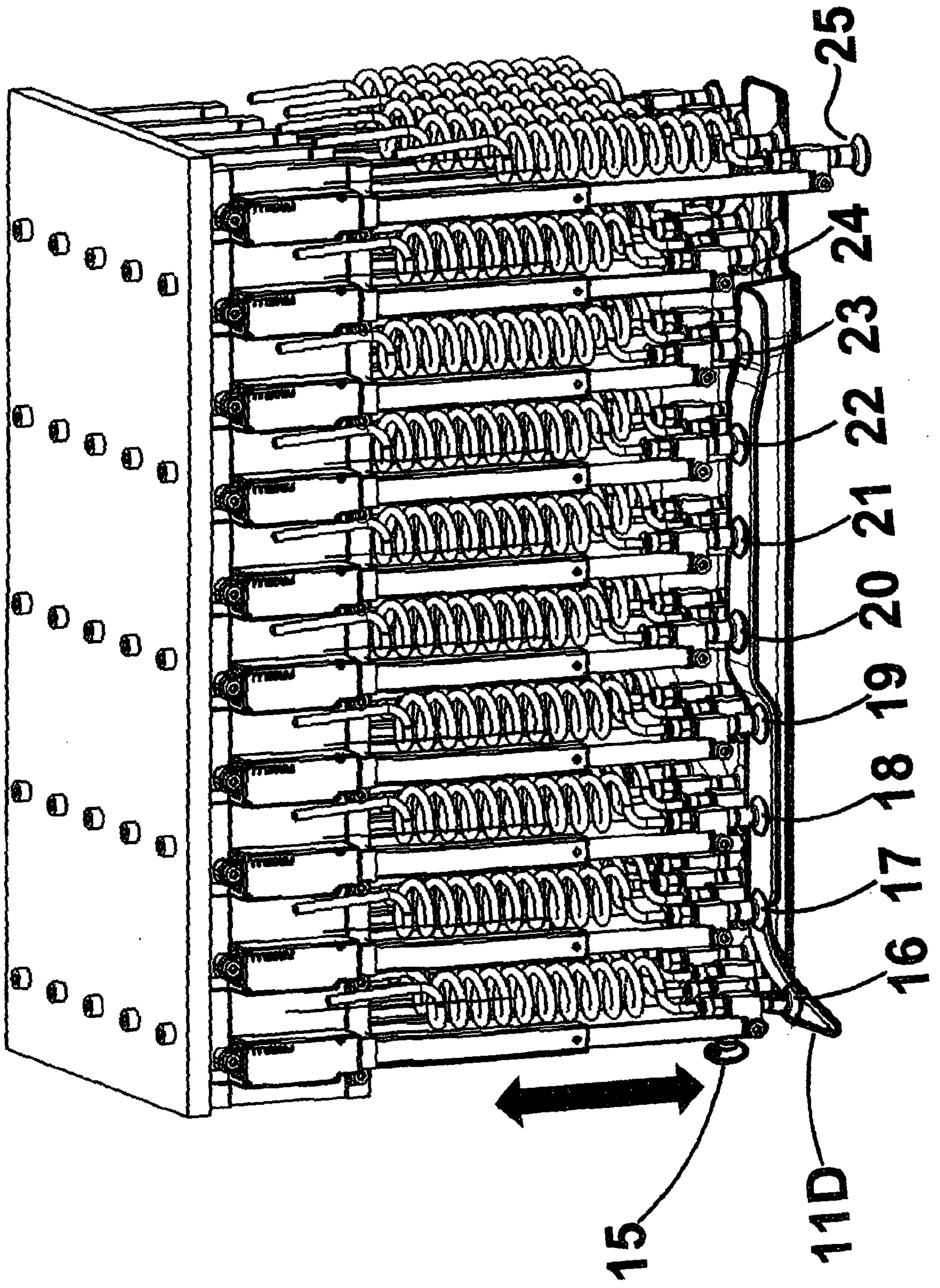


FIGURE 5

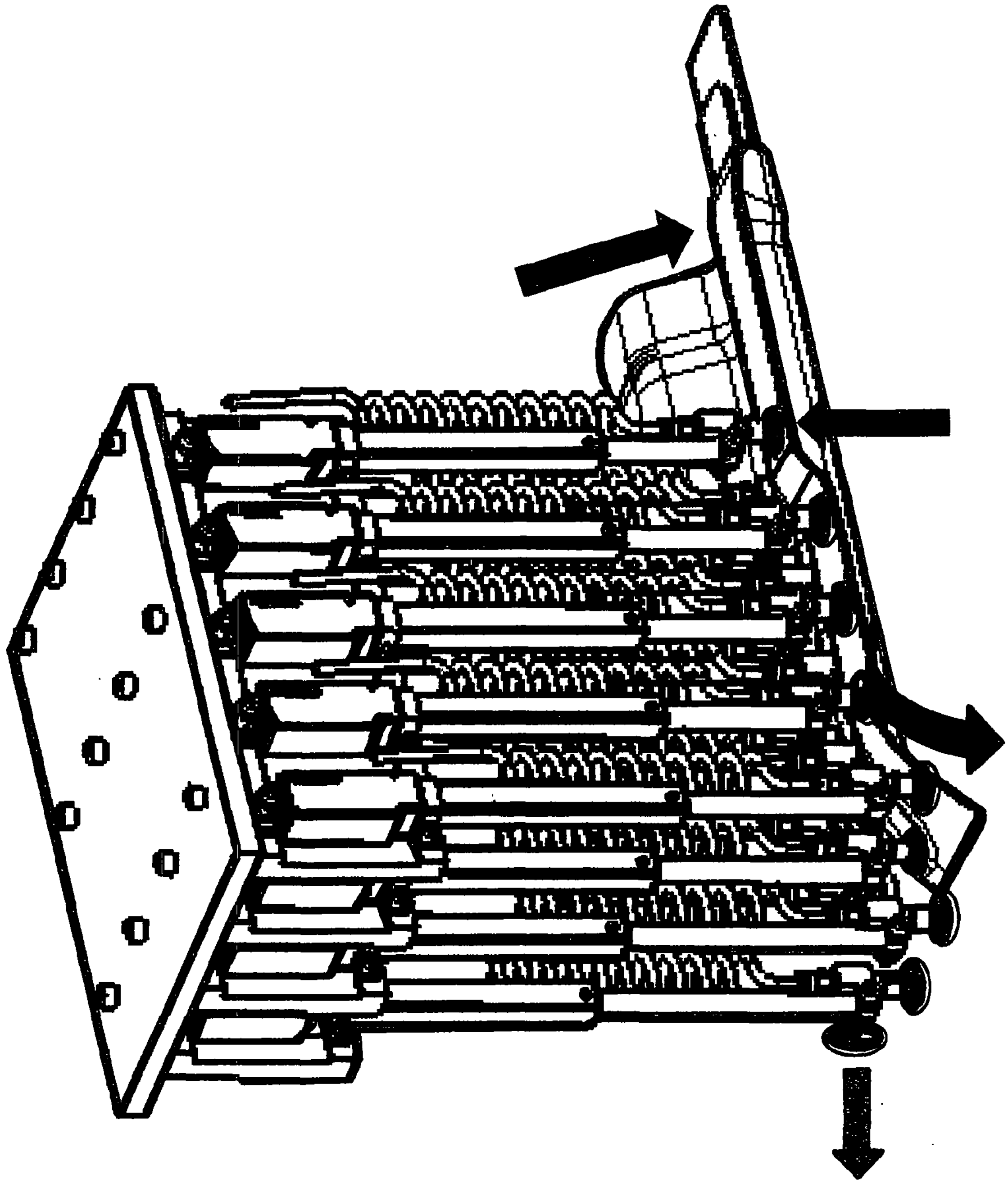


FIGURE 6

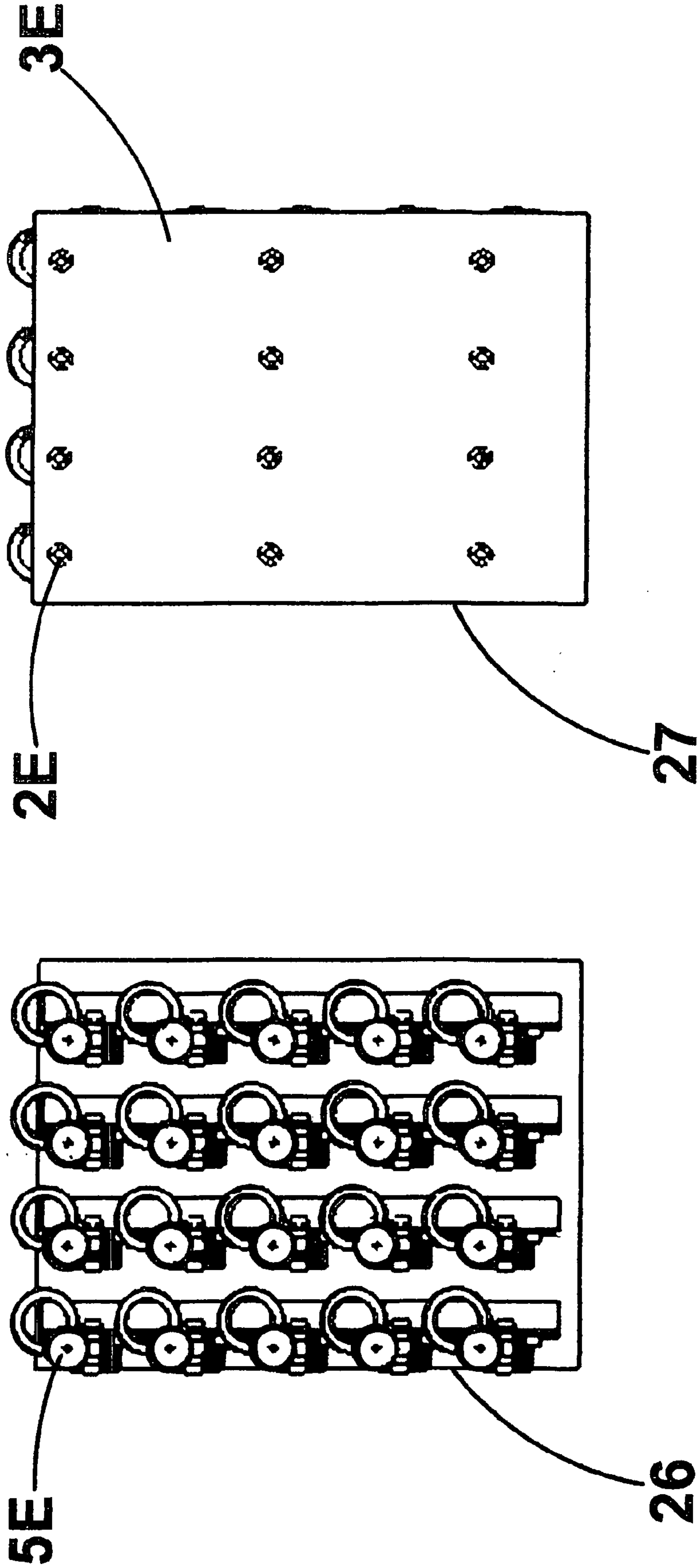
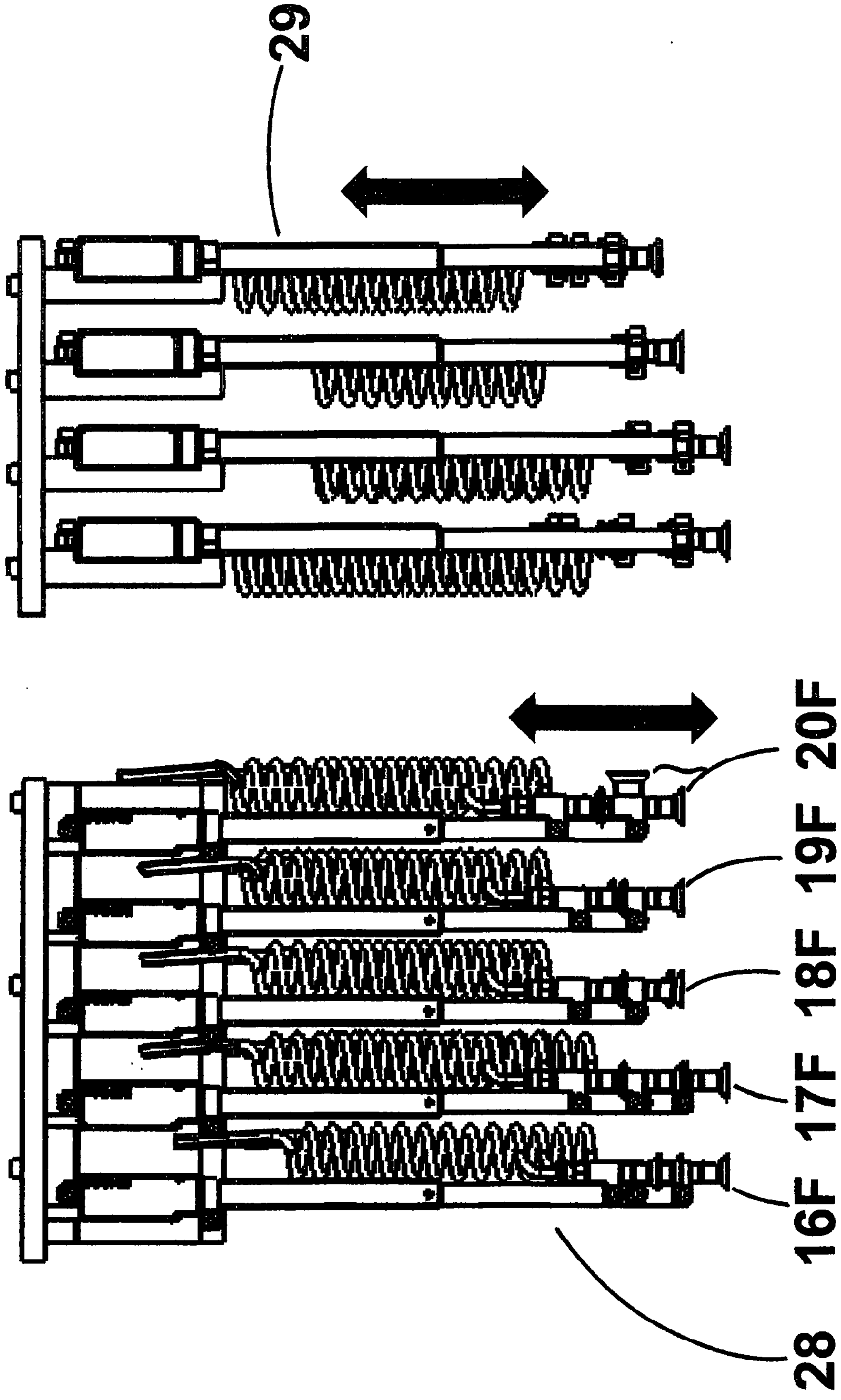


FIGURE 7

FIGURE 8



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2015/000236

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J15/00 B25J15/06
ADD.

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)
B25J

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/008928 A1 (COLLADO JIMENEZ VALENTIN [ES] ET AL) 9 January 2014 (2014-01-09) paragraph [0027]; figures 1-12	1-8
X	EP 2 756 934 A1 (AIRBUS OPERATIONS GMBH [DE]) 23 July 2014 (2014-07-23) abstract; figures 1-3	1-8
X	US 2004/130085 A1 (LIM JEONG CHAN [KR]) 8 July 2004 (2004-07-08) abstract; figures 1-3	1-8
X,P	DE 10 2013 020581 A1 (EBZ SYSTEC GMBH [DE]) 18 June 2015 (2015-06-18) figures 1-8	1-8

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

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 November 2015	20/11/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Champion, Jérôme

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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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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2015/000236

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