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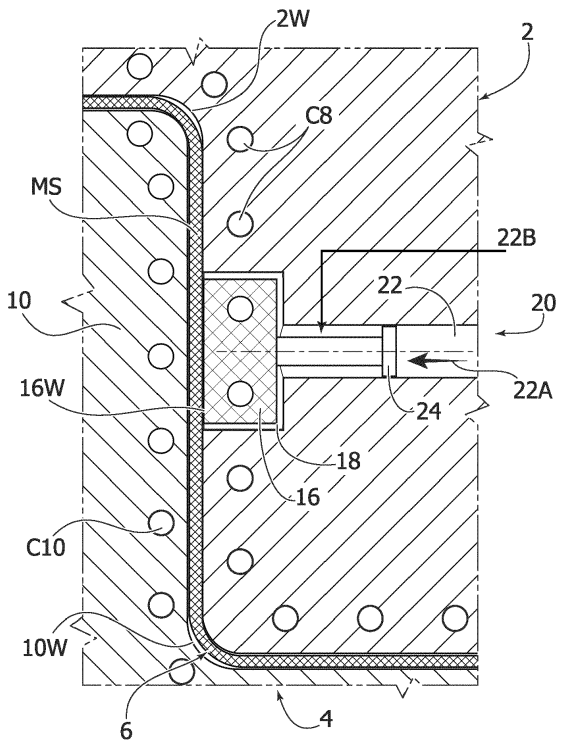
(54) APPARATUS AND METHOD FOR HOT STAMPING OF METAL SHEETS WITH MODULATION OF THE QUENCHING RATE

(57) Described herein are an apparatus (1) and a method for hot stamping of metal sheets (MS) with simultaneous modulation of the quenching rate. The apparatus (1) comprises:
- a first die portion (2);
- a second die portion (4), which defines, upon coupling with the first die portion (2), a die cavity (6) configured to impart a desired shape on a metal sheet (MS) to be subjected to stamping, the die cavity (6) being delimited by walls (2W; 16W) of the first die portion (2) and walls (10W, 12W; 16W) of the second die portion (4);
- a first cooling jacket (8) provided in at least part of the first die portion (2), the first cooling jacket (8) being configured to operate in a relation of heat exchange with the die cavity (6) through at least part of the walls (2W, 16W) of the first die portion (2) that define the die cavity (6);
- a second cooling jacket (14) provided in at least part (10, 12) of the second die portion (4), the second cooling jacket (14) being configured to operate in a relation of heat exchange with the die cavity (6) through at least part of the walls (10W, 12W, 16W) of the second die portion (4) that define the die cavity (6) .

One or more mobile elements (16) are prearranged in at least one of the die portions for modulation of the quenching rate.

FIG. 3



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Description

Field of the invention

[0001] The present invention relates to hot stamping of metal sheets, in particular for the production of bodywork components for motor vehicles.

[0002] The invention has been developed with particular reference to hot stamping with simultaneous quenching of the stamped sheet.

Prior art

[0003] The automobile industry imposes increasingly stringent requirements as regards reduction of the environmental impact and increase in active and passive safety. The first class of requirements entails, *inter alia,* exploring solutions for the reduction of the weight of the vehicle, whereas the second class of requirements generally results in a strengthening of the structure of the motor vehicle, with consequent increase in weight. The apparent conflict between the two requirements is in part solved by technologies of stamping of metal sheets based upon multi-thickness and/or multi-material metal sheets that enable strengthening of the vehicle structure in the most stressed areas and lightening thereof where the structural requirements are less stringent.

[0004] Modulation of the structural strength is carried out also by means of thermal treatment, in particular by means of quenching performed within the die thanks to the provision of multiple cooling channels.

[0005] Control of quenching within the die, in particular control of the quenching rate (i.e., the cooling rate) is far from effective as a result of intrinsic technological limits. There are in fact just a few control variables on which it is possible to act (for example, the coolant flow rate, the distribution of coolant, and the temperature of the coolant), and in any case the global time constants that govern the response of the system are too great to affect significantly the rate of the quenching process and/or to modulate the quenching rate in a specific way with respect to the area of the component that is stamped.

Object of the invention

[0006] The object of the invention is to solve the technical problems mentioned previously. In particular, the object of the invention is to provide for hot stamping of metal sheets simultaneously controlling in an accurate and localized way (i.e., specific for the area of the component that is stamped) the quenching rate thereof.

Summary of the invention

[0007] The object of the invention is achieved by an apparatus and a method having the features forming the subject of the appended claims, which form an integral part of the technical disclosure provided herein in relation to the invention.

Brief description of the drawings

[0008] The invention will now be described with reference to the annexed drawings, provided purely by way of nonlimiting example, and wherein:

- Figure 1 is a partially exploded schematic view of an apparatus according to the invention;
- Figure 2 is a schematic cross-sectional view of the apparatus of Figure 1;
- Figure 3 is a detailed schematic view of a portion of the apparatus according to the invention;
- Figure 4 is a view similar to that of Figure 3, but referring to a different embodiment;
- Figures 5A and 5B correspond to Figures 3 and 4 but illustrate further aspects of the invention; and
- Figure 6 is a schematic cross-sectional view of a further aspect of the invention.

Detailed description

[0009] The reference number 1 in Figure 1 and 2 designates as a whole an apparatus for hot stamping of metal sheets according to the invention.

[0010] The apparatus 1 comprises a first die portion 2 and a second die portion 4, which define, upon coupling with the first die portion 2, a die cavity 6 configured for imparting a desired shape on a metal sheet MS that is to undergo stamping.

[0011] The die cavity 6 is delimited by walls of the first die portion denoted as a whole by the reference 2W and walls of the second die portion denoted as a whole by the reference 4W.

[0012] The first die portion 2 comprises a first cooling jacket 8 provided in at least part of the first die portion itself and configured to operate in a relation of heat exchange with the die cavity through at least part of the walls 2W of the first die portion that define the die cavity 6. In particular, the first jacket 8 comprises a plurality of cooling channels C8 preferably arranged to follow the profile of the wall 2W so as to maximize the efficiency of heat exchange with the die cavity 6, in particular with the metal sheet MA.

[0013] The channels C8 may all be supplied in a uniform way (i.e., all with the same flow rate and the same temperature of the cooling fluid, in particular cooling liquid) or else may be supplied in an independent way individually or in groups.

[0014] This enables assignment of a variable distribution of temperature to the walls 2W that delimit the die cavity 6.

[0015] The second die portion 4 comprises a fixed die portion 10 and a mobile die portion, which in turn includes a pair of pressure bars 12. The number and arrangement of the pressure bars 12, as likewise their shape and the shape of the fixed portion 10, may obviously vary accord-

ing to the component. The pressure bars 12 are mobile along a longitudinal axis Z12 so as to vary the contact pressure on the metal sheet MS during plastic deformation in the cavity 6 so as to govern the flow of material necessary to follow the plastic deformation itself.

[0016] The die portion 4 comprises a second cooling jacket 14 provided in at least part of the second die portion 4 itself and configured to operate in a relation of heat exchange with the die cavity 6 through at least part of the walls of the second die portion that define the die cavity 6, which here in particular comprise the wall 10W of the fixed portion 10 and the wall 12W of the pressure bars 12. In this connection, the jacket 14 comprises a plurality of channels C10 (formed in the portion 10) and C12 (formed in the pressure bars 12) arranged to follow the profile of the surface of the walls 10W and 12W so as to maximize the efficiency of heat exchange with the die cavity 6, especially with the sheet MS.

[0017] As the channels C8, the channels C10 and C12 may all be supplied in a uniform way (i.e., with the same flow rate and temperature of the coolant) or else may be supplied individually or in groups in an independent way so as to assign a variable distribution of temperature to the walls 10W, 12W that delimit the die cavity 6. In this connection, the distribution of temperature can be coordinated with the distribution obtained by means of the channels C8 in such a way that the walls of the die cavity 6 arranged on opposite sides of the sheet MS during stamping have a temperature and a flow rate of the coolant consistent with one another so as to prevent generation of stresses across the thickness of the material as a result of the difference in temperature.

[0018] With reference to Figure 3 and to Figures 5A and 5B, according to the invention at least one between the first die portion 2 and the second die portion 4 comprises one or more mobile elements 16 having an outer surface 16W facing the die cavity 6 and defining a portion of the wall 2W or 10W, 12W that delimits the die cavity. In other words, the outer surface 16W delimits the die cavity 6 together with the surrounding walls 2W or 10W, 12W. As may be noted, the arrangement of the mobile elements 16 may result in the presence thereof only on the die portion 4, only on the die portion 2, or else on both of the die portions according to the needs.

[0019] Each mobile element 16 can be actuated to change the relative position of the outer surface 16W and of the walls 2W or 10W, 12W that delimit the die cavity 6. The mobile elements 16 are preferably provided as sliding blocks mobile in guides provided in the corresponding die portion.

[0020] In one embodiment, each mobile element 16 is housed in a guide 18 provided in the die portion 2, 10 or 12. With reference to Figure 3, the mobile element 16 is operatively connected to a hydraulic actuator 20, which comprises a cylinder 22 slidable in which is a piston 24, which is mechanically connected to the mobile element 16 in order to control sliding of the latter along the guide 18. The actuator 20 can be supplied by means of a hydraulic circuit independent of the circuit that supplies the cooling jackets 8, 14 or else by means of the fluid that supplies the jackets 8, 14 themselves.

[0021] With reference once again to Figures 3, 5A, and 5B, the cylinder 22 is supplied by means of a first operating port 22A and a second operating port 22B that give out upstream and downstream of the piston 24. In particular, entry of fluid through the port 22A and discharge of fluid through the port 22B bring about translation of the piston 24 that causes the mobile element 16 - in particular, the outer surface 16W thereof - to project into the die cavity 6 with respect to the surfaces of the surrounding walls, whereas discharge of fluid through the port 22A and entry of fluid through the port 22B brings about a translation of the piston 24 that causes the mobile element 16 - in particular the outer surface 16W thereof - to move back towards the outside of the die cavity 6 with respect to the surfaces of the surrounding walls.

[0022] With reference to Figure 4, in some embodiments, the mobile elements 16 are driven by means of an actuator 20' of a piezoelectric type. The same considerations already formulated with reference to Figures 5A and 5B apply as regards positioning of the mobile elements 16.

[0023] In both cases, i.e., in the case of embodiments with hydraulic actuation of the mobile elements 16 and in the case of embodiments with piezoelectric actuation of the mobile elements 16, the cooling jacket 8 and/or 14 is provided in part in the mobile elements 16 themselves. In other words, the mobile elements 16 can be traversed by cooling channels C16 that are connected upstream and downstream (in the direction of flow of the coolant in the jackets 8 and/or 14) to the channels C8 and C10, C12. In this connection, with reference to Figure 6, the hydraulic-connection interfaces on the mobile element 16 are conveniently provided in a recessed position on lateral surfaces 16J that are internal to the shape of the surface 16W so as to be able to provide flexible hydraulic connections F between the channels C8 and/or C10 or C12 upstream and downstream of the mobile element 16 and the channels C16 prearranged therein. Moreover envisaged in the schematic representation of Figure 6 is the connection of the piston 24 to the mobile element 16 by means of a piston pin P that fits into the holes of two bosses provided in the mobile element 16, but it remains understood that the mode of connection may be varied according to the needs. In the case of a piezoelectric actuator, the structure of the mobile element 16 remains unvaried, except that there will be envisaged a connection to the piezoelectric actuator 20' instead of the connection to the piston 24.

[0024] Operation of the apparatus 1 is described in what follows.

[0025] The apparatus 1 makes it possible to carry out a modulation of the quenching rate (i.e., of the cooling rate) of the sheet MS when this is subjected to hot stamping in the cavity 6.

[0026] The metal sheet MS is positioned between the

die portions 2 and 4 after being pre-heated to a temperature of 850-900°C (in any case, for steel sheets, a temperature higher than of austenization temperature). The portions 2 and 4 are coupled to define the die cavity 6, thus bringing about plastic deformation of the pre-heated sheet MS according to the shape of the die cavity 6. The pressure bars 12 are brought into contact with the sheet MS so as to govern the flow of material during deformation.

[0027] It should be noted that filling of the die cavity 6 by the deformed sheet MS is not total: there always exists a clearance between the sheet MS and the walls of the cavity 6 that is functional for the plastic deformation itself, and that moreover depends upon the tolerances of the manufacturing process. The mobile elements 16 are preferably positioned in areas where the aforesaid clearance exists in such a way that their action can be facilitated by the presence of the clearance itself. It should be noted that the clearance may be asymmetrical with respect to the two die portions 2, 4, so that it may happen that the sheet MS is in contact with one die portion but not with the other.

[0028] After coupling of the two die portions 2, 4, the cooling jackets 8, 14 are supplied so as to initiate quenching of the material of the sheet MS. Simultaneously therewith, and in a way concurrent with the possible non-uniform distribution of the quenching temperature obtained by independent supply of the channels of the cooling jackets 8, 14, the one or more mobile elements 16 are driven to vary the relative position of the respective outer surface 16W and of the walls that delimit the die cavity 6 so as to vary the pressure of contact between the outer surface 16W and the metal sheet MS in the die cavity 6 and modulate the quenching rate.

[0029] In the case where it is desired to increase the quenching rate in order to increase further the strength of the stamped sheet MS, an extraction motion of the mobile element 16 (or mobile elements 16) concerned will be controlled in such a way that the outer surface 16W thereof projects into the die cavity 6 with respect to the walls of the die cavity adjacent to the mobile element 16. In other words, the contact pressure between the outer surface 16W and the sheet MS is increased (and the local contact pressure between the walls of the die cavity 6 and the sheet MS is in general increased), thus increasing the coefficient of heat exchange between them and hence increasing the quenching rate and favouring formation of a martensitic structure (complete martensite). In the case where the element 16 is positioned in an area where a clearance exists between the sheet MS and the die cavity 6, the effect of increase in the contact pressure due to the element 16 being moved outwards is maximum.

[0030] Instead, if the aim is to reduce the quenching rate, since the specific area of the stamped sheet MS (i.e., the final component) does not present stringent requirements in terms of strength, a retraction of the mobile element 16 concerned will be governed such that the outer surface 16W thereof is brought back towards the outside of the die cavity 6 with respect to the walls of the die cavity adjacent to the mobile element. In other words, the contact pressure between the sheet MS and the mobile element 16 (or mobile elements 16) concerned is decreased, thus reducing the coefficient of heat exchange between them so as to generate a simultaneous reduction in the quenching rate.

[0031] It should hence be noted that the modulation of the quenching rate can occur with an extremely fast response in so far as it mainly depends upon the speed of operation the mobile elements 16, and with localized action thanks to the provision of the mobile elements 16 only in the areas in which modulation of the quenching rate is necessary. Evidently, this result cannot be achieved with the cooling jackets alone - not even by supplying the channels individually in an independent way - in so far as the time constant and the thermal inertia of the system would not allow appreciable effects to be achieved in the extremely short times that characterize the quenching process. The solution according to the invention in this sense separates the modulation of the quenching rate from the phenomenon of heat exchange alone relying on a purely mechanical action, which, as such, is not subject to the dynamics of response of the phenomenon of heat exchange and of the variations that involve this phenomenon.

[0032] Of course, the details of production and the embodiments may be widely varied with respect to what is described and illustrated herein, without thereby departing from the scope of the present invention as defined by the annexed claims.

Claims

1. An apparatus (1) for hot stamping of metal sheets, comprising:

   - a first die portion (2);
   - a second die portion (4), which defines, upon coupling with the first die portion (2), a die cavity (6) configured to impart a desired shape on a metal sheet (MS) that is to undergo stamping, the die cavity (6) being delimited by walls (2W; 16W) of the first die portion (2) and walls (10W, 12W; 16W) of the second die portion (4);
   - a first cooling jacket (8) provided in at least part of the first die portion (2), the first cooling jacket (8) being configured to operate in a relation of heat exchange with the die cavity (6) through at least part of the walls (2W, 16W) of the first die portion (2) that define the die cavity (6); and
   - a second cooling jacket (14) provided in at least part (10, 12) of the second die portion (4), the second cooling jacket (14) being configured to operate in a relation of heat exchange with the die cavity (6) through at least part of the walls

(10W, 12W, 16W) of the second die portion (4) that define the die cavity (6),

the apparatus (1) being **characterized in that** at least one of said first die portion (2) and second die portion (4) comprises one or more mobile elements (16) having an outer surface (16W) defining a portion of wall that delimits the die cavity (6), each mobile element (16) being operable to vary the relative position of said outer surface (16W) and of the walls (2W, 10W, 12W; 16W) that delimit the die cavity (6).

2. The apparatus (1) according to Claim 1, wherein said one or more mobile elements (16) comprise sliding blocks.

3. The apparatus (1) according to Claim 2, wherein each sliding block (16) is housed in a guide provided (18) in the corresponding die portion (2, 4) and is operatively connected to an actuator (20; 20') configured to move the sliding block along said guide (18) .

4. The apparatus (1) according to Claim 3, wherein said actuator (20) comprises a hydraulic actuator (22, 24) .

5. The apparatus (1) according to Claim 3, wherein said actuator (20') comprises a piezoelectric actuator.

6. The apparatus (1) according to Claim 4, wherein said hydraulic actuator (22, 24) is supplied by means of a hydraulic circuit independent of the cooling jacket (8, 14) of the corresponding die portion (2, 4).

7. The apparatus (1) according to Claim 4, wherein said hydraulic actuator (22, 24) is supplied by means of the cooling jacket (8, 14) of the corresponding die portion (2, 4).

8. The apparatus (1) according to Claim 1, wherein each said first cooling jacket (8) and second cooling jacket (14) comprises cooling channels (C8, C10, C12, C16) that can be supplied in an independent way individually or in groups to assign a variable distribution of temperature to the walls that delimit said die cavity (6).

9. A method for modulating the quenching rate in hot stamping of metal sheets (MS) by means of an apparatus (1) according to any one of the preceding claims, comprising:

- positioning a pre-heated metal sheet (MS) in a position comprised between said first die portion (2) and said second die portion (4);
- coupling the first die portion (2) to the second die portion (4) to define the die cavity (6), wherein said coupling brings about a plastic deformation of the pre-heated metal sheet (MS) according to the shape of the die cavity (6);
- supplying said first cooling jacket (8) and said second cooling jacket (14) to bring about quenching of the metal sheet (MS) in the die cavity (6); and
- operating said one or more mobile elements (16) to vary the relative position of the respective outer surface (16W) and of the walls that delimit the die cavity so as to vary the pressure of contact between the outer surface (16W) and the metal sheet in the die cavity (6) in order to modulate the quenching rate.

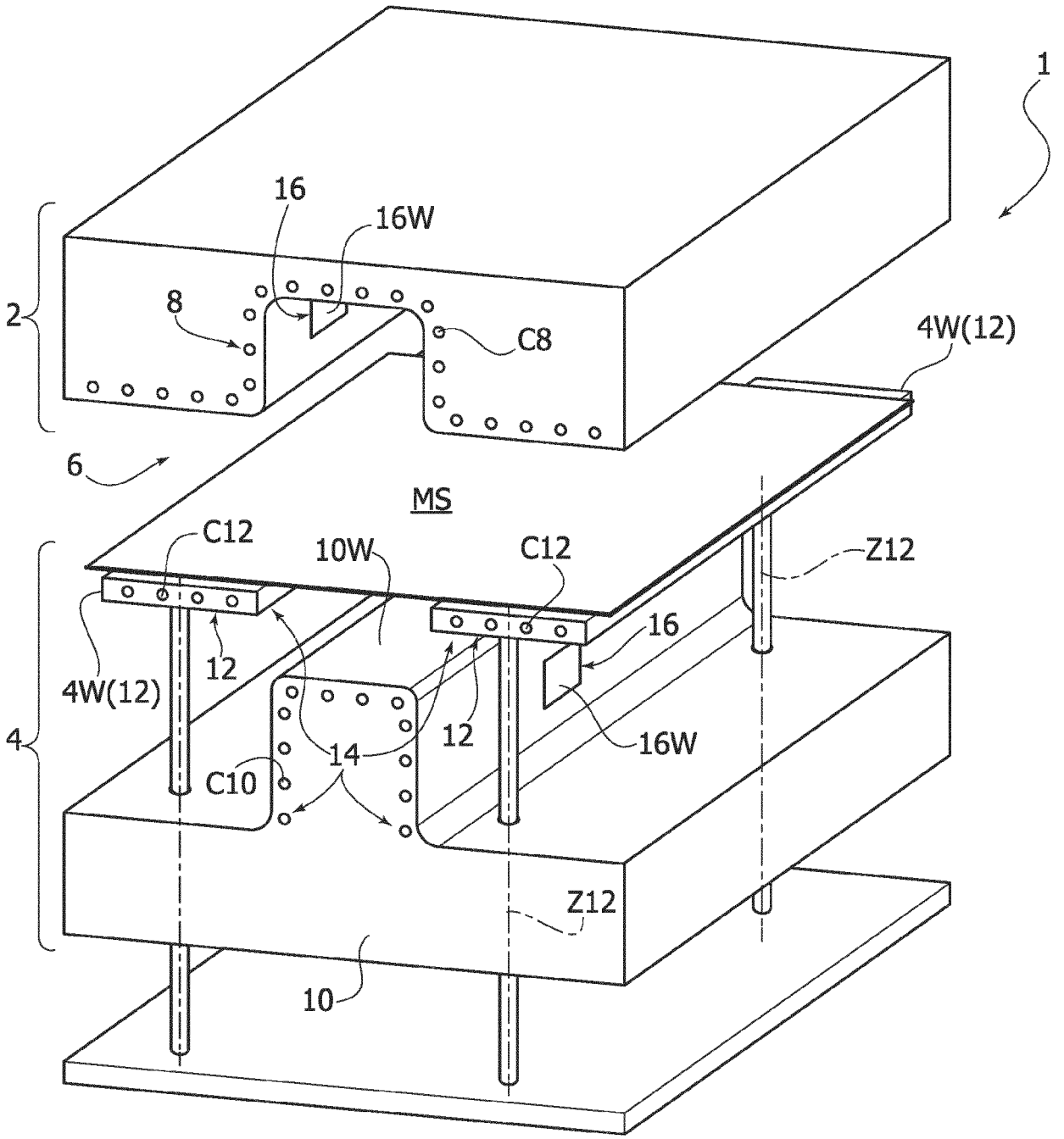
10. The method according to Claim 9, wherein said supplying the first cooling jacket (8) and the second cooling jacket (14) comprises supplying the respective cooling channels (c8, C10, C12, C16) in an independent way individually or in groups to assign a variable distribution of temperature to the walls that delimit said die cavity (6).

11. The method according to Claim 9 or Claim 10, wherein said driving the one or more mobile elements (16) comprises governing its/their movement outwards so that the outer surface (16W) thereof projects into the die cavity with respect to the walls of the die cavity adjacent to the mobile element (16) concerned in order to increase the quenching rate.

12. The method according to Claim 9, or Claim 10, or Claim 11, wherein said driving the one or more mobile elements (16) comprises controlling a retraction thereof so that the outer surface thereof is brought back towards the outside of the die cavity (6) with respect to the walls of the die cavity (6) adjacent to the mobile element (16) involved in order to reduce the quenching rate.

13. The method according to either Claim 11 or Claim 12, wherein driving said one or more mobile elements (16) is simultaneous with supply of the first cooling jacket (8) and of the second cooling jacket (14) .

FIG. 1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2
16
16W
8
C8
4W(12)
6
MS
C12
10W
C12
Z12
4W(12)
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4
C10
14
12
16W
Z12
10

FIG. 2

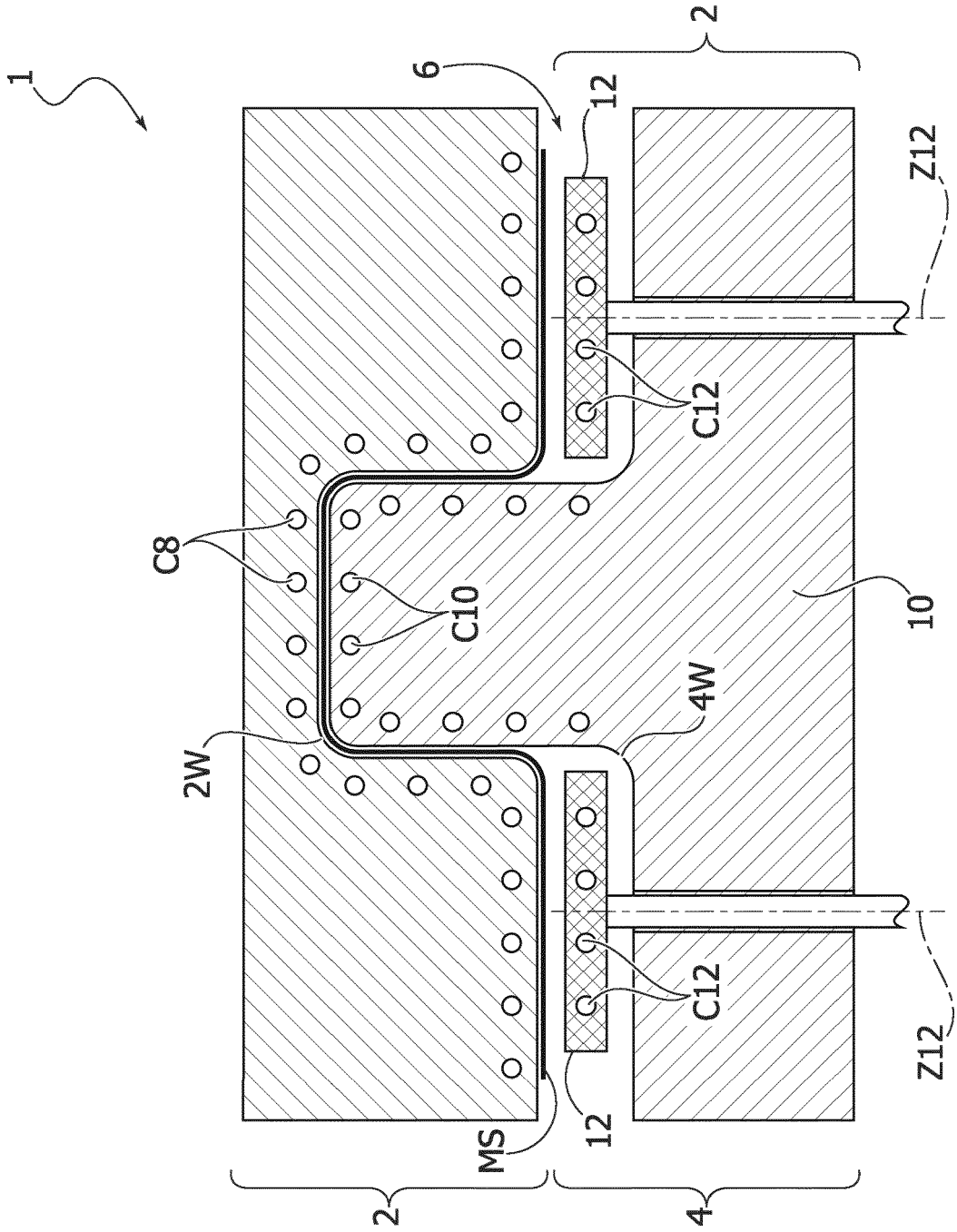
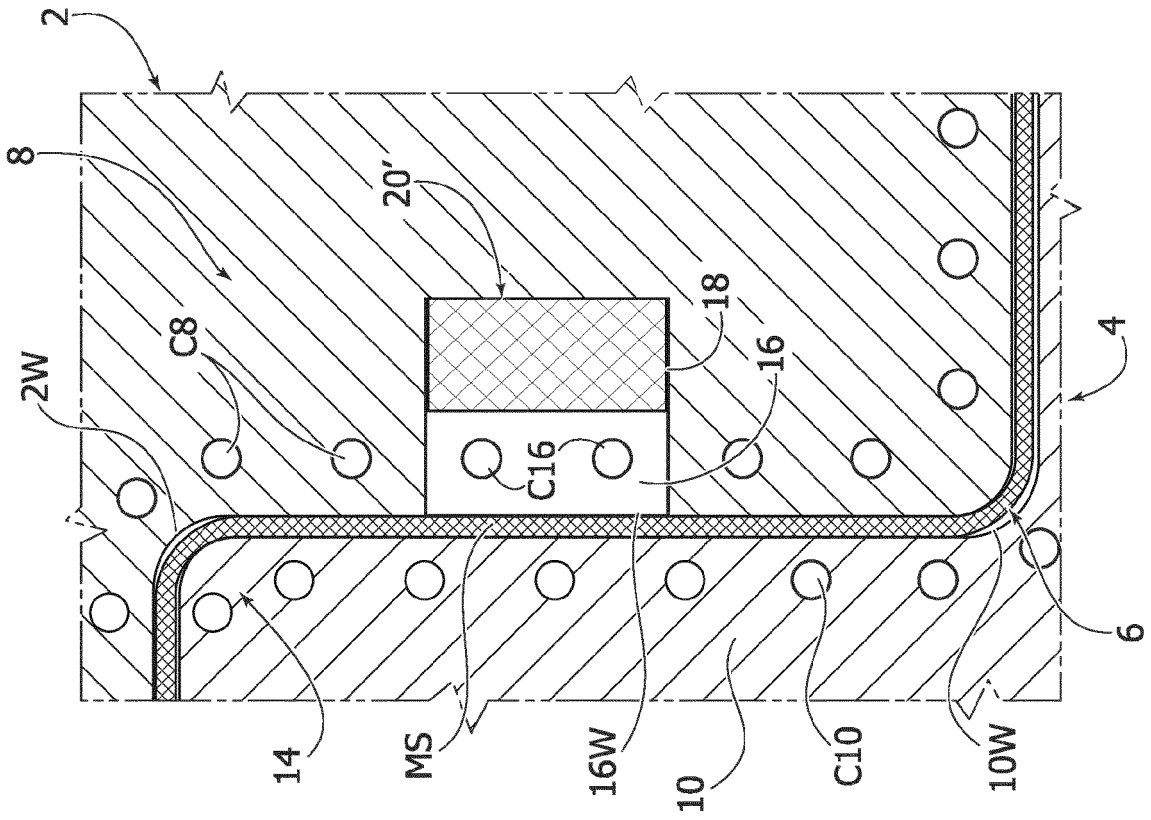


FIG. 4


2
8
20'
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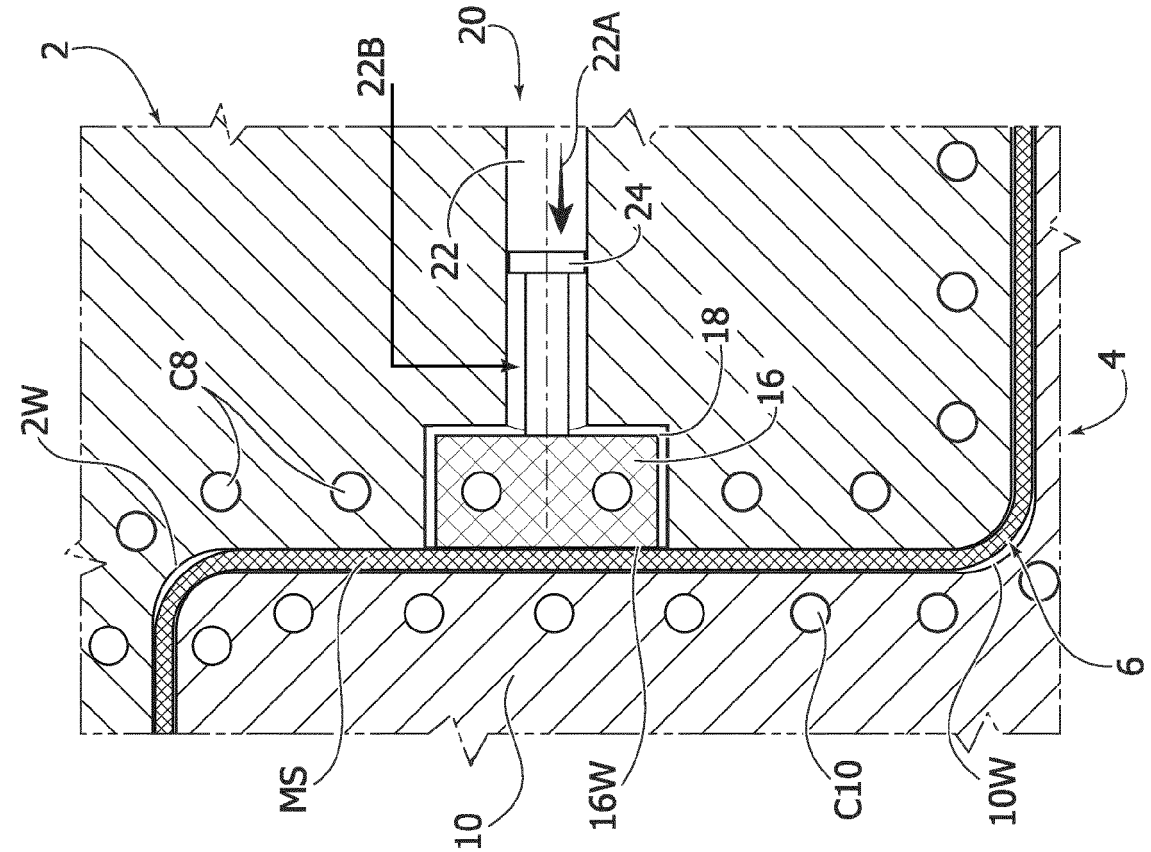
16
C8
2W
4
C16
6
14
MS
16W
10
C10
10W

FIG. 3


2
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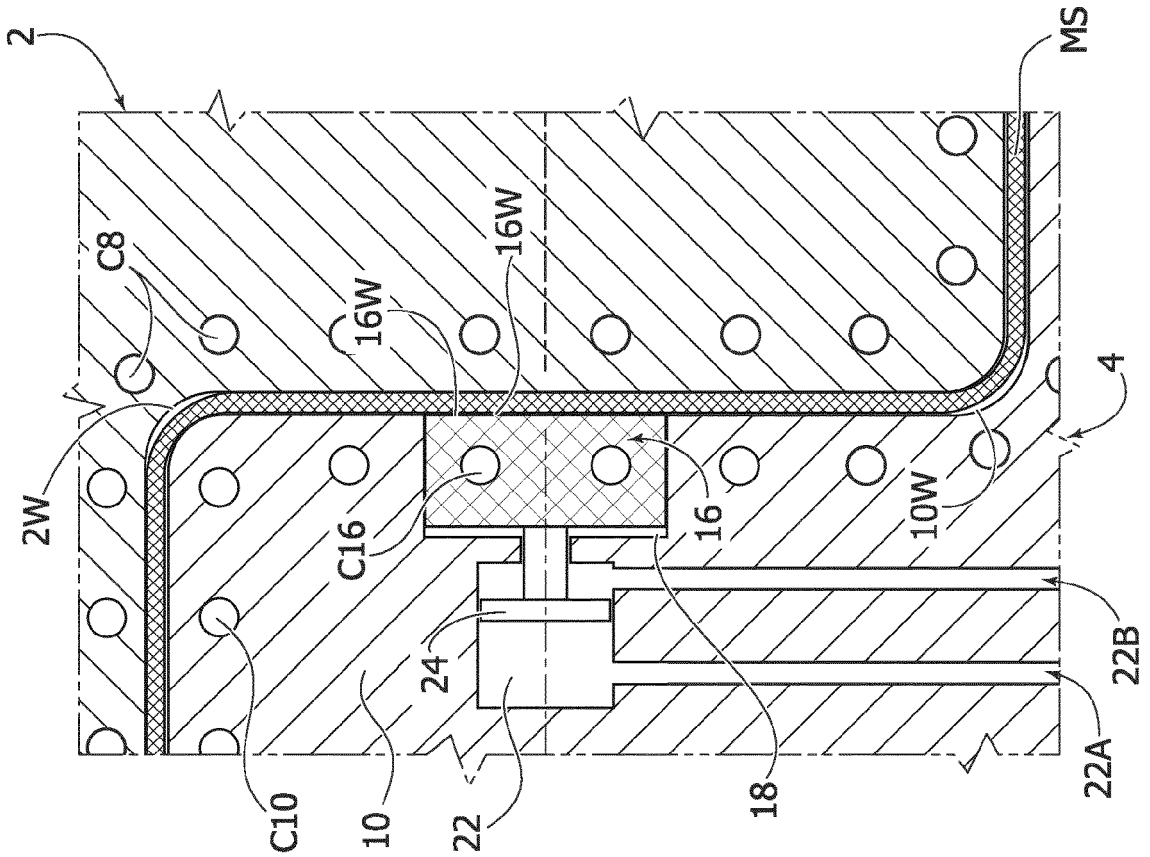
24
18
16
C8
2W
4
6
MS
10
16W
C10
10W

FIG. 5B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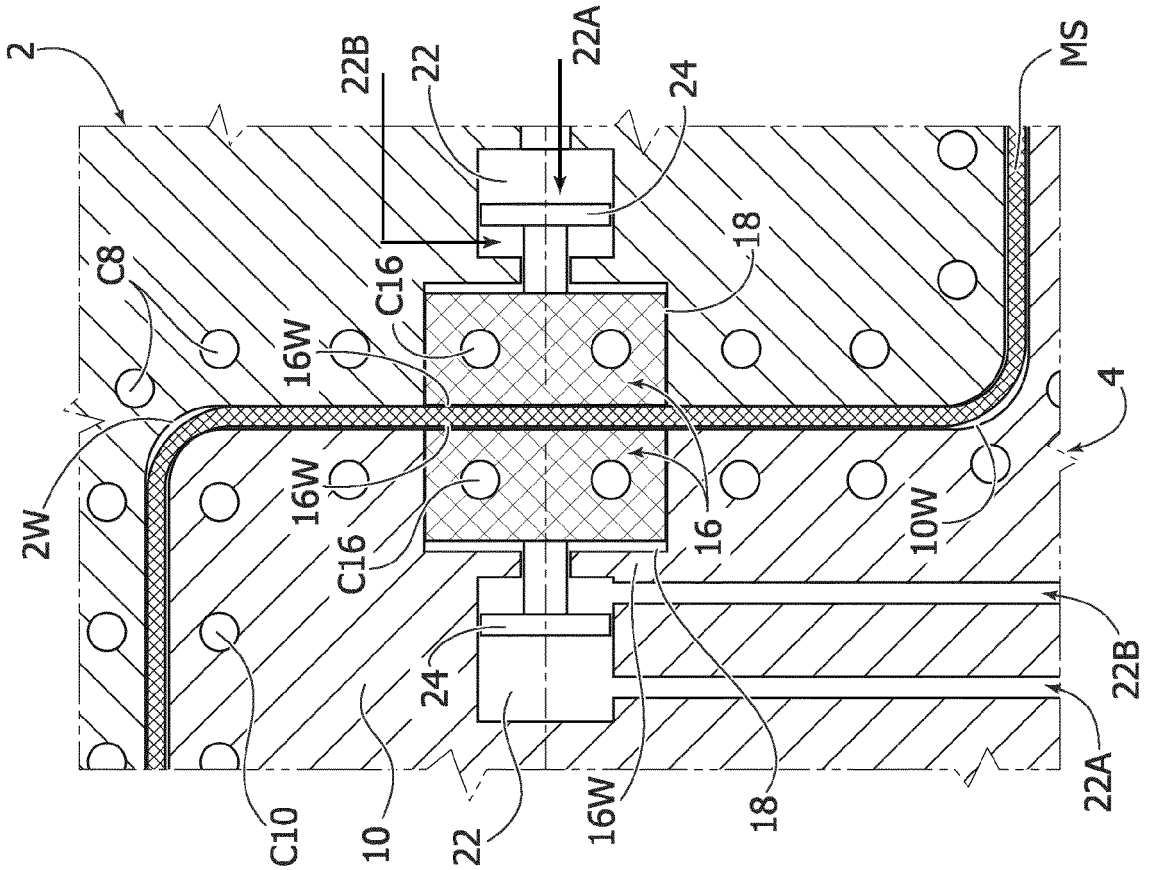
MS
C8
16W
16W
4
2W
C16
16
10W
22B
24
22A
C10
10
22
18

FIG. 5A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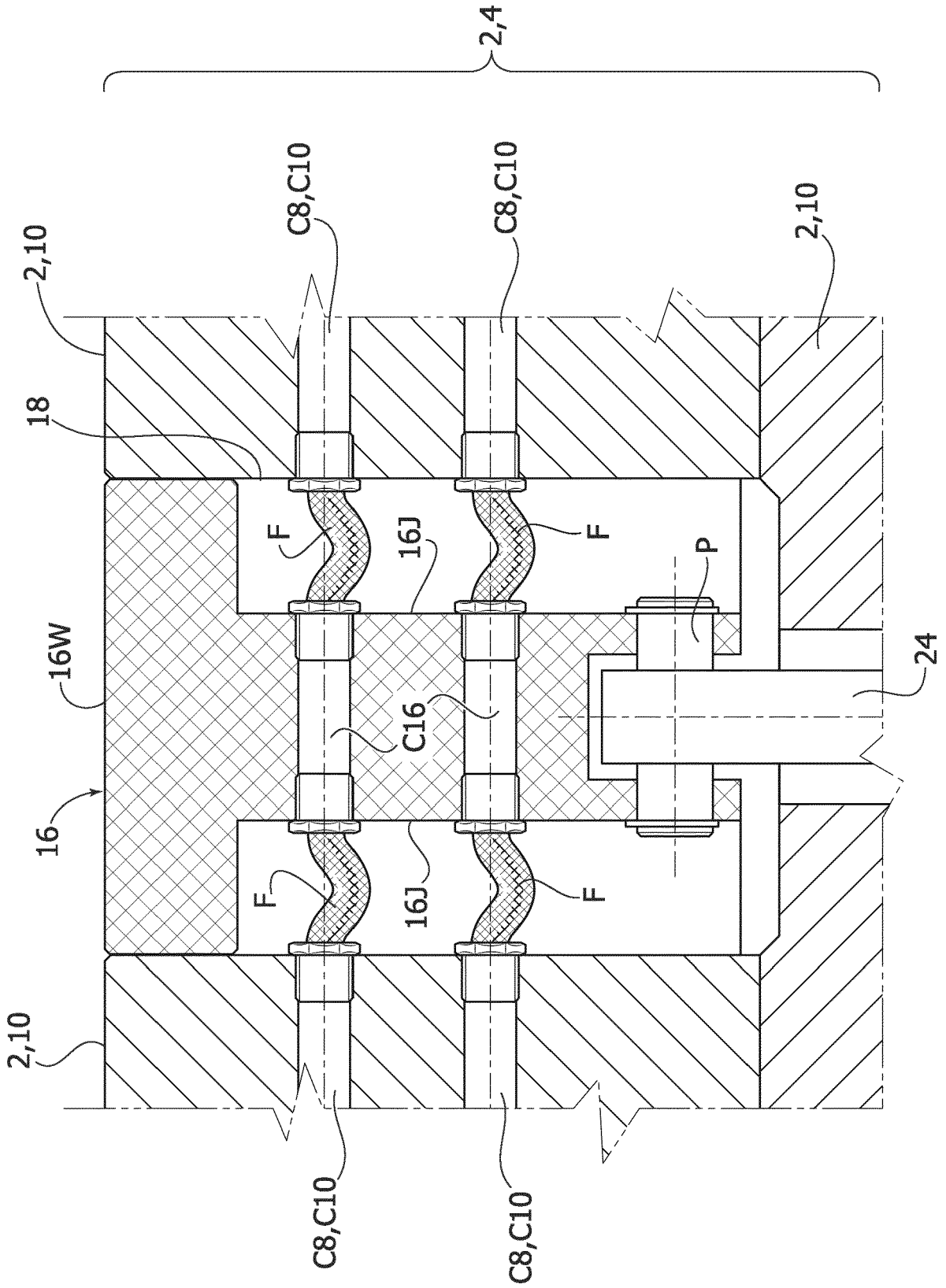
22A
C10
10
22
16W
18

FIG. 6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EUROPEAN SEARCH REPORT

Application Number
EP 21 15 3409

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TECHNICAL FIELDS SEARCHED (IPC)
B21D C21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	28 June 2021	Vassoille, Philippe

CATEGORY OF CITED DOCUMENTS

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