

(19)



(11)

EP 3 988 731 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.04.2022 Bulletin 2022/17

(21) Application number: **21187146.2**

(22) Date of filing: **22.07.2021**

(51) International Patent Classification (IPC):
E04B 2/62 (2006.01) **E04C 3/04** (2006.01)
E04C 3/08 (2006.01) **E04C 3/29** (2006.01)
E04B 2/74 (2006.01) **E04B 1/76** (2006.01)

(52) Cooperative Patent Classification (CPC):
E04C 3/04; E04B 2/62; E04B 2/7412; E04C 3/08;
E04C 3/291; E04B 2001/7679; E04C 2003/0413;
E04C 2003/0465; E04C 2003/0473

(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
 Designated Validation States:
KH MA MD TN

(30) Priority: **23.07.2020 GB 202011449**

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(54) **FAÇADE CONSTRUCTION USING THROUGH WALL THERMAL STUD**

(57) The present invention relates to a stud assembly for passing through a cavity wall, said stud assembly comprising: a quadrilateral plate comprising perforations, said plate comprising two opposing faces and four edges; an internal angle (13) for attaching to a first edge of the plate and also for attaching to an internal portion of a wall; an external angle (14) for attaching to a second edge of the plate and also for attaching to an external portion of the cavity wall; wherein the first edge and the second edge correspond to opposite edges of the quadrilateral plate. The stud assembly is prismatic and designed to be capable of being located by a robot and welded together by a robot. Therefore, the stud assembly may form a wall system suitable for automated manufacture.

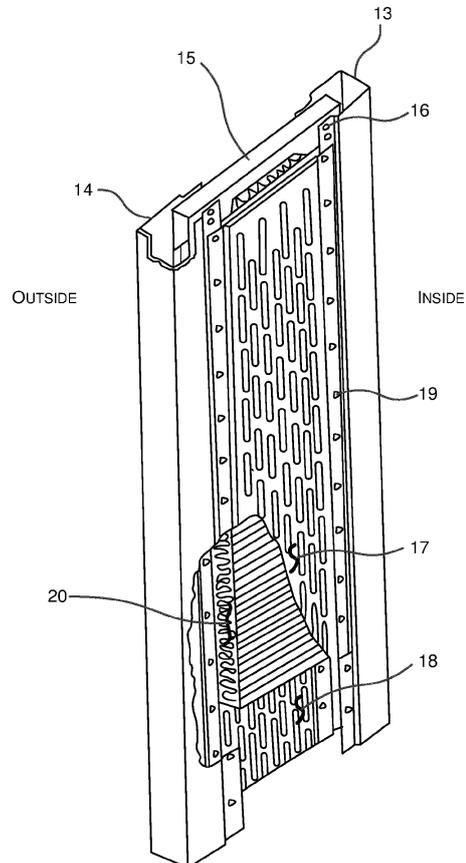


FIG. 2

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Description

[0001] The present disclosure relates to the construction of a wall, in particular, a wall for a building.

BACKGROUND

[0002] Buildings have an external envelope designed to keep weather and noise out whilst keeping heat in. The vertical elements of this envelope are called the façade. In low rise buildings, the façade is often integral with the structure of the building (e.g., brickwork), but in multi-storey building the façade is usually a panelised system attached to the edge of the building frame.

[0003] A facade may be split into different layers through its thickness. The two main layers are cladding, which gives the building its appearance and is the first line of defence against weather, and the wall structure that contains all the structure, insulation and membranes necessary to ensure the technical performance of the wall system.

[0004] There are a number of ways of differentiating façade systems from one another; whether they are substantially built in-situ at the construction site, whether they are delivered to the construction site as integrated units; whether they are predominantly glazed (curtain walling), or are dominated by large solid areas of e.g., brickwork, render, rainscreen, the solid areas being punched through by window and door openings; whether they incorporate the means of attaching balconies, or must fit around a separate balcony mounting system; whether they are designed for automated manufacture, or whether the design necessitates a high level of manual assembly; whether they can stack from the ground up such that only nominal vertical load is transferred to the building frame, or they are attached at each floor level such that the building frame takes the façade loads; whether they incorporate all the through elements of a wall construction such that everything is installed in one go, or there are several different elements to be installed in different stages; whether they are accurate enough to permit the cladding layer to be pre-installed; or whether the final cladding layer needs to be site fixed.

[0005] The examples described herein are not limited to examples which solve problems mentioned in this background section.

SUMMARY

[0006] Examples of preferred aspects and embodiments of the invention are as set out in the accompanying independent and dependent claims.

[0007] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0008] In a first aspect of the present invention, disclosed is a stud assembly for passing through a cavity wall, said stud assembly comprising: a quadrilateral plate comprising perforations, said plate comprising two opposing faces and four edges; an internal angle for attaching to a first edge of the plate and also for attaching to an internal portion of a wall; an external angle for attaching to a second edge of the plate and also for attaching to an external portion of the cavity wall; wherein the first edge and the second edge correspond to opposite edges of the quadrilateral plate.

[0009] Preferably, the quadrilateral plate is formed as a two-quadrilateral plate construction whereby each of the two quadrilateral plates comprise perforations and are positioned substantially parallel to one another and are separated by a gap, and the internal angle and external angle are an internal channel and external channel, respectively. The use of perforations causes the heat path to be simultaneously lengthened and narrowed resulting in significantly reducing the amount of heat that can be transferred through the perforated plate relative to a solid plate.

[0010] Further preferably, the stud assembly further comprising an end channel substantially perpendicular to the other two edges (e.g. the short edges if the plate is rectangular) of the plates so as to attach the internal angle to the external angle.

[0011] Preferably, the perforations are elongate perforations. Preferably, a plurality of the elongate perforations each comprise a bulbous end. Preferably, the perforations form an interlocking pattern. Further preferably, the interlocking pattern is a chevron interlocking pattern. Preferably, the stud assembly further comprising a flange protruding from at least one of the two faces of the plate at a perimeter of at least some of the perforations.

[0012] Preferably, at least one of the external angle or internal angle comprises a joggle offset where the angle meets the outside edge or the inside edge, respectively. Further preferably, the joggle offset is at least the thickness of one of the two plates. Further preferably, at least one of the first edge or second edge comprise a joggle offset where the first edge or second edge meet the channel.

[0013] Preferably, the stud assembly further comprising: a first beam connector for attaching a portion of the internal angle to an upper beam; and a second beam connector for attaching a different portion of the internal angle to a lower beam.

[0014] In another aspect of the present invention, disclosed is a wall protrusion bracket apparatus for transferring loads from a wall projection into a load-carrying structure of a building, the apparatus comprising: a vertical-beam assembly, of length x running from a lower load carrying structure to an upper load carrying structure and formed by two vertical-beam flange sections and a connecting plate, the first vertical-beam flange being to the internal face of a cavity wall; a moment-resisting attachment bracket for connecting the vertical-beam as-

assembly to a wall projection, said attachment bracket comprising: a plate of length y fixedly attached to a second flange section of the vertical-beam; and at least one rod passing through the plate and the second flange section, said at least one rod is at least partially threaded. Preferably, the apparatus further comprises an insulation layer between the vertical beam assembly and the wall projection. Preferably, the vertical beam assembly further comprises two angle beams of length $x - y$ fixedly attached to the vertical-beam at the second flange section of the I-beam so as to form a cage for the attachment of an external cladding system. Preferably, the apparatus further comprises a connection on at least one of the ends of the vertical beam. Preferably, each of the two angles are attached to the vertical beam by at least two brackets. Preferably, the apparatus further comprises an elongate plate between two or more brackets, the brackets attaching an angle beam to the vertical beam, said elongate plate for transferring vertical cladding loads from the angle beam to the vertical-beam. Further preferably, the apparatus comprises a stiffener plate between the two flange sections positioned along an upper or lower edge such that the attached plate bracket abuts the vertical-beam on the opposite side of the second flange section. Preferably, the moment-resisting attachment bracket further comprising an insulating block attached to the attachment plate by the at least two rods such that the plate is sandwiched between the insulating block and the second flange section. Preferably, a space in the cage formed between the two angle beams and the second flange section comprises insulation.

[0015] In another aspect of the present invention, disclosed is a panel-based cavity wall system for use in a building comprising top and bottom beams; comprising: a stud assembly for extending between a top beam and a bottom beam; and a moment-resisting bracket apparatus for extending between the top and the bottom beam

[0016] Preferably, the system further comprises at least two insulation batts in thermal contact with the stud assembly, one of the insulation batts positioned at an internal portion of a cavity wall and the another of the insulation batts positioned at an external portion of the cavity wall. Further preferably, the system further comprises a spacer to separate the at least two insulation batts at either side of the cavity wall. Further preferably, the system further comprises a structural column extending between the top beam and the bottom beam.

[0017] In another aspect of the present invention, disclosed is a wall system for use in a building, comprising: the stud assembly as described above; a concrete slab at an external portion of a wall, the concrete slab comprising a supporting steelwork configured to form a frame with the stud assembly; wherein the stud assembly is at least partially embedded within the concrete slab; and wherein the external angle/channel of the stud assembly comprises tabs and/or concrete-admitting holes so as to improve anchorage of the concrete slab.

[0018] As many of the vertical elements summarised

above, e.g. the stud, the wall projection bracket apparatus, the end post, etc., are essentially prismatic, they are capable of being located by a robot and welded together by a robot. Therefore, the wall system is inherently suitable for automated manufacture.

[0019] It will also be apparent to anyone of ordinary skill in the art, that some of the preferred features indicated above as preferable in the context of one of the aspects of the disclosed technology indicated may replace one or more preferred features of other ones of the preferred aspects of the disclosed technology. Such apparent combinations are not explicitly listed above under each such possible additional aspect for the sake of conciseness.

[0020] Other examples will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the disclosed technology.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 illustrates a plan section through a length of the wall system.

FIG. 2 illustrates components capable of being comprised by the thermal stud.

FIG. 3 illustrates an elevation on a thermal stud fixed to an upper and lower beam.

FIG. 4 illustrates a wall frame.

FIG. 5 illustrates an isometric view of a typical joint used to form an aperture between thermal studs.

FIG. 6 illustrates a section through two thermal studs that meet perpendicular to one another.

FIG. 7 illustrates a variation on the construction of the thermal stud.

FIG. 8 illustrates an exemplary perforated plate.

FIG. 9 illustrated an outside view of a wall panel local to an aperture corner.

FIG. 10 illustrates an exemplary means of varying the length of a thermal stud.

FIG. 11A and 11B illustrates an exemplary solution to prevent buckling of a thermal stud.

FIG. 12A and 12B illustrate the arrangement of an end post and a cross-section through the end post, respectively.

FIG. 13A and 13B illustrate a wall panel at the location of a wall protrusion bracket.

FIG. 14 illustrates a typical wall protrusion bracket from various views.

FIG. 15 illustrates a cross sectional view through a wall protrusion bracket.

FIG. 16 illustrates an apparatus whereby the thermal stud is embedded within a concrete slab.

[0022] The accompanying drawings illustrate various examples. The skilled person will appreciate that the illustrated element boundaries (e.g., boxes, groups of box-

es, or other shapes) in the drawings represent one example of the boundaries. It may be that in some examples, one element may be designed as multiple elements or that multiple elements may be designed as one element. Common reference numerals are used throughout the figures, where appropriate, to indicate similar features.

DETAILED DESCRIPTION

[0023] The following description is made for the purpose of illustrating the general principles of the present technology and is not meant to limit the inventive concepts claimed herein. As will be apparent to anyone of ordinary skill in the art, one or more or all of the particular features described herein in the context of one embodiment are also present in some other embodiment(s) and/or can be used in combination with other described features in various possible combinations and permutations in some other embodiment(s).

[0024] The present invention described below may form at least part of a façade construction system that enables integrated panels with wall-through elements to be manufactured in a substantially automated manner. In some aspects, the façade construction system may include provision for up to 60% glazing area, brackets for wall protrusion attachments/brackets and an ability to either be supported from the building frame or stack supported from the ground. The system meets required standards in terms of fire safety, acoustic isolation, air tightness and thermal performance.

[0025] The present invention, in some aspect, relates to at least part of a modular wall system for use on the outside face of a building. The system enables a high level of automation in manufacture and can be rapidly installed on site. The wall system comprises top and bottom horizontal beam elements tied together by vertical elements comprising any of the following: stud(s), end post(s), and/or balcony bracket(s).

[0026] A stud passes through the thickness of a wall from the external face of an internal cavity to the internal face of an external cavity. In some aspects, the stud comprises a perforated plate. The perforated plate is preferably a quadrilateral shape, e.g. rectangular. A first edge (e.g. a first long edge) of the plate is attached to an internal portion of a cavity wall by way of an internal angle and a second edge (e.g. a second long edge) of the plate is attached to an external portion of the cavity wall by way of an external angle. The first and second edge correspond to opposite edges of the plate, e.g. two opposing edges of a rectangular plate.

[0027] Preferably, perforations of the perforated plate are elongate in shape and run parallel to the first edge (e.g. the first long edge) of the plate. Alternate rows of perforations may be staggered by half a perforation pitch such that heat transfer from one long side to the other via the plate must "zigzag" around the perforations. This causes the heat path to be simultaneously lengthened

and narrowed resulting in significantly reducing the amount of heat that can be transferred through the perforated plate relative to a solid plate.

[0028] In some cases, the plate (sometimes referred to as a "web") is formed as a two-plate construction whereby each of the two plates comprise perforations and are substantially parallel to one another. In the two-plate construction, the two plates may be separated by a gap (the gap typically being between 10 mm and 100 mm, preferably between 25 mm and 50 mm). In the case of a two-plate construction, each of the two plates at a first side are attached to an internal portion of the cavity wall by way of an internal angle (i.e. there are two internal angles), and each of the two plates at a second side are attached to an external portion of the cavity wall by way of external angle (i.e. there are two external angles). As an alternative to the stud comprising two internal angles and/or two external angles to facilitate a two-plate construction, the stud may alternatively comprise an internal channel and/or an external channel, respectively. Although an internal angle or external angle can be used, the remainder of the description refers to internal and external channels, along with a two-plate construction, for the sake of clarity and consistency. However, a person skilled in the art would understand a single plate construction is equally suitable.

[0029] Figure 1 shows a plan section through a short length of a wall system. The stud assembly 1 runs across the wall section. Insulation batts 2 may be placed on each side of the stud 1. In some aspects of the present invention, the wall system comprises spacing 3 between the insulation batts to enhance acoustic performance and helps keep moisture on the outside. Spacers 4 may be employed to set and maintain the spacing 3.

[0030] In some aspects of the present invention, the inner insulation 2 is covered by foil faced membrane 5. A continuous fillet-strip 6 may be attached by screws 7 to the stud 1 so as to trap membrane 5 and hold it in place. In some aspects of the present invention, the fillet strip is any continuous spacer. Preferably, the fillet strip comprises a non-combustible material such as gypsum. In other aspects, the fillet strip is made of wood, i.e. a batten. In some aspects of the present invention, a non-combustible board 8 is fixed to the fillet-strip 6, creating cavity 9. Board 8 forms the internal surface of the wall. Cavity 9 may be used to run and fit services, e.g. electrical wiring. The foil-faced membrane 5 faces into cavity 9, and preferably, the membrane 5 is fixed and sealed at all edges to ensure the wall is airtight, i.e., air and vapour cannot cross into the insulation 2. Membrane 5 has the properties of blocking the passage of water vapour and air. The foil type of membrane 5 is further selected to be highly reflective. In combination with cavity 9, the foil-faced membrane contributes approximately 10% of the wall's thermal insulation.

[0031] To the outside portion of the wall system, i.e. the external portion of the wall, the insulation 2 is covered by a breather membrane 10. Breather membrane 10 is

trapped between a horizontal rail 11 and stud 1 wherever these items cross, helping to hold membrane 10 in position. Breather membrane 10 is further secured at all edges. Breather membrane 10 has the properties of preventing the passage of liquid water but allowing the passage of water vapour. In some aspects of the present invention, the horizontal rail 11 is fixed to stud 1 by screws 12, e.g. pan head screws. Horizontal rail 11 may be perforated in order to maintain at least 50% continuity of the vertical cavity to the outside of the breather membrane.

[0032] Figure 2 shows the main components of the top half of a stud 1. In figure 2, the perforated plate 17/18 is shown as a two-plate construction. Therefore, rather than internal angle for attaching one edge of the plate to internal portion of the cavity wall, and an external angle for attaching the opposite edge of the plate of the external portion of the cavity wall, the stud 1 comprises internal channel 13 for attaching the one edge of each of the two-plates to the internal portion of the wall and an external channel 14 for attaching the opposite edge of each of the two plates to the external portion of the wall. The two plates 17/18 are attached to the formed channels 13, 14 by a connection means, e.g. by rivets 19. The space formed between the two plates may comprise an insulating material 20. In some aspects of the present invention, the channels 13, 14 are connected to end channels 15 at the top and bottom by a connection means, e.g. rivets 16.

[0033] Internal channel 13 is located to the inside of a wall system, and it may be made of any metal having the appropriate strength and stiffness characteristics, e.g. ferritic steel. External channel 14 is located to the outside of a wall system. This may be subject to wetting and drying and hence needs to be made from a metal that does not corrode in normal atmospheric conditions. In some aspects of the present invention, the end channels 15 cross from inside to outside of the cavity wall. To reduce the conduction of heat along the end channels, it is made of a non-corroding metal with a low heat of conduction, for example, austenitic stainless steel. The perforated plate 17, 18 also crosses from inside to outside (when attached to the internal and external angles/channels). Heat conduction is reduced by making the plate thin, keeping the heat path long and using a metal with low thermal conductivity. Since the plate is thin and crosses to the outside, it must be from a corrosion resistant material. Rivets 16, 19 must be from materials that are galvanically compatible with the other elements. Stainless steel is typically used for all components. The internal and external angles/channels 13,14 and perforated plate(s) 17,18 are preferably made from ferritic stainless steel; The end channel 15 and rivets 16,19 are preferably made from austenitic stainless steel. The insulating material 20 is a preferably a mineral wool batt.

[0034] Figure 3 shows an elevation on a stud 1 fixed to an upper beam 21 and lower beam 22. The thermal stud 1 may be attached directly to beams 21, 22, however since the stud is typically made from stainless steel and

the beams 21, 22 are typically carbon steel, galvanic isolation is required. Connectors 23, 24 achieve this isolation. In certain forms of construction, the upper beam 21 may move down relative to lower beam 22. In this scenario, it is necessary for one of the connectors to incorporate a sliding action. This would typically be upper connector 24. Connectors 23, 24 can be located a fixed distance 25 from the end of the stud. The maximum value of distance 25 is determined by the relative stiffness of the internal channel 13 and the transverse buckling resistance of perforated plates 17, 18. The stud 1 is required to transfer forces (shown as references 26 and 27 in figure 3) to upper and lower beams 21, 22. Force 26 typically arises from the weight of any cladding system attached to the outside of the stud. Force 27 typically arises from wind pressure. Stud 1 is designed to be stiff so that forces are transferred with minimal deflection of the internal face attaching to internal channel 13.

[0035] Figure 4 shows a view of a wall frame. Upper beam 21, lower beam 22 and end posts 28 are connected to form a frame. Studs 1 are inserted into the frame and fixed top and bottom as shown in figure 3. The end posts 28 may be structural where load carrying capacity is required. Where full height openings are required, e.g. to form doors out onto a balcony, then a moment-resisting bracket 29 is fitted into the frame. Where reduced height openings are required, e.g., to form windows, then studs 1 of a variety of lengths are combined in order to form an aperture assembly 30. Typical maximum horizontal spacing of vertically oriented elements within a frame is 600mm.

[0036] Figure 5 shows an isometric view of a typical perpendicular (or substantially perpendicular) joint used to form an aperture opening from studs. The optional insulation 20 has been omitted for clarity. The connection may be made using welding 31 or an angle cleat 32 and fixing means (e.g. screw 33). Apertures are typically lined with boards 34. Boards may be affixed to the internal and external channels 13, 14 by a fixing (e.g. screws 35). The boards 34 are typically used for fixing to window and door frames. The boards 34 reinforce the stud 1 at locations of concentrated forces. Additionally, boards 34 provide a backing to internal and external membranes required to control vapour and moisture.

[0037] Figure 6 shows a part section through a vertical stud where it connects to a horizontal stud. External channels 14 butt up to each other to enable welding 31. It is necessary that fixings (e.g. rivets 16, 19) do not protrude beyond joining line 36 else they may interfere with the coming together of the external channels 14. Joining line 36 is coincidental with the external face of the wall and the external channel 14. To allow for the rivet head the external channel 14 may comprise a joggle offset 37. As shown in figure 6, it will be apparent that the offset of the joggle 37 is a function of the height of the rivet head 19 such that the rivet head (or any other fixing) does not protrude beyond the joining line 36.

[0038] To reduce thermal convection paths through a

wall, it is preferable that any gap associated with joining line 36 is reduced to a minimum. The outer surface of the perforated plate(s) 17, 18 is/are set to be flush with joining line 36 by a counter joggle offset 38. The offset dimension of counter joggle offset 38 is the offset of joggle offset 37 minus the thickness of the perforated plate 17,18.

[0039] Figure 6 shows a thermal stud with a two-plate 17,18 construction jointed to external channel 14 using fixings (e.g. rivets 19). There are other ways of jointing the perforated plates 17,18 to the internal and external channels 13, 14.

[0040] Figure 7 shows an alternative construction of the stud 1 which is also within the scope of the present invention. In this case, the external and/or internal channels 13,14 are formed without a joggle offset 37. The Perforated plate 17, 18 is shown jointed to the internal/external channel using a laser weld 39. Alternatively, the perforated plate 17, 18 is shown jointed using a resistance weld 40. Note that where a flush finish weld is used, there is no need for counter joggle offset 38 in the perforated plate(s). This requires that the thickness of the perforated plate is sufficiently small that the gap created during fit-up along joining line 36 can be welded over.

[0041] A key feature of thermal stud 1 is the perforated plate(s) 17,18. A short length of plate is shown in more detail in figure 8.

[0042] In some aspects, the perforated plate(s) 17, 18 is/are necessarily made from thin metal to minimise the amount of heat transmitted from inside to outside (top to bottom as drawn in figure 8). Such metal will be prone to out-of-plane buckling under the application of in-plane compression or shear stress, as would arise from forces 26 and 27 shown in figure 3. The perforated plate(s) can be stiffened considerably by forming the thin metal out of the plane.

[0043] Another method to reduce heat flow from an inside portion of a wall to an outside portion of the wall across the plate(s) is to increase the length of the flow path and reduce the flow path width. In some aspects, this is achieved by elongate perforations 41. By staggering the perforations, i.e. the arranging the perforations such that they form an interlocking pattern, the heat flow path 42 (shown as a dotted line) is increased significantly in length. The longer the perforations 41 and the closer their centreline spacing 43, the longer and narrower the heat flow path 42 will be.

[0044] It will be apparent that as perforation length 45 is increased and spacing 43 is reduced, there is reduced resistance to out-of-plane buckling. This is exacerbated by a reduction in a formed depth 44 (fig 8, section B) resulting from less material being available for forming as spacing 43 reduces. The formed depth 44 may also be described as a flange protruding from at least one face of the plate(s) at a perimeter of at least some of the perforations. Through analysis, a working combination of spacing 43, formed depth 44 and perforation length 45 has been found that satisfies the requirements of ther-

mal conduction and buckling resistance/strength. This is based on a given material thickness and metal properties.

[0045] In some aspects, one or more of the following features can be included in the forming of the perforated plate to improve performance:

[0046] A free edge 46 at each end of the plate that has been joggled (i.e. has a joggle offset) to increase out-of-plane stiffness and reduce the tendency for a buckle to initiate at this location; an end width 47 between free edge 46 and the end of perforations 41 that has been set to the minimum necessary to allow forming of the perforations and stability of the free edge 46. Since this end width results in a short heat flow path, it's dimension must be minimised to reduce heat flow; the perforations are elongate perforations such that they have a width along the face of the plate that is different to their height along the face of the plate; the perforations 41 have been provided with a bulbous end 48. Allowing for the real radius associated with forming the perforations, coupled with material strain hardening, the bulbous ends 48 may form a lightly interlocking pattern such that a straight-line buckle about the plane long axis is resisted. It should be noted that there are various ways of providing an interlocking pattern, chevrons being another option.; when forces are applied to the plate, the result is to induce in-plane bending stresses within the plate. Sharp changes in stress direction, e.g., as happens at the ends of the perforation 41, results in increased stresses due to stress concentration. Bulbous end 48 increases the radius at these critical points, reducing the peak magnitude of the stresses that may arise due to wind pressure forces 27 (as shown in figure 3. They are dynamic by nature and any cyclic stresses resulting from the wind or other external forces can lead to fatigue damage. In addition to finding a combination of geometry that works under static forces (Ultimate Limit State design), in some aspects of the present invention, it is also necessary that the selected geometry works under dynamic forces (Fatigue Limit state design). The profile and spacing of the perforations have been selected to meet this additional criterion.

[0047] A typical set of criteria that have been found to work based on austenitic stainless steel are given below):

- 0.4 mm < plate thickness < 1.0 mm;
- 2.5 mm < free edge offset < 4.5 mm;
- 12 mm < perforation transverse spacing 43 < 24 mm;
- 2.0 mm < perforation depth 44 < 5 mm;
- 50 mm < perforation longitudinal spacing < 150 mm;
- 6 mm < bulbous end 48 diameter < 12 mm;
- 30 mm < bulbous centreline distance 45 < 120 mm.

[0048] In some aspects of the present invention, the wall provides further measures to prevent buckling of the perforated plate. This is illustrated in figure 9 which is a scrap view on the outside of a wall panel local to an aperture corner. Studs 1 are shown in their in-use state with rigid mineral wool batts 49 fitted tightly between studs.

Calculation and testing have shown that there is enough strength and stiffness in the batts to stop the perforated plate buckling outwards, noting that the out-of-plane dimension of a buckle (which is elastic) is considerably greater than any clearance between batt 49 and stud 1. The buckle is thus prevented from fully forming, enhancing the strength of the thermal stud. In a similar manner a mineral wool batt (ref, 20 in figure 2) is provided inside the thermal stud to inhibit an inward buckle. In some aspects of the present invention, where there is an aperture through the wall, the stabilising benefit of the mineral wool batt is replaced by that of a board 34.

[0049] In some aspects of the present invention, the length of stud 1 needs to vary to enable the fabrication of aperture assemblies. Variation needs to be continuous, i.e., any length between a practical minimum and maximum. Since the plate is based on perforations of fixed length and pitch, a means of varying the length is required. Figure 10 shows how this is achieved. Holes 50 in perforated plate(s) 17, 18 (perforations omitted for clarity) and holes 51 in internal channel 13 are based on a 50mm pitch (although other sized pitches can be used), though typically only every other hole is required giving centre of rivets 19 at 100mm pitch (although other sized pitches can be used). Holes 50, 51 are positioned relative to the longitudinal centre of the internal and/or external channels 13, 14. Holes 52 are set relative to the end of internal and/or external channels 13, 14. Typically, the distance 53 between the last plate rivet 19 and the end channel rivet 16 will vary within a range of 25mm (although other distances can be employed). With a distance 53 of 25 mm at each end of a stud 1, the total range variation that can be accommodated is 50mm. Working in co-operation with the 50mm pitch of holes 50, 51, this allows for any length of stud to be made.

[0050] The fixing of stud 1 to upper beam 21 and lower beam 22 requires a special detail in some aspects of the present invention for a number of reasons.

[0051] One possible reason is that due to material incompatibility between the long beams 21, 22 and the internal channel 13. This may induce accelerated corrosion through galvanic action. The classic solution is to electrically isolate the dis-similar metals.

[0052] Another possible reason is that in an automated welding cell that would typically be used to assemble the wall panel (e.g. the wall panel shown in figure 4), a welding robot will be set up to make one type of weld. In the case of the wall panel frame, the dominant material is structurally thick carbon steel, hence a carbon steel welding metal will be used. For improved welding speed the electrode diameter will be optimised for structural sized welds. Welding thin stainless steel to structural steel is not be feasible without changing the welding wire. This adds considerable equipment costs and slows down the throughput of the automated cell.

[0053] A further possible reason is as a modular building is assembled, the load from the upper part of the building causes the column elements to reduce in length.

If the studs are fully fixed top and bottom, they will attract some of the building load. Being relatively slender components, they will buckle under the load. To prevent buckling, some form of load relief is required before the studs reach their buckling load.

[0054] Figure 11 shows one solution to the above issues by use of the top connector block 24. In figure 11a the connector block 24 is shown located on internal channel 13. In some examples, the connector block is a carbon steel connector block. In some examples, the internal channel is a stainless steel internal channel. In some examples, an isolation membrane 54 is located between block 24 and internal channel 13, ensuring electrical separation. A stainless steel screw 55 can be fitted through a slot 56 about centreline 57. An isolating sleeve washer 58 under the head of screw 55 can be used in order to maintain isolation. To complete attachment to upper beam 21, a weld 59 is made. It will be apparent that this weld is between materials of similar composition (e.g. carbon steel) and similar thicknesses, enabling the same welding set up to be used to attach the stud to the frame as is used weld up the frame itself.

[0055] Figure 11 is shown with slotted holes permitting movement at the joint. It will be apparent that if no movement is desired, then slotted holes 56 can be replaced by round holes. Typically movement is allowed at the top but not at the bottom.

[0056] The torque applied to screw 55, as shown in figure 11b, will determine the compression across the isolation membrane and hence amount of force required to slide the connection. This force is optimally set to be greater than the maximum anticipated live load applied to the lower beam 22, but less than the force that will cause stud 1 to buckle. In this manner thermal stud 1 will be able to transfer live loads up it's length, thereby causing the live load to be shared between upper beam 21 and lower beam 22. This has the benefit of reducing deflections due to live loads and eliminates the risk of noise generation (e.g. creaks and squeaks) from the sliding joint as live loads are encountered.

[0057] Figure 4 shows two additional vertical elements that work alongside studs 1, upper beam 21 and lower beam 22 to form the façade panel — these are end posts 28 and wall protrusion brackets 29.

[0058] The composition of end post 28 varies according to their function. If a façade panel is stacked such that its weight is taken down to ground level via the panel, then end post 28 will be a structural member. Figures 12a shows a typical arrangement. Posts 28 are attached by welds 60 to upper and lower beams 21, 22 thus forming a picture frame around the panel. Vertical loads are transferred along beams 21, 22 into end post 28. End posts are sized to take the cumulative load of any panels above. For stacked panels, post 28 would typically be a square hollow section.

[0059] Figure 12b shows a section through the end post 28 of figure 12a, but this time with a stud 1, insulation 2, 62 and top hat rail 11 added in. To the right hand of

the thermal stud the wall is as shown in figure 1. To the left hand of the stud, the insulation 62 has been modified to fully fill the gap. The selection of end post 28 should be such that the outside face of end post 28 results in dimension 61 being greater than 40% of the combined thickness of insulation 2. A typical combination would be substantially 260mm of mineral wool insulation and substantially 100mm square hollow section posts, although other sizes can also be used.

[0060] In some aspects of the present invention whereby a façade panel is supported from the structural frame of the building, end posts 28 would typically be aligned with and fixed to structural columns in the building. In such circumstances the size of post 28 may be reduced as there is no cumulative load to take down to ground.

[0061] It will be apparent that if upper and lower beams 21 and 22 can be fixed directly to the edges of the structural slab, then the end post 28 carries little load and could be replaced by a stud 1.

[0062] Figure 13 shows a section through a façade panel at the location of an optional wall protrusion bracket apparatus 29 shown in figure 4.

[0063] Figure 13a shows the wall protrusion bracket spanning vertically between lower structural floor 63 and upper structural floor 64. However, the lower and upper structural floors can be any horizontal load-carrying structures of a building. For the sake of simplicity, we will refer to the horizontal load-carrying structures as structural floors. The wall protrusion bracket apparatus comprises a vertical beam 65 with connection 72 at the top and connection 73 at the bottom. The bottom of vertical beam 65 has moment resisting attachment bracket 66 fixed to it. Loads from balcony 67 are transferred through moment resisting attachment bracket 66 and into vertical beam 65. The vertical beam may be any type of beam, e.g. a box beam or an I-beam. The vertical beam has a dimension from the bottom to the top of "x". Cage 68 is attached to beam 65 in order to provide a fixing location for optional horizontal rails 11.

[0064] Figure 13b shows how the vertical forces 69 are transferred to the structural floors 63, 64. These vertical forces are transferred from a wall projection onto the structural floor. The wall projection can be any wall projections, e.g. a balcony, a mezzanine floor, a bay window, etc. Forces 69 multiplied by eccentricity 71 develop a moment at moment resisting attachment bracket 66. This moment is applied to one end of beam 65. Horizontal forces of magnitude moment / length 70 are transferred via connections 72, 73 into floors 63, 64. Vertical forces 69 are also transferred via connections 72, 73. Connection 73 is vertically fixed, connection 72 has some compliance. This is necessary to limit the amount of load transferred from floor 63 down beam 65 and into floor 64. This compliance also caters for the change in height between floor 63 and floor 64 when for example concrete creeps and shrinks and the structure shortens under load.

[0065] Figure 14 shows a typical moment-resisting

bracket 29 in isometric view. At the bottom of beam 65 is attached plate 80. The attached plate has a dimension from the bottom to the top of "y". In co-operation with stiffener 78, connection 73, threaded studs 79 and insulating blocks 74 this forms the moment resisting attachment bracket 66. The threaded studs 79 take the tensile component of the moment applied to the moment resisting bracket 29.

[0066] Cage 68 is shown in more detail. The cage 68 is formed by two angle beams, each of length "z", whereby "z" is the difference between dimension "x" and dimension "y" (i.e. the lengths of the vertical beam 65 and the attached plate 80, respectively). Vertical angle 81 is connected to vertical beam 65 by brackets 75. The brackets have a slip joint type connection to the vertical angle. In this manner dimension 77 can be set accurately relative to the panel datum. The cage angles lie in the same plane as the external angle/channel forming the thermal stud, such that rail or board systems may be run over and substantially contact both the cage and the thermal stud.

[0067] In order to minimise the transfer of heat from inside to outside, in some aspect of the present invention, brackets 75 have a cross-section limited to that required to carry horizontal loads. Vertical cladding loads are transferred from angle 81 via diagonal 76 to beam 65 and thence to connectors 72, 73.

[0068] Figure 15 shows a sectional plan view through the mid height of balcony bracket 29. Datum distance 77 is shown relative to datum 82 which lies on upper and lower beams 21, 22. In some aspects of the present invention, the wall protrusion bracket apparatus 29 fits within the same inside to outside dimensions as the stud 1. To minimise cold bridging, which can be deleterious to the thermal performance of the façade wall, insulation 83 may be provided to fill any voids in vertical beam 65. In a similar manner, the space within cage 68 may comprise insulation 84.

[0069] To further minimise heat transfer from inside to outside it will be apparent that some structural sections forming vertical beam 65 are preferable to others. The optimal section will have a minimal depth in the wall transverse direction. Thermally the cross-sectional area of steel in the transverse direction should be minimised. Therefore, sections with a heavy flange and thin plate(s) will typically perform best, and hence the vertical beam is preferably a universal column section. Brackets 75 cross through the main thermal insulation. In order to reduce heat loss, brackets 75 are preferably made from a low conducting metal such as stainless steel.

[0070] Some of the key features are as follows:

A plate can take several forms, and there are several considerations when choosing a plate including perforation length & width, perforation spacing, material thickness and material type. These considerations are tuned to work together to give the required thermal performance such that overall wall U-values are

achieved;

Element assembly and manufacturing methods are selected such that the through wall dimension of the stud can be tightly controlled;

The plate perforations have formed edges to stiffen up the plate in its out-of-plane direction. This helps prevent plate buckling until higher load levels. It enables the use of thinner plate material;

Plate buckling is further controlled by filling the space between the two plates with a semi-rigid insulation material. Insulation between thermal studs serves a similar purpose;

The thicker edge channels are shaped so that studs can be butted up to each other at right angles and welded together. This permits the manufacture of aperture (e.g., 'picture frame') assemblies;

The stud has an end cap detail formed as a separate item from the plate. This permits standard hole and perforation patterns to be used whilst maintaining the ability to make a stud of variable length;

The bending stiffness of the stud is set to limit elastic deflections under wind load to a fraction of what a normal stud would deflect;

The outer vertical faces of the thermal studs are connected together horizontally by a profiled metal rail perforated to allow air through. This maintains a cavity between the cladding and the thermal studs. The perforated section is shaped such that any water in the cavity is directed towards the outside. A water proof but breathable membrane is located between the thermal stud and the perforated section.

[0071] The inner vertical face of the thermal studs has a vertical fillet strip fixed to it. Boards are fixed to the outside of this strip, forming a cavity. Cables and pipes are run in this cavity. A reflective foil vapour barrier is located between the thermal stud and the fillet strip. This acts to boost the thermal performance of the wall.

[0072] The end posts may be one of a number of elements. With top and bottom beams they form 'picture frame' around the panel. Where the panel is used as an external wall of a 3d volumetric module the end post is a machined fabrication welded to the horizontal beams with preparations to connect to the rest of the module. If façade panels are stacked, the end post is a more simple section. In both cases they carry the loads from an assembly of volumetric modules or a stack of façade panels down to the foundation. If loads are transferred to the building structure at each level, then the end column can be a light weight structural section, a thermal stud or a balcony bracket.

[0073] The balcony brackets are a means of attaching cantilever balconies to the edge of a perimeter wall without having to install back beams. They are a significant enabler in permitting the modularisation of an external wall. They comprise of a vertical beam rigidly fixed to the lower beam and compliantly attached to the upper beam. The vertical beam has a machined plate at the bottom to

which a balcony attaches.

[0074] In another example, the thermal stud may also be used as the through wall element of an external wall having a cast concrete outer cladding. In this apparatus, the thermal stud and a supporting steelwork are assembled into a frame and placed such that concrete may be poured to cover part or all of the outer angle or channel section. In some examples, the outer angle or channel has at least one protruding element formed or attached in order to enhance the anchorage into the concrete. In some examples, the concrete may include reinforcing steel.

[0075] As shown in Fig. 16, a concrete slab 91 has a frame of thermal studs 92 at least partially embedded within it. In some examples, concrete 1 comprises reinforcing steel 93. Perforated plates 94, in some examples, are also embedded directly into concrete 91, in which case the plate edge may be deformed so as to provide improved anchorage 95 into the concrete. Alternatively, or additionally, in order to help improve anchorage in the concrete 91, the external channel/angle is formed in a manner so as to create tabs 96 and concrete admitting holes 97.

[0076] All of the vertical elements, e.g. the stud, the wall projection bracket apparatus, the end post, etc., are essentially prismatic and designed to be capable of being located by a robot and welded together by a robot. Therefore, the wall system is inherently suitable for automated manufacture.

[0077] Any reference to 'an' item refers to one or more of those items. The term 'comprising' is used herein to mean including the elements identified, but that such elements do not comprise an exclusive list and an apparatus may contain additional elements. Furthermore, the elements are themselves not impliedly closed.

[0078] Where the description has explicitly disclosed in isolation some individual features, any apparent combination of two or more such features is considered also to be disclosed, to the extent that such features or combinations are apparent and capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or combinations of features solve any problems disclosed herein. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

Claims

1. A stud assembly for passing through a cavity wall, said stud assembly comprising:
 - a quadrilateral plate comprising perforations, said plate comprising two opposing faces and four edges;
 - an internal angle (13) for attaching to a first edge

- of the plate and also for attaching to an internal portion of a wall;
 an external angle (14) for attaching to a second edge of the plate and also for attaching to an external portion of the cavity wall;
 wherein the first edge and the second edge correspond to opposite edges of the quadrilateral plate.
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2. The stud assembly of claim 1, wherein the quadrilateral plate is formed as a two-quadrilateral plate construction whereby each of two quadrilateral plates comprise perforations and are positioned substantially parallel to one another and are separated by a gap, and wherein the internal angle and external angle are an internal channel and external channel, respectively.
- 10
3. The stud assembly of claim 1 or 2, further comprising an end channel substantially perpendicular to the longitudinal direction of the other two edges of the plates so as to attach the internal angle to the external angle.
- 15
4. The stud assembly of any preceding claim, wherein the perforations are elongate perforations substantially parallel to the first edge of the plate
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5. The stud assembly of any preceding claim, wherein the perforations form an interlocking pattern.
- 25
6. The stud assembly of any preceding claim, further comprising a flange protruding from at least one of the two faces of the plate at a perimeter of at least some of the perforations.
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7. The stud assembly of any preceding claim, wherein at least one of the external angle or internal angle comprises a joggle offset where the angle meets the outside edge or the inside edge, respectively.
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8. The stud assembly of any preceding claim, wherein at least one of the first edge or second edge comprise a joggle offset where the first edge or second edge meet the channel.
- 40
9. The stud assembly of any preceding claim, further comprising:
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- a first beam connector for attaching a portion of the internal angle to an upper beam (21); and
 a second beam connector for attaching a different portion of the internal angle to a lower beam (22).
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10. A wall protrusion bracket apparatus for transferring loads from a wall projection into a load-carrying structure of a building, the apparatus comprising:
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- a vertical-beam assembly, of length x running from a lower load carrying structure to an upper load carrying structure and formed by two vertical-beam flange sections and a connecting plate, the first vertical-beam flange being to the internal face of a cavity wall;
 a moment-resisting attachment bracket (66) for connecting the vertical-beam assembly to a wall projection, said attachment bracket comprising:
- a plate (80) of length y fixedly attached to a second flange section of the vertical-beam;
 and
 at least one rod (79) passing through the plate and the second flange section, said at least one rod is at least partially threaded.
11. The apparatus of claim 10, wherein the vertical beam assembly further comprises two angle beams of length x - y fixedly attached to the vertical-beam at the second flange section of the vertical-beam so as to form a cage for the attachment of an external cladding system.
12. The apparatus of any of claims 10 or 11, further comprising an elongate plate between two or more brackets, the brackets attaching an angle beam to the vertical-beam, said elongate plate for transferring vertical cladding loads from the angle beam to the vertical-beam.
13. A panel-based cavity wall system for use in a building comprising top and bottom beams; comprising:
- the stud assembly of any of the claims 1 to 9 for extending between a top beam and a bottom beam; and
 the moment-resisting bracket apparatus of any of the claims 10 to 12 for extending between the top and the bottom beam.
14. The system of claim 13, further comprising at least two insulation batts in thermal contact with the stud assembly, one of the insulation batts positioned at an internal portion of a cavity wall and the another of the insulation batts positioned at an external portion of the cavity wall.
15. A wall system for use in a building, comprising:
- the stud assembly of any of the claims 1 to 9;
 a concrete slab at an external portion of a wall, the concrete slab comprising a supporting steel-work configured to form a frame with the stud assembly;
 wherein the stud assembly is at least partially embedded within the concrete slab; and
 wherein the external angle of the stud assembly

comprises tabs and/or concrete-admitting holes
so as to improve anchorage of the concrete slab.

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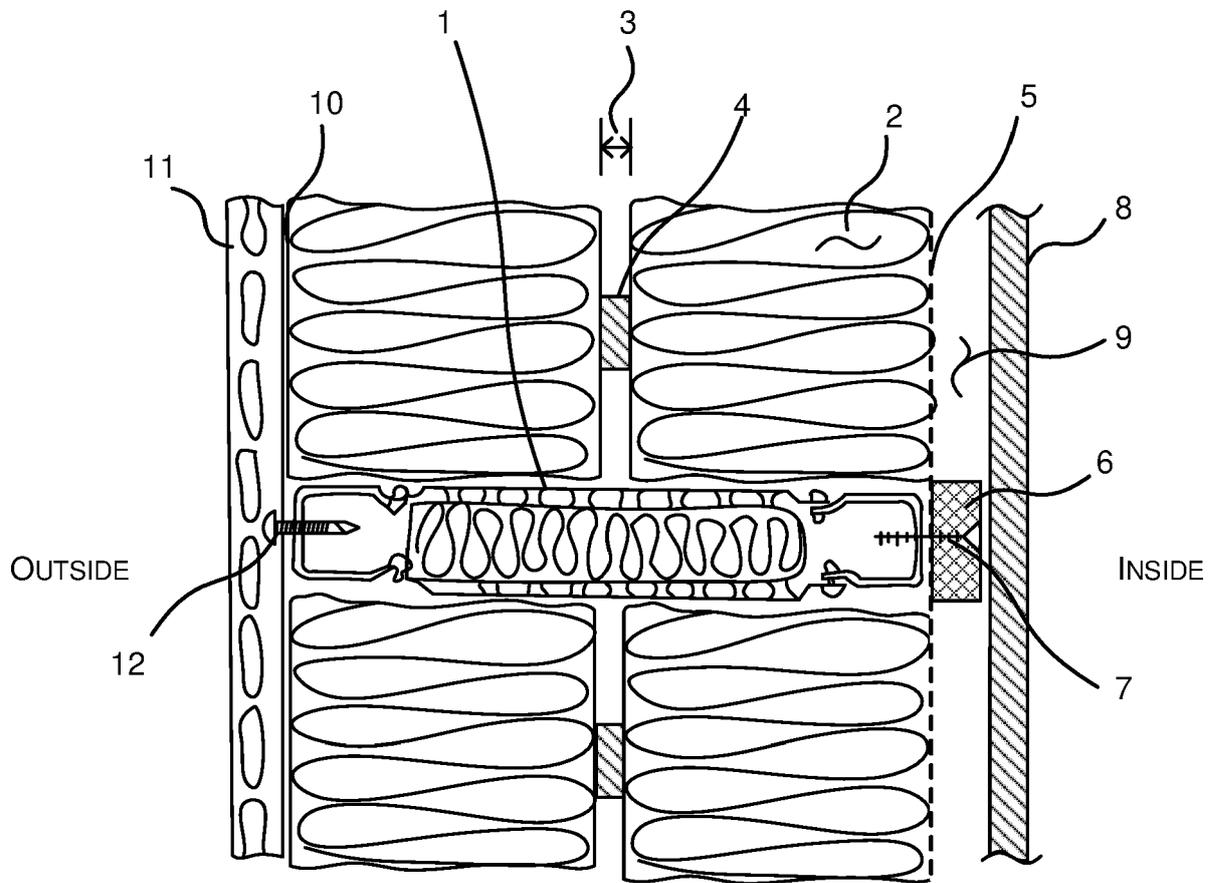


FIG. 1

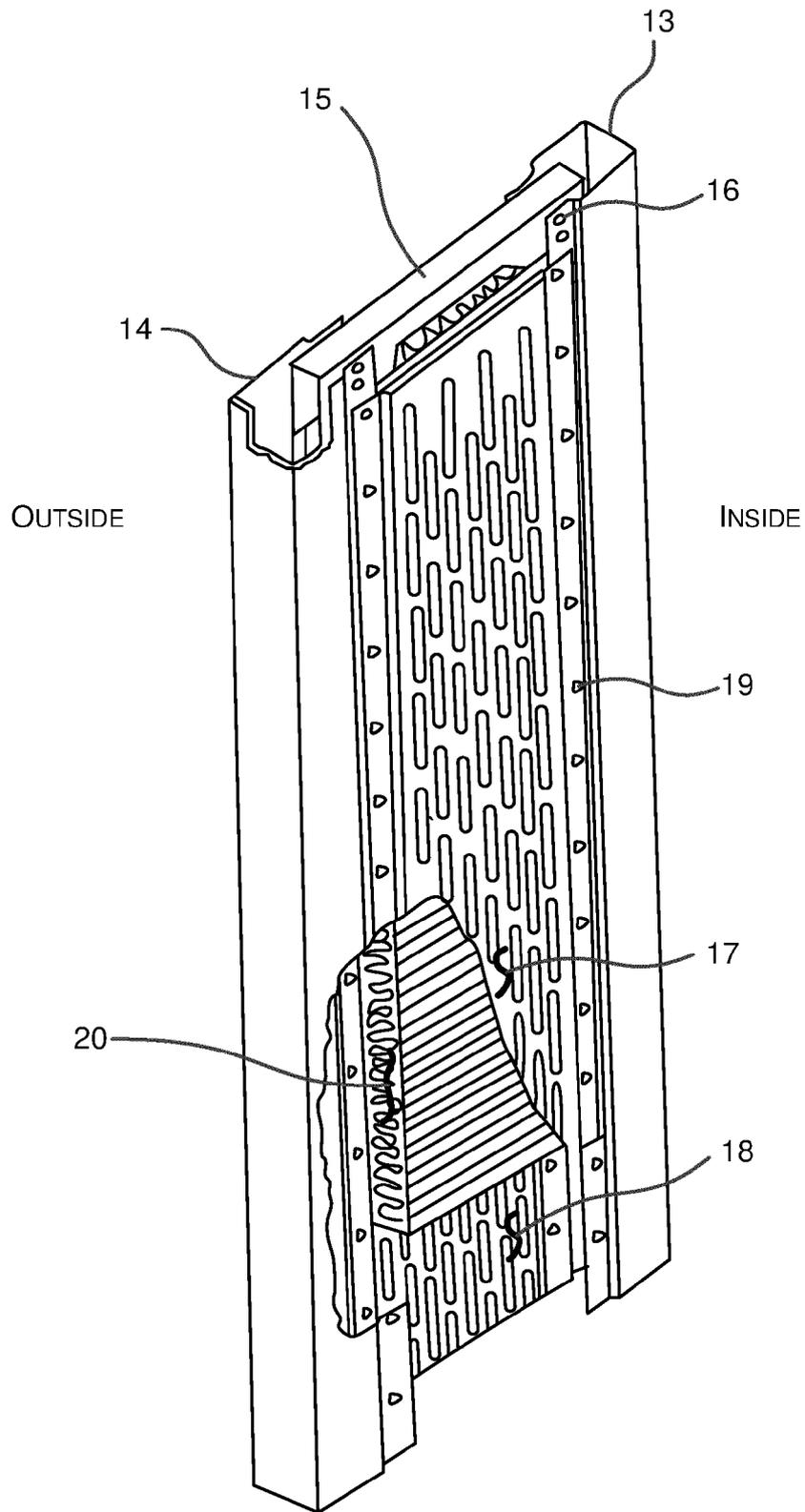


FIG. 2

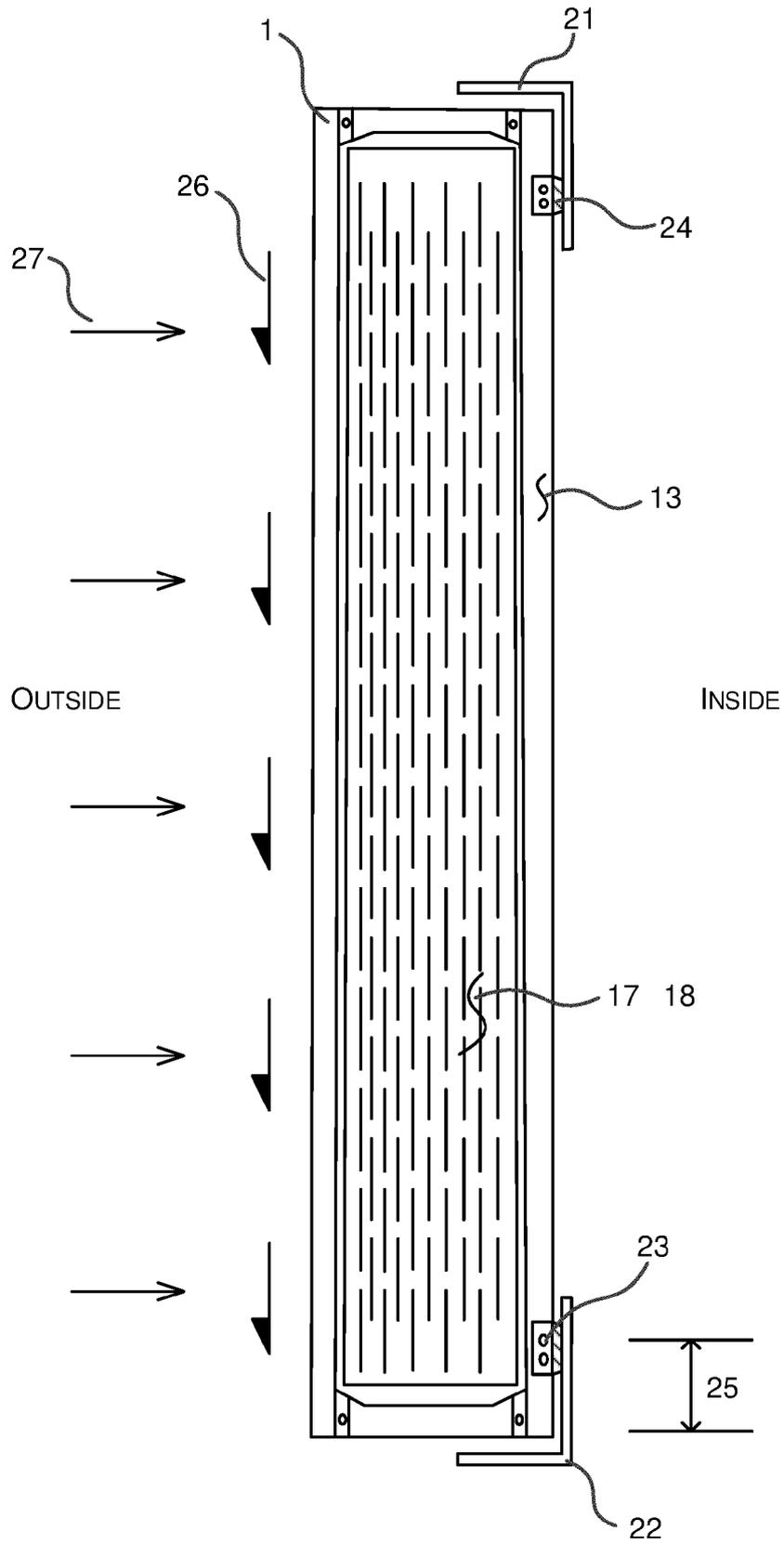


FIG. 3

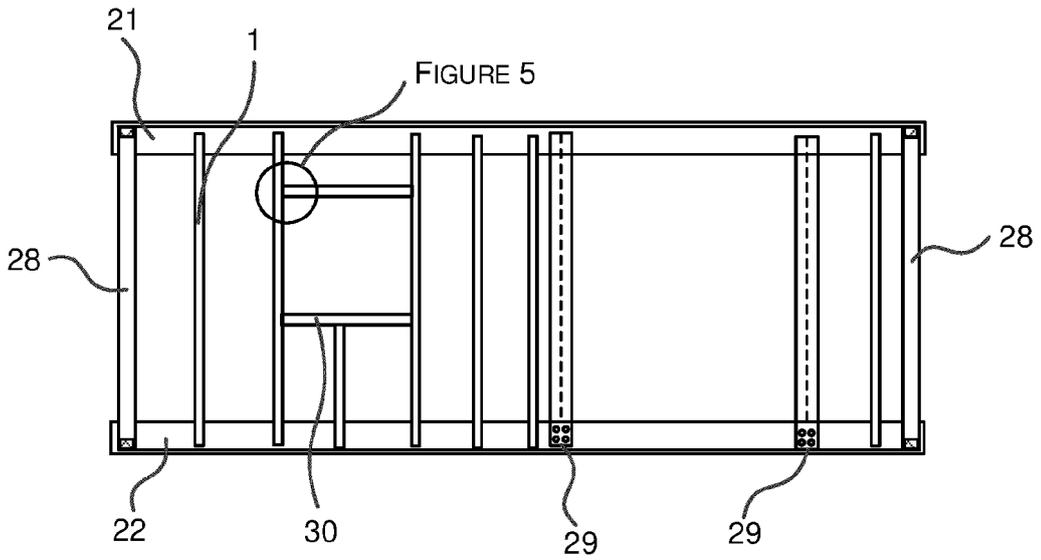


FIG. 4

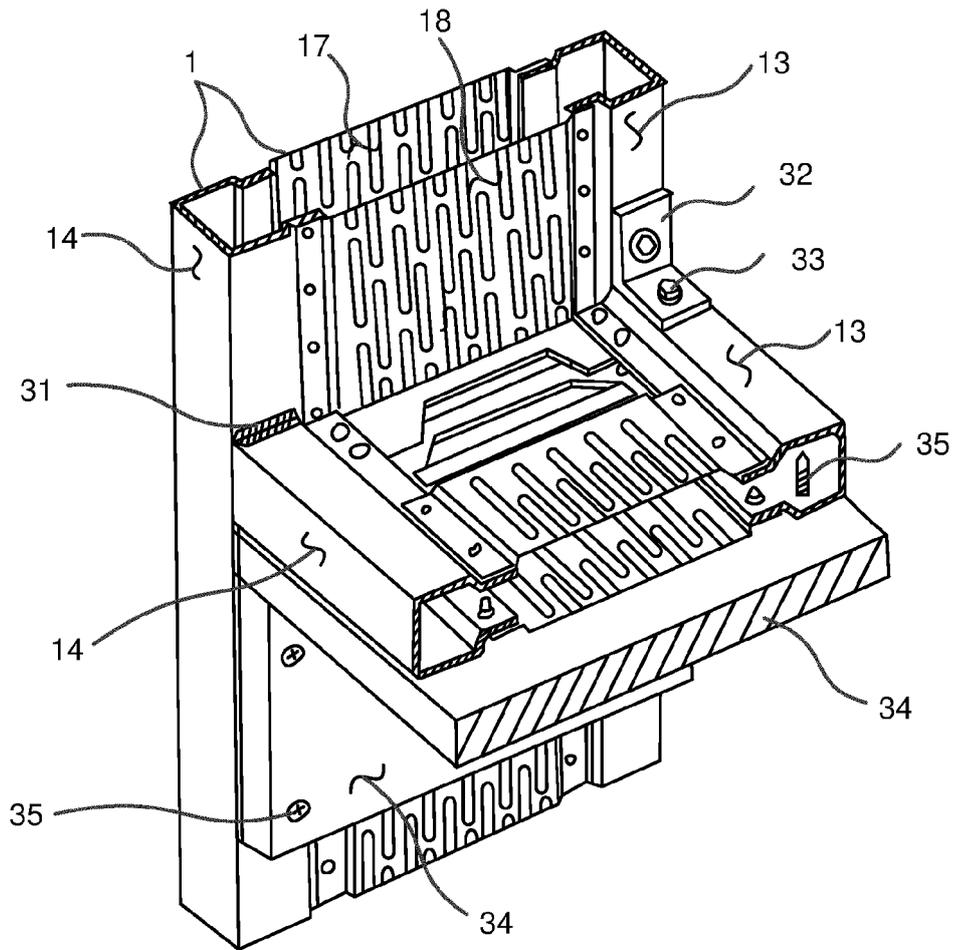


FIG. 5

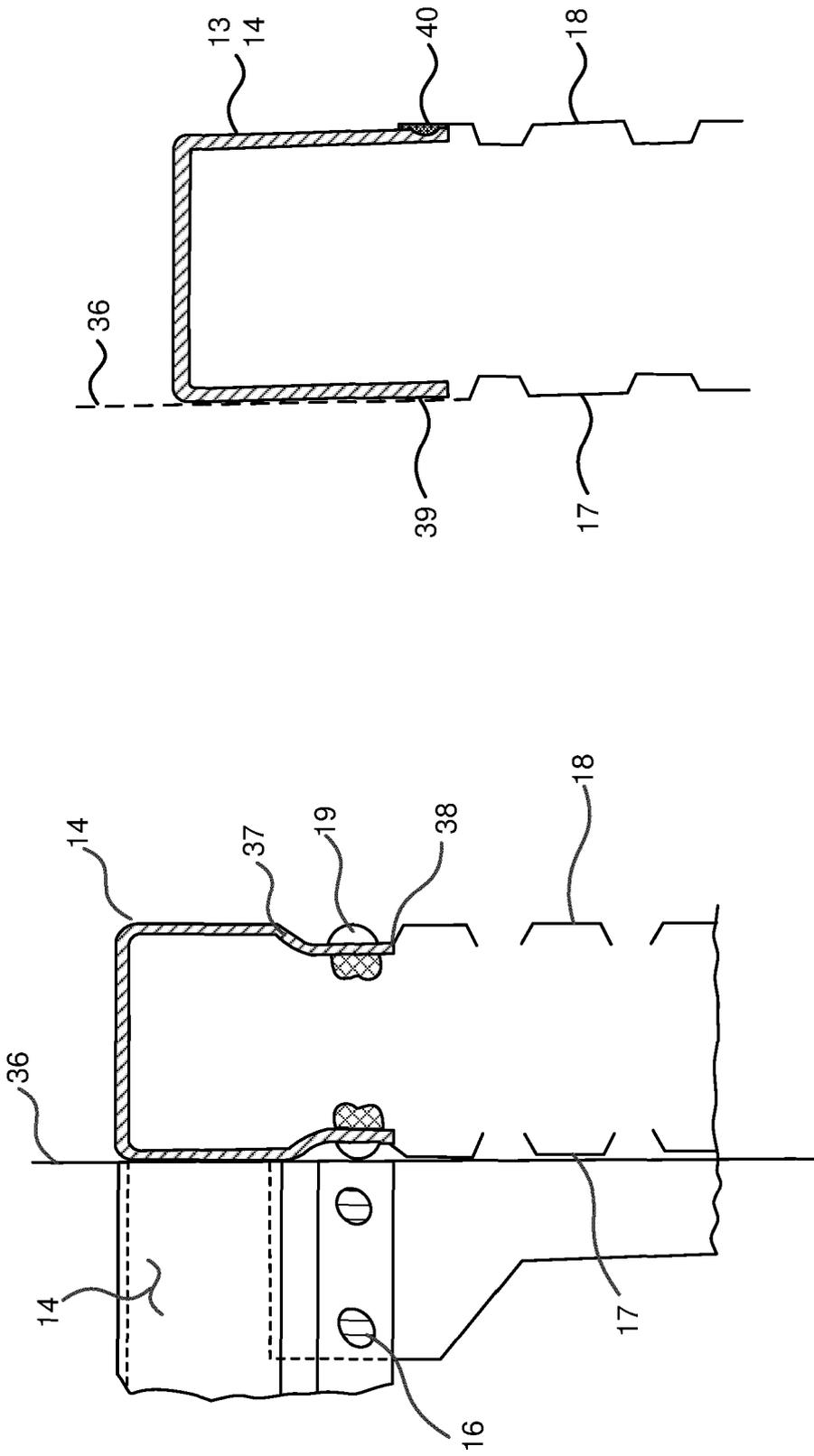


FIG. 7

FIG. 6

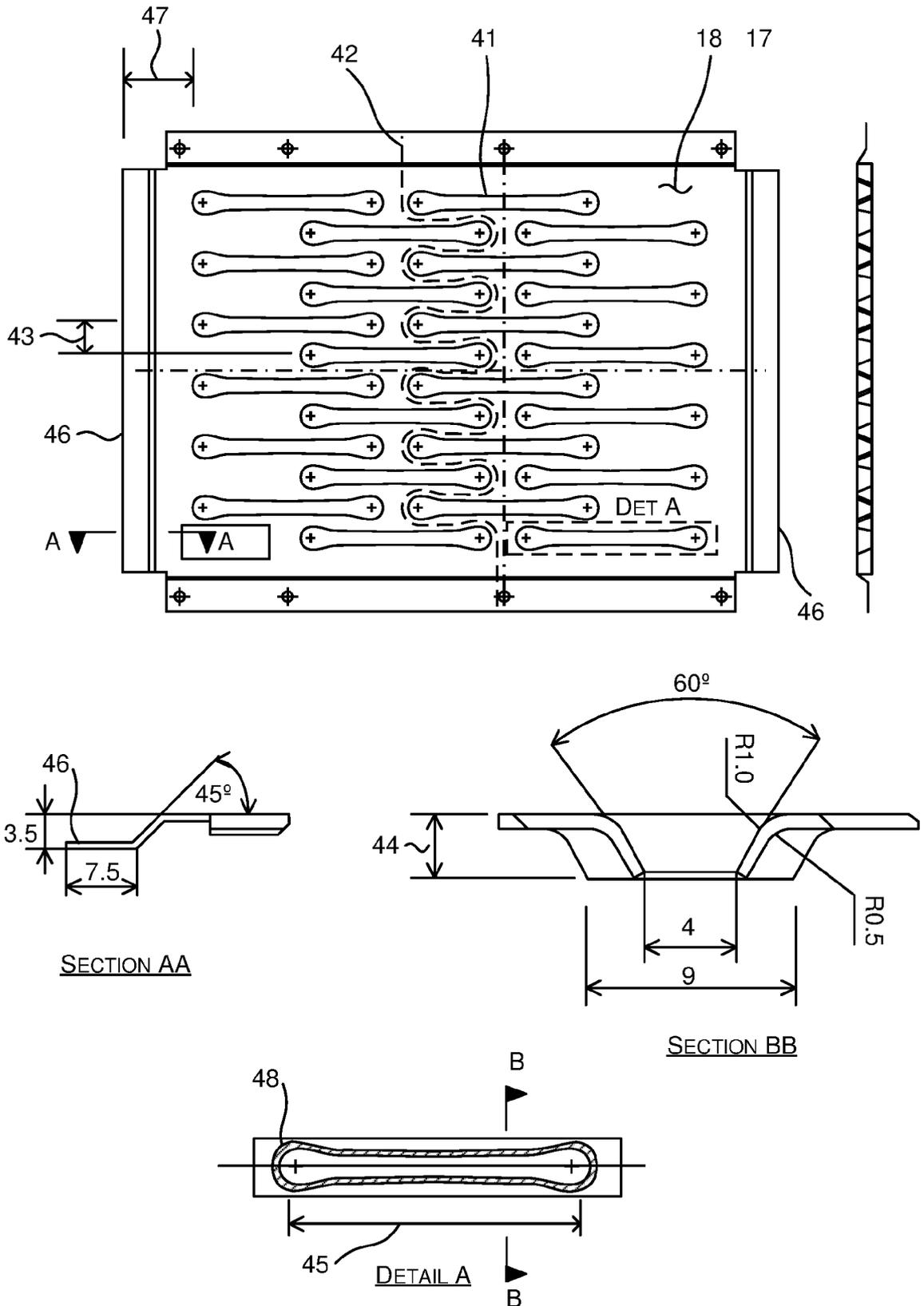


FIG. 8

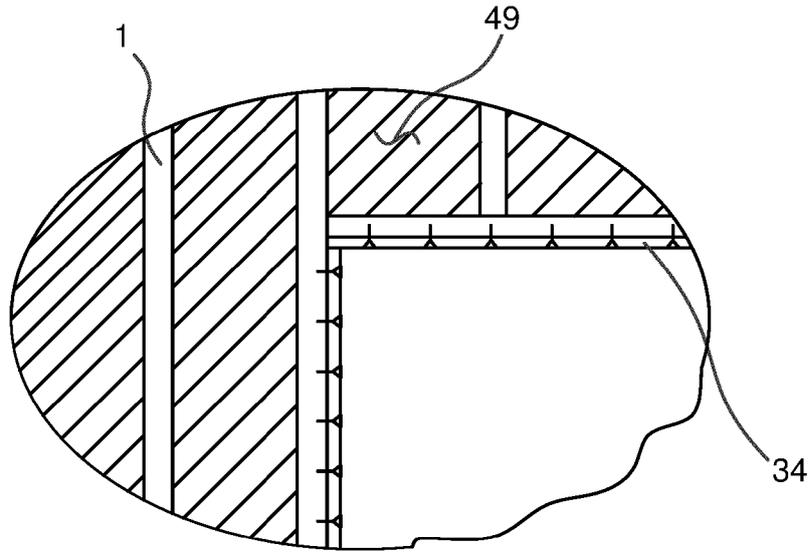


FIG. 9

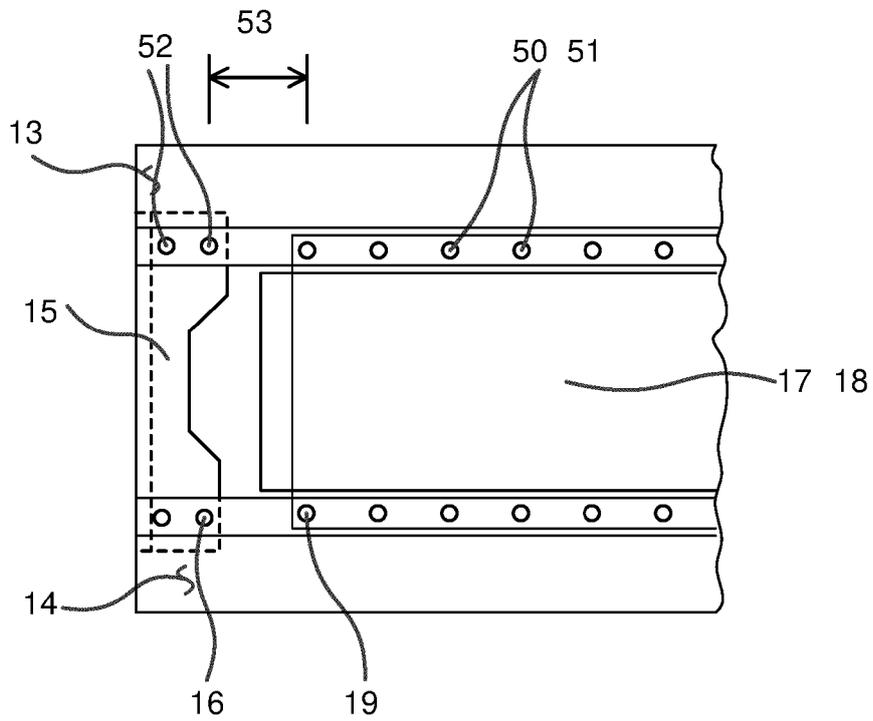


FIG. 10

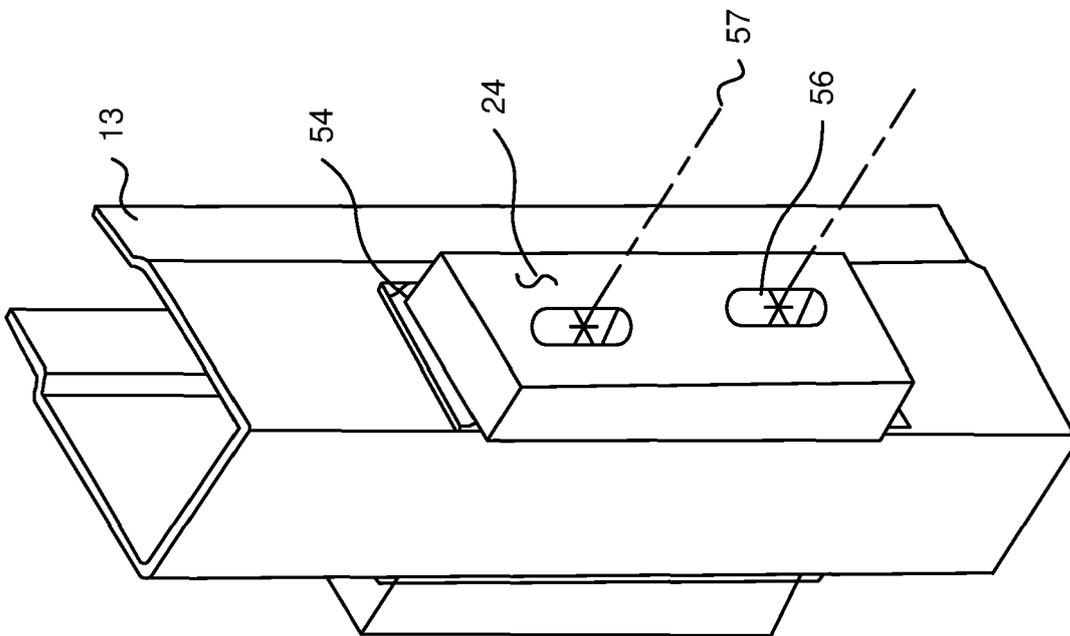


FIG. 11a

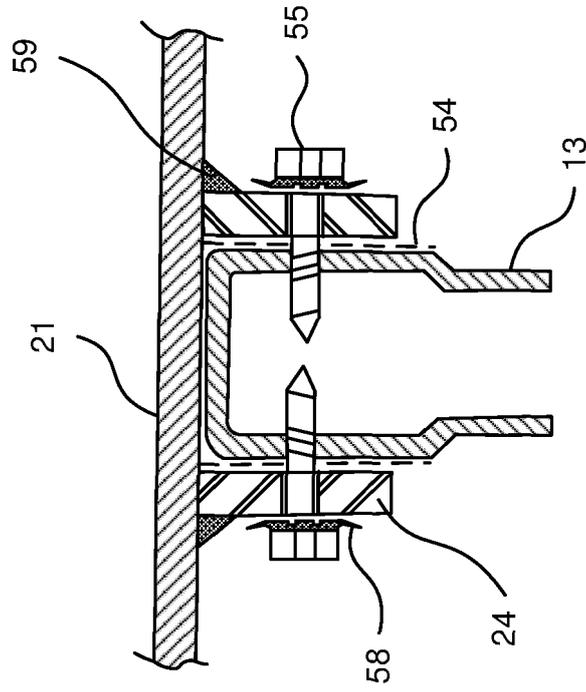


FIG. 11b

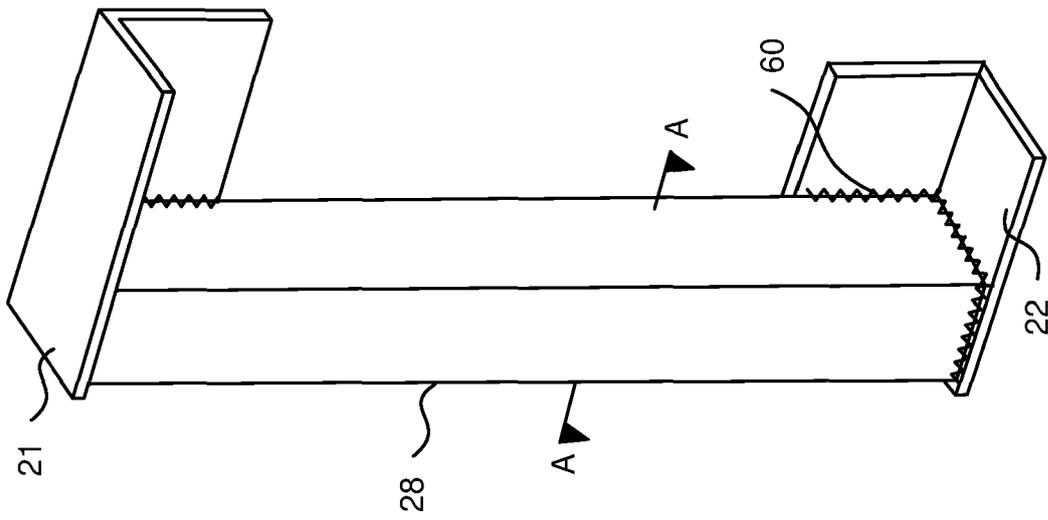


FIG. 12a

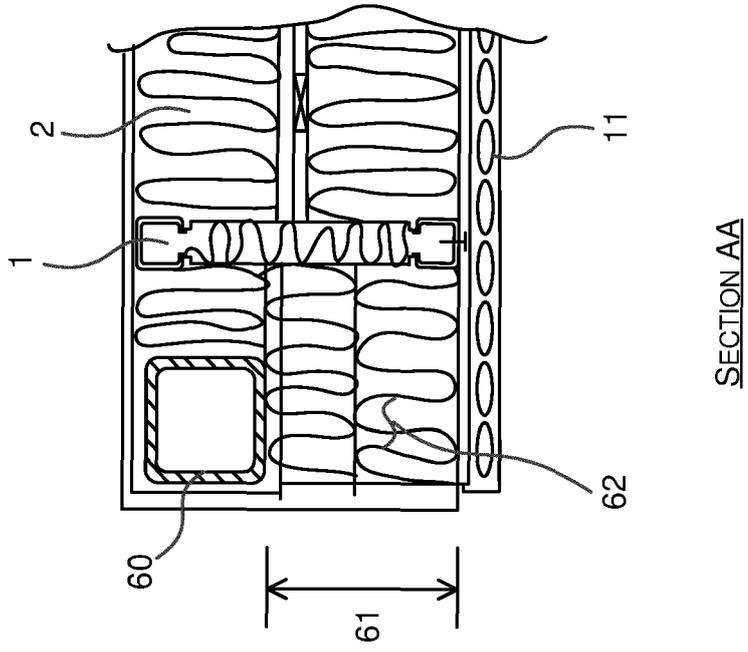
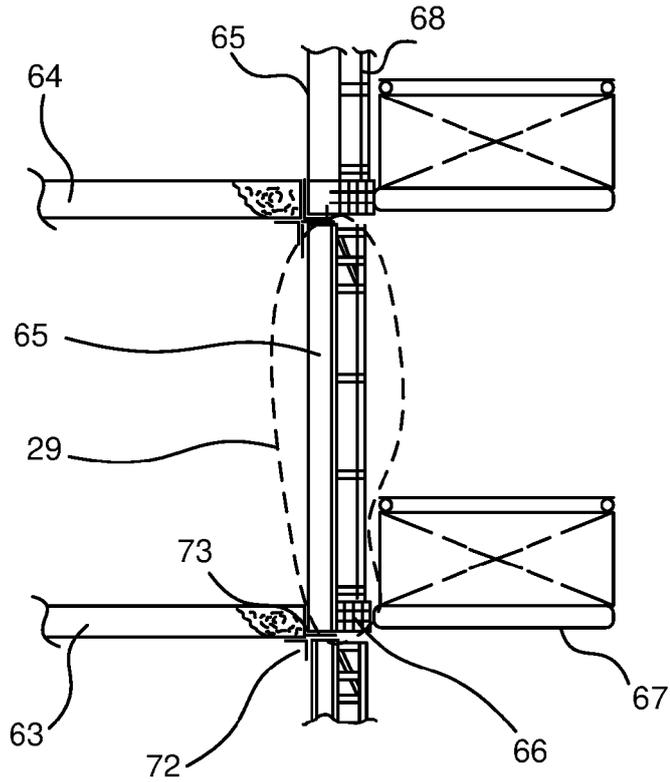
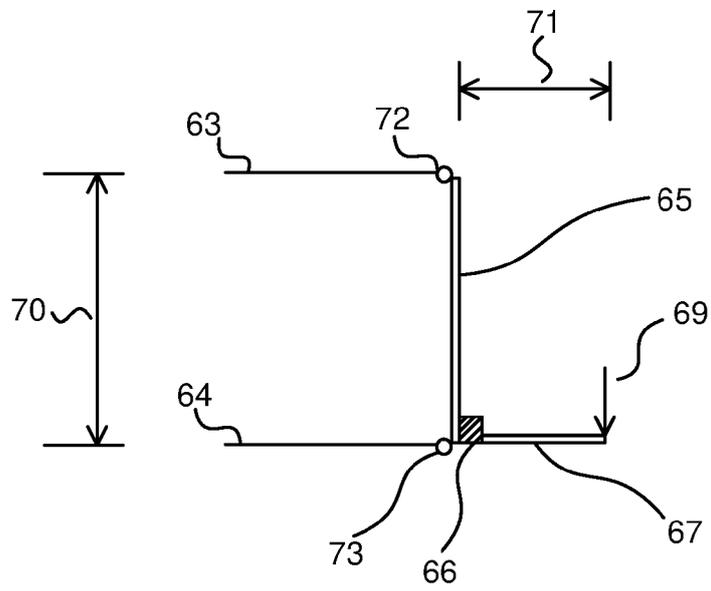


FIG. 12b



(A)



(B)

FIG. 13

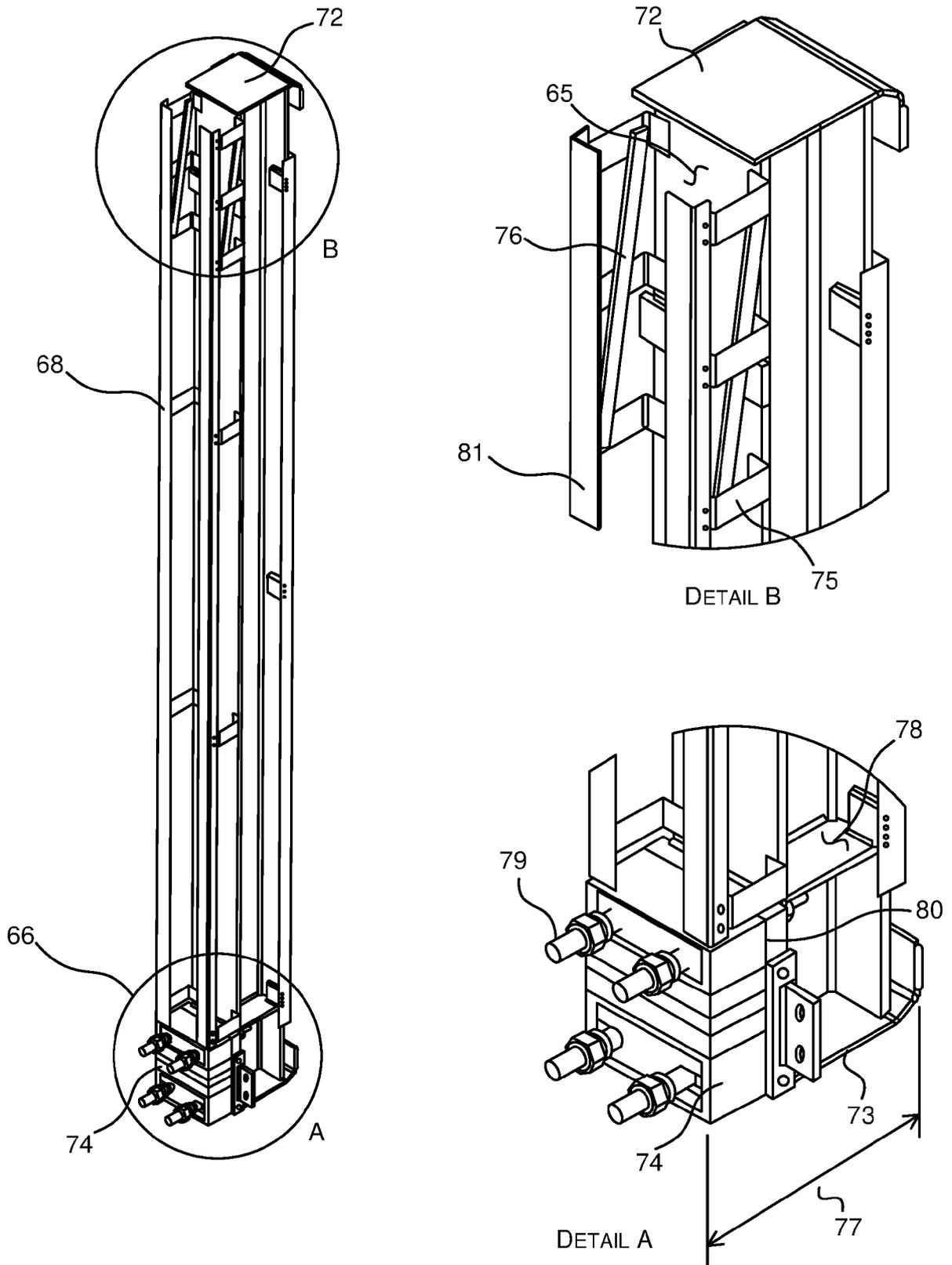


FIG. 14

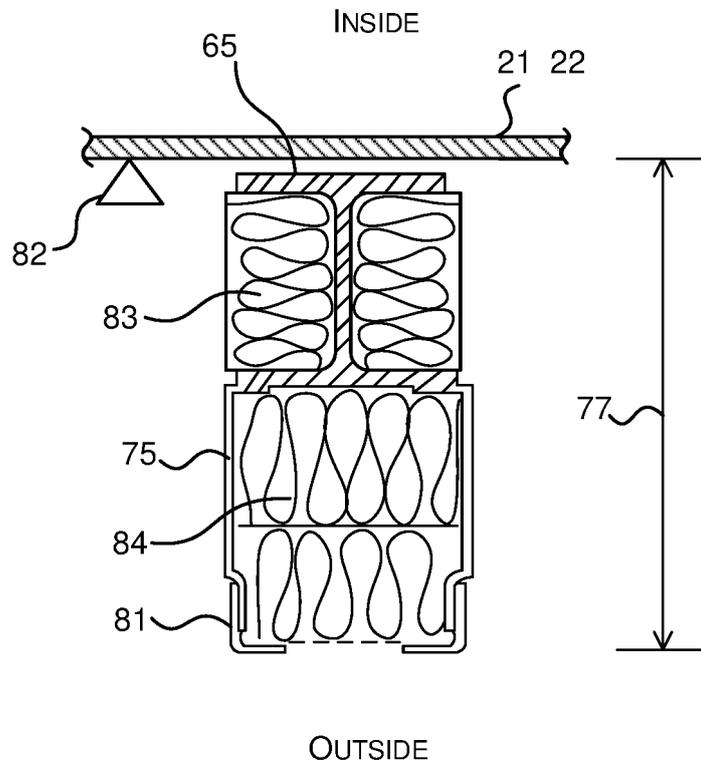


FIG. 15

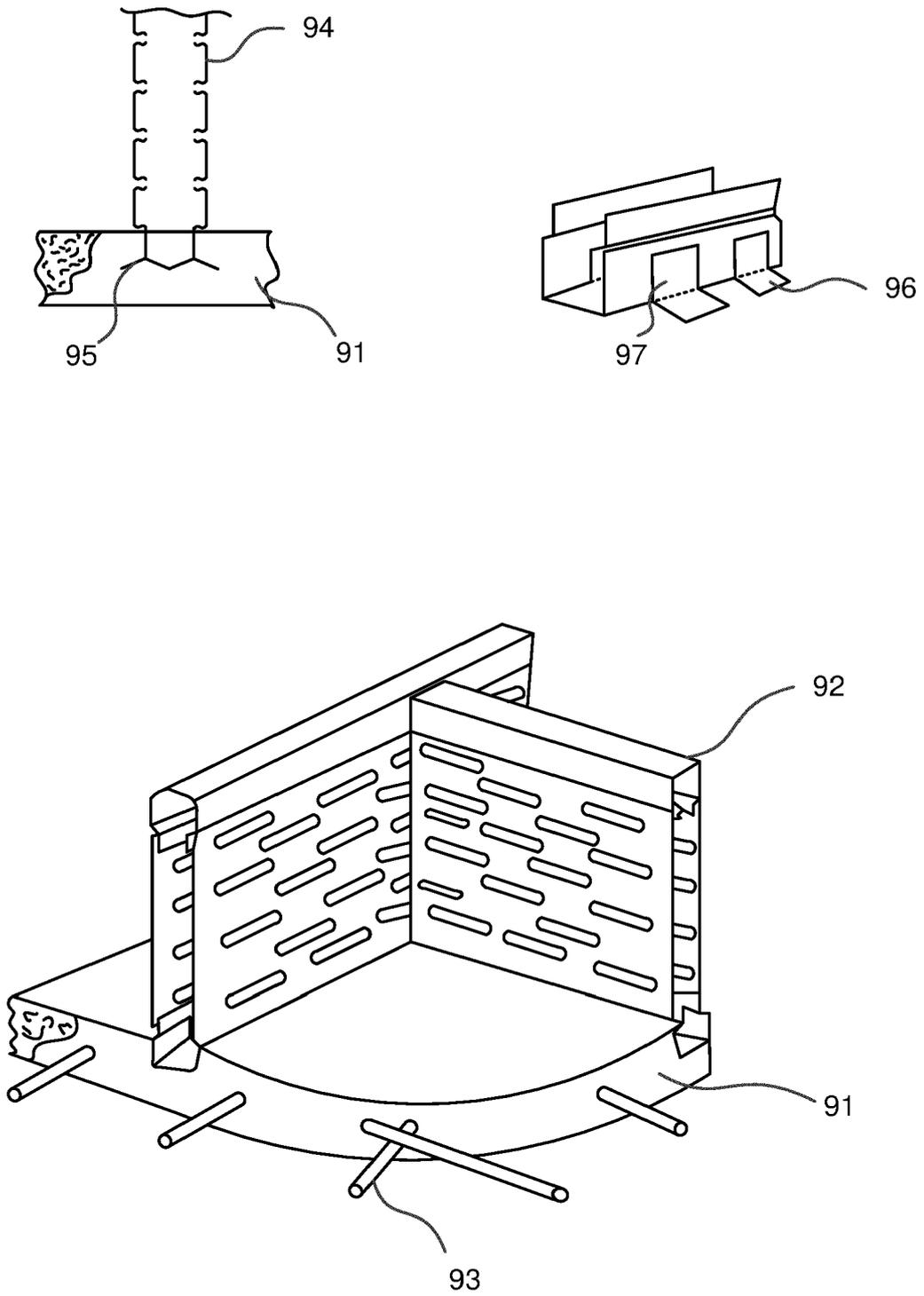


FIG. 16



PARTIAL EUROPEAN SEARCH REPORT

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of subsequent proceedings, as the European search report

EP 21 18 7146

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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 A	US 5 605 024 A (SUCATO EDWARD [US] ET AL) 25 February 1997 (1997-02-25) * column 1, lines 18-31 * * column 4, lines 22-36; figures 19, 20, 21, 22 *	1-6, 9, 13-15 7, 8	INV. E04B2/62 E04C3/04 E04C3/08 E04C3/29 E04B2/74
X A	US 2013/232911 A1 (STAL IRVING [CA] ET AL) 12 September 2013 (2013-09-12) * figures 2, 3, 4, 6, 7, 8 *	1, 3-9, 13-15 2	ADD. E04B1/76
X A	FR 1 162 523 A (PHILIBERT) 15 September 1958 (1958-09-15) * abstract; figures 49, 50, 67 *	1-5, 7-9, 13-15 6	
			TECHNICAL FIELDS SEARCHED (IPC)
			E04B E04C
INCOMPLETE SEARCH			
The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.			
Claims searched completely :			
Claims searched incompletely :			
Claims not searched :			
Reason for the limitation of the search: see sheet C			
Place of search	Date of completion of the search	Examiner	
The Hague	22 March 2022	Couprie, Brice	
CATEGORY OF CITED DOCUMENTS		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	
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			

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EPO FORM 1503 03:82 (P04E07)



**INCOMPLETE SEARCH
SHEET C**

Application Number
EP 21 18 7146

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Claim(s) completely searchable:

1-9, 15

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Claim(s) searched incompletely:

13, 14

Claim(s) not searched:

10-12

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Reason for the limitation of the search:

More than one independent claim per category (Rule 43(2) EPC)

Claims 1 and 10 have been drafted as separate independent apparatus claims.

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Under Article 84 in combination with Rule 43(2) EPC, an application may contain more than one independent claim in a particular category only if the subject-matter claimed falls within one or more of the exceptional situations set out in paragraph (a), (b) or (c) of Rule 43(2) EPC. In particular, it should be noted that the "interrelated products"-exception of Rule 43(2) (a) only applies in the following cases:

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- (i) to independent stand alone products, only performing the invention when interacting with each other (like plug and socket, transmitter and receiver, ...) and,

- (ii) to intermediate and final chemical products.

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(see Case Law of the Boards of Appeal, Version 2010, II.B.2.2.1, paragraph 4, 2nd sentence in combination with Guidelines, F-IV, 3.2.(i)). This exceptional case is however not covering the present application. Therefore, it is not justified to have multiple independent product claims. Therefore, the present set of claims does not meet the requirements of Art. 84 and Rule 43(2) EPC.

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The applicant has been requested to declare, in reply to a Rule 62a EPC objection, with regard to which of the following groups of claims he wished the search report to be drawn:

1. claims: 1-9, 15 (completely); 13, 14 (partially) - Stud assembly

2. claims: 10-12 (completely); 13, 14 (partially) - Wall protrusion bracket

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Following the objection from the search division, the applicant has requested in their reply that the search report be drawn with regard to the first group of claims.

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

EP 21 18 7146

5 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.

22-03-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5605024 A	25-02-1997	NONE	

US 2013232911 A1	12-09-2013	NONE	

FR 1162523 A	15-09-1958	FR 73317 E	30-11-1960
		FR 74421 E	04-05-1961
		FR 1162523 A	15-09-1958

EPO FORM P0459

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