



- (51) International Patent Classification:
C01B 3/36 (2006.01) *C01B 3/38* (2006.01)
- (21) International Application Number:
PCT/EP2016/066086
- (22) International Filing Date:
7 July 2016 (07.07.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
15177998.0 23 July 2015 (23.07.2015) EP
- (71) Applicant: **CASALE SA** [CH/CH]; Via Giulio Pocobelli 6, 6900 Lugano (CH).
- (72) Inventors: **ZANICHELLI, Luca**; Via Soffredini 68, 20126 Milano (IT). **HUMAIR, Daniele**; Via Campo Marzio 15, 6500 Bellinzona (CH).
- (74) Agent: **ZARDI, Marco**; c/o M. ZARDI & Co SA, Via Pi-oda, 6, 6900 Lugano (CH).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: APPARATUS FOR THE PRODUCTION OF SYNTHESIS GAS

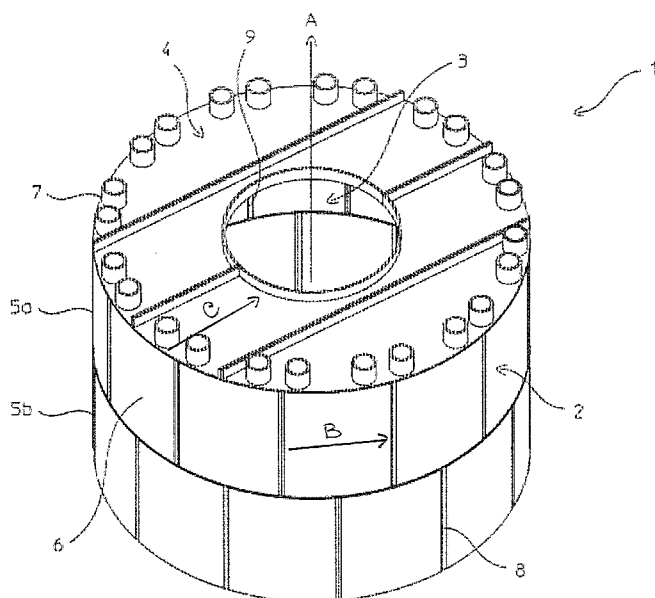


Fig. 1

(57) Abstract: Apparatus for the production of a synthesis gas from a hydrocarbon source, comprising a shell and a ceramic cylindrical pipe coaxial to said shell to delimit a reaction chamber of said apparatus, wherein said ceramic pipe comprises a plurality of elementary bricks. Groups of said elementary bricks are juxtaposed according to a tangential direction of the pipe forming several annular strips and said strips are arranged next to the other along an axial direction of the pipe. The pipe also comprises interlocking means arranged to provide a locking between bricks of adjacent strips.

Apparatus for the production of synthesis gas

DESCRIPTION

Field of the invention

- 5 The invention relates to the field of auto-thermal reforming or partial oxidation for production of a synthesis gas comprising hydrogen and carbon monoxide.

Prior art

- 10 A synthesis gas comprising carbon monoxide (CO) and hydrogen (H₂) is of industrial interest, for example for the synthesis of ammonia or methanol.

Techniques for producing said synthesis gas include steam reforming and over-stoichiometric combustion of a hydrocarbon source (e.g. natural gas). The term over-stoichiometric denotes a combustion which is performed with over-stoichiometric amount of fuel that is with defect of an oxidant.

- 15 Said combustion can be performed in a catalytic auto-thermal reformer (ATR) or in a partial oxidation (POX) reactor under harsh conditions of temperature and pressure, typically 1000 to 1700 °C and 40 to 100 bar.

- The vessel must be designed to resist such high temperature. A conventional design has the inside of the vessel protected by some layers
20 of refractive material. Usually multiple layers of different materials are used, since the inner and outer layers have different working conditions and requirements, and each layer is composed of preformed bricks or casts of a refractive cement. This technique however has some drawbacks. The refractive coating suffers from thermal stress, especially during the
25 transients, due to the different thermal properties of the different layers. Accordingly, rapid transients must be avoided since they could seriously

damage the coating. The formation of cracks in the refractory material, as a consequence of thermal stress, is also known as spalling.

Moreover, the provision of such multiple layers of refractive material inside the vessel is laborious and requires a long time.

- 5 EP 1806176 discloses an apparatus for producing synthesis gas comprising a metallic shell, an insulating layer and a pipe of ceramic material to delimit the reaction chamber and protect the metal shell. This ceramic pipe is much lighter and thinner than a conventional refractive coating thus having a low thermal inertia and exceptional resistance to
10 thermal shocks.

The practical realization of said ceramic pipe however may still be difficult. The purpose of the present invention is to provide a suitable and cost-effective way of making said ceramic pipe inside a vessel of a reactor, particularly of an auto thermal reformer or reactor for partial oxidation.

15 Summary of the invention

The above purpose is reached with a reactor vessel according to the attached claim 1. Preferred embodiments are disclosed in the dependent claims.

- The vessel comprises a ceramic pipe made of a plurality of elementary
20 bricks. Said elementary bricks are juxtaposed according to a tangential direction of the pipe forming several annular strips, also termed rings. Said rings are arranged one next to the other along an axial direction of the pipe. Interlocking means are arranged to provide locking between bricks of adjacent rings.

- 25 The ceramic pipe is coaxial to the shell and is preferably cylindrical. Accordingly, said elementary bricks may have a suitable curvature to follow the cylindrical shape.

The overall thickness of the ceramic pipe is preferably 50 mm to 300 mm and more preferably 70 mm to 200 mm. The bricks forming the pipe are preferably hollow bodies with a wall thickness between 5 mm to 50 mm and more preferably 8 mm to 20 mm.

- 5 Preferably, said interlocking means prevent a relative rotation of the rings around said axial direction. A preferred general embodiment of the interlocking means comprises at least one male part and one female part suitable for locking elementary bricks of adjacent rings. According to various embodiments, said male part and female part can be integral with
10 the bricks, or the male part can be an additional locking member.

The bricks of each ring are preferably offset relative to the bricks of the adjacent rings, for example of the upper and lower ring, with the advantage of providing a higher level of interlocking.

- The above mentioned male/female interlocking can be made following
15 various embodiments.

- A first embodiment of the male/female interlocking means provides that: each brick has a top surface and a bottom surface with one or more apertures, for example holes; the apertures of bricks of at least two adjacent rings are aligned for receiving the male part; the male part is an
20 elongated member passing through said apertures, for example a rod or tube or hollow pin. The number of said apertures may vary according to various embodiments.

- A second embodiment of the male/female interlocking means provides that: each brick has a top surface and a bottom surface with protrusions and
25 recesses integrally made in the brick. Said protrusions and recesses are arranged in such a way that two bricks can be interlocked by engagement of the protrusions/recesses. For example, the protrusions of bricks of one ring match with recesses of the bricks of another overlying or underlying

ring to provide the desired effect of interlocking.

In a particular embodiment, the female part is represented by an open face of the brick, for example an open bottom face. The male part is then represented by at least one protrusion having a suitable size to fit said open
5 face.

Said recesses may be passing-through holes. The recesses and protrusions may have a different shape, for example they may have a circular cross-section or a rectangular cross-section. The rectangular cross section may be preferred to provide a higher level of interlocking between
10 consecutive rings of the lining.

A third embodiment of the male/female interlocking means provides that said bricks are self-locking, i.e. they have a shape suitable for locking one to another.

An example of this embodiment is represented by bricks being symmetrical
15 relative to a median plane and comprising a core portion and two protruding end flanges, the core portion being defined by top and bottom faces parallel to the median plane and the end flanges being defined by two sloped surfaces joining each flange with the core portion and top and bottom faces also parallel to the median plane. The end flanges represent two male parts
20 and the space between top and bottom surface of the core portion and the flanges can be regarded as a recess, i.e. a female part.

When the bricks are juxtaposed, the end flanges of two adjacent bricks are accommodated in said space, which allow a self-locking between rings. This shape can be referred to as a “dog cookie” shape.

25 A further example of a self-locking embodiment is represented by bricks comprising different parts fitting together like a jigsaw puzzle. In a particularly preferred embodiment, each brick has a front H-shaped panel, a rear H-shaped panel and an intermediate slab. The H-shaped panels are

parallel to each other and the slab is offset relative to said panels, providing the required radial interlocking.

The bricks are made of a sintered ceramic. Preferably the bricks are made of a sintered ceramic without the addition of a binder. Accordingly, in a preferred embodiment, the bricks do not contain a binder such as bentonite.

The ceramic material for example is molded from a mass of raw material at room temperature and sintered at high temperature and a high pressure. According to preferred embodiments, the bricks are made of a technical ceramic which is selected among: silicate ceramics, oxide ceramics, non-oxide ceramics, ceramic matrix composites.

Preferably, a face of the bricks is open in order to allow for the production of bricks by slip casting, which is the most economic production method, and an opposite face is closed.

The following is a description of a particularly preferred embodiment.

The bricks are realized according to the above mentioned first embodiment including apertures on the top and bottom surfaces and are locked by an elongated member. One or more first aperture(s) are located on one of the top and bottom surfaces and at least two second apertures are located on the opposite surface. At least one first aperture is aligned with a second aperture for receiving said elongated member.

For example, one aperture is made on the top surface and two apertures are made on the bottom surface, one of them being aligned with the top aperture. Accordingly, said elongated member can pass through the aligned top and bottom apertures traversing the brick and emerging inside an overlying brick. Preferably, said elongated member emerges from the top aperture of said brick and engages one of the bottom apertures of an overlying brick. More preferably, said elongated member emerges for a length ranging between 10-90% and preferably between 20-50% of the

longitudinal length of the bricks.

In a further embodiment, said aligned top and bottom apertures are also aligned with an aperture of the overlying and/or underlying bricks, which in turn may be further aligned with apertures of bricks forming adjacent strips.

- 5 In this case, the elongated members may axially traverse at least two bricks and engage a third (or further) brick. A related advantage is a stronger connection and greater mechanical strength.

- Advantageously, the bricks and the elongated members are cemented together with suitable cement. The reduced thermal stress, due to the
10 presence of a single refractory layer, prevents the cracking of the cement providing added level of stability of the lining.

Said bricks are preferably hollow bodies with a substantially rectangular cross-section, and said elongated members are preferably in the form of hollow tubes.

- 15 In a variant of the above embodiment, each brick may have a set of four holes, allowing for insertion of full length locking members. For example the locking members may cover substantially the full axial length (height in a vertical arrangement) of the ceramic pipe.

The main advantages of the above embodiments are the following.

- 20 The invention provides an efficient way of protecting the metal vessel with a ceramic pipe and an insulation layer which is far lighter and less costly than the refractive materials of the prior art.

- The ceramic pipe is practically insensitive to the above mentioned problem of spalling, due to its properties of single-layer structure, little mass, high
25 thermal conductivity, low thermal inertia. The low thermal inertia and ability of the ceramic pipe to bear a severe temperature gradient over time are of great advantage and provide more freedom in the operation of the reactor. Rapid transients become possible without the risk of structural damage, the

metal vessel being protected by the ceramic pipe.

The hollow structure of the bricks and the tubes, according to a preferred embodiment, is of further advantage since it gives mechanical strength, simple construction and still reduced thermal inertia. Spalling is also
5 prevented by the wedged shape of the interlocking means, with particular reference to the preferred embodiment with apertures on the bricks and external elongated members.

Moreover, owing to proper cement installation, limited brick dimensions, closed top and bottom surfaces and short tubes, the risk of a longitudinal
10 gas bypass through the hollow body of the ceramic pipe is minimized.

In addition, pins emerging from the bricks forming the top and bottom rings provide fixing means for the installation of a top and bottom lining.

Another aspect of the invention concerns the realization of said elementary bricks involving the assembly of different parts in green conditions.

15 The terminology “green” conditions” is used for the technical ceramic having the consistence of wood and being able to be machined and assembled accordingly. The assembly of different parts is like gluing together wood parts, with the difference that a technical ceramic paste is used instead of glue.

20 For example, said different parts may be obtained by slip casting of a liquid suspension or by extrusion or injection molding of a ceramic paste.

Both the liquid and the paste are basically suspensions of ceramic particles in a suitable medium. As to slip casting, said liquid medium is removed by absorption through the mold walls and the resulting solid shape is said to
25 be in “green” form. As to the other techniques, the extruded or injection molded shapes reach “green” conditions after natural drying in air.

The advantages will emerge even more clearly with the aid of the detailed

description below, relating to a preferred embodiment.

Brief description of the drawings

Fig. 1 is a perspective view of a portion of a ceramic pipe for a reactor vessel, according to one of various embodiments of the invention;

- 5 Fig. 2 shows an elementary brick of the ceramic pipe of Fig. 1 according to a first embodiment.

Fig. 3 shows the locking between bricks of the type illustrated in Fig. 2.

Fig. 4 shows an elementary brick of the pipe according to a second embodiment and provided with cylindrical recesses and protrusions.

- 10 Fig. 5 shows the locking between bricks of the type illustrated in Fig. 4.

Fig. 6 is a perspective view of a portion of a ceramic pipe formed with bricks of Fig. 4.

Fig. 7-8 show a variant of the elementary brick of Figs. 4-6, with an open bottom.

- 15 Fig. 9-10 show two variants of the elementary brick of Fig. 4, with recesses and protrusions having a substantially trapezoidal cross-section.

Fig. 11 shows a “dog cookie” shaped brick according to another embodiment.

- 20 Fig. 12 is a perspective view of a portion of a ceramic pipe formed with bricks of Fig. 11.

Fig. 13 shows a perspective view of a brick according to another embodiment.

Figs. 14-15 show lateral and top view of the brick of Fig. 13.

- 25 Fig. 16 is a perspective view of a portion of a ceramic pipe formed with the bricks of Figs. 13-15.

Fig. 17 shows an apparatus for the production of a synthesis gas comprising a ceramic pipe.

Detailed description

Fig. 1 shows a ceramic pipe 1 to be fitted in an ATR or POX reactor vessel,
5 according to an embodiment of the invention.

Said pipe 1 has an outer wall 2, an inner wall 3, a top lining 4 and a bottom lining (not shown). The pipe 1 is installed in a reactor such as ATR or POX to delimit a reaction chamber and protect the outer metal shell. The top lining 4 has a central opening 9 for the installation of a process burner 103
10 (shown in Fig. 17).

Said pipe 1 has an axial direction indicated by the arrow A, a tangential direction indicated by the arrow B and a radial direction indicated by the arrow C in the figure.

The radial space between the outer wall 2 and the inner wall 3 can be
15 regarded as the overall thickness of the ceramic pipe 1 and is preferably comprised between 70 and 200 mm. Preferably the ceramic pipe is hollow which means that the actual thickness of the outer wall 2 and inner wall 3 is smaller, for example 8 to 20 mm.

The ceramic pipe 1 is formed by a number of annular rings, which are
20 arranged one next to the other along the axial direction A. For example the rings are placed one above the other in a vertical vessel. Each of said rings is formed by a plurality of elementary bricks 6, which are juxtaposed along the tangential direction B. Fig. 1 for example shows two rings 5a, 5b.

The bricks 6 are made of a sintered ceramic material. Preferably the bricks
25 6 are made by pressure-driven sintering without the addition of a binder.

The bricks 6 of the ring 5a are offset relative to the bricks 6 of the adjacent ring 5b, as illustrated in Fig. 1 by the boundary lines 8 between the bricks 6.

In the figure, the ring 5a is the top ring of the pipe 1.

The bricks of ring 5a are locked to bricks of ring 5b by pins 7 passing through apertures of the bricks 6 as explained below.

5 Figs. 2 and 3 show a preferred embodiment of the bricks and their interlocking connection.

Each brick 6 is a hollow body defined by a top face 10, a bottom face 11, two lateral faces 12, 13 a front face 14 and a rear face 15, and having a substantially rectangular cross-section and a height h .

10 The top face 10 and bottom face 11 are provided with apertures for interlocking pins 7; in the embodiment of Figs. 2-3 each brick 6 has a single aperture 16 on the top face 10 and two apertures 17 (left) and 18 (right) on the bottom face 11. The axes of said left and right apertures 17, 18 are distanced by a pitch p and the aperture left 17 is aligned with the above aperture 16 along the axis A-A. In the example all the apertures are circular
15 holes but different shapes may be adopted.

The lateral face 12 is preferably open to allow for the bricks production by slip casting, while the opposite lateral face 13 is preferably a closed surface.

20 In order to prevent crashing or bursting during pressurization and depressurization cycles, a small pressure equalization hole is also advantageously drilled in the closed surfaces of said hollow-shaped bricks.

The locking between bricks 6 by means of the pins 7 is shown in Fig. 3.

Different sets of bricks define superimposed rings 5a, 5b, 5c and 5d. Bricks of the first ring 5a are offset relative to underlying bricks of the second ring
25 5b, which are in turn offset relative to bricks of the third ring 5c, and so on.

The offset distance d between the strips is equal to the above mentioned pitch p between the left and right apertures of the bottom face of each brick.

More in detail, a generic brick 6 of an intermediate ring is bound to one brick of the overlying ring with a first pin 7 and is further bound to another brick of the underlying ring with a second pin 7.

For example, looking at Fig. 3, a brick 6.1 of ring 5b is bound to a brick 6.2 of the overlying ring 5a by a first pin 7.1 fitted in the left aperture 17 of the brick 6.1 and emerging from the top aperture 16 of the same brick 6.1 to engage the bottom right aperture 18 of the above brick 6.2; the same brick 6.1 is further connected to a brick 6.3 of the underlying ring 5c by a second pin 7.2 passing through the bottom right aperture 18 of the brick 6.1 and the top aperture 16 of the brick 6.3 to fit in the left aperture 17 of the latter brick 6.3.

Preferably the offset distance d is half the length of the top and bottom surface. In accordance, as seen in Fig. 3, the bricks of ring 5a are aligned with bricks of ring 5c and so on.

The portion 7a of pins 7 emerging from top faces 10 of the bricks has a length preferably comprised between 20% and 50% of the height h of the bricks.

As a result of the above arrangement of bricks 6 and pins 7, the various strips of the lining 1 are interlocked one to another. Said pins 7 and apertures of the bricks provide male/female interlocking means.

Preferably the pins 7 are realized with hollow tubes.

Turning back to Fig. 1, the pins 7 emerging from the bricks 6 of the top ring 5a provide fixing means for the top lining 4. For example said top lining 4 is realized with ribbed extruded C-shaped profiles provided with holes for engagement with said pins 7. The bottom lining can be fixed in a similar way.

Preferably the top lining 4 is also made of ceramic material.

Figs. 4-6 show a second embodiment of the invention where the male fixing parts are integrally formed in the bricks.

Each elementary bricks now referred to as 26 includes protrusions 27 and corresponding recesses 28 on opposite faces, for example on a top and on
5 a bottom face. Said recesses 28 can be, for example, passing-through holes. In the example of the Figs 4-6 said protrusions 27 and said recesses 28 have a circular cross-section.

Figs. 5 and 6 show the interlocking between two bricks 26 of this second embodiment, wherein the protrusions 27 of one brick are fitted in the
10 recesses 28 of other bricks.

A preferred method for manufacturing the bricks 26 is the following. The protrusions 27 are integral with the body of the brick 26 and are obtained together by slip casting in a single mold. Said protrusions 27 have preferably the same thickness of the brick walls. The bottom surface 29
15 with holes 28 is then glued at green conditions on the lower side of the slip casted brick 26.

Figs. 7-8 illustrate a third embodiment of bricks 36 which is a variant of the second embodiment, wherein the male/female interlocking parts of bricks 36 include protrusions 37 and an open bottom 38 (e.g. slit). Hence the
20 relative position of two interlocked bricks may vary according to the position of a protrusion 37 engaged with the slit 38 (Fig. 8) instead of being dictated by the position of holes 28 as in Fig. 5.

The body of the brick 36 in this case is preferably realized by extrusion, and the top surface 39 can be a flat plate glued on the upper side of the
25 extruded part; the protrusions 37 are extruded cylinders glued at green conditions on the plate 39.

Fig. 9 shows a fourth embodiment of a brick 46 with male/female interlocking parts made with the protrusions 47 and holes 48 of a

substantially rectangular cross-section.

Fig. 10 shows a fifth embodiment of a brick 56 which is a variant of the fourth embodiment featuring a full open bottom 58 to receive the protrusions 57; preferably, in this embodiment, the protrusions 57 extends
5 to cover substantially all the top surface.

Fig. 11-12 shows a sixth embodiment of interlocking bricks 66 wherein each elementary brick 66 has basically a core portion 60 and two end flanges 67. The brick 66 is symmetrical relative to a median plane 61. Each flange 67 comprises two sloped surfaces 62 joining the flange 67 with the core
10 portion 60 and top/bottom faces 63 parallel to the median plane 61. The core portion 60 has top and bottom faces 64 also parallel to said plane 61.

In this embodiment, the end flanges 67 form two male interlocking parts; a corresponding female part is represented by a space 68 between the planes of faces 63 and 64. Said space 68 receives the end flanges 67 of a
15 pair (left/right) of adjacent bricks. The interconnection between bricks 66 of this embodiment is shown in Fig. 12.

Figs. 13 to 16 show a seventh embodiment of a bricks 76. Said brick 76 comprises a front H-shaped panel 70, a rear H-shaped panel 71 and an intermediate rectangular slab 72 between the two H-shaped panels. The
20 two H-shaped panels and the intermediate slab are parallel to each other. The intermediate slab 72 is offset relative to said two H-shaped panels as shown in Fig. 13.

The H-shaped panels 70, 71 and the offset slab 72 form upper/lower and front/rear male interlocking parts 77 and corresponding female parts 78
25 (Figs. 13-15).

The interconnection between bricks 76 of this embodiment is shown in Fig. 16. The bricks 76 fit together like a jigsaw puzzle as the lateral arms of two bricks are received within the cavity 78 of bricks forming over- and

underlying rings.

Said bricks 76 are for example realized as single monolithic pieces or joining together the three different parts in green conditions.

Fig. 17 shows the ceramic pipe 1 in a reactor 100. The ceramic pipe 1
5 delimits the internal reaction chamber 101 of said reactor 100 and protects the metal shell 102. The interspace 104 between the tube 1 and the metal shell 102 can be filled with ceramic fibers 105.

CLAIMS

1. Apparatus for the production of a synthesis gas from a hydrocarbon source, comprising a shell and a ceramic cylindrical pipe (1) coaxial to said shell to delimit a reaction chamber of said apparatus,
5 said shell to delimit a reaction chamber of said apparatus,
characterized in that:
said ceramic pipe (1) comprises a plurality of elementary bricks (6, 26, 36, 46, 56, 66, 76), said bricks being made of a sintered ceramic material;
10 groups of said elementary bricks are juxtaposed according to a tangential direction (B) of the pipe forming several annular strips (5) and said strips (5) are arranged next to the other along an axial direction (A) of the pipe,
and the pipe also comprises interlocking means arranged to provide a
15 locking between bricks of adjacent strips.
2. Apparatus according to claim 1, said bricks being made of a ceramic material selected among: silicate ceramics, oxide ceramics, non-oxide ceramics, ceramic matrix composites.
3. Apparatus according to claim 1 or 2, said pipe (1) comprising only one
20 set of said bricks in the radial direction.
4. Apparatus according to any of claims 1 to 3 wherein the bricks forming each annular strip are offset relative to the bricks of the adjacent strips.
5. Apparatus according to any one of the previous claims, wherein the overall thickness of said pipe (1) is 50 to 300 mm and preferably 70 to
25 200 mm.

6. Apparatus according to any one of the previous claims, wherein said bricks are hollow bodies with a wall thickness of 5 to 50 mm and preferably 8 to 20 mm.
7. Apparatus according to any one of the previous claims, wherein said
5 interlocking means are arranged to prevent a relative rotation between said strips (5).
8. Apparatus according to any one of the previous claims, wherein said interlocking means comprise at least one male part (7, 27, 37, 47, 57, 67, 77) and one female part (16, 17, 18, 28, 38, 48, 58, 68, 78).
- 10 9. Apparatus according to claim 8, wherein said male parts are elongated members (7) engaging said female parts, said female parts being apertures (16, 17, 18) obtained on opposite faces (10, 11) of said bricks (6), at least two of said apertures (16, 17) being aligned to accommodate said elongated member (7).
- 15 10. Apparatus according to claim 9, wherein said elongated member (7) axially traverses at least one brick (6.1) and emerges inside an overlying or underlying brick (6.2) for a length ranging between 10-90% and preferably between 20-50% of the longitudinal length of the bricks.
- 20 11. Apparatus according to claim 8, wherein said male and female parts are protrusions (27, 37, 47, 57) and recesses (28, 38, 48, 58), said protrusions and recesses being arranged on opposite faces of said bricks so as the protrusions of bricks of one annular strip engage the recesses of bricks of another overlying or underlying annular strip.
- 25 12. Apparatus according to claim 11, wherein the female part is represented by an open face (38, 58) of the brick and the male part is represented by at least one protrusion (37, 57) having suitable size to fit

said open face.

13. Apparatus according to claim 8, wherein said elementary bricks (66, 76) are self-locking and have a shape suitable for locking one to another.
14. Apparatus according to claim 13, wherein said bricks (66) are
5 symmetrical relative to a median plane (61) and comprise a core portion (60) with top/bottom faces (64) parallel to said plane and two protruding end-flanges (67) with two sloped surfaces (62) joining each flange with the core portion (60) and top/bottom faces (63) parallel to the median plane, the end-flanges forming two male parts and the corresponding
10 female parts being represented by recesses (68) formed between the planes of faces (63) and (64).
15. Apparatus according to claim 13, wherein said bricks (76) comprise a front H-shaped panel (70), a rear H-shaped panel (71) and an intermediate slab (72) offset relative to said two H-shaped panels, said
15 H-shaped panels and slab form upper/lower and front/rear male parts (77) and corresponding female parts (78).
16. A method for making a ceramic pipe (1) inside the vessel of an apparatus for production of synthesis gas, said pipe (1) to define a reaction chamber of the apparatus, the method comprising the provision
20 of elementary bricks (6, 26, 36, 46, 56, 66, 76) made of a sintered ceramic material, wherein groups of said elementary bricks are juxtaposed according to a tangential direction (B) of the pipe (1) forming several annular strips (5) and said strips (5) are arranged next to the other along an axial direction (A) of the pipe, and the method also
25 comprising the locking between bricks of adjacent strips by interlocking means of the bricks.

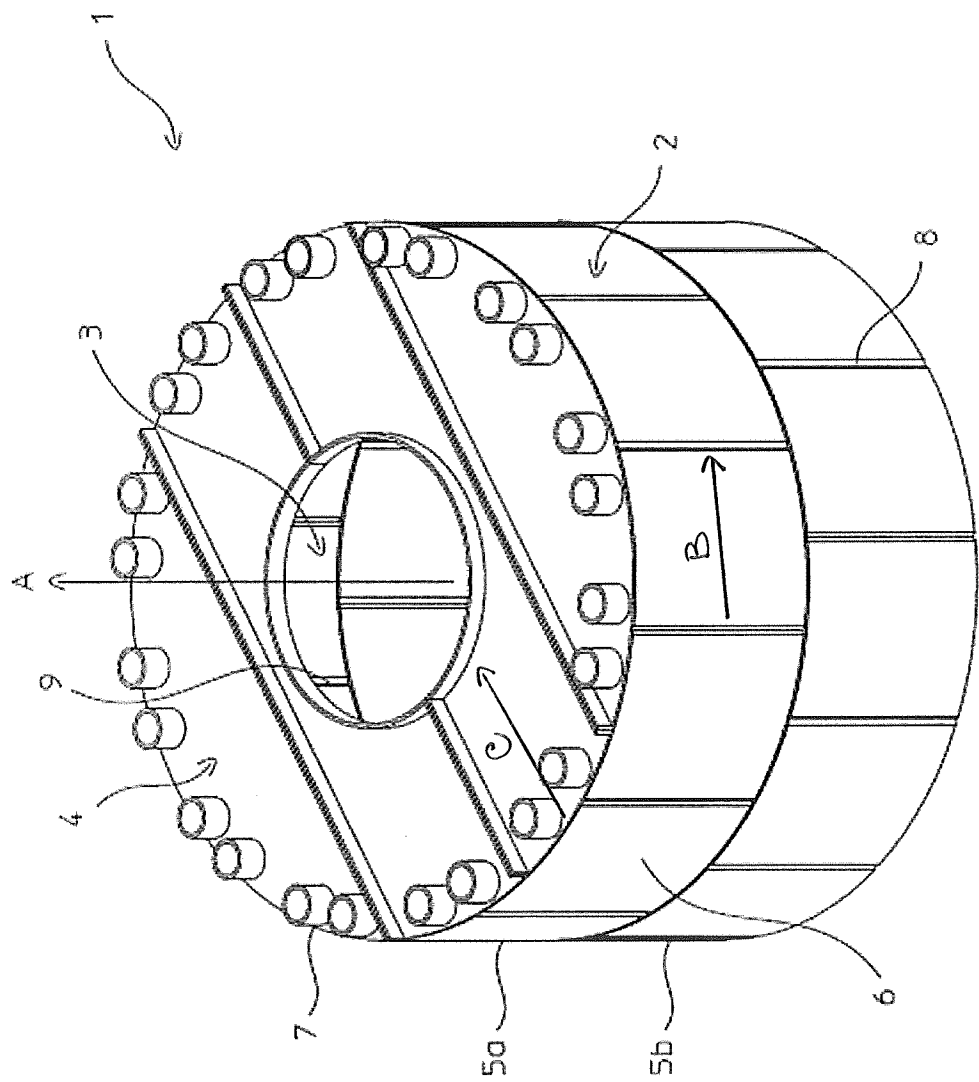


Fig. 1

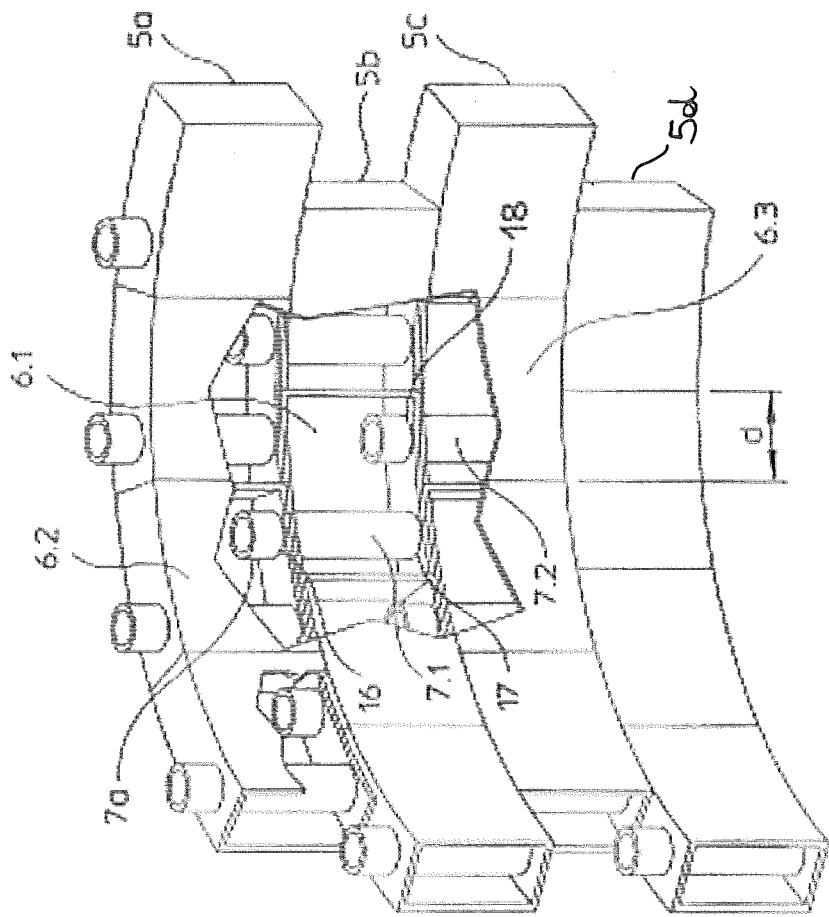


Fig. 3

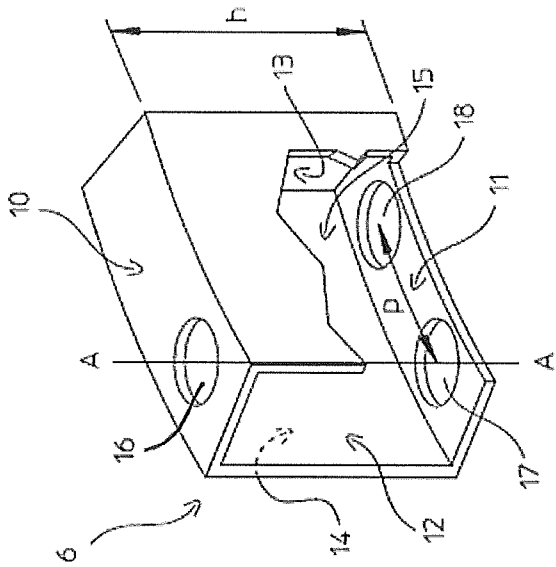


Fig. 2

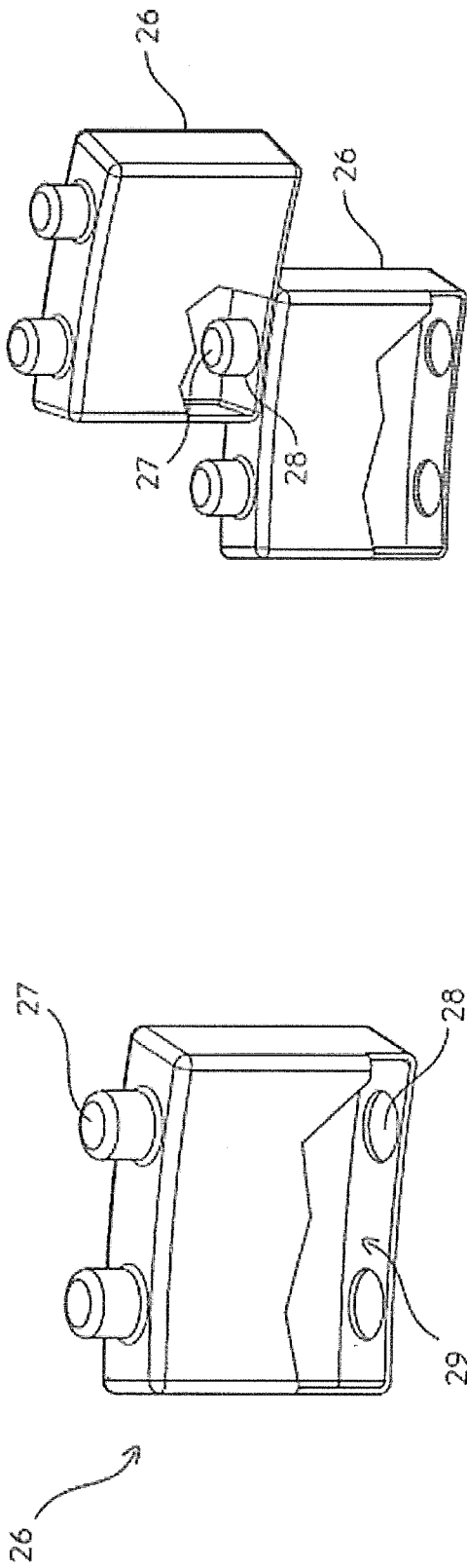


Fig. 4

Fig. 5

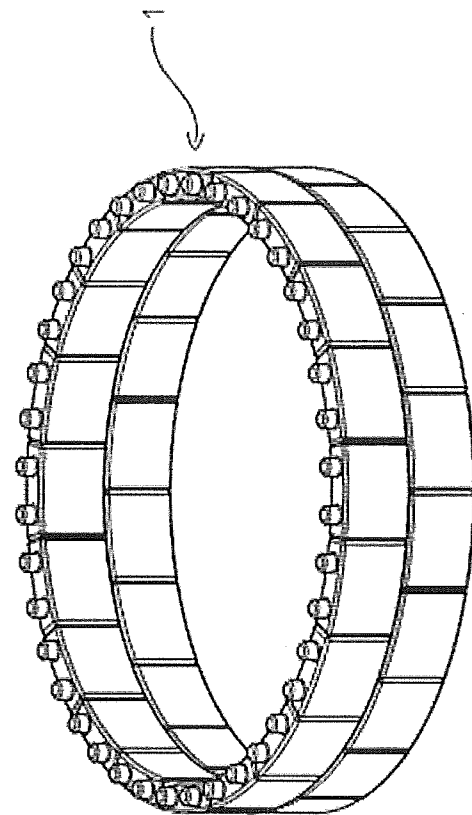
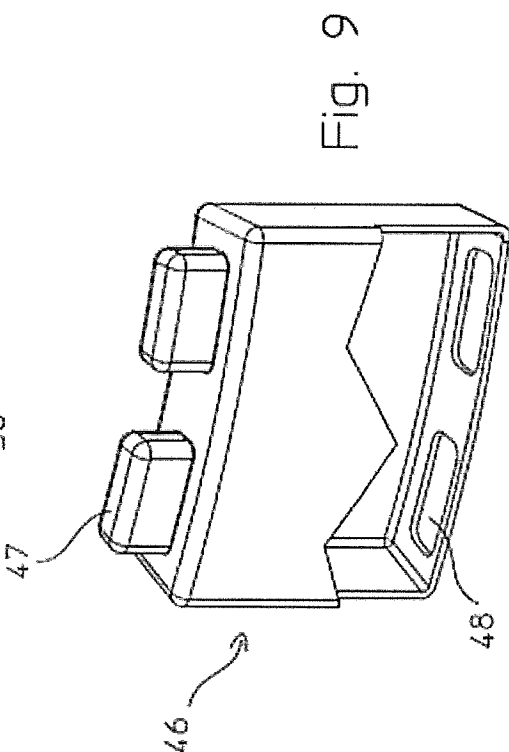
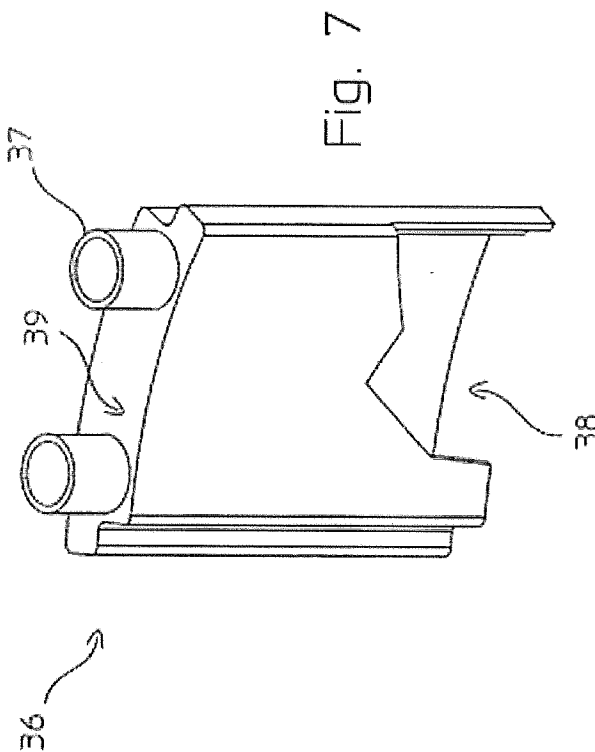
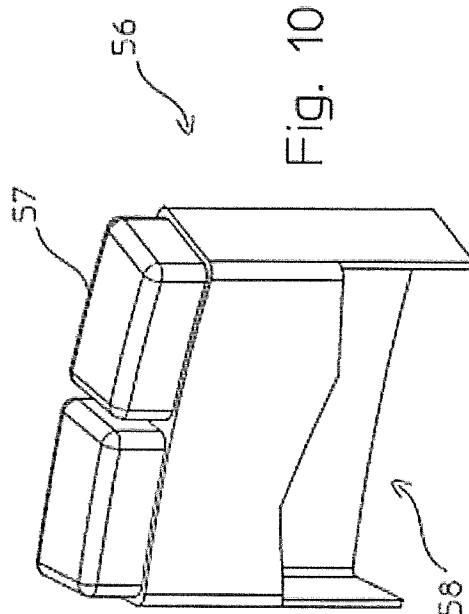
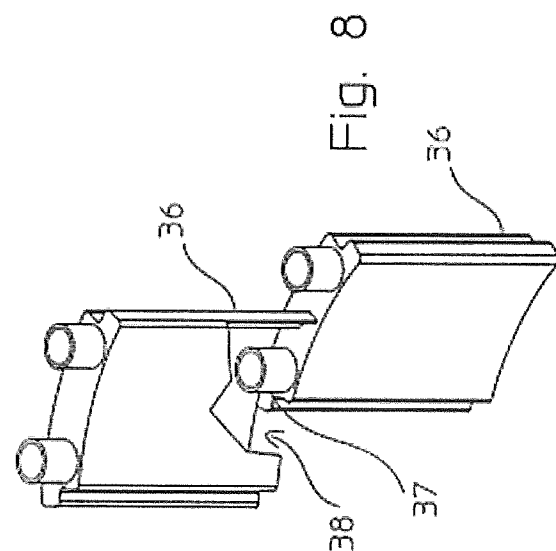


Fig. 6



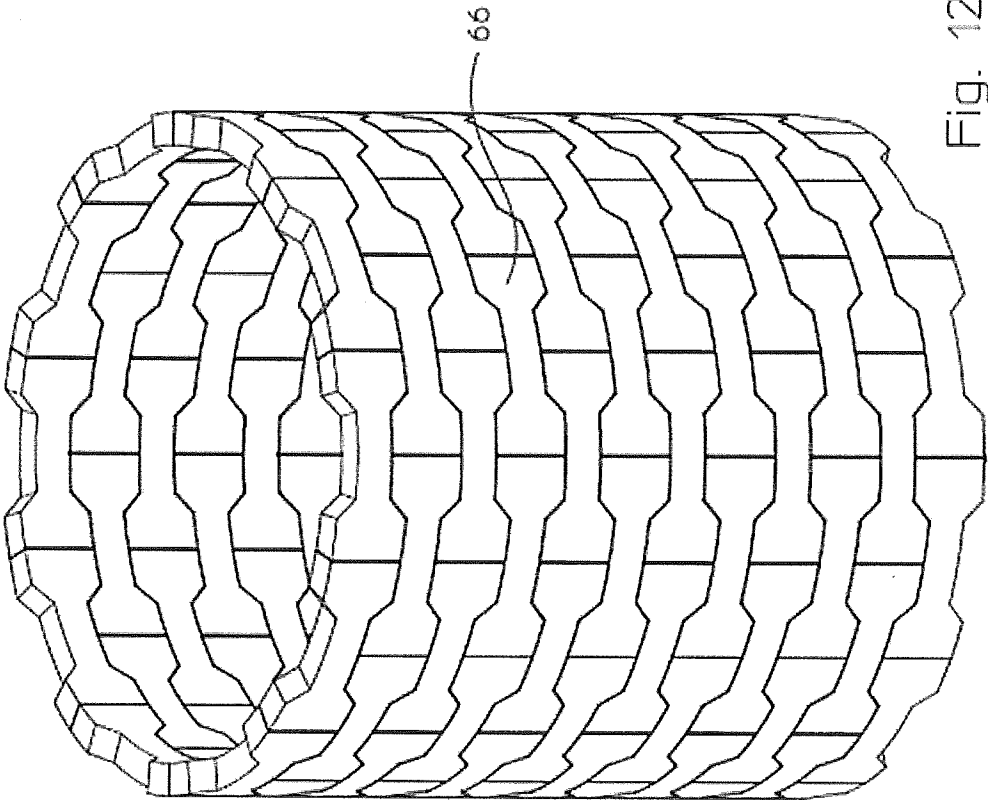


Fig. 12

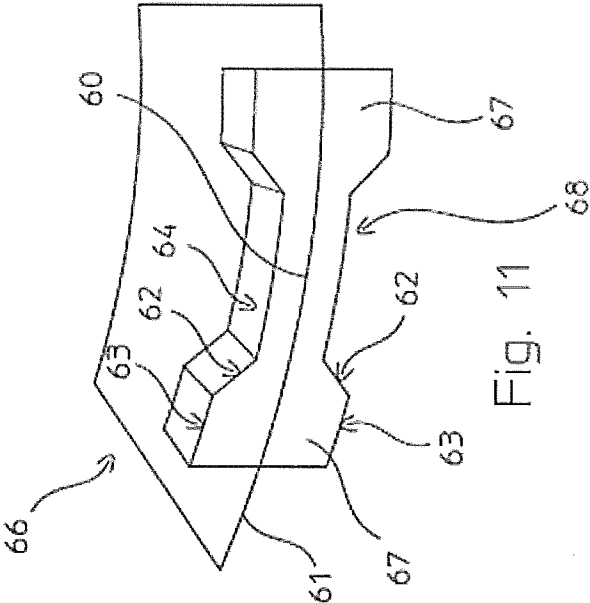
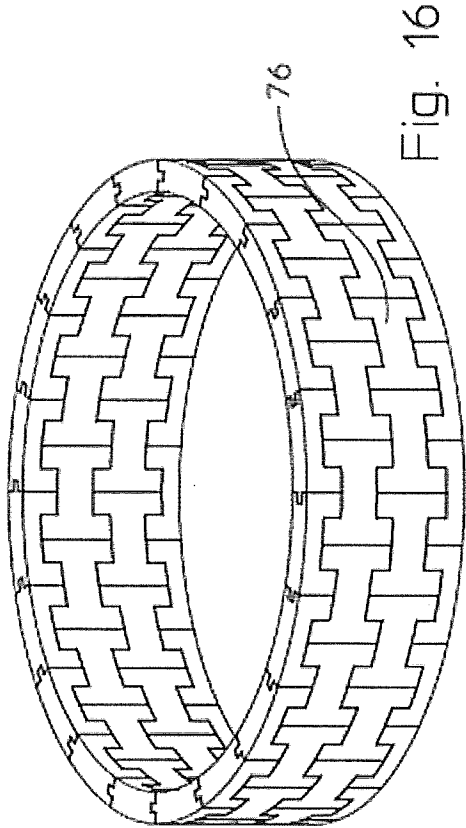
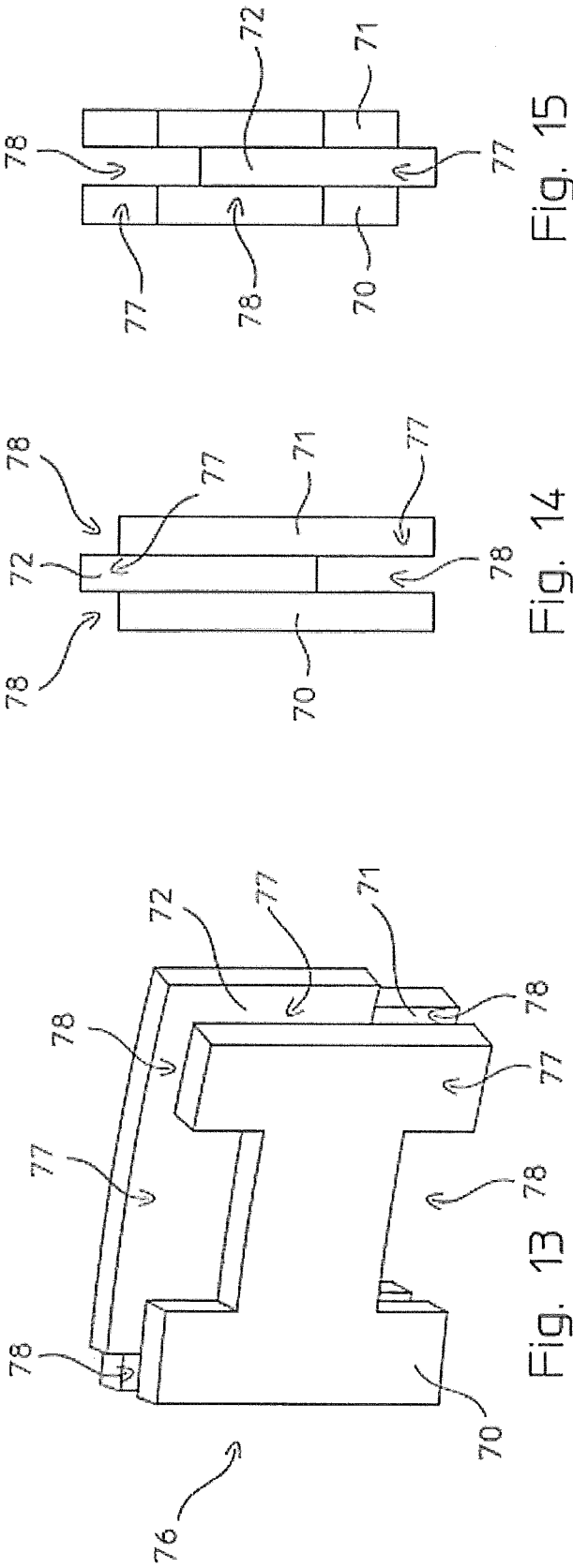


Fig. 11



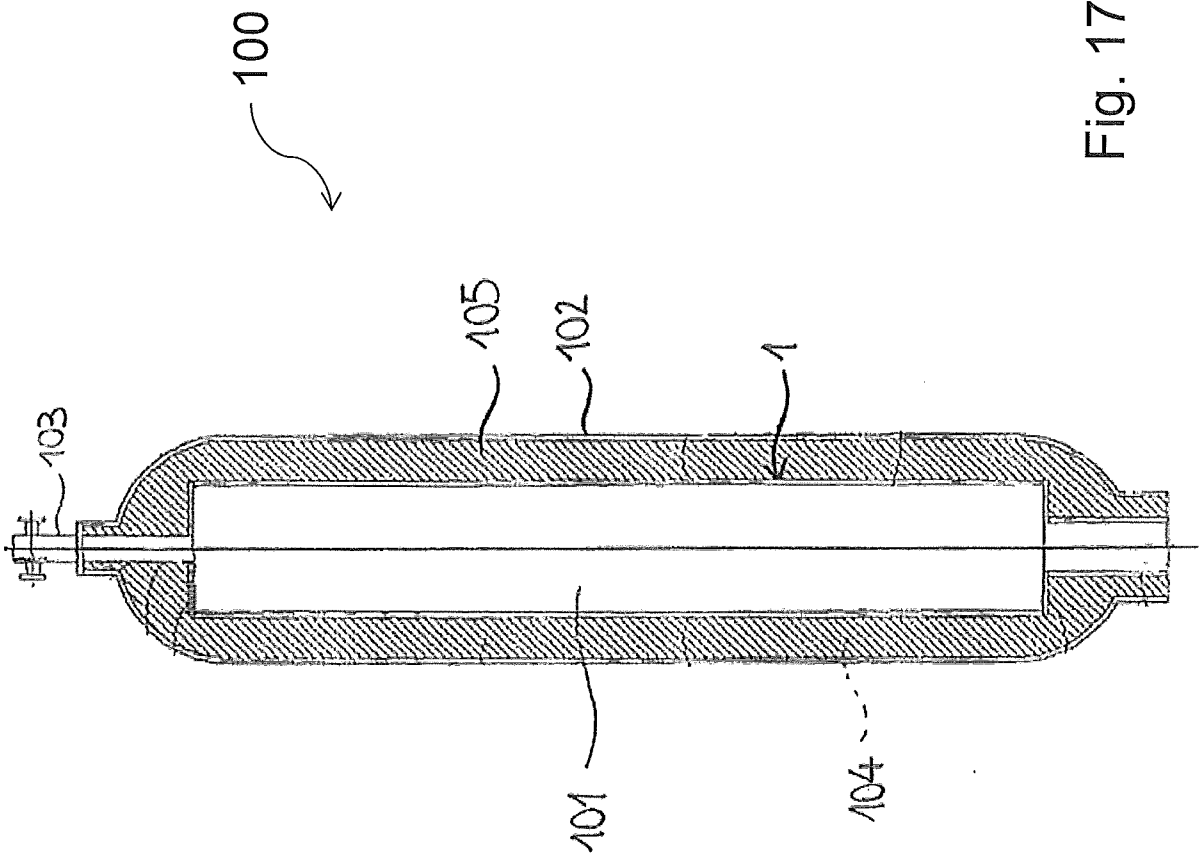


Fig. 17

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/066086

A. CLASSIFICATION OF SUBJECT MATTER
INV. C01B3/36 C01B3/38
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)
C01B

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 2 281 003 A (HENSON WILLIAM H ET AL) 28 April 1942 (1942-04-28) page 1, left-hand column, line 1 - line 11 page 1, right-hand column, line 35 - line 37 page 2, left-hand column, line 23 - line 40 page 2, left-hand column, line 71 - right-hand column, line 59 page 2, right-hand column, line 35 - line 47 figures 1,4,6	1-8,11, 13,16
X	US 6 540 510 B1 (ABDULLAH ZIA [US] ET AL) 1 April 2003 (2003-04-01) column 2, line 50 - column 3, paragraph 63 figures 1,2 ----- -/--	1,2,4,8, 11,13,16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 September 2016

Date of mailing of the international search report

29/09/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Harf-Bapin, E

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/066086

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DATABASE WPI Week 201215 2012 Thomson Scientific, London, GB; AN 2012-C01209 XP002752978, -& CN 102 329 646 A (HUAIBEI WHIRLPOOL BUILDING CERAMICS CO) 25 January 2012 (2012-01-25) abstract figure	1-4, 7-11,13, 14,16
Y	----- CN 204 268 893 U (ACRE COKING & REFRACTORY ENG CONSULTING) 15 April 2015 (2015-04-15) abstract figures	1-4,7, 13,14,16
T	----- DATABASE WPI Week 201542 Thomson Scientific, London, GB; AN 2015-357353 XP002752979, -& CN 204 268 893 U (ACRE COKING & REFRACTORY ENG CONSULTING) 15 April 2015 (2015-04-15) abstract figures	
Y	----- EP 0 079 247 A1 (ENGLISH ELECTRIC CO LTD [GB]) 18 May 1983 (1983-05-18) figures	1-4, 7-11,16
A	----- WO 2004/098770 A1 (LINDE AG [DE]; MUSCHELKNAUTZ SEBASTIAN [DE]; RANKE HARALD [DE]; TAUTZ) 18 November 2004 (2004-11-18) the whole document	1-16
A	----- US 1 888 039 A (HUFF LYMAN C) 15 November 1932 (1932-11-15) the whole document -----	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/066086

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2281003	A	28-04-1942	NONE
US 6540510	B1	01-04-2003	AU 2003200135 A1 25-09-2003 BR 0300158 A 10-08-2004 CA 2416024 A1 11-09-2003 DE 10303709 A1 30-10-2003 FI 20030129 A 12-09-2003 FR 2844255 A1 12-03-2004 NO 20030482 A 12-09-2003 NZ 523717 A 31-10-2003 US 6540510 B1 01-04-2003
CN 102329646	A	25-01-2012	NONE
CN 204268893	U	15-04-2015	NONE
CN 204268893	U	15-04-2015	NONE
EP 0079247	A1	18-05-1983	AU 550298 B2 13-03-1986 AU 9030782 A 19-05-1983 DE 3266865 D1 14-11-1985 EP 0079247 A1 18-05-1983 GB 2109026 A 25-05-1983 IE 53479 B1 23-11-1988 NZ 202455 A 21-02-1986
WO 2004098770	A1	18-11-2004	CA 2525271 A1 18-11-2004 DE 10320966 A1 25-11-2004 RU 2346737 C2 20-02-2009 US 2007092415 A1 26-04-2007 WO 2004098770 A1 18-11-2004 ZA 200509013 B 25-10-2006
US 1888039	A	15-11-1932	NONE