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(54) Benævnelse: **REAKTOR MED KATALYTISK FAST LEJE, DER INTEGRERER ET ELEKTRISK VARMEELEMENT, ENHED TIL PRODUKTION AF HYDROGEN VED DAMPREFORMING OMFATTENDE EN SÅDAN REAKTOR OG EN ELEKTRISK DAMPGENERATOR SAMT TILKNYTTET FREMGANGSMÅDE TIL DRIFT**

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Description

Technical field

The present invention pertains to the field of decentralized production of hydrogen for the marketable hydrogen sector and the supplying of hydrogen distribution stations.

More specifically, the invention relates first and foremost to the reactor for producing hydrogen by steam reforming and the decentralized unit for producing marketable or vehicular hydrogen that employs said reactor. It is recalled here that the term "marketable hydrogen" refers to the hydrogen which is produced, and packaged by a merchant, in tubes on a road trailer or cylindrical bottles, then transported over a significant distance and sold to a consumer other than the producer, generally to small-scale consumers.

Prior art

Production of hydrogen requires a substance containing hydrogen (water, methane, etc.) and energy (heat, electricity) for extracting hydrogen from the substance. In order to produce hydrogen locally, this substance and this energy must be available locally either via a distribution network with sufficiently fine branching, or by local production facilities available close to the site of production and hence of requirement.

The production intended locally ranges from a few kilograms to a few hundred kilograms per hour, and the production unit must be located close to the consumer market (small-scale industrial or service consumers, hydrogen stations for road and river traffic).

The prime advantage of this market at least in Europe, beside the fact that it presently exists and represents one tenth of a % of the hydrogen market in France already, is that the costs of packaging and transporting the hydrogen have the potential to open up a margin for local production of low capacity relative to the current production, which is massive, centralized at two or three locations in Europe and therefore at a distance from consumers.

The market in hydrogen distribution stations for traffic is a future market.

The primary constraints for delocalized production may be summarized as follows:
- small-scale production, typically less than a daily amount of the order of 500 to 1000 kg;
- rapid temporal adaptation to requirements, i.e. a high production dynamic with a short production time, to prevent substantial and hence highly expensive buffer storage of hydrogen,
- a reduced footprint and high degree of compactness, meaning that the volume of the facility must be low,
- an investment cost as low as possible, given that for this type of facility, i.e. small-scale production, the investment cost represents the major factor in the production cost; etc.

A further constraint, particularly for hydrogen stations intended for traffic, is the need to have a very low CO_2 footprint.

In light of the existence of networks for transport and for highly branched distribution of the hydrogen source material and for the energy required for producing hydrogen, the two technologies which have been developed industrially to date, in France and in Europe, and which are capable of realizing delocalized production, are water electrolysis and the reforming of natural gas.

As regards water electrolysis, the marginal hydrogen production cost of this technology is three to four times greater than that of gas (depending on country) and the technology has a facility capex (acronym for capital expenditure) which is higher than for a reforming unit, typically 2 to 3 times higher, even if they are comparable, as the capacities of existing units are very different from those of present-day reforming; twice the consumption of water, a reduced energy efficiency, typically from 5% less to 20% less, including at the level of the unit, and CO_2 emissions which depend on the nature of the electrical mix in the country. In this last respect, in the United Kingdom, the emissions are 400 g CO_2/kWh, which is very high. Conversely, major advantages of water electrolysis are that it is suitable for small production capacities, requires an occupied space, and exhibits a greater dynamism in terms of feedstock variation and start-up than the thermal steam reforming unit facilities as described hereinafter. Lastly, owing to the nature of the energy used, it offers the opportunity for opportunity gains over the electric network services ("power to gas" route).

As already observed, the existence of a highly branched natural gas network in France (less than 30 km between network nodes), but also in Europe, raises the possibility of contemplating delocalized production of hydrogen by reforming of natural gas.

The most suitable natural gas reforming technology for the production of hydrogen is steam reforming, which has been developed industrially for more than 50 years.

The chemical reactions producing hydrogen with this technology are as follows:

- the reaction for reforming methane using steam, which is highly endothermic:

[Chem 1]

$CH_4 + H_2O \leftrightarrow CO + 3H_2$, with $\Delta H = +247$ kJ/mol;

- the reaction for reforming carbon monoxide using steam, referred to as WGS (Water Gas Shift), which is exothermic:

[Chem 2]

$CO + H_2O \leftrightarrow CO_2 + H_2$, with $\Delta H = -41.6$ kJ/mol;

each of these reactions is carried out in a separate stage of the production unit, these stages usually being referred to

respectively as SMR (Steam Methane Reformer) and WGS (Water Gas Reaction).
The overall reaction is written as follows:
[Chem 3]
$CH_4 + 2H_2O \leftrightarrow 4H_2 + CO_2$, with $\Delta H = +206$ kJ/mol.

A unit for producing hydrogen by steam reforming as envisaged from the 2010s onwards is a complex system having a number of functional stages or stations, which tends towards the greatest energy efficiency and the lowest possible release of CO_2 to the stack towards the atmosphere.

Figure 1 shows a schematic representation of such a unit, denoted overall by the reference 1, which in addition operates capture and subsequent conditioning of the CO_2 produced.

This steam reforming unit 1 comprises primarily the following stations or stages:
- at least one stage 2 for steam reforming of methane to syngas (a mixture of species: H_2, CO, CO_2, CH_4);
- at least one desulfurization stage 3, upstream of the steam reforming stage 2;
- at least one stage 4 for steam reforming of CO, downstream of the methane steam reforming stage 2. The reaction for reforming CO with water is catalytic. It takes place between 400 and 300°C and is exothermic, meaning that the one or more reforming stages 4 have to be cooled;
- at least one burner 5 suitable for producing the heat required for the reforming reaction, but also for the production of the steam. Each burner 5 carries out the combustion of the purge gases from the downstream separation stages, particularly for the purification of hydrogen, with generally a significant input, typically of 20 to 30%, of natural gas;
- at least one steam generator 6 which is supplied with heat by the one or more burners 5 and by a heat recovery system for heat given off by the CO reforming stage 4;

- a station 7 for capturing the CO_2 produced, generally by adsorption on amines, downstream of the CO reforming stage 4, this station 7 being fed with steam by the steam generator 6;
- a hydrogen purification stage 8, operating generally by pressure swing adsorption (PSA), downstream of the capture stage 7, with the purge gases from this purification being either sent to a burner 5 or being reinjected at the start of steam reforming, typically in the desulfurization stage 3 as shown in Figure 1;
- compression stages 9 and 10 for the CO_2 and H_2 production outlets, respectively;
- an electrical supply 11 for the operation of the various electrical components, particularly the compressors 9 and 10 for the CO_2 produced and for the hydrogen produced, respectively, and also for the operation of the control elements of the unit. As shown in Figure 1, the electrical supply 9 is preferably taken from the electricity network.

Figure 2 shows a steam reforming stage 2 as it is constituted in the unit 1 shown in Figure 1.

The stage 2 comprises an oven with a chamber 20 accommodating a plurality of gas burners 21, the oven containing suspended tubes each forming a reformer reactor 22, which are heated by convection of combustion gases and within which the reforming of the methane to syngas takes place. These tubes 22 are filled with catalyst and are fed at the top, from inlet collectors 23, with a mixture of natural gas and steam. The syngas produced is extracted by outlet collectors 24.

Represented schematically in Figure 3 is a reforming tube 22 with a catalyst 25, the arrows symbolizing the feed and the exit of the gases. The temperature in the catalyst 25 must be at least 800°C, requiring much higher temperatures in the chamber 20 of the oven, and therefore requiring external temperatures in the vicinity of the reforming tube walls 26 which are in general more than 1000°C. This implies that the pressure of the gases that must prevail on the inside of a reforming tube is less than approximately 20 bar, so as to ensure the mechanical integrity of the tube.

The main advantages of this steam reforming unit may be summarized as follows:
- supply ensured by the availability of a single-substance energy source throughout the territory at a distance of less than 30 km, with the natural gas transport network;
- a mature technology, although having been proven at production scales much greater than that of the intended application, i.e. the delocalized production of hydrogen;
- energy and feedstock costs which are 3 to 4 times lower than for the other forms of network energy;
- a high pressure level in the natural gas pipeline system, of more than 60 bar or even 80 bar in a large part of the network, this having a beneficial impact on the sizing of the unit, its energy consumption and its cost.

On the other hand, it still has major drawbacks, as follows:
- a very high cost for the reforming tubes 22, which are to be made of high-temperature (T > 1100°C) alloy in order to be able to withstand the temperatures in the oven chamber. The cost of the alloy or alloys employed may be of the order of 70 times that of steel;
- a limitation on the internal pressure to less than 20 bar, in order to ensure mechanical integrity at the temperatures in the oven chamber, and at a reasonable cost, with severe and direct consequences for the sizing, efficiency and cost of the stages downstream of the steam reforming stage 2 (reforming stage 4, PSA hydrogen purification stage 8 and downstream compressors 9 and 10). In this regard, in a unit 1, the cost of a stage 8 employing PSA adsorption is greater than that of the steam reforming stage 2;
- complex thermal integration in order to ensure proper energy efficiency of the oven of the steam reforming stage 2, which nevertheless is still subject to losses in the oven flue gases;
- a low possible dynamic in respect of variations in the feedstock, owing partly to the natural gas burners used and to

the substantial inertia of the reforming stage 2 and oven assembly;
- start-up and shutdown times which, for the reasons set out earlier, are substantial and may typically take several tens of hours;
- very low level of compactness, linked to the substantial dimensions of the steam reforming stage 2, including partly of the chamber 20 of the oven, and to the difficulty of giving the reforming tubes 22 anything other than straight geometries (in order to ensure the temperature and pressure stabilities), and to the dimensions of the downstream stages, owing to the limit on pressure to 20 bar;
- consumption of natural gas, of the order of 20 to 30%, which is used solely to make heat and which, firstly, gives rise to emissions of NOx and, secondly, increases the local emission of CO_2 owing to the combustion of gas in the one or more burners. This CO_2, highly diluted in nitrogen and steam, is difficult to capture, moreover, and this further increases the cost and the energy consumption.

Lastly, it should be noted that the use of a biogas obtained from biomass or waste methanization, in place of the natural gas, has recently been proposed for the production of hydrogen.

The potential drawbacks of this resource are the price of the biogas, which may exceed the nominal price of electricity, the excess energy and financing cost owing to the installation of the upstream CO_2 capture station, and, lastly, the possible limitation of the local energy resource.

Lastly, Patent Application DE10040539 describes a membrane reactor for production of hydrogen by steam reforming, from a hydrocarbon stream, said reactor comprising an electrical heater located in the centre of the reactor. The membrane is permselective for hydrogen and the reforming catalyst is preferably contained in or carried by the membrane.

There is therefore a need to improve the solutions for localized production of hydrogen in order to remedy the above-mentioned drawbacks, with the aim in particular of improving the investment cost and/or operating cost and the yield.

The objective of the invention is to respond at least partly to this need.

Summary of the invention

To accomplish this, the invention, in one of its aspects, relates to a catalytic fixed bed reactor, comprising:
- at least one reforming chamber which is to be fed at the top with a mixture of natural gas or biogas and steam and which accommodates a catalytic fixed bed for steam reforming, the reforming chamber being delimited by at least one wall;
- at least one electric heating element inserted into the catalytic fixed bed for heating thereof;
- at least one heat insulation element disposed between the catalytic fixed bed and the wall or walls delimiting the reforming chamber.

The catalytic fixed bed reactor preferably has a tubular general shape.

The electric heating element advantageously is a tube based on inconel or a ceramic fibre or a metal heating wire moulded directly into a ceramic.

The heat insulation element is formed more advantageously by a textile consisting of sheets of mineral fibres or of silica felts or by an inorganic refractory coating.

The reactor comprises at least one hydrogen-permselective membrane, disposed in the reforming chamber, on the periphery of and/or inserted into the catalytic fixed bed, with a space being left between the membrane and the wall(s) delimiting the chamber or the heat insulation element, the space being suitable for the recovery of the hydrogen produced by steam reforming.

The membrane is advantageously an inorganic membrane consisting of nickel or of palladium deposited on a porous ceramic support.

The membrane is preferably coaxial with the catalytic fixed bed.

The invention also concerns a unit for producing hydrogen by steam reforming, comprising:
- at least one steam methane reforming stage comprising at least one catalytic fixed bed reactor as described above;
- at least one electric steam generator connected fluidically upstream of the reactor, for supplying steam to said reactor.
An "electric steam generator", here and in the context of the invention, is a generator which uses electricity as a supply source for producing the heat which generates the steam, rather than burning fuel.

According to one advantageous embodiment, the outlet of the reactor is connected fluidically to the natural gas distribution network.

According to another advantageous embodiment, the unit comprises a return line which is connected between the outlet of the reactor and the natural gas network, for returning the gas partially reformed in the reactor to said network.

A final subject of the invention is a method for operating a unit for producing hydrogen by steam reforming as described above, wherein the mixture of gas and steam fed to the catalytic fixed bed reactor is at a pressure of greater than or equal to 20 bar.

In this method, the gas is preferably the natural gas of the distribution network with the pressure at which the catalytic fixed bed reactor is fed.

By analysing the drawbacks of the existing units for producing hydrogen by steam reforming, as illustrated in Figure 1, the inventors have uncovered the fact that the major drawbacks originated from the actual design of the steam reforming stages 2 employed, as detailed above with reference to Figure 2.

As a result, they have come up with the judicious idea of replacing the gas burners in the steam reforming stage with an electrical heater integrated directly into the catalytic zone of a fixed bed reactor.

This integration enables high-pressure working, since the wall of the reforming/confinement chamber accommodating the catalyst no longer has to ensure the passage of heat from the outside that is needed for the reaction.

The wall of the reforming/confinement chamber can therefore be cold, and can typically be at a temperature of less than 400°C, and can be isolated thermally from the hot catalytic reaction zone either by an added heat insulator or by the bed of catalyst itself, which has a low heat conductivity.

Removing the need to have to conduct heat from the outside makes it possible, very advantageously, for a permselective membrane to be integrated inside the reforming chamber, at the periphery of the heated zones of the bed. Implanting a membrane of this kind enables a portion of the hydrogen produced in the catalytic bed to be withdrawn, with the beneficial effect of counterbalancing the negative effect of the pressure on the conversion of the methane. In other words, with a permselective membrane implanted as described, the membrane surface area and hence the level of recovery of the hydrogen produced are increased.

The advantages of a reforming reactor with integration of an electric heating element according to the invention within a hydrogen production unit, in place of the gas burners of the traditional units such as those of Figure 1, are many, and they may be summarized as follows:

- simplification of the unit for producing hydrogen by steam reforming, with an improvement in the designs and in the optional integration of functions into the major components of the unit; the simplification of the unit at the single reforming station, with return of the unreformed gas either to the natural gas pipeline upstream, with a low level of energy expenditure, or to a natural gas pipeline downstream (distribution circuit P < 40 bar);
- improvement in the compactness, the cost and the operating dynamics both of the reforming stage and of the complete unit, with the highly advantageous possibility of employing an exclusively electrically heated steam generator;
- reduction by 20 to 30% in the consumption of natural gas;
- reduction in emissions of greenhouse gases and pollutants, especially suppression of the emission of NOx associated with the combustion of natural gas, and reduction in the emission of CO_2 correspondingly to the decrease in the consumption of natural gas;
- improvement in the energy efficiency of the unit, the inventors envisaging this improvement to be greater than 83% with the implementation of the invention,
- possibility of raising the operating pressure to the pressure prevailing in the natural gas transport/distribution pipeline (distribution circuit with a pressure of less than 40 bar), this being manifested in an efficiency gain in the hydrogen extraction yield and by a decrease in the volume and cost of the components of the unit (reforming stages);
- possibility of increasing the effective temperature of the catalyst bed, owing to the location of the electric heating inside the reactor, with the accompanying possibility of possibly bringing back up again the conversion yield lowered by the preceding rise in pressure;
- possibility, by virtue of the integrated permselective membrane, of extracting a portion of the hydrogen produced, of lowering the temperature for given conversion and of reducing the flow towards the WGS reactor and increasing the

concentration of CO in this flow, with advantageous consequences for the compactness and the material efficiency of the WGS stage and with the likely disappearance of at least one WGS stage;
- possibility, owing to the high pressure of the catalytic bed, of returning the partially reformed gas emerging from the reactor to the natural gas pipeline, if the unit is sited at a transport-distribution connection node, this return taking place with a low compression-related energy loss (loss of head in the bed); the downstream stages may no longer be required;
- possibility of extracting high-purity hydrogen at a high pressure, typically greater than 10 or 20 bar depending on the pressure of the reforming reactor (depending on the selectivity of the membrane);
- improvement in the dynamics of production, since a reactor according to the invention that incorporates an electric heating element has much lower inertia than the prior-art gas burners, with a heating power which is also easier to regulate;
- possibility of opportunity gain over the electric network services ("power to gas" application).

Other advantages and features of the invention will become more readily apparent when the detailed description of practical examples of the invention is read, this description being given by way of illustration and not of limitation, with reference to the figures below.

Brief description of the drawings

[Fig. 1] is a schematic view of a unit for producing hydrogen by steam reforming in accordance with the prior art.
[Fig. 2] is a schematic perspective view of a steam reforming stage according to the prior art, as is used in a unit according to Figure 1.
[Fig. 3] is a schematic view in longitudinal section of a catalytic fixed bed reforming tube according to the prior art, as is used in a reforming stage of Figure 2.

[Fig. 4] is a schematic view in longitudinal section of a catalytic fixed bed reforming reactor which is not in accordance with the invention.

[Fig. 5] is a schematic view in longitudinal section of a catalytic fixed bed reforming reactor according to one advantageous embodiment of the invention.

[Fig. 6] illustrates, in the form of curves, the effect of withdrawal of hydrogen on the conversion yield.

[Fig. 7] is a view, schematically, of a unit for producing hydrogen by steam reforming, which is not in accordance with the invention.

Detailed description

Figures 1 to 3 relate to an example of a steam reforming stage and hydrogen production unit according to the prior art. These Figures 1 to 3 have already been the subject of comment earlier, and there is therefore no further comment on them below.

For clarity, identical references denoting the same elements according to the prior art and according to the invention are used for all of Figures 1 to 7.

The dotted arrows in the figures denote electrical lines, whereas those in solid lines denote fluidic lines.

Figure 4 shows a catalytic fixed bed reactor 2 (outside the invention).

It comprises a reforming chamber 22, of tubular general shape, which is to be fed at the top with a mixture of natural gas or biogas and steam and which accommodates a catalytic fixed bed 25 for steam reforming.

According to the invention, an electric heating element 27 is inserted directly into the catalytic fixed bed for heating thereof. The electric heating element 27 may be a tube based on inconel or a ceramic fibre or a metal heating wire moulded directly into a ceramic.

A heat insulation element 28 is disposed between the catalytic fixed bed 25 and the wall 26 delimiting the reforming chamber 22. This heat insulator 28 allows the heat produced by the electrical heater to be confined inside the reforming chamber 22 and therefore enables a relatively cold wall 26, typically at a temperature of less than 400°C during the steam reforming reaction. The heat insulation element 28 may consist of a textile consisting of sheets of mineral fibres or of silica felts or by an inorganic refractory coating.

One advantageous embodiment of the catalytic fixed bed reactor 2 according to the invention is shown in Figure 5.

According to this embodiment, a membrane 29 which is permselective for hydrogen is disposed in the reforming chamber 22, coaxially with the catalytic fixed bed 25, with a space being left between the membrane 29 and the heat insulation element 28. This space allows a portion of the hydrogen produced by steam reforming to be withdrawn in the catalytic bed 25, with the advantage of counterbalancing the negative effect of the pressure on the conversion of the methane. This advantage is in fact highlighted in Figure 6, which is taken from the publication [1].

The membrane 29 may be an inorganic membrane consisting of nickel or of palladium deposited on a porous ceramic support.

Figure 7 shows a unit 1 for producing hydrogen by steam reforming, which incorporates at least one steam methane reforming stage comprising a catalytic fixed bed reactor 2 as just described, said reactor not being in accordance with the invention.

As can be seen in this Figure 7, the incorporation of a steam reforming reactor 2 with internal electric heating allows an improvement in the possible integration of functions into the major components of the unit.

More particularly, in place of a steam generator 6 heated by the heat of combustion from a gas burner as in the prior art (Figure 1), the unit 1 comprises an electric steam generator 60, connected fluidically upstream of the steam reforming reactor, for supplying steam to said reactor.

This steam reforming unit 1 also includes, primarily, the following stations or stages:
- at least one desulfurization stage 3, upstream of the steam reforming reactor 2 according to the invention;
- at least one steam CO reforming stage 4, downstream of the steam reforming reactor 2. As shown in Figure 7, the heat given off from the reforming stage 4 may also supply the electric steam generator 60;
- a station 7 for capturing the CO_2 produced, by adsorption on amines, downstream of the CO reforming stage 4, which is supplied with steam by the electric steam generator 60;
- a hydrogen purification stage 8, operating by pressure swing adsorption (PSA), downstream of the capture stage 7, with the purge gases arising from this purification being reinjected at the start of steam reforming, typically in the desulfurization stage 3 as shown in Figure 7;
- compression stages 9 and 10 for the CO_2 and H_2 production outlets, respectively;
- an electrical supply 11 for the operation of the various electrical components, particularly the respective compressor 9 for the CO_2 produced and 10 for the hydrogen produced, and also for the operation of the elements for controlling the unit. As shown in Figure 7, the electrical supply 9 is preferably taken from the electricity network.

The hydrogen production unit 1 is operated advantageously by feeding of the catalytic fixed bed reactor 2 with a mixture of natural gas from distribution and of steam at a pressure greater than or equal to 20 bar.

Other variants and improvements may be envisaged without departing from the scope of the invention as claimed below.

List of references cited:

[1] Gallucci 2011, "*Modeling of Membrane reactors for hydrogen production and purification, Royal Society of Chemistry 2011*."

Patentkrav

1. Reaktor (2) med katalytisk fast leje, hvilken reaktor omfatter:
- mindst ét reformingkammer (22), der er beregnet til at blive tilført en blanding af naturgas eller biogas og damp i toppen, og hvori der er anbragt et katalytisk fast leje (25) til dampreforming med vand, idet reformingkammeret afgrænses af mindst én væg (26)
- mindst ét elektrisk varmeelement (27), der er indsat i det katalytiske faste leje for at opvarme det
- mindst et termisk isoleringselement (28), der er anbragt mellem det katalytiske faste leje og den væg eller de vægge (26), der afgrænser reformingkammeret
- mindst én membran (29), der er permselektiv for brint, og som er anbragt i reformingkammeret (22) ved periferien af og/eller indsat i det katalytiske faste leje, idet der efterlades et mellemrum mellem membranen og kammerets afgrænsningsvæg(gene) eller det termiske isoleringselement, idet mellemrummet er beregnet til genvinding af det hydrogen, der fremstilles ved dampreforming.

2. Katalytisk reaktor (2) med fast leje ifølge krav 1, som har en generel rørformet form.

3. Katalytisk reaktor (2) med fast leje ifølge krav 2, hvor membranen er koaksial med det katalytiske faste leje.

4. Katalytisk reaktor (2) med fast leje ifølge et af de foregående krav, hvor det elektriske varmeelement (27) er et rør på basis af superlegeringer eller en keramisk fiber eller en varmetråd af metal, der er støbt direkte i en keramik.

5. Katalytisk reaktor (2) med fast leje ifølge et af de foregående krav, hvor det termiske isoleringselement udgøres af et tekstil, der består af lag af mineralske fibre eller filt af siliciumdioxid eller af en uorganisk ildfast belægning.

6. Katalytisk reaktor med fast leje ifølge et af de foregående krav, hvor membranen er en uorganisk membran, der udgøres af nikkel eller palladium, som er pålagt på en porøs keramisk bærer.

7. Enhed (1) til fremstilling af hydrogen ved dampreforming, hvilken enhed omfatter:
- mindst et trin til reforming af methan ved hjælp af vanddamp, der omfatter mindst et katalytisk fast leje (2) ifølge et af de foregående krav
- mindst en elektrisk dampgenerator (60), der er fluidummæssigt forbundet opstrøms for reaktoren, til ar føre vanddampen til reaktoren.

8. Enhed (1) ifølge krav 7, hvor reaktorens udløb er konfigureret til at være fluidummæssigt forbundet med naturgasdistributionsnettet.

9. Enhed (1) ifølge krav 8, der omfatter en returledning, som er konfigureret til at blive forbundet mellem reaktorens udløb og naturgasnettet og til at føre den i reaktoren delvist reformede gas tilbage til naturgasnettet.

10. Fremgangsmåde til drift af en enhed til produktion af hydrogen ved dampreforming ifølge et af kravene 7 til 9, hvorved den blanding af gas og damp, der tilføres til reaktoren med katalytisk fast leje, har et tryk, der er større end eller lig med 20 bar.

11. Fremgangsmåde til drift ifølge krav 10, hvorved gassen er naturgas fra distributionsnettet, hvis tryk er det samme som trykket for tilførslen til den katalytiske reaktor med fast leje.

[Fig 1]

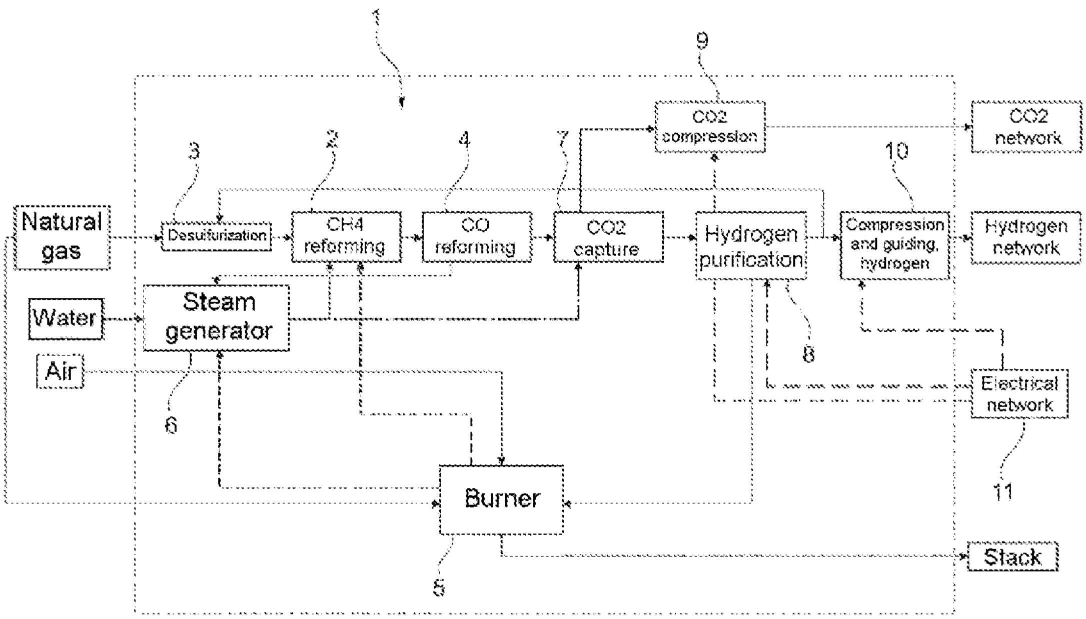

Fig. 1
(PRIOR ART)

[Fig 2]

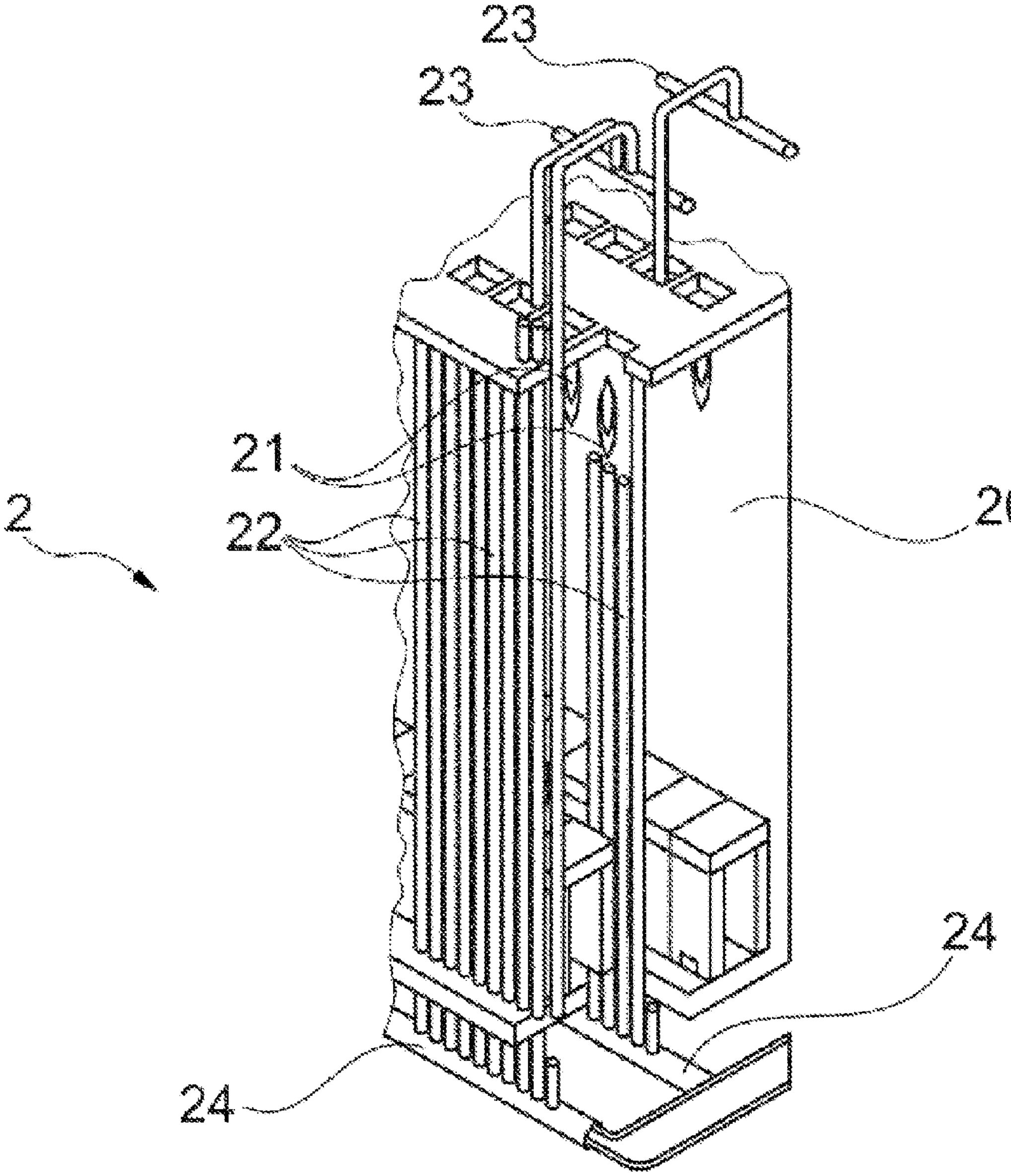

Fig. 2
(PRIOR ART)

[Fig 3]

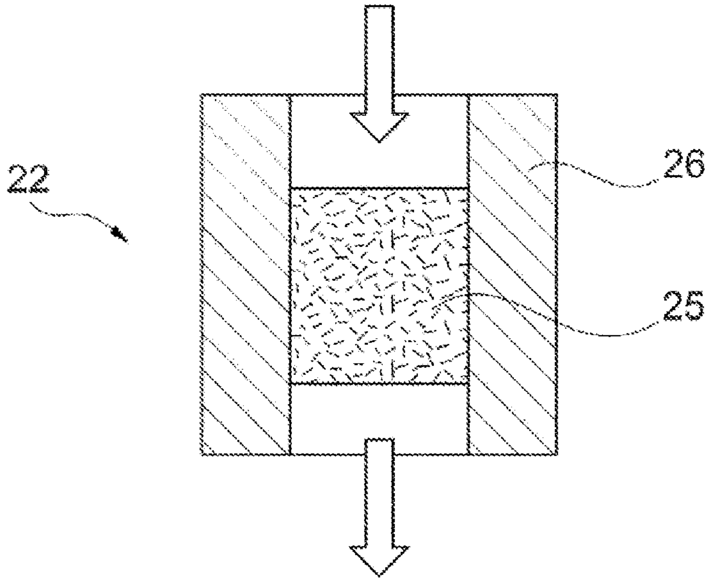

Fig. 3
(PRIOR ART)

[Fig 4]

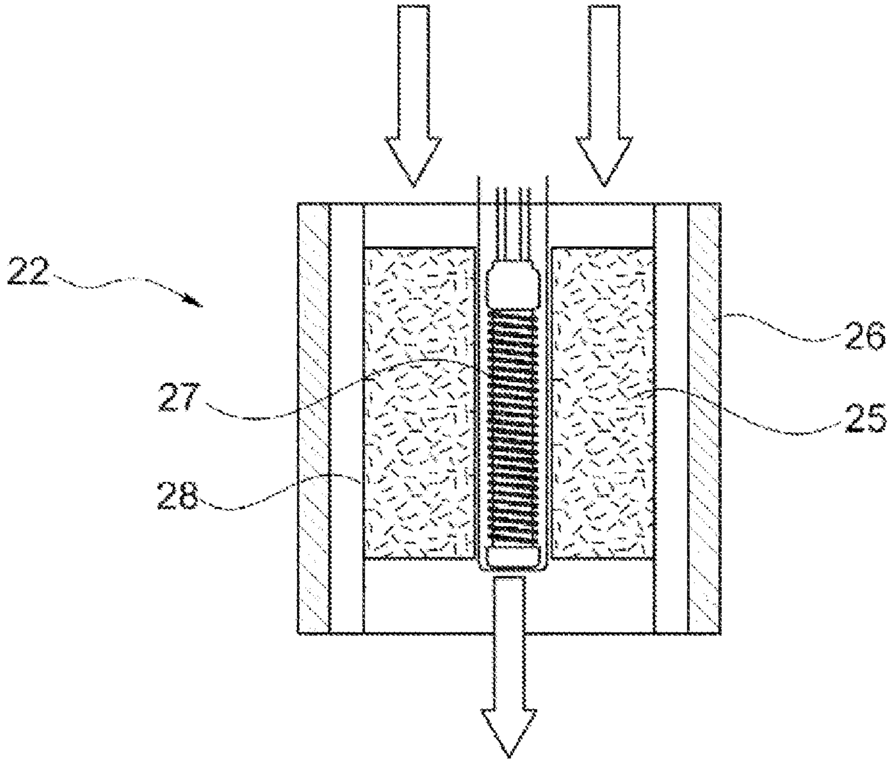

Fig. 4

[Fig 5]

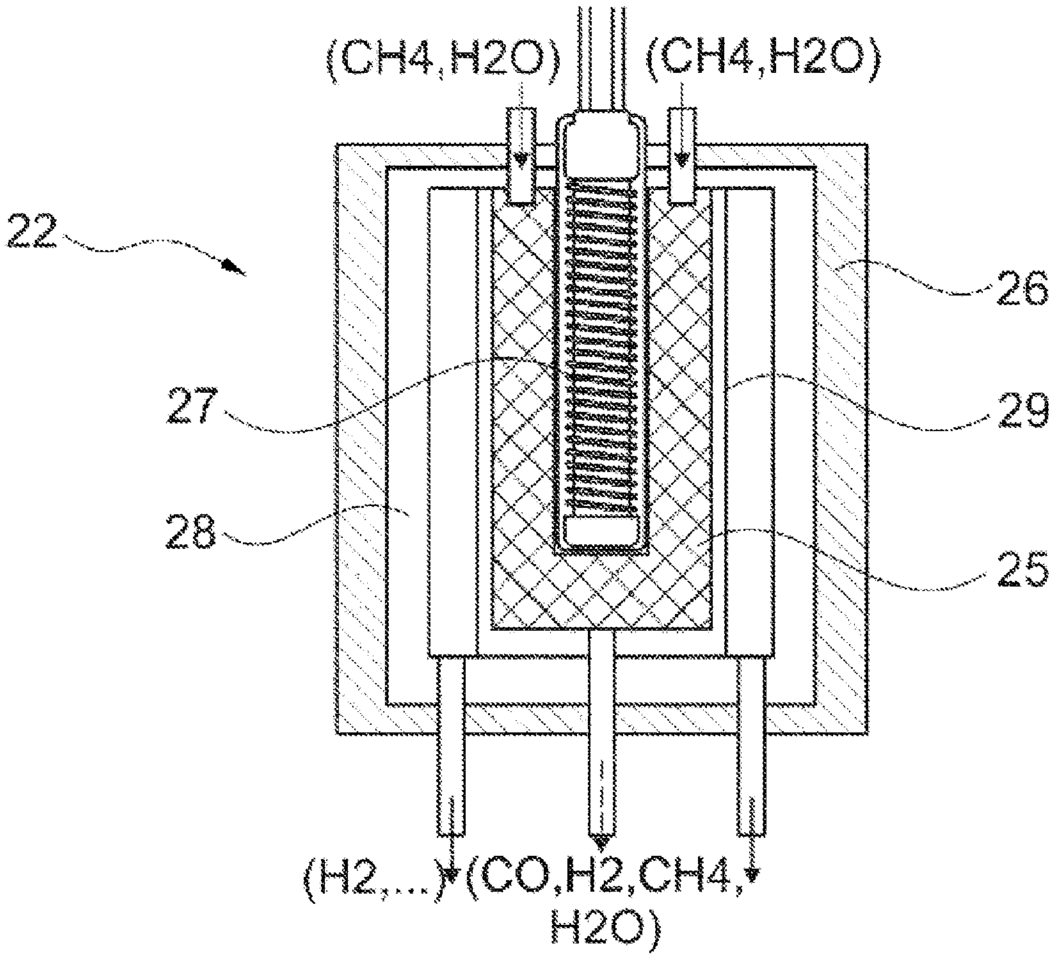

Fig. 5

[Fig 6]

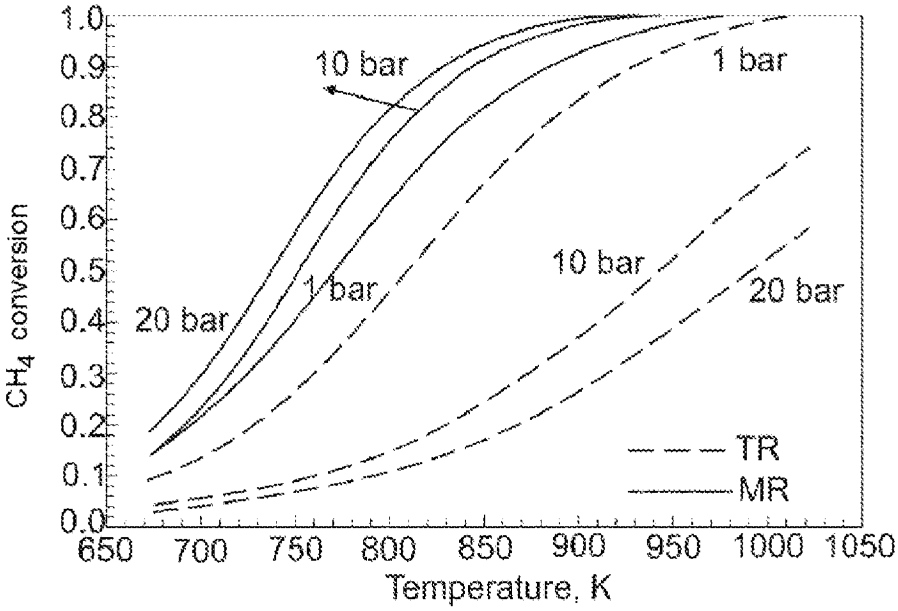

Fig. 6

[Fig 7]

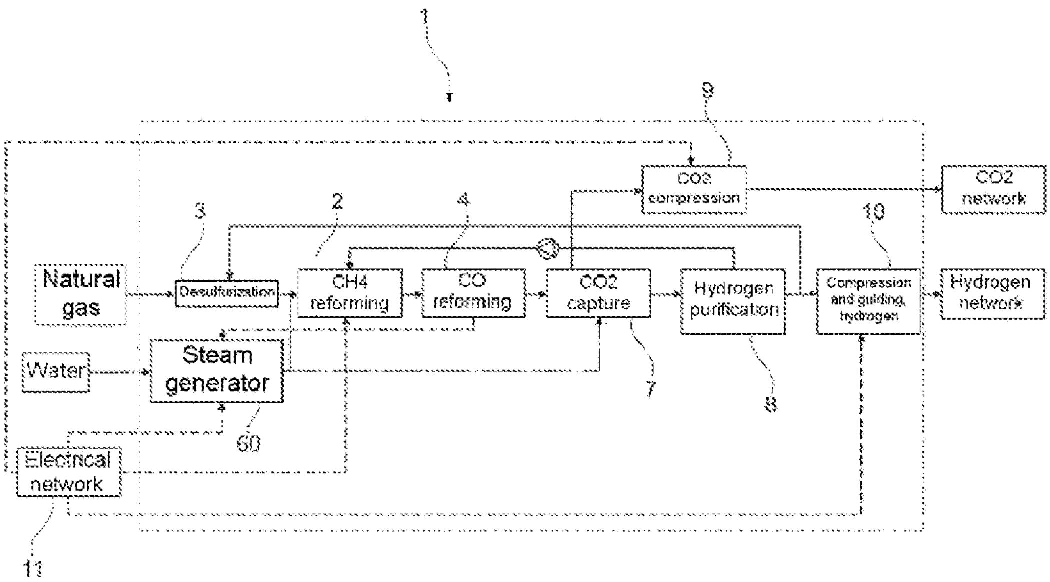

Fig. 7