Abstract:
The invention relates to a process and an installation for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides and installation for the application of the process.
and/or sulphur oxides; a catalyst chamber [14] wherein a magnesium catalyst [13] is placed as a mixture of chips and powder; copper or stainless steel pipes [7] and [8], respectively, which ensure the transport and uniform distribution of H₂ and respectively of the mixture of carbon oxides, nitrogen oxides and/or sulphur oxides on the surface of the quartz layer [18], but also of the catalyst [13]; a deflector [16] for the homogenization of the gaseous mixture, and to the outer side of the housing there being provided: a conduit for the completion of the catalyst [17]; conduit for supplying H₂ [2], conduit for supplying with mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides CO₂ [4] and a conduit for discharging carbon and/or sulphur [10].
PROCESS FOR OBTAINING THERMAL ENERGY BY THE COMBUSTION OF HYDROGEN IN ADMIXTURE WITH CARBON OXIDES, NITROGEN OXIDES AND/OR SULPHUR OXIDES AND INSTALLATION FOR THE APPLICATION OF THE PROCESS

The subject-matter of the invention is a process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides in the presence of a magnesium catalyst and an adequate installation for the application of this process.

The process for obtaining the thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides in the presence of a magnesium catalyst is based on the reaction between hydrogen and oxygen with the formation of water and the spontaneous release of the atom of carbon, nitrogen and/or sulphur, the thermal energy obtained by this process being well controlled in a simple, reliable, efficient and highly secure installation which may contribute to substantially lowering the emissions from the atmosphere or any gas mixture, e.g. carbon dioxide which is in excess in nature, carbon monoxide, nitrogen oxides and/or sulphur oxides, especially sulphur dioxide, from industrial gas mixtures, the claimed process having domestic and industrial applications as well. The carbon dioxide may be used in the process of combustion as such or in admixture with other substances, for example oxygen, nitrogen, nitrogen oxides, carbon monoxide, sulphur oxides, offering the possibility to reduce the carbon, nitrogen and/or sulphur oxides to carbon, nitrogen and/or sulphur.

The global heating caused by the increase of the concentrations of gases with greenhouse effect in the atmosphere constitutes a major concern related to the air quality. The carbon dioxide is the most abundant gas with greenhouse effect released by the combustion of the fossil fuels used for heating, producing electricity and transport, being responsible for the most of the climate changes. In order to reduce the CO2 emissions measures, such as lowering the energy consumption, increasing the energetic efficiency or the use of the alternating renewable energies, are imposed.

A major alternative to using fossil fuels for obtaining energy is constituted by the power engineering based on hydrogen. Object of some high specificity uses in the chemical industry, electronic and spatial industries for more than three decades, hydrogen also attracted the interest of the public authorities and of the research organizations as well as that of business people as clean fuel for the means of transportation or as a source for generating electric energy. There were worldwide initiated and developed with priority ample multi-disciplinary research-development
activities, following the elaboration of some efficient technologies of generating, separating, purifying, storing, transport and use of hydrogen in safety conditions.

Hydrogen is the cleanest fuel as far as the environment is concerned (by the combustion of hydrogen there results only water) and at the same time the most efficient energy carrier, having an energetic content per weight unit of 2.1 times higher than that of the natural gases. Hydrogen is also the most versatile renewable energy source, being used anywhere in the world, independently of the traditional energy resources, as fuel for the engines of all types of vehicles, as well as for the thermal installations which serve a wide range of uses (dwellings, buildings, localities etc) as well as for supplying the fuel cells which produce electric energy without pollution, having a wide variety of applications, including electronics, telecommunications and information technology.

For the use of hydrogen as fuel, an important problem to be solved is that of the burner. The combustion rate of pure hydrogen ranges between 265-325 cm/s being very high, in comparison with the methane combustion rate which ranges between 37-45 cm/s. For this reason, under normal conditions, hydrogen cannot sustain a flame. Consequently, it is necessary to reduce the hydrogen combustion rate concomitantly with lowering the explosion hazard.

The flame temperature and the propagation speed thereof are dependent on the combustion mixture composition, this composition being able to determine the increase of the flame size and the lowering of the speed thereof. Depending on the concrete requirements imposed by certain utilization, the combustion mixture composition shall be optimized with great care. Hydrogen combustion involves, as a rule, more frequent burners maintenance works, since the rapid combustion often makes possible the contact of the flame with the burner components, leading to the rapid degradation thereof.

On a global level, solutions were conceived and implemented which concern adapting the electric power stations functioning with fossil fuels to the operation with hydrogen. Starting from 1993 within a demonstrative project carried on in Germany by the SWB company there was tested the operation of some boilers of a thermal capacity of 20 KW by using burners modified for the combustion of hydrogen, natural gas or some mixtures of these gases (International Journal of Hydrogen Energy, vol. 19, no. 10, 1994). In Japan there were elaborated new Rankine cycles for electric power stations using hydrogen as a fuel (International Journal of Energy, vol. 1, no. 1, pages 29-46, 2004).

The inadequately designed hydrogen burners vibrate and produce noise. More important is the fact that in such inadequately designed burners the flame may be very unstable and may detach from the burner. Some burners' producers limit the hydrogen concentration to 90-95%,
the difference being constituted by methane. Worldwide recognized remarkable results were obtained by the American Company Coen of California. There was reported the designing and commencing the operation of some boilers in the range of 250,000 lb/h (113.5 t/h) by using 95% hydrogen as fuel with Coen burners, as well as the fact that this company may produce burners to burn 100% hydrogen in Rentech or Babcock&Wilcox type steam boilers.

The Taiwanese company De Fu Technology currently produces "hydrogen-oxygen" burners with maximum thermal capacity of 250,000 kcal/h meant for boilers, heat treatment furnaces and to other applications ([www.dfb.com.tw](http://www.dfb.com.tw)).

In order to burn hydrogen in safety conditions it is essential to reduce the burning rate at the level of the hydrogen injectors so that the conventional flow rate and pressure control devices are not sufficient. The American company C-B NATCOM designed (for the chemical plant Olin Chlor Chemicals) a burner using multiple hydrogen injection zones (hydrogen being a product in excess of the company, available at a pressure of 0.48 bar] which are opened and closed so as to maintain the pressure within optimal limits (meant for aquatubular boilers of the 34 t/h capacity and operating at pressures of the order of 10 bar]. A system of 6 such zones ensures an adjustment ratio of 20:1. The elaborated control system allows the secure and efficient operation in five burning modes: only natural gas, only black oil, only hydrogen, hydrogen with natural gas and hydrogen with black oil. In order to diminish the formation of nitrogen oxides there is avoided the immediate contact of the fuel with the air by injecting steam to the periphery of hydrogen injectors. Also, for avoiding the nitrogen oxides formation, the operation temperature shall be maintained below 650°C. In the mentioned chemical plant the project of installing two steam boilers to use the hydrogen in excess and in case of need (the hydrogen availability as product in excess not being constant] the natural gas or black oil necessitated a period of 14 months to be finalized. The benefits increasing from a year to another due to the increase in fuel prices were estimated to 2.5 million of USD annually.

In August 2008 a similar system of employing hydrogen in excess for the fuel supply of some steam boilers was also put into operation by the Runcorn plant (in north-west of England] of INEOS CHLOR company, a world leader in producing chlorinated derivatives. ([http://www.chemicalprocessing.com/articles/2010/132](http://www.chemicalprocessing.com/articles/2010/132) html).

The PCT patent application WO 2009/068424 Al (applicant Alstom Technology Ltd, Switzerland] which is an improved version of the PCT patent application WO 2006/058843 Al, discloses a transition sector coupled upstream with the vortex generator and a mixing sector, coupled upstream with the transition sector and coupled downstream with the combustion chamber.
The PCT patent application WO 2007/021053 Al [applicant Daum Energy Co. Ltd of South Korea] discloses a burner for gaseous hydrogen and a system for supplying heat, which employs this burner. The hydrogen is generated in situ in an electrolytic cell by the electrolysis of an aqueous solution and it is filtered before use. There is also provided the possibility of temporarily storing the electrolytically produced hydrogen in a metal alloy, with a view to being subsequently used in a burner. There is ensured an efficient dissipation of the released heat, while preventing overheating of the hydrogen supply nozzle. The burner according to this invention may be used in a domestic cooking installation.

The PCT patent application WO 2006/136316 Al (applicant Giacomini S.p.A- Italy) discloses a catalytic hydrogen burner, operating in reliable conditions at low temperatures (about 300°C), without flame. A first catalyst for priming the hydrogen oxidation in the air flow at the ambient temperature is followed by other catalysts located downstream in the combustion chamber for further sustaining the oxidation. In order to prevent clogging the catalysts pores, the employed air is purified and supplied by a compressor. The burner is conceived to offer a heat source for the residential systems of supplying warm and/or heating water.

The PCT patent application WO 2006/058843 Al (applicant Alstom Technology Ltd of Switzerland) discloses a method and a device for the combustion of a gaseous fuel containing hydrogen or consisting of hydrogen. The burner is provided with a vortex generator, the gaseous fuel being introduced axially and/or coaxially therein, the air stream necessary for the combustion is tangentially introduced and it is rotary.

In the PCT patent application WO 2007/024301 Al (applicant Giacomini S.p.A. Italy), the hydrogen is mixed with air and burnt in a combustion chamber on a catalyst (for example palladium, platinum), at a low temperature (200-450°C) without flame. Hydrogen is supplied at a low pressure, preferably 20 millbar. The combustion chamber is surrounded by a heat exchanger crossed by the flue gases, the heat released upon combustion being taken over by a circuit of cooling water. The heated water may be stored in a tank and used in case of need. Hydrogen may be produced in situ by electrolysis or may be taken from storage cylinders after lowering the pressure. The patent protected burner is conceived to equip a system of providing warm water to buildings. When warm water is not required, the hydrogen may be accumulated in metal hydrides and stored.

**Brief description of the invention**

The process claimed by the present invention is a process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur
oxides, in the presence of a magnesium catalyst which is a mixture of magnesium chips and powder, which eliminates the previously mentioned disadvantages.

The subject-matter of the invention is a process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides, wherein, in a first stage, the hydrogen combustion is carried out in the presence of the magnesium catalyst consisting of a mixture of magnesium chips and powder, in an enclosure with orifices for discharging the gases and the carbon atoms and/or the sulphur atoms when sulphur oxides are present in the mixture, with the formation of MgO and water, and in a second stage, the magnesium is regenerated within the same enclosure by introducing extra hydrogen. The two stages are carried out according to the following reactions:

\[ \text{H}_2 + \text{C}O_x + \text{Mg} \rightarrow \text{MgO} + \text{C} + \text{H}_2\text{O} + \text{Q}, \text{ and/or} \]

\[ \text{H}_2 + \text{N}_2\text{O}_y + \text{Mg} \rightarrow \text{MgO} + \text{N}_2 + \text{H}_2\text{O} + \text{Q}, \text{ and/or} \]

\[ \text{H}_2 + \text{SO}_x + \text{Mg} \rightarrow \text{MgO} + \text{S} + \text{H}_2\text{O} + \text{Q} \] in the first stage, and

\[ \text{MgO} + \text{H}_2 \rightarrow \text{Mg} + \text{H}_2\text{O} + \text{Q} \] in the second stage.

\( CO_x \) may be carbon monoxide or dioxide, or a mixture thereof. \( N_2O_y \) may be any nitrogen oxide, for example nitrogen monoxide, nitrogen dioxide, nitrous oxide, nitrogen trioxide, nitrogen tetroxide, nitrogen pentoxide and the like or any mixture thereof. \( SO_x \) may be any sulphur oxide, for example sulphur dioxide or sulphur trioxide, especially sulphur dioxide which is present in the waste gases form thermal power plants which use fossil fuels.

According to an embodiment, the invention refers to a process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon dioxide, wherein in a first stage, the hydrogen combustion is carried out in the presence of the magnesium catalyst consisting of a mixture of magnesium chips and powder, in an enclosure with orifices for discharging the gases and the carbon atoms, with the formation of MgO and water, and in a second stage, the magnesium is regenerated within the same enclosure by introducing extra hydrogen. The two stages are carried out according to the following reactions:

\[ \text{H}_2 + \text{CO}_2 + \text{Mg} \rightarrow \text{MgO} + \text{C} + \text{H}_2\text{O} + \text{Q} \]

\[ \text{MgO} + \text{H}_2 \rightarrow \text{Mg} + \text{H}_2\text{O} + \text{Q} \]

and according to the general balance reaction:

\[
\text{catalyst (Mg)}
\]

\[ 2\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{C} + 2\text{H}_2\text{O} + \text{Q}. \]

the cycle being continuous.

By reacting the mixture of carbon oxides, nitrogen oxides and/or sulphur oxides with hydrogen, the carbon, nitrogen and/or sulphur oxides are reduced, the process of the invention
having a substantial impact upon the decrease in the air pollution by eliminating said oxides. The carbon, nitrogen and/or sulphur oxides are generally found in the combustion gases from the thermal power plants where fossil fuels are used.

The installation for combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides, according to the present invention, eliminates the disadvantages of the technical solutions previously presented by that it consists of a stainless steel housing (1), for example a stainless pipe, whereupon there is secured a cover (3) connected to a hydrogen supplying conduit (2), within the housing there being comprised:

• a chamber for uniform hydrogen distribution (MI) which is formed between the cover (3) and a cover (5) arranged inside the housing (1), both covers being made of stainless steel;
• a chamber for the uniform distribution of the gas mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (M2) which is formed between the cover (5) and a cover (6), being arranged inside the housing (1) and manufactured of stainless steel;
• a chamber for homogenization of the hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides (M3) which is formed between a cover (9) made of stainless steel and a catalyst chamber (14), said chamber for homogenization of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides (M3) containing quartz sand or hexagon-shaped quartz crystals, hereinafter called quartz layer (18) in the present description;
• a catalyst chamber (14) wherein there is a magnesium catalyst (13) which is a mixture of magnesium chips and powder, the magnesium powder being arranged towards the inner side of the enclosure, and the magnesium chips being arranged to the outer side around the magnesium powder, this special arrangement determining the lowering of the hydrogen flow velocity and maintaining the magnesium powder in the catalyst chamber (14);
• pipes (7), (8) manufactured from copper or stainless steel, which serve for the transport and the uniform distribution of the hydrogen - pipes (7) and respectively of the gas mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides - pipes (8), on the surface of the quartz layer (18) and of the catalyst (13);
• a homogenization deflector (16) ensuring swirling of the hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides. The homogenization deflector is a part that may be made of sheet metal, with a configuration which ensures the swirling of the gaseous mixture;
and on the outer side of the housing (1), before the inlet into the quartz layer (18) there being provided:
• a pipe supplying catalyst (17) for completing the losses, which communicates with the catalyst chamber (14);
• a conduit for supplying with hydrogen (2) connected to the cover (3);
• a conduit for supplying with gas mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (4) which communicates with the chamber for the uniform distribution of the gas mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (M2);
• a carbon and/or sulphur recovery conduit (10);
• optionally, an installation directing warm air in case of industrial applications.

The installation and process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides, in the presence of a magnesium catalyst as a mixture of magnesium chips and magnesium powder, for the thermal and thermal-electrical power plants in the domestic or industrial fields, as claimed by the invention, presents the following advantages:

- it allows the combustion of hydrogen with a mixture of oxides both at low and at average pressure (0.1-0.6 bar);
- it contributes to the lowering of the environment pollution by recovering the carbon atoms and/or sulphur atoms;
- it allows obtaining high purity carbon which may be used in various fields;
- it allows controlling the hydrogen combustion rate as well as the desired temperature, with numerous applications in the industrial field;
- it ensures a well-controlled combustion atmosphere which allows to use the same in the industrial heat treatments;
- it ensures the superior use of extra hydrogen produced in the chemical plants and in the specialized units, with a view to obtaining caloric energy or electric energy;
- it uses a relatively cheap catalyst (Mg) which ensures a transfer of O₂ from carbon oxides, nitrogen oxides and/or sulphur oxides, to H₂ based on simple reactions in which for 2 moles of H₂ a maximum of one mole of CO₂ is used;
- it has a relatively simple construction;
- it presents security in exploitation;
- it has high reliability;
- the process allows monitoring the temperature and the combustion mixture by adjusting the hydrogen burning rate.
The invention is presented in detail below, with reference to an embodiment wherein a mixture which contains mainly carbon dioxide is used. Figures 1-6 represent:
  o fig. 1, the installation for the combustion of hydrogen in admixture with carbon dioxide;
  o fig. 2, a cross-section through the installation for the combustion of hydrogen in admixture with carbon dioxide;
  o fig. 3, detail B, example of securing the catalyst chamber;
  o fig. 4, detail C, example of securing the deflector;
  o fig. 5, example of deflector shape;
  o fig. 6, variants of directing heat by means of the air offered by a fan for the industrial applications.

The process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon dioxide, as claimed by the invention, involves, in a first stage, the combustion of hydrogen in the presence of the magnesium catalyst as a mixture of magnesium chips and magnesium powder, in an enclosure with orifices for discharging the gases and the carbon atoms, while forming MgO and water, and in a second stage, the magnesium regeneration in the same enclosure by introducing extra hydrogen.

The two stages are carried on according to the following reactions:

1) \( \text{H}_2 + \text{CO}_2 + \text{Mg} \rightarrow \text{MgO} + \text{C} + \text{H}_2\text{O} + Q \)

2) \( \text{MgO} + \text{H}_2 \rightarrow \text{Mg} + \text{H}_2\text{O} + Q \)

and according to the general balance reaction:

\[
\text{catalyst (Mg)} \\
2\text{Hz} + \text{CO}_2 \rightarrow \text{C} + 2\text{H}_2\text{O} + Q
\]

the cycle being continuous.

From the thermal balance of the reaction it can be seen that two moles of hydrogen are used for a mole of carbon dioxide. Quantitatively, in the reaction there can be about 2400 Nm\(^3\) of \( \text{H}_2\) / hour and 1200 Nm\(^3\) of \( \text{CO}_2\) / hour, namely 2 moles of \( \text{Hz} \) for utmost 1 mole of \( \text{CO}_2 \), in a volume of the cylindrical chamber with magnesium, for example, of D 300 x 30 (about 5.7 kg Mg).

The combustion takes place at the surface of the layer of magnesium chips, where hydrogen is combined with oxygen and the carbon atom is released, the layer of magnesium chips being arranged to the outer side of the layer of magnesium powder which is placed at the inner side of the enclosure. Magnesium has the tendency to oxidize, but it is regenerated by introducing hydrogen into the enclosure, which leads to the release of the oxygen atom towards the hydrogen atom. Both the magnesium oxidation and the hydrogen oxidation are strongly exothermal.
reactions which lead to a higher output of the energetic balance as against the loss of energy necessary to decompose the carbon dioxide. The catalyst and the maximum allowable flow rate of CO$_2$ [a maximum of 1 mole of CO$_2$ for two moles of H$_2$] ensure the lowering of the H$_2$ combustion rate to about the combustion rate of the methane (37-45 m/s) and the quartz layer ensures the homogenization of the mixture of H$_2$ and CO$_2$ and stops the flame when the hydrogen supply is stopped (it does not allow the propagation of the flame into the ¾ supply circuit).

The process for obtaining the thermal energy by the combustion of hydrogen in admixture with carbon dioxide according to the invention may have various domestic or industrial applications.

When applied in the domestic field, the process according to the invention is carried out sequentially, as follows:

- the H$_2$ conduit valve is opened to the minimum flow rate of about 10% of the nominal flow rate;
- hydrogen is ignited, for example with a piezoelectric installation;
- the hydrogen flow rate is increased after at least 10 s;
- the valve of the conduit for the supply with the CO$_2$ containing mixture is opened up to ensuring an optimum hydrogen : carbon dioxide molar ratio of at least 2 : 1.

For stopping, the operations are reversed as against the ones carried on upon the start-up.

In the industrial application variant, the process according to the invention is carried out sequentially as follows:

- a pilot flame with methane brought through a supply conduit is ignited by means of a piezoelectric installation, the pilot flame being directed perpendicular to the hydrogen burner axis;
- the hydrogen supply valve is opened progressively up to the maximum flow rate, which, depending on the installation type, may vary from a few m$^3$/h to several thousands of m$^3$/h;
- the valve of the conduit for the supply with the CO$_2$ containing mixture is opened progressively up to ensuring the molar ratio H$_2$ : CO$_2$ of at least 2 : 1 (for two moles of H$_2$ a maximum of one mole of CO$_2$ is allowed - according to the chemical reaction).

The operation of stopping the installation is carried out in reverse order as against the starting operation, namely: stopping the supply with CO$_2$ containing mixture, stopping the H$_2$ supply, stopping the methane pilot flame. The industrial installations will also be provided with two optical sensors for the pilot flame and for the H$_2$ and CO$_2$ mixture flame which enters a special
automatization scheme which is not the object of the present invention and it is known, being carried out by specialists based on the work sequences presented above.

In the industrial application variant the installation is cooled by means of an air stream blown by a fan, which is directed into a chamber which allows cooling the installation presented in figure 1. The heated air is swirled through a frustoconical space inside the burner furnace. The housing for directing the warm air into the boiler is provided with a circuit which contains a filler made from copper pipes which ensures the heat transfer to the ventilated air.

The installation claimed by the invention, both in the variant used in the domestic field and in the variant used in the industrial field solves the problem of the combustion of hydrogen in admixture with carbon dioxide or other oxides as described above, by means of a catalyst consisting of magnesium chips and powder, which allows to obtain carbon atoms and thus contributes to eliminating the carbon dioxide in excess in nature, in conditions of maximum security, according to the claimed process.

The installation claimed by the invention consists of a housing [1] made of stainless steel, for example a pipe made of stainless steel, whereupon a cover (3) is fixed, said cover (3) being connected to a conduit for supplying hydrogen (2), inside the housing (1) there being contained:

- a chamber for the uniform distribution of hydrogen (M1) which is formed between the cover (3) and a cover (5) arranged inside the housing (1), both covers being manufactured of stainless steel;

- a chamber for the uniform distribution of the carbon dioxide (M2) which is formed between the cover (5) and a cover (6), both arranged inside the housing (1) and manufactured of stainless steel sheet;

- a chamber for homogenization of the hydrogen in admixture with the carbon dioxide (M3) which is formed between a cover (9) made of stainless steel and the chamber for the catalyst (14), this chamber for the homogenization of the hydrogen in admixture with the carbon dioxide (M3) containing the quartz layer (18); the quartz sand or the quartz crystals in the quartz layer (18) may have a grain size of 0.8-2 mm;

- a catalyst chamber (14) inside which there is a magnesium catalyst (13) which is a mixture of magnesium chips and powder, the magnesium powder being arranged towards the inner side of the enclosure, and the magnesium chips towards the outer side around the magnesium as powder, this special arrangement determining the lowering of the hydrogen rate of flow; the catalyst chamber (14) may be made from a stainless steel gauze, for example with perforations of 50 μm wherein the magnesium catalyst (13) is contained as a mixture of magnesium chips and powder in the mentioned arrangement;
pipes (7), (8) made of copper or stainless steel, which ensure the transport and uniform distribution of hydrogen and of the carbon dioxide, respectively, on the surface of the quartz layer (18) and of catalyst (13); a homogenization deflector (16) which ensures a swirling motion of hydrogen in admixture with the carbon dioxide through the quartz layer (18). The homogenization deflector is a part that can be made of sheet metal, for example stainless steel, with a configuration which ensures a swirling motion of the gaseous mixture; and on the outer side of the housing (1), there being provided:
a conduit for supplying the catalyst (17) for completing the losses, which communicates with the catalyst chamber (14);
a conduit for supplying hydrogen (2), connected to the cover (3);
a conduit for supplying carbon dioxide (4) which communicates with the chamber for uniform distribution of the carbon dioxide (M2);
a conduit for recovering carbon (10);
optionally, an installation for directing the warm air, in case of the industrial applications.

An example of arranging the pipes (7) and (8) inside the housing (1) can be seen in figure 2. An example of securing the catalyst chamber (14) with the Mg element which has the role of catalyst, can be seen in figure 3, the securing being made in this case with a nut (11), a gasket (12) and a resilient element (15).

In a preferred variant, at the lower side of the chamber for the catalyst (14), there is technologically carried out an inclination of 15°, in the height thereof, so that the carbon which remains in the catalyst can be recovered through the conduit (10).

A preferred example for the shape and for securing the deflector (16) is given in figure 4, and in figure 5, respectively. The bolt made of stainless steel (19) has a tight fit for fixing in the pipe for the distribution of CO2 and it is provided with holes to allow the CO2 to enter the quartz layer (18).

The Mg catalyst is present both as chips and as powder and occupies the catalyst chamber (14), which may be made of a perforated sieve. The Mg chips/Mg powder mass ratio may vary from 5/1 to 4/1.

From the chamber for the uniform distribution of hydrogen (MI), hydrogen is distributed uniformly through the pipes (7), which can be expanded or welded on the covers (5), (6) and (9) to achieve a sealing of the chambers.

CO2 is also uniformly distributed through the pipes (8). These are secured to the covers (6) and (9), for example by expanding or welding, depending on the employed material (for example
copper or stainless steel). Following to the combustion process, the catalyst \[13\) which ensures the oxygen transfer from the carbon dioxide (CO\(_2\)) to hydrogen (H\(_2\)) may have some losses which periodically require the completion thereof in the catalyst chamber \(14\), for example through the conduit \(17\).

In the industrial applications there is also necessary to direct the flame and heat by means of the cold air blown from outside the combustion installation, according to figure \(6\).

The cold air blown by a fan equipping the thermal boiler, which is not represented in the drawings, is directed into a chamber which allows to cool the installation described in figure \(1\), then the heated air is swirled through a frustoconical space in which there are welded fins made of sheet metal \(27\) inside the boiler furnace \(20\). The housing \(22\) is provided with a circuit containing supply pipes \(23\), for example in number of \(12\) pieces and may contain copper pipe filler \(26\), for example a pipe of \(10\) mm with the wall thickness of \(1\) mm, cut to the length of \(10\) mm, which ensures the heat transfer from the housing to the ventilated air. In the industrial applications there shall also be ensured a pilot flame through a supply conduit \(25\) and a piezoelectric system \(21\) for igniting the flame.

A portion of the carbon resulting from the process of decomposing the CO\(_2\) due to the hydrogen reactivity with the oxygen from CO\(_2\), is recovered through the conduit \(10\), and another part is scattered at the bottom of the thermal boiler furnace, where the installation is located, this being periodically recovered. It is important to state precisely that it is not allowed to create in the furnace (the place of burning inside the boiler, which is represented in the drawing) an amount of atomic carbon higher than about 50 kg for the industrial installation, since there exists the risk of this being ignited and consequently the risk of melting the furnace.

For situations in which carbon dioxide in concentrations higher than 98-99% is not available, in the process claimed by the invention there may also be used carbon dioxide in gaseous mixture, for example in admixture with oxygen and nitrogen or with nitrogen oxides.

In an embodiment, there may also be used a mixture of gas containing nitrogen in a ratio of 40-60%; oxygen in a ratio of 2-4%; CO\(_2\) in a ratio of 36-48%, said gas being obtained from the extant chemical processes.

In another embodiment, there may also be used a mixture of gas which contains oxygen in a ratio of 10-12%, CO\(_2\) in a ratio of 10-12%, NO\(_x\) in an amount of 250-300 mg/m\(^3\) and nitrogen for the remainder.

In another embodiment, the gas may additionally contain sulphur dioxide, for example when waste gases form thermal power plants which use fossil fuels are employed.
Examples

Example 1

An installation is used having the outside diameter of 300 mm, the length of 300 mm, the thickness of the layer of magnesium chips of 30 mm and the thickness of the layer of Mg powder of 5 mm, and the thickness of the quartz layer of 20 mm.

In this overall dimension of the installation hydrogen may be burnt at flow rates of 900 mm³/h and 3000 m³/h and carbon dioxide proportionally, with a flow rate representing a half of the used hydrogen flow rate, at the most (in 2 moles of H₂, 1 mole of CO₂, at the most).

In all situations the need of O₂ both in free state and that in combination with CO₂ is taken into consideration, so as to ensure a complete hydrogen combustion.

Example 2

In the industrial application variant, besides the installation described in example 1, a housing having the diameter of 1200 mm and a fan are used, wherein the fan ensures both the cooling of the previously presented installation and the directing of the flame. A conduit for the methane gas intake is also used, with a view to achieving the pilot flame, and the ignition is carried out with a piezoelectric installation. The operation cycle is the following: upon the start-up - ventilating the boiler, stopping the ventilation, igniting the pilot flame, progressively opening the hydrogen valve, progressively opening the CO₂ valve, introducing warm air for directing the flame and heat, and upon stopping - stopping the ventilation, stopping CO₂, stopping H₂, blowing out the pilot flame.

It will be obvious for the person skilled in the art that the process and the installation according to the invention disclosed above with reference to a specific embodiment wherein the combustion of hydrogen is performed with a mixture which comprises mainly carbon dioxide, may be applied in a similar manner for the combustion of hydrogen with any other gas mixtures comprising any carbon oxides and/or any nitrogen oxides and/or any sulphur oxides in any combination and any proportion.
CLAIMS

1. Process for obtaining thermal energy by the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides, wherein:
   a) in a first stage, the hydrogen combustion is carried out in the presence of a magnesium catalyst which is a mixture of magnesium chips and powder, in an enclosure with orifices for discharging the gases and the carbon and/or sulphur atoms, with the formation of MgO and water, and
   b) in a second stage, the magnesium catalyst is regenerated in the same enclosure, by introducing extra hydrogen, with the formation of water and heat.

2. Process according to claim 1 suitable for an industrial application, characterized in that the flame and the heat released by the combustion of hydrogen and magnesium are taken over by a cold air stream directed by means of warm air, after the air flows through a circuit containing a filler made from copper pipes, based on the following operation cycle: upon the start-up - ventilating the boiler, stopping the ventilation, igniting the pilot flame, progressively opening the hydrogen valve, progressively opening the valve for the admission of oxide containing mixture, introducing warm air for directing the flame and heat, and upon stopping - stopping the ventilation, stopping the admission of oxide containing mixture, stopping H2, stopping the pilot flame.

3. Installation suitable for the combustion of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides, according to the process claimed in claim 1, characterized in that, it consists of a housing (1) of stainless steel, whereupon a cover (3) is secured, said cover [3] being connected to a hydrogen supply conduit (2), inside the housing (1) there being comprised:
   • a chamber for the uniform distribution of hydrogen (M1) which is formed between the cover (3) and a cover (5) arranged inside the housing (1), both covers being made of stainless steel;
   • a chamber for the uniform distribution of the mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (M2) which is formed between the cover (5) and a cover (6), both arranged inside the housing (1) and made of stainless steel;
   • a chamber for the homogenization of hydrogen in admixture with the carbon oxides, nitrogen oxides and/or sulphur oxides (M3), wherein said chamber is formed between the
cover [9] made of stainless steel and the catalyst chamber [14], and it contains a quartz layer (18);
• a catalyst chamber (14) wherein a magnesium catalyst (13) is present as a mixture of magnesium chips and powder;
• pipes (7), (8) made of copper or stainless steel, wherein pipes (7) ensure the transport and uniform distribution of hydrogen and pipes (8) ensure the transport and uniform distribution of the mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides, on the surface of the quartz layer (18) and of the catalyst (13);
• a homogenization deflector (16) which ensures a swirling of hydrogen in admixture with carbon oxides, nitrogen oxides and/or sulphur oxides through the quartz layer (18);
and on the outer side of the housing (1) being provided:
• a conduit for supplying the catalyst (17) which communicates with the catalyst chamber (14);
• a conduit for hydrogen supply (2) connected to the cover (3);
• a conduit for supplying with a mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (4) which communicates with the chamber for the uniform distribution of the mixture comprising carbon oxides, nitrogen oxides and/or sulphur oxides (M2);
• a conduit for recovery of carbon and/or sulphur (10).

4. Installation according to claim 3 suitable for the industrial application of the process defined in claim 2, characterized in that, it further comprises:
• a housing (22);
• more pipes (23) for introducing air into the filler made from copper pipes (26);
• a conduit for supplying methane for ensuring the pilot flame (25);
• a group of holes arranged along the maximum diameter of the housing in the frustoconical side (24) which ensure the exit of the warm air from the burner.
FIGURE 6
Modes of directing the heat with air from a fan