

DEVICE AND PROCESS FOR COOLING A FLOW OF A TARGET FLUID
PREDOMINANTLY COMPRISING DIHYDROGEN, AND ASSOCIATED USE
THEREOF

Technical field of the invention

The present invention is directed to a device for cooling a flow of a target fluid predominantly comprising dihydrogen, a method for cooling a flow of a target fluid predominantly comprising dihydrogen and a corresponding use. It applies, for
5 example, to the field of the liquefaction of dihydrogen obtained by water electrolysis.

State of the art

Hydrogen is an energy carrier predominantly produced by reforming or gasifying hydrocarbons and in a minority by water electrolysis, water thermochemical
10 dissociation or biomass. The increasing use of renewable electricity sources is supporting the development of water electrolysis to promote carbon-neutral hydrogen. However, hydrogen produced in this way should subsequently be packaged for transport. One of these options is to liquefy it.

The hydrogen liquefaction process is divided into three major temperature
15 technology sequences: compression, pre-cooling and refrigeration. The purpose of precooling is to lower the inlet temperatures between 273 K and 320 K of the hydrogen fluid of interest and the fluid used for refrigeration in the following sequence, to a so-called precooling temperature between 78 K and 120 K.

The electrolysis process generates eight kilogrammes of oxygen for each
20 kilogramme of hydrogen produced. In most cases, this oxygen is released to the atmosphere, which is fatal oxygen.

Some systems use co-generated fatal oxygen during water electrolysis for precooling hydrogen liquefaction by expanding compressed oxygen at the electrolyser outlet to atmospheric pressure. This operation lowers the temperature to around 140
25 K. This allows this oxygen to flow in the opposite direction into a heat exchanger from where it exits at ambient temperature, thus cooling hydrogen. The oxygen is then released into the atmosphere.

The main drawback of these systems is that there is a danger of an oxygen flow crossing with a hydrogen flow within the same heat exchanger (in case of leakage in the exchanger, and in case of explosion to a more extreme extent).

An improvement in previous systems suggests the use of a buffer circuit. Oxygen thus cools not hydrogen directly, but an inert gas, preferably nitrogen, helium or neon, which in turn cools hydrogen.

However, this improvement requires the additional or increased use of gas compressors to compensate for head losses related to the intermediate circuit.

There is therefore no cost-effective solution (reduced compressor size) and energy-efficient solution for the liquefaction of dihydrogen and in particular for the precooling cycle thereof.

Patent application GB 2,142,423 is known, which discloses a cooling device of a flow using an intermediate refrigerant fluid. The intermediate refrigerant fluid is in gaseous form at ambient temperature at the inlet of a compressor and in supercritical form at the outlet of said compressor after it has been cooled to ambient temperature.

Object of the invention

The present invention aims to remedy all or part of these drawbacks.

For this purpose, according to a first aspect, the present invention is directed to a device for cooling a flow of a target fluid predominantly comprising dihydrogen, which comprises:

- a first heat exchanger configured to cool an intermediate refrigerant fluid by heat exchange with an expanded dioxygen flow,
- an intermediate closed circuit for transporting the intermediate refrigerant fluid from the first heat exchanger to a second heat exchanger,
- a means for compressing the intermediate refrigerant fluid along the intermediate closed circuit,
- the intermediate refrigerant fluid, configured to remain in the liquid or supercritical state at least upon passing through the compression means and
- the second heat exchanger configured to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchanger.

With these provisions, it is possible to set up a cooling buffer circuit between the dioxygen flow and the dihydrogen flow to avoid safety risks without, however, requiring

a gas compressor to compress the intermediate refrigerant fluid. These provisions also make it possible to provide a cost-effective (reduced compressor size) and energy-efficient solution for the liquefaction of dihydrogen and in particular for its precooling cycle by optimised reclaiming of the fatal oxygen co-produced during water electrolysis. In addition, these provisions allow simplified operational implementation with respect to existing solutions.

In embodiments, the intermediate refrigerant fluid is predominantly:

- an n-pentane,
- a i-butane,
- an n-hexane,
- an n-heptane,
- an n-octane,
- a 2-methylpentane,
- a 2,2-dimethylbutane,
- acetone,
- ether,
- methanol,
- an n-butane or
- ammonia.

These embodiments make it possible to implement a refrigerant fluid having a wide temperature range in the supercritical or liquid state.

The use of an n-pentane has the most flexible use, i.e. no concession has to be made to keep it in liquid form (lowest melting temperature).

The uses of an n-butane or ammonia are advantageous, but require the use of the compression means downstream of the first exchanger or the partial reduction of cooling power of these intermediate refrigerant fluids.

In embodiments, the second heat exchanger is configured to cool the target fluid flow with, in addition to the intermediate refrigerant fluid, a refrigerant fluid flow, the device comprising a closed refrigerant fluid circuit, this circuit comprising:

- a means for compressing the low-pressure refrigerant fluid at the outlet of the second compression means to form a high-pressure refrigerant fluid,
- a means for inserting the high-pressure refrigerant fluid into the second heat exchanger,

- a means for expanding the high pressure refrigerant fluid to form a low pressure refrigerant fluid,

- a third heat exchanger configured to cool the target fluid flow by heat exchange with the low pressure refrigerant fluid and

5 - a means for inserting the low pressure refrigerant fluid into the second heat exchanger.

These embodiments make it possible to improve the performance of cooling the target fluid.

10 In embodiments, the device object to the present invention comprises a fourth heat exchanger configured to cool the target fluid flow by heat exchange with the low-pressure refrigerant fluid from the means for expanding the high-pressure refrigerant fluid, the means for inserting the low-pressure refrigerant fluid into the second heat exchanger being configured to insert the flow of the low-pressure refrigerant fluid from the fourth heat exchanger.

15 These embodiments make it possible to optimise the fluid gas cooling process.

In embodiments, the device object to the present invention comprises the refrigerant fluid, this refrigerant fluid being predominantly:

- nitrogen,

- argon,

20 - a mixture of nitrogen and argon or

- a mixture of hydrocarbons and nitrogen.

In embodiments, the device object to the present invention comprises a means for expanding dioxygen upstream of the first heat exchanger.

25 These embodiments make it possible to obtain a flow of dioxygen from an electrolysis process likely to cool the refrigerant fluid.

In embodiments, the device object to the present invention comprises a water electrolysis means, configured to produce dioxygen and dihydrogen, the dioxygen produced being provided to the dioxygen expansion means.

30 These embodiments make it possible to generate both the fluid to be cooled and the dioxygen by indirectly allowing cooling.

In embodiments, the device object to the present invention comprises a means for injecting dihydrogen from the water electrolysis means into the second heat exchanger.

These embodiments make it possible to reclaim renewable electric power sources in order to generate hydrogen with a carbon neutral balance.

According to a second aspect, the present invention is directed to a method for cooling a flow of a target fluid comprising predominantly dihydrogen, which comprises:

5 - a first heat exchange step to cool an intermediate refrigerant fluid by heat exchange with an expanded dioxygen flow,

 - an intermediate step of circulating in a closed circuit the intermediate refrigerant fluid from the first heat exchange step to a second heat exchange step,

10 - a step of compressing the intermediate refrigerant fluid during the intermediate closed circuit circulation step and

 - the second heat exchange step to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchange step,

 the intermediate refrigerant fluid being configured to remain in the liquid or supercritical state at least upon performing the compression step.

15 This method has the same advantages as the device object of the present invention.

 According to a third aspect, the present invention is directed to the use of a flux predominantly of n-pentane in a supercritical state or liquid in a closed circuit to cool a body by accumulation of frigories during the heat exchange between a flow
20 predominantly of compressed n-pentane and predominantly a dioxygen flow.

 This use has the same advantages as the device object of the present invention.

 In embodiments, the body is predominantly a dihydrogen flow.

 In embodiments, the body is predominantly a solid body.

25 Brief description of the figures

 Further particular advantages, purposes and characteristics of the invention will become clearer from the non-limiting description that follows of at least one particular embodiment of the device and method object of the present invention, with regard to the appended drawings, wherein:

30 - Figure 1 schematically represents a first particular embodiment of the device object to the present invention and

 - Figure 2 schematically represents as a flowchart, a succession of particular steps of the method subject to the present invention.

Description of the embodiments

This description is provided for non-limiting purposes, wherein each characteristic of an embodiment can be advantageously combined with any other characteristic of any other embodiment.

From now on, it is noted that the figures are not drawn to scale.

It is noted here that the term “predominantly” denotes a relative majority among other compounds or an absolute majority of a compound in a mixture. The term “predominantly” denotes a composition comprising at least 30% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 40% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 50% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 60% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 70% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 80% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 85% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 90% of the compound designated.

In alternatives, the term “predominantly” denotes a composition comprising at least 95% of the compound designated.

It is noted here that the target fluid 101 to be cooled is preferably a gas and, even more preferably predominantly hydrogen. Such a gas can also be predominantly:

- methane,
- carbon dioxide,
- carbon monoxide,
- nitrogen or
- argon.

Generally speaking, the fluid to be cooled can denote any fluid or fluid mixture with a boiling temperature above 275K and a crystallisation temperature between 80K and 200K.

A schematic view of one embodiment of the device 100 subject of the present invention is observed in figure 1, which is not to scale.

It is noted that this device 100 forms the cooling device of a larger (non-referenced) system comprising the systems for transporting, cooling and compressing the fluid to be precooled. In Figure 1, this system comprises:

- an inlet 1025 for fluid to be cooled, the fluid flow 101 successively passing through the second heat exchanger 125, the third heat exchanger 160 and the fourth heat exchanger 180 when this fourth heat exchanger 180 is present,

- a fluid cooling stage 1010 with two outlets:

- an outlet for cooling fluid, which may be the fluid to be cooled, at low pressure 1020 and

- an outlet for medium pressure cooling fluid 1015,

the low pressure 1020 and medium pressure 1015 coolant flows successively passing through the fourth heat exchanger 180 when present, the third heat exchanger 160 and the second heat exchanger 125 before reaching a compression stage 1005 and

- said compression stage comprising an outlet for high pressure cooling fluid 1030,

the flow of high-pressure coolant successively passing through the second heat exchanger 125, the third heat exchanger 160 and the fourth heat exchanger 180.

It is noted that devices of the same type, for example compressors or exchangers, may not be separate devices, but stages of a single device for all or part of the devices of a given type. For example, the second exchanger 125, the third exchanger 160 and the fourth exchanger 180 may correspond to three separate stages of a single exchanger.

It is noted that, in alternatives, the fourth exchanger 180 is absent from the device 100.

The device 100 for cooling a fluid flow comprises:

- a first heat exchanger 105 configured to cool an intermediate refrigerant fluid 110 by heat exchange with an expanded dioxygen flow 115,

- a closed intermediate circuit 120 for transport the intermediate refrigerant fluid from the first heat exchanger to a second heat exchanger 125,

- a means 130 for compressing the intermediate refrigerant fluid along the intermediate closed circuit,

5 - the intermediate refrigerant fluid 110, configured to remain in the liquid or supercritical state at least when passing through the compression means and

- the second heat exchanger 125 configured to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchanger.

10 The first heat exchanger 105 is, for example, a plate, spiral, tube, shell tube or fin tube heat exchanger. These examples are also applicable to the second, third and fourth heat exchangers 125 and 160, and 180.

15 The intermediate refrigerant fluid 110 is selected for the ability of said fluid 110 to remain in a liquid or supercritical state at least under the action of the compression means 130. Preferably, this intermediate refrigerant fluid 110 remains in the liquid or supercritical state throughout the closed circuit 120.

In preferred embodiments, the intermediate refrigerant fluid 110 is configured to have boiling and melting temperatures at atmospheric pressure of respectively greater than 300 K and less than at least 200 K.

20 In preferred embodiments, the intermediate refrigerant fluid 110 is configured to have a mass flow ratio of 4.8 kgn-C5/kgLH2.

Thus, depending on the size and type of compression means 130, the nature of the intermediate refrigerant fluid may vary. In preferential alternatives, the intermediate refrigerant fluid 110 is predominantly:

- an n-pentane,
- 25 -a i-butane,
- an n-hexane,
- an n-heptane,
- an n-octane,
- a 2-methylpentane,
- 30 -a 2,2-dimethylbutane,
- acetone,
- ether,
- methanol,

- an n-butane or
- ammonia.

In other alternatives, the refrigerant fluid 110 is predominantly ammonia implemented at a pressure below 8 bara used over a range of 200 K – 300 K. This
 5 refrigerant fluid 110 is liquid after being cooled by oxygen and could therefore be pumped and/or compressed. Ammonia, on the other hand, is gaseous at a temperature above approximately 240 K.

In other alternatives, the refrigerant fluid 110 is predominantly n-butane at a pressure below 1.5 bara which can be used in the range 140 K – 300 K. As ammonia,
 10 n-butane is liquid after cooling by oxygen and therefore can be pumped, but gaseous at a temperature above 283 K. This makes it possible to achieve lower temperatures.

These alternatives require the implementation of a cryopump, which is a priori more expensive, but less expensive than a compressor. These alternatives also imply an additional difficulty in process optimisation due to change of state management.

15 In other alternatives, the intermediate refrigerant fluid 110 is conveyed to the second exchanger 125 by transporting the refrigerant fluid 110 not by piping, but by mobile storage. This could be the case for an island production of hydrogen whose liquefaction takes place elsewhere. The intermediate refrigerant fluid 110 from the second exchanger 125 is then conveyed by transport to the first exchanger 105 (and
 20 optionally the means compression 130).

Preferably, the compression means 130 is positioned between downstream of the second exchanger 125 and upstream of the first exchanger 105 along the flow of the refrigerant fluid 110.

The predominantly dioxygen flow 115 may come from a dedicated storage or,
 25 preferably, from a water electrolysis means 175. In all cases, the predominantly dioxygen flow 115 is preferably expanded before being inserted into the first heat exchanger 105. This expansion is ensured by an expansion means 170. Such an expansion means 170 may be of any known type such as, for example, an expansion turbine, an expansion valve or a turboexpander.

30 In alternatives, the predominantly dioxygen flow is released into the atmosphere once implemented in the first heat exchanger 105.

Thus, as is understood, in some embodiments, the device 100 comprises a means 170 for expanding dioxygen upstream of the first heat exchanger 105.

In embodiments, the expansion means 170 is configured to lower the dioxygen flow pressure from 30 bara to 1.1 bara, preferably at ambient temperature. Such embodiments allow the dioxygen flow temperature to be lowered to 119 K (-154°C).

Furthermore, as is understood, in some embodiments, the device 100 comprises
 5 a water electrolysis means 175, configured to produce dioxygen and dihydrogen, the dioxygen produced being provided to the dioxygen expansion means 170. Such a water electrolysis means 175 is, for example, an electrolyser. Preferably, the first heat exchanger 105 is positioned as close as possible to the means 175 of electrolysis to reduce head losses of the oxygen generated during the water electrolysis process.

10 Preferably, the mass flow ratio of dioxygen to dihydrogen generated by the electrolysis means 175 is configured to reach 8 kg_{O2}/kg _{LH2}, as determined by the stoichiometry of the electrolysis reaction.

In embodiments, such as that represented in Fig. 1, the flow of target fluid 101 to be cooled is predominantly dihydrogen, the device 100 comprising a means 1025 for
 15 injecting dihydrogen from the water electrolysis means 175 into the second heat exchanger 125.

The purpose of the closed circuit 120 is to store frigories in the first heat exchanger 105 to restore them to the second heat exchanger 125. This circuit 120 thus comprises, along the intermediate refrigerant fluid flow, at least the two exchangers,
 20 105 and 125, as well as a means 130 for compressing the intermediate refrigerant fluid from the second heat exchanger 125.

This compression means 130 is, for example, a pump, preferably centrifugal. In alternatives, the compression means 130 is a turbocompressor, a mechanical or reciprocating compressor.

25 In preferred embodiments, the compression means 130 is configured to compress the intermediate refrigerant fluid 110 to a pressure of 3 bara.

The optimal operating conditions of the present invention within the scope of the use of an n-pentane are met for the parameters defined as:

Table 1

Parameter	Lower limit	Upper limit
Pressure [bara]	1.0	15
Ratio (kg _{C5} /kg _{LH2})	4.0	10
Cooling temperature (K)	136	230

If the flow rate of liquid intermediate refrigerant fluid (defined by the ratio kg_{C5}/kg_{LH2}, because it is relative and proportional to the amount of H₂ to be liquefied) is too low, there is a risk of crystallisation of the liquid present in the second heat exchanger 125 due to excessive cooling by oxygen. If the flow rate of liquid intermediate refrigerant fluid 110 is too high, this fluid 110 will not be cooled to a temperature low enough to cool the fluids sufficiently during hydrogen cooling.

If the pressure of the intermediate refrigerant fluid 110 is too low, there is a risk that the fluid will no longer circulate, as it does not compensate enough for head losses induced by the flow in the circuit 120.

In embodiments, the parameter values of the flows are:

Table 2

Parameter	Lower limit	Upper limit
O ₂ Inlet pressure [bara]	10	80
O ₂ Outlet pressure [bara]	1	9
C ₅ Pressure [bara]	1.0	30
Ratio (kg _{C5} /kg _{LH2})	1.5	5.5
H ₂ ref High pressure [bara]	20	80
H ₂ ref Mean pressure [bara]	4	10
H ₂ ref Low pressure [bara]	1	2.5
Ratio (kg _{N2} /kg _{LH2})	14.5	30
N ₂ High pressure [bara]	25	63
N ₂ Low pressure [bara]	1	5

In preferred embodiments, such as that represented in Fig. 1, the second heat exchanger 125 is configured to cool the target fluid flow 101 with, in addition to the intermediate refrigerant fluid 110, a refrigerant fluid flow 135, the device comprising a closed refrigerant fluid circuit 140, this circuit comprising:

- 5 - a means 145 for compressing the low-pressure refrigerant fluid at the outlet of the second heat exchanger 125 to form a high-pressure refrigerant fluid,
- a means 150 for inserting the high-pressure refrigerant fluid into the second heat exchanger,
- a means 155 for expanding the high pressure refrigerant fluid to form a low
- 10 pressure refrigerant fluid,
- a third heat exchanger 160 configured to cool the target fluid flow by heat exchange with the low pressure refrigerant fluid and
- a means 165 for inserting the low pressure refrigerant fluid into the second heat exchanger.

15 The refrigerant fluid 135 may be of any type likely to accumulate frigories to restore them to the target fluid flow 101. Preferably, this refrigerant fluid 135 contains at least partially nitrogen. Preferably, this refrigerant fluid 135 contains at least 75% nitrogen. Preferably, this refrigerant fluid 135 consists entirely (to the nearest impurities) of nitrogen.

20 In alternatives, the refrigerant fluid 135 is predominantly:

- argon,
- a mixture of nitrogen and argon or
- a mixture of hydrocarbons and nitrogen.

 In alternatives, the refrigerant fluid 135 is a fluid mixture predominantly

25 comprising one or more compounds from methane, ethane, propane, butane, pentane and their isomers.

 The purpose of the closed circuit 140 is to not release any refrigerant fluid into the atmosphere and its purpose is that the refrigerant fluid 135 accumulates frigories and restores them to the second exchanger 125 and that, after expansion by the

30 expansion means 155, this refrigerant fluid 135 participates in cooling the target fluid 101 in the third, and optionally fourth, exchangers, 160 and/or 180.

After exchange between the low pressure intermediate refrigerant fluid 110 and the dioxygen 115 expanded, the refrigerant fluid 135 is compressed by the compression means 145.

The compression means 145 is, for example, a turbocompressor, a mechanical or reciprocating compressor. In alternatives, the compression means 145 is a pump, preferably centrifugal. Optionally, several compressors or pumps are positioned in series to form the compression means 145.

In preferred embodiments, the compression means 145 is configured to compress the refrigerant fluid 135 from 1.1 bara to 50 bara.

In preferred embodiments, the mass flow ratio in the closed circuit 140 is 18 kg_{N2}/kg_{LH2}.

The (so-called “high pressure”) compressed refrigerant fluid 135 is then reinjected into the second heat exchanger 125 via the insertion means 150. This insertion means 150 is, for example, a tubing configured to connect the outlet of the compression means 145 to the second heat exchanger 125.

In preferred embodiments, the second heat exchanger 125 is configured to lower the temperature of the compressed refrigerant fluid 135 to 200 K (-73°C).

Downstream of the second passage through the second heat exchanger 125, the high-pressure refrigerant fluid 135 is expanded via the expansion means 155. This expansion means 155 is, for example, an expansion turbine, an expansion valve or a turboexpander.

In preferred embodiments, the expansion means 155 is configured to lower the pressure of the refrigerant fluid 135 from 50 bara to 1.1 bara, resulting in lowering the temperature of the refrigerant fluid 135 to 78.06 K.

Once expanded to form the low pressure refrigerant fluid 135, this fluid is injected into the third heat exchanger 160 via the insertion means 165. This insertion means 165 is, for example, a dedicated tubing configured to connect the outlet of the expansion means 155 to the third heat exchanger 160.

In embodiments, such as that represented in Fig. 1, the device 100 further comprises a fourth heat exchanger 180 configured to cool the target fluid 101. This fourth heat exchanger 180 is positioned downstream along the circuit of fluid 101 entering the device through the inlet 1025. In such embodiments, the insertion means 165 may be configured to inject the refrigerant fluid 135 at low pressure into the fourth

exchanger 180, the refrigerant fluid 135 from the fourth exchanger 180 then being injected into the third exchanger 160 before being injected into the second exchanger 125.

In preferred embodiments, the fourth exchanger 180 is configured to perform catalytic conversion from a target fluid flow 101 having a temperature of less than 100 K to produce a flow of fluid 101 having a temperature of around 80 K.

Alternatives not represented in the present invention may consist in:

- adding additional compression means 130,
- moving the position of the compression means 130 in the circuit 120 of intermediate refrigerant fluid 110,
- adding intermediate exchangers, similar to the first heat exchanger 105,
- adding additional compression means 145;
- modifying the number of exchangers among the second, third and fourth exchangers, 125, 160 and 180 and/or
- performing all or part of the cooling (catalysis) in an absorption column.

A particular embodiment of the method 200 object of the present invention is schematically observed, in Fig. 2. This method 200 of cooling a flow of a target fluid comprises:

- a first heat exchange step 205 to cool an intermediate refrigerant fluid by heat exchange with an expanded dioxygen flow,
- an intermediate step 210 of circulating in a closed circuit the intermediate refrigerant fluid from the first heat exchange step to a second heat exchange step,
- a step 215 of compressing the intermediate refrigerant fluid during the intermediate step 210 of circulating in a closed circuit and
- the second heat exchange step 220 to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchange step, the intermediate refrigerant fluid being configured to remain in the liquid or supercritical state at least upon performing the compression step.

These steps are described mutatis mutandis with regard to Fig. 1.

It is also understood that the present invention is directed to the use of a flow predominantly of n-pentane in a supercritical or liquid state in a closed circuit to predominantly cool a body by accumulation of frigories during the heat exchange

between a flow predominantly of compressed n-pentane and a flow predominantly of dioxygen.

In embodiments, the body is predominantly a dihydrogen flow.

In embodiments, the body is predominantly a solid body.

5 Thus, as is understood, unlike solutions implemented up to now, the present invention implements an intermediate cooling loop made up of a liquid fluid that recovers refrigerating power of the oxygen directly expanded at the outlet of the electrolyser. Thus, the present invention separates oxygen-using units from hydrogen-using units. The present invention benefits from at least two main advantages over
10 existing solutions:

- the present invention makes it possible to replace compressors compensating for head losses by centrifugal pumps whose capital and energy cost is much lower;
- the present invention makes it possible to increase refrigeration power of oxygen, as it is expanded over a wider range of pressures.

15 Finally, a last more situational benefit can be cited: compared to existing solutions using an inert gas such as neon, the present invention allows the cost of purchasing the intermediate refrigerant fluid to be reduced, since liquids considered are cheaper.

The present invention is of interest in cases of production of liquid hydrogen juxtaposed with the production of hydrogen by water electrolysis and where oxygen
20 reclaiming is not cost-effective due to difficulties related to its packaging and/or sale on the market. This last condition seems to be met, in particular, because oxygen is most often simply released into the atmosphere.

The present invention also has an interest in the case of the production of liquid e-methane from carbon dioxide and hydrogen produced by water electrolysis where
25 oxygen reclaiming is not profitable for the same reasons as mentioned above

Furthermore, the present invention has the advantage of reducing power consumption, which proves to be an asset giving rise to two trends:

- the greater the capacity and the more interesting the present invention and
- the greater the cost of acquiring electricity and the more interesting the present
30 invention.

CLAIMS

1. A device (100) for cooling a flow (101) of a target fluid predominantly comprising dihydrogen, characterised in that it comprises:

- a first heat exchanger (105) configured to cool an intermediate refrigerant fluid (110) by heat exchange with an expanded dioxygen flow (115),

5 - an intermediate closed circuit (120) for transporting the intermediate refrigerant fluid from the first heat exchanger to a second heat exchanger (125),

- a means (130) for compressing the intermediate refrigerant fluid along the intermediate closed circuit,

10 - the intermediate refrigerant fluid, configured to remain in the liquid or supercritical state at least upon passing through the compression means and

- the second heat exchanger configured to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchanger.

2. The device (100) according to claim 1, wherein the intermediate refrigerant fluid (110) is predominantly:

- an n-pentane,

-a i-butane,

-an n-hexane,

-an n-heptane,

20 -an n-octane,

- a 2-methylpentane,

-a 2,2-dimethylbutane,

- acetone,

- ether,

25 - methanol,

-an n-butane or

- ammonia.

3. The device (100) according to any of claims 1 or 2, wherein the second heat exchanger (125) is configured to cool the target fluid flow (101) with, in addition to the intermediate refrigerant fluid (110), a refrigerant fluid flow (135), the device comprising

30 a refrigerant fluid closed circuit (140), this circuit comprising:

- a means (145) for compressing the low pressure refrigerant fluid at the outlet of the second exchanger (125) to form a high pressure refrigerant fluid,

- a means (150) for inserting the high-pressure refrigerant fluid into the second heat exchanger,

5

- a means (155) for expanding the high pressure refrigerant fluid to form a low pressure refrigerant fluid,

- a third heat exchanger (160) configured to cool the target fluid flow by heat exchange with the low pressure refrigerant fluid and

10

- a means (165) for inserting the low pressure refrigerant fluid into the second heat exchanger.

4. The device (100) according to claim 3, which comprises a fourth heat exchanger (180) configured to cool the target fluid flow (101) by heat exchange with the low-pressure refrigerant fluid (135) from the means (155) for expanding the high-pressure refrigerant fluid, the means (165) for inserting the low-pressure refrigerant fluid into the second exchanger (160) temperature being configured to insert the flow of the low pressure refrigerant fluid from the fourth heat exchanger.

15

5. The device (100) according to any of claims 3 or 4, comprising the refrigerant fluid (135), wherein the refrigerant fluid is predominantly:

20

- nitrogen,

- argon,

- a mixture of nitrogen and argon or

- a mixture of hydrocarbons and nitrogen.

25

6. The device (100) according to any of claims 1 to 5, which comprises a means (170) for expanding dioxygen upstream of the first heat exchanger (105).

7. The device (100) according to claim 6, which comprises a water electrolysis means (175), configured to produce dioxygen and dihydrogen, the dioxygen produced being provided by means (170) for expanding dioxygen.

30

8. The device (100) according to claim 7, which comprises a means (1025) for injecting dihydrogen from the water electrolysis means into the second heat exchanger (125).

- 5 9. A method (200) for cooling a flow of a target fluid predominantly comprising dihydrogen, characterised in that it comprises:
- a first step (205) of heat exchange to cool an intermediate refrigerant fluid by heat exchange with an expanded dioxygen flow,
 - an intermediate step (210) of circulating in a closed circuit the intermediate
 - 10 refrigerant fluid from the first heat exchange step to a second heat exchange step,
 - a step (215) of compressing the intermediate refrigerant fluid during the intermediate closed circuit circulation step and
 - the second step (220) of heat exchange to cool the target fluid flow by heat exchange with the intermediate refrigerant fluid cooled in the first heat exchange step,
 - 15 the intermediate refrigerant fluid being configured to remain in the liquid or supercritical state at least upon performing the compression step.