Claims

[Claim 1] A method for hydrogen liquefaction comprising at least:
a pre-cooling step, wherein a hydrogen feed flow is cooled by a first refrigerant,
a cooling step, wherein the hydrogen feed flow is cooled by a second refrigerant, and
a step of expanding, in particular substantially adiabatically expanding, the hydrogen feed flow,
and wherein each of the first and second refrigerants is successively subjected to at least one compression and to at least one expansion in order to cool it, and a liquid phase of the first refrigerant cools the second refrigerant between at least three stages of a compression of the second refrigerant, so that the second refrigerant does not exceed a temperature of 150 K, preferably 113 K, during said compression of the second refrigerant.

[Claim 2] The method for hydrogen liquefaction according to claim 1, wherein the first refrigerant comprises nitrogen and/or argon.

[Claim 3] The method for hydrogen liquefaction according to either of claims 1 or 2, wherein the liquid phase of the first refrigerant cools the second refrigerant upstream of each of said at least three compression stages of the second refrigerant.

[Claim 4] The method for hydrogen liquefaction according to any one of claims 1 to 3, wherein the second refrigerant comprises hydrogen, neon and/or helium.

[Claim 5] The method for hydrogen liquefaction according to any one of claims 1 to 4, wherein the second refrigerant is divided into a first stream which is subject to an expansion in order to cool it, and a second stream which is

cooled by the first stream of the second refrigerant after the expansion of the first stream of the second refrigerant.

[Claim 6] The method for hydrogen liquefaction according to claim 5, wherein the second stream of the second refrigerant is subject to an expansion, in particular to a substantially adiabatic expansion, after having been cooled by the first stream of the second refrigerant.

[Claim 7] The method for hydrogen liquefaction according to any one of claims 1 to 6, wherein the first refrigerant is divided into a first stream which is subject to an expansion in order to cool it and a second stream which is cooled by the first stream of the first refrigerant after the expansion of the first stream of the first refrigerant.

[Claim 8] The method for hydrogen liquefaction according to claim 7, wherein the second stream of the first refrigerant is subject to an expansion, in particular to a substantially adiabatic expansion, after having been cooled by the first stream of the first refrigerant.

[Claim 9] The method for hydrogen liquefaction according to any one of claims 1 to 8, wherein the hydrogen feed flow is also cooled by a third refrigerant during the precooling step.

[Claim 10] A hydrogen liquefaction plant comprising, at least:
a hydrogen feed circuit,
a first refrigerant circuit containing a first refrigerant,
a second refrigerant circuit containing a second refrigerant,
a first heat exchanger assembly passed through by the hydrogen feed circuit and by the first refrigerant circuit,
a second heat exchanger assembly passed through by the second refrigerant circuit and by the hydrogen feed circuit downstream of the first heat exchanger assembly, and

an expansion valve, for example an adiabatic expansion valve, passed through by the hydrogen feed circuit downstream of the second heat exchanger assembly,

wherein the first refrigerant circuit includes one or more compressors and one or more expansion valves, and the second refrigerant circuit comprises at least three compressors and a cooling device comprising a plurality of intermediate exchangers interposed between said at least three compressors of the second refrigerant circuit so as to carry out at least three compressions of the second refrigerant without exceeding a temperature of 150 K, preferably 113 K, and one or more expansion valves, the cooling device being configured to cool the second refrigerant in the second refrigerant circuit with a liquid phase of the first refrigerant in the first refrigerant circuit, in particular in a tank of the first refrigerant circuit.

[Claim 11] The hydrogen liquefaction plant according to claim 10, wherein one of said intermediate exchangers is disposed upstream of each of said at least three compressors of the second refrigerant circuit.

[Claim 12] The hydrogen liquefaction plant according to either of claims 10 or 11, wherein said at least three compressors of the second refrigerant circuit have magnetic bearings, in particular active magnetic bearings.

[Claim 13] The hydrogen liquefaction plant according to any one of claims 10 to 12, wherein said at least three compressors of the second refrigerant circuit (R2) are centrifugal compressors.

[Claim 14] The hydrogen liquefaction plant according to any one of claims 10 to 13, wherein at least one heat exchanger of the first heat exchanger assembly or of the second heat exchanger assembly is a catalytic exchanger.

[Claim 15] The hydrogen liquefaction plant according to any one of claims 10 to 14, wherein the second refrigerant circuit includes a branching,

downstream of said at least three compressors of the second refrigerant circuit, with a first branch including one or more of said expansion valves of the second refrigerant circuit and passing through, downstream, at least one of the heat exchangers of the second assembly, and a second branch passing through at least one of the heat exchangers of the second assembly before rejoining the first branch of the second refrigerant circuit upstream of said compressors of the second refrigerant circuit.

[Claim 16] The hydrogen liquefaction plant according to any one of claims 10 to 15, wherein the first refrigerant circuit includes a branching , downstream of the compressors of the first refrigerant circuit, with a first branch including at least one of said expansion valves of the first refrigerant circuit and passing through, downstream, at least one of the heat exchangers of the first heat exchanger assembly, and a second branch passing through at least one of the heat exchangers of the first heat exchanger assembly before rejoining the first branch of the first refrigerant circuit upstream of the compressors of the first refrigerant circuit.

[Claim 17] The hydrogen liquefaction plant according to any one of claims 10 to 16, further including a third refrigerant circuit containing a third refrigerant and also passing through one or more heat exchangers of the first heat exchanger assembly.