Claims

[Claim 1]

A methanation device for removing a saturated hydrocarbon having two or more carbon atoms from a raw material gas containing methane and the saturated hydrocarbon through methanation, in which the saturated hydrocarbon is converted into methane by reacting the saturated hydrocarbon with hydrogen, the methanation device comprising:

at least two catalyst layers composed of a catalyst for the methanation, the at least two catalyst layers being provided at intervals in a flow direction of a mixed gas containing the raw material gas and a hydrogen-containing gas;

a hydrogen supply line configured to supply the hydrogen-containing gas to an upstream side of a most upstream catalyst layer in the flow direction of the mixed gas;

a raw material gas supply line configured to supply the raw material gas to each of the upstream side of the most upstream catalyst layer in the flow direction of the mixed gas and a space between two adjacent catalyst layers in the flow direction of the mixed gas; and

a cooler provided between two adjacent catalyst layers in the flow direction of the mixed gas and cooling the mixed gas flowing out from an upstream catalyst layer in the flow direction of the mixed gas among the two adjacent catalyst layers.

[Claim 2]

The methanation device according to claim 1, wherein an amount of the catalyst constituting each of the at least two catalyst layers is larger as the catalyst layer is disposed further downstream in the flow direction of the mixed gas.

[Claim 3]

The methanation device according to claim 1 or 2, wherein the catalyst is a supported catalyst in which nickel, iron, cobalt, or a noble metal element is supported on alumina.

[Claim 4]

A hydrocarbon direct decomposition device comprising:

the methanation device according to any one of claims 1 to 3;

a reactor containing a catalyst for direct decomposition reaction of a hydrocarbon; and

a processed gas supply line configured to supply a processed gas, which is a gas flowing out from the methanation device, to the reactor.

[Claim 5]

The hydrocarbon direct decomposition device according to claim 4, comprising:

a product gas flow line through which a product gas containing hydrogen generated by direct decomposition of hydrocarbon in the reactor flows after flowing out from the reactor; and

a hydrogen recycle line communicating the product gas flow line with the hydrogen supply line.

[Claim 6]

A methanation method for removing a saturated hydrocarbon having two or more carbon atoms from a raw material gas containing methane and the saturated hydrocarbon through methanation, in which the saturated hydrocarbon is converted into methane by reacting the saturated hydrocarbon with hydrogen, the methanation method comprising:

causing a hydrogen-containing gas to flow into a most upstream catalyst layer among at least two catalyst layers composed of a catalyst for the methanation, the at least two catalyst layers being provided at intervals in a flow direction of a mixed gas containing the raw material gas and the hydrogen-containing gas;

causing a part of the raw material gas to flow into the most upstream catalyst layer in the flow direction of the mixed gas;

supplying a remainder of the raw material gas between two adjacent catalyst layers in the flow direction of the mixed gas;

cooling the mixed gas flowing out from an upstream catalyst layer among the two adjacent catalyst layers; and

causing the cooled mixed gas and the raw material gas supplied between the two adjacent catalyst layers in the flow direction of the mixed gas to flow into a downstream catalyst layer among the two adjacent catalyst layers.

[Claim 7]

The methanation method according to claim 6, wherein a supply amount of the hydrogen-containing gas is adjusted so that a concentration ratio of hydrogen to the saturated hydrocarbon in the mixed gas is 1 or more.

[Claim 8]

The methanation method according to claim 6 or 7, wherein the hydrogen-containing gas contains hydrogen and a component that does not contribute to the methanation.

[Claim 9]

The methanation method according to any one of claims 6 to 8, comprising:

detecting a decrease in activity of the methanation; and

increasing a supply amount of the hydrogen-containing gas when the decrease in the activity is detected.

[Claim 10]

The methanation method according to any one of claims 6 to 9, wherein the raw material gas is natural gas, compressed natural gas, city gas, liquefied petroleum gas, or naphtha.

[Claim 11]

A hydrocarbon direct decomposition method comprising:

converting the saturated hydrocarbon in the raw material gas into methane by the methanation method according to any one of claims 6 to 10; and

directly decomposing methane in a processed gas, which is a gas after conversion of the saturated hydrocarbon into methane, into hydrogen and carbon by contacting the processed gas with a catalyst for direct decomposition reaction of a hydrocarbon.

[Claim 12]

The hydrocarbon direct decomposition method according to claim 11, wherein at least a part of a product gas containing hydrogen generated by directly decomposing methane in the processed gas into hydrogen and carbon is used as at least a part of the hydrogen-containing gas supplied to an most upstream catalyst layer among at least two catalyst layers provided at intervals in a flow direction of the mixed gas.