SUMMARY

It has been found by the present inventor(s) that improvements in methanol production, and in a methanol plant itself can be achieved by changes upstream the compressor. The disclosure is based on the recognition that an electrically heated RWGS reactor can be operated at a higher temperature than a fired RWGS reactor, and that hence the RWGS reaction can be shifted to form more CO and water. Hence the use of an electrically heated RWGS reactor makes it possible to reduce the amount of synthesis gas, which is required to be compressed and moved through the plant by the compressor located between the water removal unit and the methanol synthesis section. This in turn reduces the electricity requirement of the compressor and reduces operational costs while making it more feasible to operate the compressor using sustainable electricity. Also, the use of an electrically heated RWGS reactor makes it possible to operate the RWGS reactor on sustainable electricity rather than using a hydrocarbon fuel for a fired RWGS reactor, hence avoiding CO_2 emissions from the plant.

Accordingly, the present technology provides a methanol plant, said methanol plant comprising:

- a first feed comprising CO_2 to said plant,
- a second feed comprising H_2 to said plant,
- a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and being arranged to receive the first feed and the second feed and provide a first synthesis gas stream,
- a water removal unit arranged to remove water from said first synthesis gas stream and provide a second synthesis gas stream,
- a methanol synthesis section, arranged to receive at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, and provide a product stream comprising methanol and an off-gas stream.

in one aspect, there is provided a methanol plant, said methanol plant comprising:

- a first feed comprising CO_2 to said plant,
- a second feed comprising H_2 to said plant,
- a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and being arranged to receive the first feed and the second feed and provide a first synthesis gas stream,
- a water removal unit arranged to remove water from said first synthesis gas stream and provide a second synthesis gas stream,

- a methanol synthesis section, arranged to receive at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, and provide a product stream comprising methanol and an off-gas stream.

A process for producing a product stream comprising methanol, in a methanol plant described herein is also provided. The process comprising the steps of:

- providing a methanol plant as described herein,
- supplying first feed and second feed to the CO_2 shift unit, and providing a first synthesis gas stream,
- supplying the first synthesis gas stream to the water removal unit and removing water from said first synthesis gas stream so as to provide a second synthesis gas stream,

- supplying at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, to the methanol synthesis section, and providing a product stream comprising methanol and an off-gas stream.

In another aspect, there is provided a process for producing a product stream comprising methanol, in a methanol plant according to any one of the preceding claims, said process comprising the steps of:

- providing a methanol plant according to any one of the preceding claims,
- supplying first feed and second feed to the CO_2 shift unit, and providing a first synthesis gas stream,
- supplying the first synthesis gas stream to the water removal unit and removing water from said first synthesis gas stream so as to provide a second synthesis gas stream,
- supplying at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, to the methanol synthesis section, and providing a product stream comprising methanol and an off-gas stream.

A process is also provided for retrofitting a carbon dioxide-to-methanol plant (X), in which said plant (X) comprises:

- a first feed comprising CO_2 to said plant, and a second feed comprising H_2 to said plant;
- or a combined feed comprising CO_2 and H_2 to said plant;
- a methanol synthesis section.

The retrofitting process comprises the steps of:

- incorporating a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and a water removal unit in said plant, upstream said methanol synthesis section,
- arranging at least a portion of said first feed and said second feed, or of said combined feed comprising CO_2 and H_2, to be supplied to the CO_2 shift unit so as to provide a first synthesis gas stream,
- feeding at least a portion of said first synthesis gas stream from the CO_2 shift unit to the water removal unit, to remove water from said first synthesis gas stream and provide a second synthesis gas stream,

- arranging at least a portion of the second synthesis gas stream to be supplied to a compressor and compressing it, so as to provide a compressed second synthesis gas stream,
- arranging at least a portion of the compressed second synthesis gas stream to be supplied to the methanol synthesis section, and providing a product stream comprising methanol.

In another aspect, there is provided a process for retrofitting a carbon dioxide-to-methanol plant (X), said plant (X) comprising:

- a first feed comprising CO_2 to said plant, and a second feed comprising H_2 to said plant;
- or a combined feed comprising CO_2 and H_2 to said plant;
- a methanol synthesis section;

wherein said retrofitting process comprises the steps of:

- incorporating a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and a water removal unit in said plant (X), upstream said methanol synthesis section,
- arranging at least a portion of said first feed and said second feed, or of said combined feed comprising CO_2 and H_2, to be supplied to the CO_2 shift unit so as to provide a first synthesis gas stream,
- feeding at least a portion of said first synthesis gas stream from the CO_2 shift unit to the water removal unit, to remove water from said first synthesis gas stream and provide a second synthesis gas stream,
- arranging at least a portion of the second synthesis gas stream to be supplied to a compressor and compressing it, so as to provide a compressed second synthesis gas stream,
- arranging at least a portion of the compressed second synthesis gas stream to be supplied to the methanol synthesis section, and providing a product stream comprising methanol.

The present disclosure allows for an increase in the methanol production in an existing CO_2-to-MeOH plant by shifting the feed gas to a more reactive gas mixture in an upstream CO_2 shift unit. By means of the present technology, all central equipment of the existing CO_2-to-MeOH plant can be reused as the concept allows for replacing the existing gas flow with a new and more reactive gas flow to the methanol synthesis section.

Further details of the technology are provided in the enclosed dependent claims, figures, and examples.

CLAIMS

1. A methanol plant, said methanol plant comprising:

- a first feed comprising CO_2 to said plant,
- a second feed comprising H_2 to said plant,
- a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and being arranged to receive the first feed and the second feed and provide a first synthesis gas stream,
- a water removal unit arranged to remove water from said first synthesis gas stream and provide a second synthesis gas stream,
- a methanol synthesis section, arranged to receive at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, and provide a product stream comprising methanol and an off-gas stream.

2. The methanol plant according to claim 1, wherein a compressor is located between the water removal unit and the methanol synthesis section, and arranged to compress said second synthesis gas stream and provide a compressed second synthesis gas stream to the methanol synthesis section.

3. The methanol plant according to any one of the preceding claims, wherein the first feed and the second feed are combined to a combined feed prior to being fed to the CO_2 shift unit.

4. The methanol plant according to any one of the preceding claims, wherein the water removal unit is a flash separation unit.

5. The methanol plant according to any one of the preceding claims, wherein at least a portion of the off-gas stream from the methanol synthesis section is arranged to be fed to the inlet of the CO_2 shift unit, preferably in admixture with the first stream comprising CO_2.

6. The methanol plant according to any one of claims 3-5, further comprising a feed compressor, wherein the feed compressor is arranged to receive the first feed, the second feed or the combined feed and to output a compressed stream, upstream the CO_2 shift unit.

7. The methanol plant according to any one of the preceding claims, further comprising a first heat exchanger, arranged to cool the first synthesis gas stream from the CO_2 shift unit to provide a cooled first synthesis gas stream.

8. The methanol plant according to any one of the preceding claims, further comprising a feed-effluent heat exchanger, arranged to receive the compressed stream from the feed compressor and heat it to a heated stream in heat exchange with the first synthesis gas stream or the cooled first synthesis gas stream, which is cooled to form a further cooled first synthesis gas stream.

9. The methanol plant according to claim 8, further comprising an additional heat exchanger, preferably a synthesis gas distillation column, arranged downstream the feed-effluent heat exchanger and arranged to cool the further cooled first synthesis gas stream.

10. The methanol plant according to any one of the preceding claims, further comprising a hydrogen recovery unit arranged to receive at least a portion of the off-gas stream from the methanol synthesis section and to output a hydrogen rich gas stream and a reject stream, preferably wherein at least a portion of said hydrogen rich gas stream is arranged to be recycled upstream the CO_2 shift unit and/or wherein at least a portion of said hydrogen rich gas stream is arranged to be recycled upstream the methanol synthesis section.

11. The methanol plant according to any one of the preceding claims, further comprising a low pressure separator arranged to receive at least a portion of the product stream comprising methanol from the methanol synthesis section and to output a purified methanol stream and a carbon-rich stream, preferably wherein at least a portion of said carbon-rich off-gas stream is arranged to be recycled upstream the CO_2 shift unit and/or wherein at least a portion of said carbon-rich stream arranged to be recycled upstream the methanol synthesis section.

12. The methanol plant according to any one of the preceding claims, further comprising a methanol distillation section arranged to receive at least a portion of the product stream comprising methanol from the methanol synthesis section or at least a portion of the purified methanol stream from the low pressure separator and to output a high-purity methanol stream and a higher alcohols stream, preferably wherein at least a portion of said higher alcohols stream is arranged to be recycled upstream the CO_2 shift unit.

13. The methanol plant according to claim 12, wherein at least a portion of the heat required for the methanol distillation section is arranged to be provided from the first heat exchanger.

14. A process for producing a product stream comprising methanol, in a methanol plant according to any one of the preceding claims, said process comprising the steps of:

- providing a methanol plant according to any one of the preceding claims,
- supplying first feed and second feed to the CO_2 shift unit, and providing a first synthesis gas stream,
- supplying the first synthesis gas stream to the water removal unit and removing water from said first synthesis gas stream so as to provide a second synthesis gas stream,
- supplying at least a portion of said second synthesis gas stream, and – optionally – a portion of said second feed and/or said first feed, to the methanol synthesis section, and providing a product stream comprising methanol and an off-gas stream.

15. The process according to claim 14, wherein said first feed additionally comprises up to 20%, such as up to 10% hydrocarbons.

16. The process according to claim 15, wherein said first feed additionally comprises steam, preferably wherein the steam is present in a ratio of 1-3 relative to the content of hydrocarbons.

17. A process for retrofitting a carbon dioxide-to-methanol plant (X), said plant (X) comprising:

- a first feed comprising CO_2 to said plant, and a second feed comprising H_2 to said plant;
- or a combined feed comprising CO_2 and H_2 to said plant;
- a methanol synthesis section;

wherein said retrofitting process comprises the steps of:

- incorporating a CO_2 shift unit, being an electrically heated Reverse Water Gas Shift (e-RWGS) unit, and a water removal unit in said plant (X), upstream said methanol synthesis section,
- arranging at least a portion of said first feed and said second feed, or of said combined feed comprising CO_2 and H_2, to be supplied to the CO_2 shift unit so as to provide a first synthesis gas stream,
- feeding at least a portion of said first synthesis gas stream from the CO_2 shift unit to the water removal unit, to remove water from said first synthesis gas stream and provide a second synthesis gas stream,
- arranging at least a portion of the second synthesis gas stream to be supplied to a compressor and compressing it, so as to provide a compressed second synthesis gas stream,

- arranging at least a portion of the compressed second synthesis gas stream to be supplied to the methanol synthesis section, and providing a product stream comprising methanol.

18. The process according to claim 17, wherein said carbon dioxide-to-methanol plant (X) comprises a compressor, wherein – before the retrofitting process – said compressor is arranged to compress the combined feed, and wherein – after said retrofitting process – said compressor is arranged to compress at least a portion of the second synthesis gas stream and provide a compressed second synthesis gas stream.

19. The process according to any one of claims 17-18, wherein said combined feed also comprises hydrocarbons.

20. The process according to claim 19, said combined stream is obtained by mixing a biogas with hydrogen.

21. The process according to any one of claims 17-20, wherein said methanol synthesis section of said carbon dioxide-to-methanol plant (X) remains unchanged under said retrofitting process.

22. The process according to claim 21, wherein the production of methanol from the carbon dioxide-to-methanol plant after the retrofitting process is at least 10% higher, 20% higher, 33% higher, 50% higher, 100% higher or 250% higher than the methanol production from the carbon dioxide-to-methanol plant (X) prior to the retrofitting process, when evaluated on the flow of methanol molecules from the methanol synthesis section.

23. The process according to any one of claims 17-22, wherein the methanol synthesis section comprises a recycle compressor, a heat exchanger, a flash separation vessel, and/or a cooling unit, wherein said refitting process further comprises one or more further steps of upgrading one or more of said recycle compressor, heat exchanger, flash separation vessel and cooling unit.

24. The process according to any one of claims 17-20 or 23, wherein the methanol synthesis section comprises a methanol synthesis reactor, wherein said refitting process further comprises one or more further steps of reducing the catalyst loading in the methanol synthesis reactor.

25. The process according to any one of claims 23 or 24, wherein the production of methanol from the carbon dioxide-to-methanol plant after the retrofitting process is at least the production of methanol from the carbon dioxide-to-methanol plant after the retrofitting process is at least 10% higher, 20% higher, 33% higher, 50% higher, 100% higher, 250% higher, 500 % higher, 750% higher or 1000% higher than the methanol production of the conventional carbon dioxide-to-methanol plant (X) prior to the retrofitting process when evaluated on the flow of methanol molecules from the methanol synthesis section.

26. The process according to any one of claims 17 - 25, wherein said retrofitting process further comprises a step of arranging a hydrogen recovery unit so as to receive at least a portion of the off-gas stream from the methanol synthesis section and to output a hydrogen rich gas stream and a reject stream, preferably wherein at least a portion of said hydrogen rich gas stream is arranged to be recycled upstream the CO_2 shift unit and/or wherein at least a portion of said hydrogen rich gas stream is arranged to be recycled upstream the methanol synthesis section.