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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                | Attorney Docket Number | 2019P00370 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                | Application Number     |            |
| Title of Invention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |
| <p>The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.</p> <p>This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.</p> |                                                                                |                        |            |

**Secrecy Order 37 CFR 5.2:**

|                          |                                                                                                                                                                                                                                       |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> | Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.) |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Inventor Information:**

|                                                                                                                                                                                 |                   |                                          |                    |               |                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------|--------------------|---------------|------------------------|
| <b>Inventor 1</b>                                                                                                                                                               |                   |                                          |                    |               | <a href="#">Remove</a> |
| <b>Legal Name</b>                                                                                                                                                               |                   |                                          |                    |               |                        |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b> | <b>Middle Name</b>                       | <b>Family Name</b> | <b>Suffix</b> |                        |
|                                                                                                                                                                                 | Sophia            |                                          | SCHMIDT            |               |                        |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                   |                                          |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Frankfurt am Main | <b>Country of Residence <sup>i</sup></b> | DE                 |               |                        |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                   |                                          |                    |               |                        |
| <b>Address 1</b>                                                                                                                                                                |                   | Air Liquide IP Dept.                     |                    |               |                        |
| <b>Address 2</b>                                                                                                                                                                |                   | 9811 Katy Freeway, Suite 100             |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Houston           | <b>State/Province</b>                    | TX                 |               |                        |
| <b>Postal Code</b>                                                                                                                                                              | 77024             | <b>Country <sup>i</sup></b>              | US                 |               |                        |
| <b>Inventor 2</b>                                                                                                                                                               |                   |                                          |                    |               | <a href="#">Remove</a> |
| <b>Legal Name</b>                                                                                                                                                               |                   |                                          |                    |               |                        |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b> | <b>Middle Name</b>                       | <b>Family Name</b> | <b>Suffix</b> |                        |
|                                                                                                                                                                                 | Teja              |                                          | SCHMID McGUINESS   |               |                        |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                   |                                          |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Frankfurt am Main | <b>Country of Residence <sup>i</sup></b> | DE                 |               |                        |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                   |                                          |                    |               |                        |
| <b>Address 1</b>                                                                                                                                                                |                   | Air Liquide IP Dept.                     |                    |               |                        |
| <b>Address 2</b>                                                                                                                                                                |                   | 9811 Katy Freeway, Suite 100             |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Houston           | <b>State/Province</b>                    | TX                 |               |                        |
| <b>Postal Code</b>                                                                                                                                                              | 77024             | <b>Country <sup>i</sup></b>              | US                 |               |                        |
| All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the <b>Add</b> button. <a href="#">Add</a>                 |                   |                                          |                    |               |                        |

**Correspondence Information:**

IPR2025-01173, -01174, Topsoe Ex. 1002

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

Enter either Customer Number or complete the Correspondence Information section below.  
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence information of this application.

|                 |                            |                                          |                                             |
|-----------------|----------------------------|------------------------------------------|---------------------------------------------|
| Customer Number | 40582                      |                                          |                                             |
| Email Address   | IP-USOffice@airliquide.com | <input type="button" value="Add Email"/> | <input type="button" value="Remove Email"/> |

## Application Information:

|                                         |                                                                                |                                           |                          |
|-----------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------|--------------------------|
| Title of the Invention                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                                           |                          |
| Attorney Docket Number                  | 2019P00370                                                                     | Small Entity Status Claimed               | <input type="checkbox"/> |
| Application Type                        | Nonprovisional                                                                 |                                           |                          |
| Subject Matter                          | Utility                                                                        |                                           |                          |
| Total Number of Drawing Sheets (if any) | 3                                                                              | Suggested Figure for Publication (if any) | 3                        |

## Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

|                                                        |                          |                                            |
|--------------------------------------------------------|--------------------------|--------------------------------------------|
| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country |
|                                                        |                          |                                            |

## Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

## Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

|                    |                                                  |                                              |                                                         |
|--------------------|--------------------------------------------------|----------------------------------------------|---------------------------------------------------------|
| Please Select One: | <input checked="" type="radio"/> Customer Number | <input type="radio"/> US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) |
| Customer Number    | 40582 IPR2025-01173, -01174, Topsoe Ex. 1002     |                                              |                                                         |

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

## Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

|                                                                                                                       |                 |                          |                                    |
|-----------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------|------------------------------------|
| Prior Application Status                                                                                              |                 |                          | <a href="#">Remove</a>             |
| Application Number                                                                                                    | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
|                                                                                                                       |                 |                          |                                    |
| Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> button. |                 |                          |                                    |

## Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

|                                                                                                        |                      |                          |                                          |
|--------------------------------------------------------------------------------------------------------|----------------------|--------------------------|------------------------------------------|
| Application Number                                                                                     | Country <sup>i</sup> | Filing Date (YYYY-MM-DD) | <a href="#">Remove</a>                   |
| 20020366.9                                                                                             | EP                   | 2020-08-11               | Access Code <sup>i</sup> (if applicable) |
|                                                                                                        |                      |                          | D3A6                                     |
| Additional Foreign Priority Data may be generated within this form by selecting the <b>Add</b> button. |                      |                          |                                          |

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.<br>NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA. |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

## Applicant Information:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           |                                                                        |       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                                                                        |       |
| <b>Applicant 1</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                           |                                                                        |       |
| <p>If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.</p> |                                                                                           |                                                                        |       |
| <input type="button" value="Clear"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                           |                                                                        |       |
| <input checked="" type="radio"/> Assignee                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                           | <input type="radio"/> Legal Representative under 35 U.S.C. 117         |       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           | <input type="radio"/> Joint Inventor                                   |       |
| <input type="radio"/> Person to whom the inventor is obligated to assign.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                           | <input type="radio"/> Person who shows sufficient proprietary interest |       |
| If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                           |                                                                        |       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           |                                                                        |       |
| Name of the Deceased or Legally Incapacitated Inventor: <input type="text"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                           |                                                                        |       |
| If the Applicant is an Organization check here. <input checked="" type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                                                                        |       |
| Organization Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude |                                                                        |       |
| <b>Mailing Address Information For Applicant:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                           |                                                                        |       |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 75, Quai d'Orsay                                                                          |                                                                        |       |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                           |                                                                        |       |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Paris                                                                                     | State/Province                                                         |       |
| Country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | FR                                                                                        | Postal Code                                                            | 75007 |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                           | Fax Number                                                             |       |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           |                                                                        |       |
| Additional Applicant Data may be generated within this form by selecting the Add button.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                           |                                                                        |       |

## Assignee Information including Non-Applicant Assignee Information:

|                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office. |
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|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

|        |            |             |             |        |
|--------|------------|-------------|-------------|--------|
| Prefix | Given Name | Middle Name | Family Name | Suffix |
|        |            |             |             |        |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

|                      |  |                |  |
|----------------------|--|----------------|--|
| Address 1            |  |                |  |
| Address 2            |  |                |  |
| City                 |  | State/Province |  |
| Country <sup>i</sup> |  | Postal Code    |  |
| Phone Number         |  | Fax Number     |  |
| Email Address        |  |                |  |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

**Signature:**

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

|            |                    |           |                   |                           |
|------------|--------------------|-----------|-------------------|---------------------------|
| Signature  | /Elwood L. Haynes/ |           | Date (YYYY-MM-DD) | 2021-08-11                |
| First Name | Elwood L.          | Last Name | Haynes            | Registration Number 55254 |

Additional Signature may be generated within this form by selecting the Add button.

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**



catalytic reforming of the intermediate with steam, is likewise a synthesis gas comprising mainly hydrogen, carbon monoxide and carbon dioxide.

In order to make the processes mentioned more environmentally friendly, there has previously been development of processes in order to separate the carbon dioxide produced in SMR or ATR as a carbon dioxide product of maximum purity from the synthesis gas mixture produced as the primary product. For this purpose, gas scrubbing processes based on physical or chemical absorption in absorbents such as methanol or amines are available, as is cryogenic liquid separation and purification of the carbon dioxide by compression, condensation and distillation. However, the carbon dioxide which is absorbed in absorbents in large volumes and then desorbed again or separated out by condensation at low temperatures frequently cannot be sent to any viable further industrial use. Therefore, the only option that remains is frequently to store the unusable carbon dioxide over a long period of time in order not to allow it to get into the atmosphere. The combination of separation (by gas scrubbing or condensation) and storage of carbon dioxide is also referred to as sequestration or CCS (*carbon capture and storage*).

It is therefore necessary to improve known processes for producing hydrogen in such a way that smaller amounts of carbon dioxide per tonne of hydrogen produced are generated from the outset.

US 2015/0321914 A1 discloses a process in which a synthesis gas produced as the primary product by steam reforming or autothermal reforming is converted to carbon dioxide and hydrogen by conversion of the carbon monoxide present in the synthesis gas produced as the primary product with steam (water-gas shift reaction). Subsequently, hydrogen is separated from the carbon dioxide- and hydrogen-enriched converted synthesis gas with the aid of a pressure swing adsorption unit. The residual gas which is depleted of hydrogen but still rich in carbon dioxide is subsequently treated in an apparatus referred to as cryogenic purification unit (CPU), in order to separate carbon dioxide out of the residual gas and liquefy it in a form of maximum purity. The liquefied carbon dioxide can subsequently be sent to storage or used for industrial or consumable purposes.

## Summary

It is a general object of the present invention to overcome the abovementioned disadvantages of the prior art.

More particularly, it is an object of the present invention to modify known processes so as to reduce the amount of carbon dioxide formed per unit weight of hydrogen produced.

More particularly, it is an object of the present invention to reduce carbon dioxide emissions from processes that combine autothermal reforming of methane with cryogenic carbon dioxide separation.

A contribution to the at least partial achievement of at least one of the above objects is made by the independent claims. The dependent claims provide preferred embodiments which contribute to the at least partial achievement of at least one of the objects. Preferred embodiments of constituents of one category according to the invention are, where relevant, likewise preferred for identically named or corresponding constituents of a respective other category according to the invention.

The terms "having", "comprising" or "containing", etc., do not preclude the possible presence of further elements, ingredients, etc. The indefinite article "a" does not preclude the possible presence of a plurality.

The objects of the invention are at least partly achieved by a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the process comprises the following steps:

- (a) providing a feed gas stream **FG**, wherein the feed gas stream **FG** comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;
- (b) reforming at least a portion of the feed gas stream **FG** in an endothermic reforming step over a reforming catalyst to give a synthesis gas stream **SG1**, wherein the synthesis gas stream **SG1** comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;
- (c) reforming a portion of the feed gas stream **FG** in an autothermal reforming step to give a synthesis gas stream **SG2**, and combining the synthesis gas streams **SG1** and **SG2** to give a synthesis gas stream **SG3**, or  
reforming the synthesis gas stream **SG1** in an autothermal reforming step to give a synthesis gas stream **SG3**,

wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein

the synthesis gas streams **SG2** and **SG3** comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and wherein heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);

(d) converting the carbon monoxide present in the synthesis gas stream **SG3** with steam to give hydrogen and carbon dioxide to give a synthesis gas stream **SG4**, wherein the synthesis gas stream **SG4** comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);

(e) separating hydrogen from the synthesis gas stream **SG4** by pressure swing adsorption, giving a hydrogen-rich stream **HG1** and a residual gas stream **RG1**, wherein the residual gas stream **RG1** comprises carbon dioxide, carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane;

(e) separating carbon dioxide from the residual gas stream **RG1** obtained in step (e) by cryogenic carbon dioxide separation, giving a carbon dioxide-rich stream **CG1** and a residual gas stream **RG2**, wherein the residual gas stream **RG2** comprises carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), carbon dioxide not separated off in step (f), and unreacted methane.

Compared to processes known from the prior art, it is a feature of the process according to the invention that a combination of endothermic and autothermal reforming steps is used in steps (b) and (c), and heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b). The autothermal reforming step is performed in an autothermal reforming unit (autothermal reformer). The endothermic reforming step is performed in an endothermic reforming unit (endothermic reformer, for example steam reformer). This surprisingly significantly lowers the specific carbon dioxide emissions with regard to the overall process. "Specific carbon dioxide emissions" is understood to mean the mass of CO<sub>2</sub> formed throughout the process per standard cubic metre of hydrogen produced. The specific carbon dioxide emissions can be reported, for example, in kg CO<sub>2</sub>/m<sup>3</sup> (STP).

In the endothermic reforming step of step (b), the feed gas **FG** is converted to the synthesis gas **SG1** over a suitable catalyst by supply of heat. The catalyst is, for example, a nickel catalyst known to the person skilled in the art. The heat required for the reforming reaction to proceed for the endothermic reforming step is provided at least partly, preferably completely, by heat formed in the autothermal reforming step. According to the arrangement of the reforming units, the feed gas **SG** is introduced partly or fully into the reforming unit of the endothermic reforming step and converted to the synthesis gas **SG1**.

The autothermal reforming step in step (c) comprises a step of partial oxidation of the feed gas stream **FG** and a subsequent endothermic reforming step with steam for conversion of the feed gas stream **FG** to the synthesis gas stream **SG2** or to the synthesis gas stream **SG3**. The step of partial oxidation in the autothermal reforming step entails the supply of an oxidizing agent such as air, pure oxygen, or oxygen-enriched air. The oxidizing agent is typically introduced into the autothermal reformer via a burner. The partial oxidation of the feed gas stream **FG** to the synthesis gas stream **SG2** or to the synthesis gas stream **SG3** in the course of the autothermal reforming step is an exothermic reaction. The waste heat generated as a result is utilized for the "endothermic portion" of the autothermal reforming step. The autothermal reforming step is designed such that sufficient heat is generated in total, over two reaction stages (partial oxidation and endothermic reforming), which is utilizable for heating of the endothermic reforming step for conversion of the feed gas **FG** to the synthesis gas **SG1**.

The process according to the invention includes two alternatives defined by step (c).

In the first alternative, a portion of the feed gas stream **FG** is reformed in the endothermic reforming step to give the synthesis gas stream **SG1**. A further portion of the feed gas stream **FG**, preferably the remaining portion of the feed gas stream **FG**, is reformed in the autothermal reforming step to give the synthesis gas stream **SG2**. The synthesis gas streams **SG2** and **SG3** are then combined to give a synthesis gas stream **SG3**. This results in a parallel arrangement or connection of the reforming units for the endothermic reforming step and for the autothermal reforming step.

In the second alternative of the process according to the invention, the feed gas **SG** is introduced fully into the reforming unit of the endothermic reforming step and converted to the synthesis gas stream **SG1**. This converts the feed gas **FG** only partly

to the synthesis gas **SG1**, meaning that there remains a comparatively high proportion of methane and possibly other reformable hydrocarbon components in the synthesis gas **SG1**. This remaining amount is subsequently reformed in the autothermal reforming step to give the synthesis gas **SG3**. This results in a series arrangement or connection of the reforming units for the endothermic reforming step and for the autothermal reforming step, with the autothermal reforming step following on from the endothermic reforming step. In other words, the reforming unit for the autothermal reforming step is arranged downstream of the reforming unit for the endothermic reforming step in gas flow direction.

Preferably, the synthesis gas stream produced in the autothermal reforming step, i.e. synthesis gas stream **SG2** in the case of parallel arrangement of the reforming units or synthesis gas stream **SG3** in the case of series arrangement of the reforming units, is utilized directly for the transfer of heat in the endothermic reforming step. The synthesis gas stream **SG2** and/or the synthesis gas stream **SG3** here preferably have a temperature of 750 to 1100°C.

The feed gas stream **FG** includes at least one hydrocarbon component which is reformable with steam to give a synthesis gas **SG1**, **SG2**, **SG3** or **SG4**. The synthesis gas includes at least hydrogen, carbon monoxide and carbon dioxide as product components. The feed gas stream **FG** includes at least methane as hydrocarbon component. Further higher analogous hydrocarbons, for example ethane, propane or butane, may be present in the feed gas stream **FG**.

A feed gas may first be treated in what is called a preliminary reformer in order to convert higher hydrocarbons with steam to short-chain hydrocarbons, especially with the purpose of increasing the methane content in the feed gas stream **FG**. The purpose of the preliminary reformer is thus generally to convert hydrocarbons having at least two carbon atoms to carbon monoxide, hydrogen and methane. A feed gas stream **FG** treated in a preliminary reformer may thus already contain certain amounts of carbon monoxide and hydrogen.

The synthesis gas stream **SG3** formed by the combination of autothermal and endothermic reforming steps is sent to a conversion step (d). In this conversion step, carbon monoxide present in the synthesis gas stream **SG3** is reacted with water by what is called the water-gas shift reaction over a suitable catalyst to give hydrogen and carbon dioxide. Prior to introduction into step (d), the synthesis gas **SG3** is cooled. Depending on whether step (d) is what is called a low-temperature shift or a high-

temperature shift, the synthesis gas **SG3** is cooled to a greater or lesser degree prior to introduction into step (d).

The synthesis gas stream **SG4** formed by the conversion step (d) is enriched with hydrogen and carbon dioxide, and depleted of carbon monoxide. Synthesis gas stream **SG4** is subsequently subjected to a separation step (e) in which substantially pure hydrogen is produced from the synthesis gas stream **SG4** by pressure swing adsorption (PSA). The hydrogen-rich stream **HG1** obtained by the pressure swing adsorption regularly has a hydrogen content of at least 95 mol%, preferably of at least 99 mol%, further preferably of at least 99.5 mol% and further preferably of at least 99.9 mol%. The hydrogen-depleted by-product of the pressure swing adsorption step, the residual gas stream **RG1**, is greatly depleted of hydrogen and greatly enriched with carbon dioxide compared to the synthesis gas stream **SG4**. It also comprises carbon monoxide unconverted in step (d), and methane unconverted in steps (b) and (c). As a result of the presence of gases having high calorific value (methane, carbon monoxide and hydrogen), it can be used as fuel within or outside the process.

For separation of carbon dioxide from the residual gas stream **RG1**, it is sent to a cryogenic carbon dioxide separation in step (f), which affords a carbon dioxide-rich stream **CG1** and a further residual gas stream **RG2**. The separation step (f) requires the partial condensation of the carbon dioxide present in the residual gas stream **RG1**, and, for achievement of a particular purity, subsequently and optionally the distillation of the carbon dioxide-rich stream **CG1**. The cryogenic carbon dioxide separation is preferably performed at a temperature of less than 35°C, or less than 20°C, or less than 0°C, or less than -20°C, or less than -40°C, or less than -50°C, or less than -55°C. The cryogenic carbon dioxide separation is also preferably performed at a temperature of more than -60°C.

The synthesis gas stream **SG1** can also be referred to as the first synthesis gas stream, the synthesis gas stream **SG2** as the second synthesis gas stream, and so forth. This is also applicable *mutatis mutandis* to all other fluid streams RG, CG and HG numbered in the context of this disclosure.

A preferred embodiment of the process according to the invention is characterized in that hydrogen is separated from the residual gas stream **RG2**, giving a hydrogen-rich stream **HG2** and a residual gas stream **RG3**. The residual gas stream **RG2**, in spite of the preceding separation step by pressure swing adsorption, regularly includes relatively large amounts of residual hydrogen of up to 50 mol%. It is therefore

advantageous to feed the residual gas stream 2 to a further separation step for separation or at least enrichment of hydrogen. Preference is given to separating the hydrogen from the residual gas stream **RG2** by membrane separation.

In one example of the process according to the invention, the hydrogen-rich stream **HG2** is supplied to the synthesis gas stream **SG4** for separation of hydrogen by pressure swing adsorption in step (e). Membrane separation processes in particular do not have sufficient selectivity to obtain a hydrogen stream having high purity, for example of more than 99 mol%, from the residual gas stream **RG2**. Since a second pressure swing adsorption step in the sense of a second pressure swing adsorption apparatus would be too complex and costly, the hydrogen-rich stream **HG2** is advantageously sent to step (e), which increases the hydrogen yield based on the overall process.

Alternatively, gases present in the hydrogen-rich stream **HG2** are utilized as fuel gases for heating in the autothermal reforming step of step c). For the autothermal reforming step, the feed gas **FG** has to be warmed, which can be effected, for example, by means of a fired heating unit. The fired heating unit may be heated at least partly with the aid of the gases present in the hydrogen-rich stream **HG2** that have a high calorific value, especially carbon monoxide, methane and hydrogen, in order to improve the thermal integration of the process.

A preferred embodiment of the process according to the invention is characterized in that the carbon dioxide-rich stream **CG1** comprises unreacted methane, and the carbon dioxide-rich stream **CG1** is subjected to a thermal separation process for separation of methane, giving a carbon dioxide-rich stream **CG2**. The carbon dioxide-rich stream may, as a result of the cryogenic carbon dioxide separation, contain significant amounts of methane, for example up to 0.2 mol% of methane, or up to 0.5 mol% of methane. A further step including a thermal separation process can further increase the carbon dioxide content of the carbon dioxide-rich stream **CG1**. The thermal separation process is preferably a distillation. This can give a largely pure carbon dioxide product that can more easily be sent to an environmentally viable valorization than a methane-contaminated carbon dioxide product. For example, pure carbon dioxide can be mixed with electrolysis hydrogen in the correct ratio as synthesis gas for methanol production. In the sequestration of the carbon dioxide too, a pure carbon dioxide product has advantages since especially

methane-contaminated carbon dioxide, in the event of unintended release after sequestration, would enhance the greenhouse effect in a known manner.

A preferred embodiment of the process according to the invention is characterized in that carbon dioxide is separated from the residual gas stream **RG3**, giving a carbon dioxide-rich stream CG3 and a residual gas stream RG4. The carbon dioxide is preferably separated by membrane separation from the residual gas stream **RG3**, in order to obtain the carbon dioxide-rich stream CG3 and the residual gas stream RG4.

In one example of the process according to the invention, gases present in the residual gas stream RG4 are utilized as fuel gases for heating in the autothermal reforming step of step c).

The carbon dioxide-rich stream CG3 is preferably supplied to the residual gas stream **RG1** for cryogenic carbon dioxide separation in step (f). This increases the yield of utilizable carbon dioxide and reduces the amount of carbon dioxide actually emitted to a minimum.

A preferred embodiment of the process according to the invention is characterized in that the residual gas stream **RG1**, for cryogenic carbon dioxide separation in step (f), is subjected to at least one compression step and at least one cooling step, giving the carbon dioxide-rich stream **CG1** at least partly in the form of a condensed carbon dioxide stream. The cryogenic carbon dioxide separation is preferably conducted under pressure by compression, for example a pressure between 5 and 74 bar, with simultaneous cooling of residual gas stream **RG1**, preferably to a temperature above the triple point of carbon dioxide (minus 56°C) or another temperature suitable for the condensation. Under these temperature and pressure conditions, the carbon dioxide partly condenses out, enriching the liquid phase with carbon dioxide and enriching the gas phase with uncondensable gases. Preferably, and to the extent required, step (f) includes multiple compression steps and/or multiple cooling steps, meaning that the condensation of carbon dioxide out of the residual gas stream **RG1** is effected in multiple successive compression and cooling steps.

Preferably, and to the extent required, the residual gas stream **RG1** is dried in one or more steps in the course of step (f). A drying step can be performed before a compression step, between two compression steps and/or after a compression step.

A drying step can also be performed before a cooling step, between two cooling steps and/or after a cooling step.

Preferably, and to the extent required, the residual gas stream **RG1**, in the course of step (f), is subjected to one or more separation steps for removal of condensable constituents such as methanol. A separation step can be performed before a compression step, between two compression steps and/or after a compression step. A separation step can also be performed before a cooling step, between two cooling steps and/or after a cooling step.

The objects of the invention are also at least partly achieved by a plant, wherein the plant is configured for performance of the process according to the invention.

The objects of the invention are also at least partly achieved by a plant for preparation of hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the plant comprises the following plant components in fluid connection with one another:

- (a) means of providing a feed gas stream **FG**, wherein the feed gas stream **FG** comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;
- (b) a first reforming unit, wherein the first reforming unit is configured for reforming at least a portion of the feed gas stream **FG** in an endothermic reforming step over a reforming catalyst, wherein a synthesis gas stream **SG1** is obtainable in the endothermic reforming step, wherein the synthesis gas stream **SG1** comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;
- (c) a second reforming unit, arranged parallel to or downstream of the first reforming unit, wherein
  - the second reforming unit, in the case of parallel arrangement to the first reforming unit, is configured for reforming of a portion of the feed gas stream **FG** in an autothermal reforming step, wherein
    - the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst and
    - a synthesis gas stream **SG2** is obtainable in the autothermal reforming step, and

the first and second reforming unit, in the case of parallel arrangement, are configured such that the synthesis gas streams **SG1** and **SG2** can be combined to give a synthesis gas stream **SG3**,

- the second reforming unit, in the case of arrangement downstream of the first reforming unit, is configured for reforming of at least a portion of the synthesis gas stream **SG1** in an autothermal reforming step, wherein

the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein

a synthesis gas stream **SG3** is obtainable in the autothermal reforming step, wherein

the synthesis gas streams **SG2** and **SG3** comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and

the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b);

(d) a converter unit, arranged

- downstream of the first and second reforming unit in the case of parallel arrangement of the first and second reforming unit, or
- arranged downstream of the second reforming unit in the case of arrangement of the second reforming unit downstream of the first reforming unit, wherein

the converter unit is configured for conversion of the carbon monoxide present in the synthesis gas stream **SG3** with steam to give carbon dioxide and hydrogen, giving a synthesis gas stream **SG3**, and

the synthesis gas stream **SG3** comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in the converter unit;

(e) a pressure swing adsorption unit, arranged downstream of the converter unit, wherein

the pressure swing adsorption unit is configured to separate hydrogen from the synthesis gas stream **SG3**, wherein a hydrogen-rich stream **HG1** and a residual gas stream **RG1** are obtainable, wherein the residual gas stream **RG1** comprises carbon dioxide, carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, and unreacted methane;

- (f) a separation unit arranged downstream of the pressure swing adsorption unit, wherein the separation unit is configured for cryogenic separation of carbon dioxide from the residual gas stream **RG1** produced in the pressure swing adsorption unit, wherein a carbon dioxide-rich stream **CG1** and a residual gas stream **RG2** are obtainable, wherein the residual gas stream **RG2** comprises carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, carbon dioxide not separated off in the separation unit, and unreacted methane.

According to the invention, the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b). The first reforming unit is configured for an endothermic reforming step. The second reforming unit is configured for an autothermal reforming step. The second reforming unit is preferably an autothermal reformer. The second reforming unit is arranged parallel to the first reforming unit or downstream of the first reforming unit.

In the case of parallel arrangement to the first reforming unit, the second reforming unit produces a synthesis gas stream **SG2** that can be combined with the synthesis gas stream **SG1** from the first reforming unit. The synthesis gas stream **SG2** is preferably utilized directly for heating in the first reforming unit, meaning that the heat present in the synthesis gas stream **SG2** is utilized directly for heating in the first reforming unit. What is meant by "directly" in this connection is that the heat present in the synthesis gas stream **SG2** is not transferred to a further heat transport medium. The heat present in the synthesis gas stream **SG2** is accordingly utilized for production of the synthesis gas stream **SG1** in the endothermic process in the first reforming unit.

In the case of arrangement downstream of the first reforming unit, the second reforming unit produces a synthesis gas stream **SG3**. The synthesis gas stream **SG3** is preferably utilized directly for heating in the first reforming unit, meaning that the

heat present in the synthesis gas stream **SG3** is utilized directly for heating in the first reforming unit. What is meant by "directly" in this connection is that the heat present in the synthesis gas stream **SG3** is not transferred to a further heat transport medium. The heat present in the synthesis gas stream **SG3** is accordingly utilized for production  
 5 of the synthesis gas stream **SG1** in the endothermic process in the first reforming unit.

### Brief Description of the Drawings

The invention is elucidated in detail hereinafter by two inventive working examples and one noninventive comparative example in conjunction with three drawings, where the  
 10 working examples and the drawings do not mean any restriction of the invention.

The figures show:

- Figure 1 is a block flow diagram of a process or plant according to the prior art,
- Figure 2 is a block flow diagram of a first alternative of a process  
 15 according to the invention or of a plant according to the invention with parallel arrangement of the reforming units for the endothermic and autothermal reforming steps,
- Figure 3 is a block flow diagram of a second alternative of a process according to the invention or of a plant according to the invention with series  
 20 arrangement of the reforming units for the endothermic and autothermal reforming steps.

### Detailed Description of Preferred Embodiments

Figure 1 shows a highly simplified block flow diagram of a process or plant according to the prior art, as disclosed, for example, in US 2015/0321914. A feed gas stream **FG** is introduced into an autothermal reforming unit **100** and converted to a synthesis gas stream **SG1**. Synthesis gas stream **SG1** is subsequently introduced into a converter unit **101**, which results in reaction of carbon monoxide present in synthesis gas stream **SG1** with steam to give carbon dioxide and hydrogen. Hydrogen-enriched  
 30 synthesis gas stream **SG2** is subsequently introduced into a pressure swing adsorption unit **102** in order to separate hydrogen from the synthesis gas stream **SG2** with high purity. Hydrogen separated from the pressure swing adsorption unit **102** is discharged from the pressure swing adsorption unit **102** in the form of a hydrogen-rich stream **HG1**. A hydrogen-depleted residual gas stream **RG1** is likewise drawn off from

the pressure swing adsorption unit **102** and introduced into a separation unit **103**. In the separation unit **103**, carbon dioxide is separated out in high purity by means of multiple compression and cooling steps and drying steps, and drawn off from the separation unit in the form of a carbon dioxide-rich stream **CG1**. Carbon dioxide-rich stream **CG1** still contains significant residual amounts of methane that can optionally be removed by distillation of the carbon dioxide-rich stream **CG1** (not shown). The resulting pure carbon dioxide product is suitable for the sequestration of carbon dioxide or for further use, for example the synthesis of methanol by reaction with hydrogen produced from an electrolysis stream. A highly carbon dioxide-depleted residual gas stream **RG2** is also drawn off from the separation unit **103** and introduced into a membrane unit **104**. A hydrogen-rich stream **HG2** which is enriched with hydrogen compared to residual gas stream **RG2** is produced by membrane separation in membrane unit **104** and drawn off from the membrane unit **104**. In addition, a residual gas stream **RG3** depleted of hydrogen compared to residual gas stream **RG2** is produced and drawn off from the membrane unit **104**. Hydrogen-rich stream **HG2**, for further use, can optionally either be recycled to the pressure adsorption unit **102** to increase the hydrogen yield or can be used as fuel gas in the autothermal reforming unit **100**.

Table 1 below shows a material balance of a simulation of a process according to Figure 1. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 1: Material balance in comparative example**

|                                |        | FG    | SG1   | SG2   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperature                    | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Pressure                       | bar    | 51    | 47    | 43    | 43    | 2     | 20    | 30    | 30    | 3     |
| Molar flow rate                | kmol/h | 3869  | 16768 | 14272 | 8923  | 5349  | 2570  | 2750  | 1841  | 729   |
| CO <sub>2</sub>                | mol%   | 0.77  | 6.46  | 24.57 | 0.00  | 65.57 | 29.69 | 99.77 | 33.77 | 19.39 |
| CO                             | mol%   | 0.00  | 15.77 | 0.97  | 0.00  | 2.58  | 5.38  | 0.00  | 1.84  | 14.33 |
| H <sub>2</sub>                 | mol%   | 0.00  | 46.88 | 71.04 | 99.99 | 22.75 | 47.35 | 0.00  | 61.96 | 10.44 |
| N <sub>2</sub>                 | mol%   | 0.54  | 0.12  | 0.15  | 0.00  | 0.38  | 0.80  | 0.00  | 0.19  | 2.32  |
| CH <sub>4</sub>                | mol%   | 94.31 | 2.17  | 2.55  | 0.00  | 6.81  | 13.93 | 0.23  | 2.24  | 43.44 |
| C <sub>2</sub> H <sub>6</sub>  | mol%   | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol%   | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol%   | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |

|                  |      |      |       |      |      |      |      |      |      |      |
|------------------|------|------|-------|------|------|------|------|------|------|------|
| H <sub>2</sub> O | mol% | 0.00 | 28.57 | 0.52 | 0.00 | 1.38 | 1.78 | 0.00 | 0.00 | 6.28 |
| Methanol         | mol% | 0.00 | 0.00  | 0.17 | 0.00 | 0.46 | 0.92 | 0.00 | 0.00 | 3.24 |
| Ar               | mol% | 0.00 | 0.02  | 0.03 | 0.00 | 0.08 | 0.16 | 0.00 | 0.00 | 0.55 |

The specific carbon dioxide emission of the process according to the process of Figure 1 with the material balance according to table 1 is 0.140 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced.

5 Rather than the autothermal reforming unit **100**, it is also possible, as likewise disclosed in US 2015/0321914, to use an endothermic reforming unit. More particularly, the endothermic reforming unit may be a steam reformer known to the person skilled in the art. In the case of use of a steam reformer, the specific carbon dioxide emission, at 0.396 kg of CO<sub>2</sub> per standard cubic metre of hydrogen produced,  
10 is several times higher than in the case of use of an autothermal reformer.

Figure 2 shows a highly simplified block flow diagram of a process or plant in a first example of the invention (Example 1) with a parallel arrangement of the reforming units. A feed gas stream **FG** is divided into two substreams. A first substream of the feed gas stream **FG** is introduced into an endothermic reforming unit **200** (first reforming unit, configured for an endothermic reforming step). A second substream of the feed gas stream **FG** is introduced into an autothermal reforming unit **201** (second reforming unit, configured for an autothermal reforming step). In the endothermic reforming unit **200**, the first substream of the feed gas stream **FG** is converted to a synthesis gas stream **SG1**. In the autothermal reforming unit **201**, the second substream of the feed gas stream **FG** is converted to a synthesis gas stream **SG2**.  
15 The heat generated in the autothermal reforming step of the autothermal reforming unit **201** is utilized for heating in the endothermic reforming step in the endothermic reforming unit **200**, indicated by the heat flow **202**. The second synthesis gas stream **SG2** is preferably utilized directly for heating in the endothermic reforming step in the endothermic reforming unit **200**, meaning that the heat present in the second synthesis gas stream **SG2** is utilized without transfer to a further heat transport medium for heating in the endothermic reforming step in the endothermic reforming unit **201**.  
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The synthesis gas streams **SG1** and **SG2** that are produced by the endothermic reforming unit **200** and the autothermal reforming unit **201** are combined to give a mixed synthesis gas stream **SG3** which is introduced into a converter unit **203**, as a result of which carbon monoxide present in the synthesis gas stream **SG3** is reacted  
30

with steam to give carbon dioxide and hydrogen. Hydrogen-enriched synthesis gas stream **SG4** is subsequently introduced into a pressure swing adsorption unit **204** in order to separate hydrogen from the synthesis gas stream **SG4** with high purity. Hydrogen separated from the pressure swing adsorption unit **204** is discharged from the pressure swing adsorption unit **204** in the form of a hydrogen-rich stream **HG1**. A hydrogen-depleted first residual gas stream **RG1** is likewise drawn off from the pressure swing adsorption unit **204** and introduced into a separation unit **205**. In the separation unit **205**, carbon dioxide is separated out in high purity by means of multiple compression and cooling steps and drying steps, and drawn off from the separation unit **205** in the form of a carbon dioxide-rich stream **CG1**. Carbon dioxide-rich stream **CG1** still contains significant residual amounts of methane that can optionally be removed by distillation of the carbon dioxide-rich stream **CG1** (not shown). The resulting pure carbon dioxide product is suitable for the sequestration of carbon dioxide or for further use, for example the synthesis of methanol by reaction with hydrogen produced from electrolysis.

A highly carbon dioxide-depleted residual gas stream **RG2** is also drawn off from the separation unit **205** and introduced into a membrane unit **206**. A hydrogen-rich stream **HG2** which is enriched with hydrogen compared to the residual gas stream **RG2** is produced by membrane separation in membrane unit **206** and drawn off from the membrane unit **206**. In addition, a residual gas stream **RG3** depleted of hydrogen compared to the residual gas stream **RG2** is produced and drawn off from the membrane unit **206**. The hydrogen-rich stream **HG2**, for further use, can optionally either be recycled to the pressure adsorption unit **204** to increase the overall hydrogen yield of the process or can be used as fuel gas in the autothermal reforming unit **201**.

Table 2 below shows a material balance of a simulation of the first example of a process according to the invention as per Figure 2. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 2: Material balance of Example 1**

|                 |        | FG   | SG3   | SG4   | HG1  | RG1  | RG2  | CG1  | HG2  | RG3 |
|-----------------|--------|------|-------|-------|------|------|------|------|------|-----|
| Temperature     | °C     | 40   | 958   | 40    | 40   | 40   | 40   | 40   | 40   | 40  |
| Pressure        | bar    | 51   | 47    | 42    | 41   | 2    | 20   | 20   | 40   | 5   |
| Molar flow rate | kmol/h | 3252 | 15139 | 12476 | 8923 | 5400 | 2671 | 2729 | 1847 | 824 |

|                                |      |       |       |       |       |       |       |       |       |       |
|--------------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| CO <sub>2</sub>                | mol% | 0.77  | 6.07  | 22.93 | 0.00  | 64.40 | 28.32 | 99.71 | 33.36 | 17.01 |
| CO                             | mol% | 0.00  | 13.96 | 0.88  | 0.00  | 2.70  | 5.46  | 0.00  | 1.93  | 13.36 |
| H <sub>2</sub>                 | mol% | 0.00  | 47.34 | 72.13 | 99.99 | 22.53 | 45.54 | 0.00  | 61.74 | 9.24  |
| N <sub>2</sub>                 | mol% | 0.54  | 0.12  | 0.14  | 0.00  | 0.38  | 0.78  | 0.00  | 0.20  | 2.08  |
| CH <sub>4</sub>                | mol% | 94.31 | 2.65  | 3.21  | 0.00  | 8.37  | 16.63 | 0.29  | 2.77  | 47.69 |
| C <sub>2</sub> H <sub>6</sub>  | mol% | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol% | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol% | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| H <sub>2</sub> O               | mol% | 0.00  | 29.85 | 0.53  | 0.00  | 1.23  | 2.49  | 0.00  | 0.00  | 8.07  |
| Methanol                       | mol% | 0.00  | 0.00  | 0.15  | 0.00  | 0.34  | 0.69  | 0.00  | 0.00  | 2.25  |
| Ar                             | mol% | 0.00  | 0.02  | 0.02  | 0.00  | 0.05  | 0.10  | 0.00  | 0.00  | 0.31  |

The specific carbon dioxide emission of the process according to Figure 2 with the material balance according to table 2 is 0.128 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced. Compared to the comparative example, this corresponds to a reduction in specific carbon dioxide emissions of 9%.

Figure 3 shows a highly simplified block flow diagram of a process or plant in a second example of the invention (Example 2). The process or plant according to Figure 3 differs from the process or plant according to Figure 2 by the series arrangement or connection of the reforming units. The endothermic reforming unit **200** (first reforming unit, configured for an endothermic reforming step) is arranged upstream of the autothermal reforming unit **201** (second reforming unit, configured for an autothermal reforming step) in gas flow direction, and the latter is correspondingly arranged downstream of the endothermic reforming unit **200** in gas flow direction. A feed gas stream **FG** is introduced into an endothermic reforming unit **200** and converted to a synthesis gas stream **SG1**. The synthesis gas stream **SG1** is converted to a synthesis gas stream **SG3** in the autothermal reforming unit **201**. The heat generated in the autothermal reforming step of the autothermal reforming unit **201** is utilized for heating in the endothermic reforming step in the endothermic reforming unit **200**, indicated by the heat flow **202**. Synthesis gas stream **SG3** is preferably utilized directly for heating in the endothermic reforming step in the endothermic reforming unit **200**, meaning that the heat present in synthesis gas stream **SG3** is utilized without further transfer to a heat transport medium for heating in the endothermic reforming step in the endothermic reforming unit **200**. All the subsequent process steps correspond to Example 1 according to Figure 2.

Table 3 below shows a material balance of a simulation of the second example of a process according to the invention as per Figure 3. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 3: Material balance of Example 2**

|                                |        | FG    | SG3   | SG4   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperature                    | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Pressure                       | bar    | 51    | 44    | 39    | 39    | 2     | 20    | 20    | 40    | 5     |
| Molar flow rate                | kmol/h | 2540  | 15037 | 11714 | 8923  | 4281  | 4281  | 2242  | 1491  | 549   |
| CO <sub>2</sub>                | mol%   | 0.77  | 5.02  | 20.09 | 0.00  | 66.80 | 66.80 | 99.82 | 34.01 | 21.01 |
| CO                             | mol%   | 0.00  | 11.40 | 0.66  | 0.00  | 2.39  | 2.39  | 0.00  | 1.68  | 14.08 |
| H <sub>2</sub>                 | mol%   | 0.00  | 49.59 | 76.71 | 100.0 | 23.16 | 23.16 | 0.00  | 62.35 | 11.31 |
| N <sub>2</sub>                 | mol%   | 0.54  | 0.09  | 0.12  | 0.00  | 0.39  | 0.39  | 0.00  | 0.19  | 2.50  |
| CH <sub>4</sub>                | mol%   | 94.31 | 1.37  | 1.76  | 0.00  | 5.44  | 5.44  | 0.18  | 1.77  | 36.91 |
| C <sub>2</sub> H <sub>6</sub>  | mol%   | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol%   | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol%   | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| H <sub>2</sub> O               | mol%   | 0.00  | 32.52 | 0.56  | 0.00  | 1.54  | 1.54  | 0.00  | 0.00  | 12.04 |
| Methanol                       | mol%   | 0.00  | 0.00  | 0.10  | 0.00  | 0.27  | 0.27  | 0.00  | 0.00  | 2.08  |
| Ar                             | mol%   | 0.00  | 0.00  | 0.00  | 0.00  | 0.01  | 0.01  | 0.00  | 0.00  | 0.09  |

The specific carbon dioxide emission of the process according to Figure 3 with the material balance according to table 3 is 0.118 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced. Compared to the comparative example, this corresponds to a reduction in specific carbon dioxide emission of 15%. In addition, the series arrangement of the reforming units **200** and **201**, with regard to the reduction in specific carbon dioxide emission, results in an advantage over the parallel arrangement of the reforming units **200** and **201** according to Figure 2.

#### List of Reference Symbols

|     |                      |
|-----|----------------------|
| FG  | feed gas stream      |
| SG1 | synthesis gas stream |
| SG2 | synthesis gas stream |
| SG3 | synthesis gas stream |
| SG4 | synthesis gas stream |

|    |     |                                |
|----|-----|--------------------------------|
|    | HG1 | hydrogen-rich stream           |
|    | HG2 | hydrogen-rich stream           |
|    | CG1 | carbon dioxide-rich stream     |
|    | RG1 | residual gas stream            |
| 5  | RG2 | residual gas stream            |
|    | RG3 | residual gas stream            |
|    | 100 | autothermal reforming unit     |
|    | 101 | converter unit                 |
| 10 | 102 | pressure swing adsorption unit |
|    | 103 | separation unit                |
|    | 104 | membrane unit                  |
|    | 200 | endothermic reforming unit     |
| 15 | 201 | autothermal reforming unit     |
|    | 202 | heat flow                      |
|    | 203 | converter unit                 |
|    | 204 | pressure swing adsorption unit |
|    | 205 | separation unit                |
| 20 | 206 | membrane unit                  |

It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims. Thus, the present invention is not intended to be limited to the specific embodiments in the examples given above.

What is claimed is:

1. A process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, comprising:

5 (a) providing a feed gas stream, wherein the feed gas stream comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;

(b) reforming at least a portion of the feed gas stream in an endothermic reforming step over a reforming catalyst thereby producing a first synthesis gas stream, wherein the first synthesis gas stream comprises hydrogen, carbon  
10 monoxide, carbon dioxide, and unreacted methane;

(c) reforming a portion of the feed gas stream in an autothermal reforming step thereby producing a second synthesis gas stream, and combining the first synthesis gas stream and the second synthesis gas stream thereby producing a third  
15 synthesis gas stream, or

reforming the first synthesis gas stream in an autothermal reforming step thereby producing a third synthesis gas stream,

wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst,

20 wherein the second synthesis gas stream and the third synthesis gas stream comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and

wherein heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);

25 (d) converting the carbon monoxide present in the third synthesis gas stream with steam thereby producing hydrogen and carbon dioxide thereby producing a fourth synthesis gas stream, wherein the fourth synthesis gas stream comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);

30 (e) separating hydrogen from the fourth synthesis gas stream by pressure swing adsorption, thereby producing a first hydrogen-rich stream and a first residual gas stream, wherein the first residual gas stream comprises carbon dioxide, carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane;

(f) separating carbon dioxide from the first residual gas stream obtained in step (e) by cryogenic carbon dioxide separation, thereby producing a first carbon dioxide-rich stream and a second residual gas stream RG2, wherein the second residual gas stream comprises carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), carbon dioxide not separated off in step (f), and unreacted methane.

2. The process according to Claim 1, wherein hydrogen is separated from the second residual gas stream, thereby producing a second hydrogen-rich stream and a third residual gas stream.

3. The process according to Claim 2, wherein the hydrogen is separated from the second residual gas stream by membrane separation.

4. The process according to Claim 2, wherein the second hydrogen-rich stream is supplied to the fourth synthesis gas stream for separation of hydrogen by pressure swing adsorption in step (e).

5. The process according to Claim 2, wherein gases present in the second hydrogen-rich stream are utilized as fuel gases for heating in the autothermal reforming step of step c).

6. The process according to Claim 1, wherein the first carbon dioxide-rich stream comprises unreacted methane, and the first carbon dioxide-rich stream is subjected to a thermal separation process for separation of methane, thereby producing a second carbon dioxide-rich stream.

7. The process according to Claim 2, wherein carbon dioxide is separated from the third residual gas stream, thereby producing a third carbon dioxide-rich stream and a fourth residual gas stream.

8. The process according to Claim 7, wherein the carbon dioxide is separated from the third residual gas stream by membrane separation.

9. The process according to Claim 7, wherein gases present in the fourth residual gas stream are utilized as fuel gases for heating in the autothermal reforming step of step c).

10. The process according to Claim 7, wherein the third carbon dioxide-rich stream is supplied to the first residual gas stream for cryogenic carbon dioxide separation in step (f).

11. The process according to Claim 1, wherein the first residual gas stream, for cryogenic carbon dioxide separation in step (f), is subjected to at least one compression step and at least one cooling step, thereby producing the first carbon dioxide-rich stream at least partly in the form of a condensed carbon dioxide stream.

12. A plant configured for performance of the process according to Claim 1.

13. A plant for preparation of hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, comprising the following plant components in fluid connection with one another:

(a) a means of providing a feed gas stream, wherein the feed gas stream comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;

(b) a first reforming unit, wherein the first reforming unit is configured for reforming at least a portion of the feed gas stream in an endothermic reforming step over a reforming catalyst, wherein a first synthesis gas stream is obtainable in the endothermic reforming step, wherein the first synthesis gas stream comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;

(c) a second reforming unit, arranged parallel to or downstream of the first reforming unit, wherein

- the second reforming unit, in the case of parallel arrangement to the first reforming unit, is configured for reforming of a portion of the feed gas stream in an autothermal reforming step,

wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst and

a second synthesis gas stream is obtainable in the autothermal reforming step, and

the first and second reforming unit, in the case of parallel arrangement, are configured such that the first synthesis gas stream and the second synthesis gas stream can be combined to produce a third synthesis gas stream,

- the second reforming unit, in the case of arrangement downstream of the first reforming unit, is configured for reforming of at least a portion of the first synthesis gas stream in an autothermal reforming step,

wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst,

wherein a third synthesis gas stream is obtainable in the autothermal reforming step,

wherein the second synthesis gas stream and the third synthesis gas stream comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and

the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b);

(d) a converter unit, arranged

- downstream of the first and second reforming unit in the case of parallel arrangement of the first and second reforming unit, or

- arranged downstream of the second reforming unit in the case of arrangement of the second reforming unit downstream of the first reforming unit,

wherein the converter unit is configured for conversion of the carbon monoxide present in the third synthesis gas stream with steam thereby producing carbon dioxide and hydrogen, thus producing a fourth synthesis gas stream, and

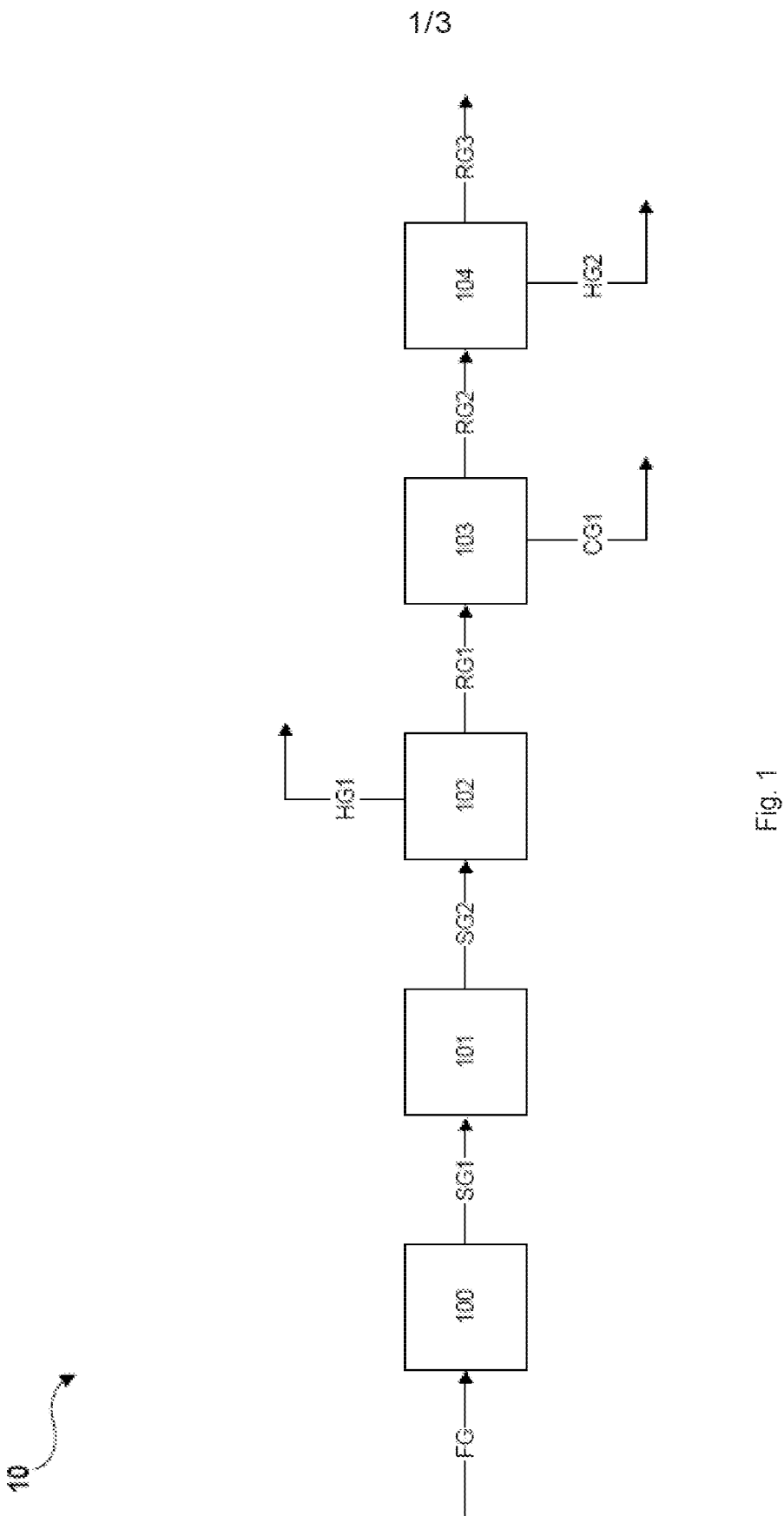
the fourth synthesis gas stream comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in the converter unit;

(e) a pressure swing adsorption unit, arranged downstream of the converter unit, wherein the pressure swing adsorption unit is configured to separate hydrogen from the fourth synthesis gas stream, wherein a hydrogen-rich stream and a residual gas stream are obtainable, wherein the residual gas stream comprises carbon dioxide, carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, and unreacted methane;

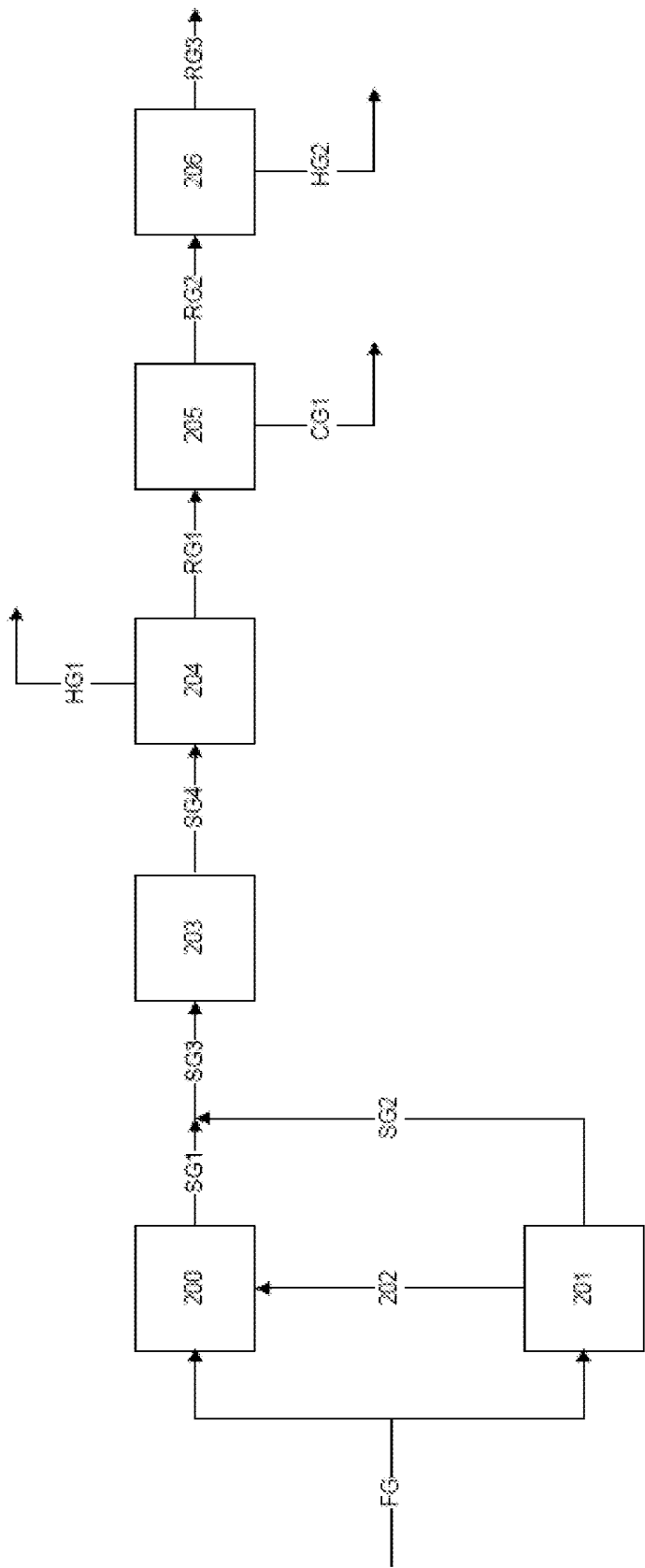
(f) a separation unit arranged downstream of the pressure swing adsorption unit, wherein the separation unit is configured for cryogenic separation of carbon dioxide from the residual gas stream produced in the pressure swing adsorption unit, wherein a carbon dioxide-rich stream and a residual gas stream are obtainable, wherein the residual gas stream comprises carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, carbon dioxide not separated off in the separation unit, and unreacted methane.

### Abstract

The invention relates to a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide. The process includes one endothermic and one autothermal reforming step for production of a synthesis gas stream, wherein heat generated in the autothermal reforming step is utilized for heating in the endothermic reforming step. The process also includes a step of converting the synthesis gas stream obtained for enrichment with hydrogen, a step of separating the hydrogen thus prepared by pressure swing adsorption, and a step of separation of carbon dioxide from the residual gas obtained in the pressure swing adsorption. The reforming units for the endothermal and autothermal reforming steps are arranged parallel to one another or in series.



20



2/3

Fig. 2

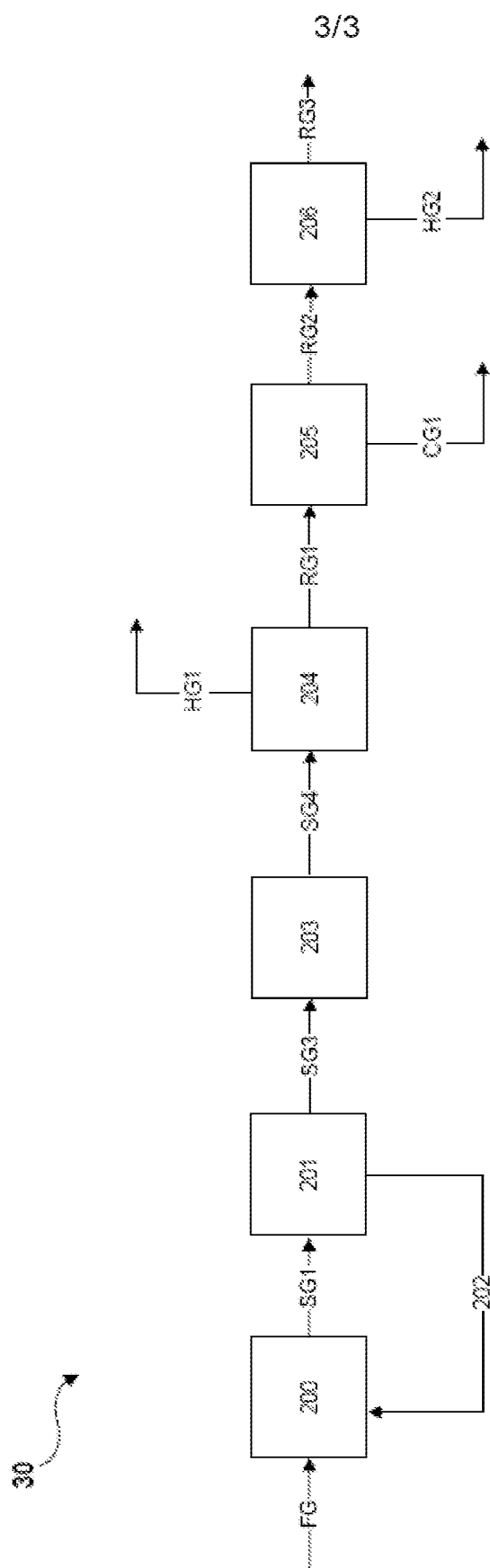


Fig. 3

11 August 2020 / StefSta

5

AIR LIQUIDE reference: 2019P00370 EP

10                    **Process and plant for preparation of hydrogen and separation of carbon dioxide**

**Field of the invention**

15        The invention relates to a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide. The invention further relates to a plant for preparation of hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide.

20        **Prior art**

          A current estimate of the volume of hydrogen produced globally is 70 Mt/a, with the greatest proportion thereof produced by endothermic reforming of natural gas with steam over a nickel-based reforming catalyst. In this process, referred to as steam methane reforming (SMR), there is reaction mainly of methane and steam to give a  
25        mixture of mainly hydrogen, carbon monoxide and carbon dioxide. The steam reforming process has a large carbon dioxide footprint since about 9 tonnes of carbon dioxide are emitted for every tonne of hydrogen produced. According to calculations, steam reforming of natural gas alone contributes to global carbon dioxide emissions with a share of 1.5% (Wisman et al., Science 364, 756-759, 2019).

30

          Hydrogen is also produced by autothermal reforming (ATR) of natural gas. Autothermal reforming differs from steam reforming in that the endothermic reforming step is preceded by an exothermic partial oxidation step that provides the heat of reaction needed for the downstream endothermic catalytic step. In general, air or oxygen, for

example, from an air fractionation plant, is used as oxidation medium for the partial oxidation. Moreover, ATR requires a burner which, with the aid of a fuel gas, provides the activation energy required for the partial oxidation. The result of these two reaction steps, the partial oxidation of methane and the subsequent endothermic catalytic reforming of the intermediate with steam, is likewise a synthesis gas comprising  
5 mainly hydrogen, carbon monoxide and carbon dioxide.

In order to make the processes mentioned more environmentally friendly, there has previously been development of processes in order to separate the carbon dioxide  
10 produced in SMR or ATR as a carbon dioxide product of maximum purity from the synthesis gas mixture produced as the primary product. For this purpose, gas scrubbing processes based on physical or chemical absorption in absorbents such as methanol or amines are available, as is cryogenic liquid separation and purification of the carbon dioxide by compression, condensation and distillation. However, the  
15 carbon dioxide which is absorbed in absorbents in large volumes and then desorbed again or separated out by condensation at low temperatures frequently cannot be sent to any viable further industrial use. Therefore, the only option that remains is frequently to store the unusable carbon dioxide over a long period of time in order not to allow it to get into the atmosphere. The combination of separation (by gas  
20 scrubbing or condensation) and storage of carbon dioxide is also referred to as sequestration or CCS (*carbon capture and storage*).

It is therefore necessary to improve known processes for producing hydrogen in such a way that smaller amounts of carbon dioxide per tonne of hydrogen produced are  
25 generated from the outset.

US 2015/0321914 A1 discloses a process in which a synthesis gas produced as the primary product by steam reforming or autothermal reforming is converted to carbon dioxide and hydrogen by conversion of the carbon monoxide present in the synthesis  
30 gas produced as the primary product with steam (water-gas shift reaction). Subsequently, hydrogen is separated from the carbon dioxide- and hydrogen-enriched converted synthesis gas with the aid of a pressure swing adsorption unit. The residual gas which is depleted of hydrogen but still rich in carbon dioxide is subsequently treated in an apparatus referred to as cryogenic purification unit (CPU), in order to

separate carbon dioxide out of the residual gas and liquefy it in a form of maximum purity. The liquefied carbon dioxide can subsequently be sent to storage or used for industrial or consumable purposes.

## Description of the invention

It is a general object of the present invention to overcome the abovementioned disadvantages of the prior art.

5

More particularly, it is an object of the present invention to modify known processes so as to reduce the amount of carbon dioxide formed per unit weight of hydrogen produced.

10 More particularly, it is an object of the present invention to reduce carbon dioxide emissions from processes that combine autothermal reforming of methane with cryogenic carbon dioxide separation.

15 A contribution to the at least partial achievement of at least one of the above objects is made by the independent claims. The dependent claims provide preferred embodiments which contribute to the at least partial achievement of at least one of the objects. Preferred embodiments of constituents of one category according to the invention are, where relevant, likewise preferred for identically named or corresponding constituents of a respective other category according to the invention.

20

The terms "having", "comprising" or "containing", etc., do not preclude the possible presence of further elements, ingredients, etc. The indefinite article "a" does not preclude the possible presence of a plurality.

25 The objects of the invention are at least partly achieved by a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the process comprises the following steps:

30 (a) providing a feed gas stream FG, wherein the feed gas stream FG comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;

(b) reforming at least a portion of the feed gas stream FG in an endothermic reforming step over a reforming catalyst to give a synthesis gas stream SG1, wherein the synthesis gas stream SG1 comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;

- (c) reforming a portion of the feed gas stream FG in an autothermal reforming step to give a synthesis gas stream SG2, and combining the synthesis gas streams SG1 and SG2 to give a synthesis gas stream SG3, or
- 5 reforming the synthesis gas stream SG1 in an autothermal reforming step to give a synthesis gas stream SG3,
- wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein
- 10 the synthesis gas streams SG2 and SG3 comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and wherein heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);
- (d) converting the carbon monoxide present in the synthesis gas stream
- 15 SG3 with steam to give hydrogen and carbon dioxide to give a synthesis gas stream SG4, wherein the synthesis gas stream SG4 comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);
- (e) separating hydrogen from the synthesis gas stream SG4 by pressure swing adsorption, giving a hydrogen-rich stream HG1 and a residual
- 20 gas stream RG1, wherein the residual gas stream RG1 comprises carbon dioxide, carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane;
- (e) separating carbon dioxide from the residual gas stream RG1 obtained
- 25 in step (e) by cryogenic carbon dioxide separation, giving a carbon dioxide-rich stream CG1 and a residual gas stream RG2, wherein the residual gas stream RG2 comprises carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), carbon dioxide not separated off in step (f), and unreacted methane.

Compared to processes known from the prior art, it is a feature of the process according to the invention that a combination of endothermic and autothermal reforming steps is used in steps (b) and (c), and heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b). The auto-  
5 thermal reforming step is performed in an autothermal reforming unit (autothermal reformer). The endothermic reforming step is performed in an endothermic reforming unit (endothermic reformer, for example steam reformer). This surprisingly significantly lowers the specific carbon dioxide emissions with regard to the overall process. "Specific carbon dioxide emissions" is understood to mean the mass of CO<sub>2</sub> formed  
10 throughout the process per standard cubic metre of hydrogen produced. The specific carbon dioxide emissions can be reported, for example, in kg CO<sub>2</sub>/m<sup>3</sup> (STP).

In the endothermic reforming step of step (b), the feed gas FG is converted to the synthesis gas SG1 over a suitable catalyst by supply of heat. The catalyst is, for example, a nickel catalyst known to the person skilled in the art. The heat required  
15 for the reforming reaction to proceed for the endothermic reforming step is provided at least partly, preferably completely, by heat formed in the autothermal reforming step. According to the arrangement of the reforming units, the feed gas SG is introduced partly or fully into the reforming unit of the endothermic reforming step and converted to the synthesis gas SG1.

20 The autothermal reforming step in step (c) comprises a step of partial oxidation of the feed gas stream FG and a subsequent endothermic reforming step with steam for conversion of the feed gas stream FG to the synthesis gas stream SG2 or to the synthesis gas stream SG3. The step of partial oxidation in the autothermal reforming step entails the supply of an oxidizing agent such as air, pure oxygen, or oxygen-  
25 enriched air. The oxidizing agent is typically introduced into the autothermal reformer via a burner. The partial oxidation of the feed gas stream FG to the synthesis gas stream SG2 or to the synthesis gas stream SG3 in the course of the autothermal reforming step is an exothermic reaction. The waste heat generated as a result is utilized for the "endothermic portion" of the autothermal reforming step. The autother-  
30 mal reforming step is designed such that sufficient heat is generated in total, over two reaction stages (partial oxidation and endothermic reforming), which is utilizable for heating of the endothermic reforming step for conversion of the feed gas FG to the synthesis gas SG1.

The process according to the invention includes two alternatives defined by step (c).

- In the first alternative, a portion of the feed gas stream FG is reformed in the endo-  
thermic reforming step to give the synthesis gas stream SG1. A further portion of the  
5 feed gas stream FG, preferably the remaining portion of the feed gas stream FG, is  
reformed in the autothermal reforming step to give the synthesis gas stream SG2.  
The synthesis gas streams SG2 and SG3 are then combined to give a synthesis gas  
stream SG3. This results in a parallel arrangement or connection of the reforming  
units for the endothermic reforming step and for the autothermal reforming step.
- 10 In the second alternative of the process according to the invention, the feed gas SG  
is introduced fully into the reforming unit of the endothermic reforming step and con-  
verted to the synthesis gas stream SG1. This converts the feed gas FG only partly to  
the synthesis gas SG1, meaning that there remains a comparatively high proportion  
of methane and possibly other reformable hydrocarbon components in the synthesis  
15 gas SG1. This remaining amount is subsequently reformed in the autothermal re-  
forming step to give the synthesis gas SG3. This results in a series arrangement or  
connection of the reforming units for the endothermic reforming step and for the au-  
tothermal reforming step, with the autothermal reforming step following on from the  
endothermic reforming step. In other words, the reforming unit for the autothermal  
20 reforming step is arranged downstream of the reforming unit for the endothermic re-  
forming step in gas flow direction.

Preferably, the synthesis gas stream produced in the autothermal reforming step, i.e.  
synthesis gas stream SG2 in the case of parallel arrangement of the reforming units  
or synthesis gas stream SG3 in the case of series arrangement of the reforming units,  
25 is utilized directly for the transfer of heat in the endothermic reforming step. The syn-  
thesis gas stream SG2 and/or the synthesis gas stream SG3 here preferably have a  
temperature of 750 to 1100°C.

The feed gas stream FG includes at least one hydrocarbon component which is re-  
formable with steam to give a synthesis gas SG1, SG2, SG3 or SG4. The synthesis  
30 gas includes at least hydrogen, carbon monoxide and carbon dioxide as product  
components. The feed gas stream FG includes at least methane as hydrocarbon

component. Further higher analogous hydrocarbons, for example ethane, propane or butane, may be present in the feed gas stream FG.

5 A feed gas may first be treated in what is called a preliminary reformer in order to convert higher hydrocarbons with steam to short-chain hydrocarbons, especially with the purpose of increasing the methane content in the feed gas stream FG. The purpose of the preliminary reformer is thus generally to convert hydrocarbons having at least two carbon atoms to carbon monoxide, hydrogen and methane. A feed gas stream FG treated in a preliminary reformer may thus already contain certain amounts of carbon monoxide and hydrogen.

10 The synthesis gas stream SG3 formed by the combination of autothermal and endothermic reforming steps is sent to a conversion step (d). In this conversion step, carbon monoxide present in the synthesis gas stream SG3 is reacted with water by what is called the water-gas shift reaction over a suitable catalyst to give hydrogen and carbon dioxide. Prior to introduction into step (d), the synthesis gas SG3 is cooled.  
15 Depending on whether step (d) is what is called a low-temperature shift or a high-temperature shift, the synthesis gas SG3 is cooled to a greater or lesser degree prior to introduction into step (d).

The synthesis gas stream SG4 formed by the conversion step (d) is enriched with hydrogen and carbon dioxide, and depleted of carbon monoxide. Synthesis gas  
20 stream SG4 is subsequently subjected to a separation step (e) in which substantially pure hydrogen is produced from the synthesis gas stream SG4 by pressure swing adsorption (PSA). The hydrogen-rich stream HG1 obtained by the pressure swing adsorption regularly has a hydrogen content of at least 95 mol%, preferably of at least 99 mol%, further preferably of at least 99.5 mol% and further preferably of at least  
25 99.9 mol%. The hydrogen-depleted by-product of the pressure swing adsorption step, the residual gas stream RG1, is greatly depleted of hydrogen and greatly enriched with carbon dioxide compared to the synthesis gas stream SG4. It also comprises carbon monoxide unconverted in step (d), and methane unconverted in steps (b) and (c). As a result of the presence of gases having high calorific value (methane,  
30 carbon monoxide and hydrogen), it can be used as fuel within or outside the process.

For separation of carbon dioxide from the residual gas stream RG1, it is sent to a cryogenic carbon dioxide separation in step (f), which affords a carbon dioxide-rich

stream CG1 and a further residual gas stream RG2. The separation step (f) requires the partial condensation of the carbon dioxide present in the residual gas stream RG1, and, for achievement of a particular purity, subsequently and optionally the distillation of the carbon dioxide-rich stream CG1. The cryogenic carbon dioxide separation is preferably performed at a temperature of less than 35°C, or less than 20°C, or less than 0°C, or less than -20°C, or less than -40°C, or less than -50°C, or less than -55°C. The cryogenic carbon dioxide separation is also preferably performed at a temperature of more than -60°C.

The synthesis gas stream SG1 can also be referred to as the first synthesis gas stream, the synthesis gas stream SG2 as the second synthesis gas stream, and so forth. This is also applicable *mutatis mutandis* to all other fluid streams RG, CG and HG numbered in the context of this disclosure.

A preferred embodiment of the process according to the invention is characterized in that hydrogen is separated from the residual gas stream RG2, giving a hydrogen-rich stream HG2 and a residual gas stream RG3. The residual gas stream RG2, in spite of the preceding separation step by pressure swing adsorption, regularly includes relatively large amounts of residual hydrogen of up to 50 mol%. It is therefore advantageous to feed the residual gas stream 2 to a further separation step for separation or at least enrichment of hydrogen. Preference is given to separating the hydrogen from the residual gas stream RG2 by membrane separation.

In one example of the process according to the invention, the hydrogen-rich stream HG2 is supplied to the synthesis gas stream SG4 for separation of hydrogen by pressure swing adsorption in step (e). Membrane separation processes in particular do not have sufficient selectivity to obtain a hydrogen stream having high purity, for example of more than 99 mol%, from the residual gas stream RG2. Since a second pressure swing adsorption step in the sense of a second pressure swing adsorption apparatus would be too complex and costly, the hydrogen-rich stream HG2 is advantageously sent to step (e), which increases the hydrogen yield based on the overall process.

Alternatively, gases present in the hydrogen-rich stream HG2 are utilized as fuel gases for heating in the autothermal reforming step of step c). For the autothermal

reforming step, the feed gas FG has to be warmed, which can be effected, for example, by means of a fired heating unit. The fired heating unit may be heated at least partly with the aid of the gases present in the hydrogen-rich stream HG2 that have a high calorific value, especially carbon monoxide, methane and hydrogen, in order to  
5 improve the thermal integration of the process.

A preferred embodiment of the process according to the invention is characterized in that the carbon dioxide-rich stream CG1 comprises unreacted methane, and the carbon dioxide-rich stream CG1 is subjected to a thermal separation process for separation of methane, giving a carbon dioxide-rich stream CG2. The carbon dioxide-rich  
10 stream may, as a result of the cryogenic carbon dioxide separation, contain significant amounts of methane, for example up to 0.2 mol% of methane, or up to 0.5 mol% of methane. A further step including a thermal separation process can further increase the carbon dioxide content of the carbon dioxide-rich stream CG1. The thermal separation process is preferably a distillation. This can give a largely pure carbon  
15 dioxide product that can more easily be sent to an environmentally viable valorization than a methane-contaminated carbon dioxide product. For example, pure carbon dioxide can be mixed with electrolysis hydrogen in the correct ratio as synthesis gas for methanol production. In the sequestration of the carbon dioxide too, a pure carbon dioxide product has advantages since especially methane-contaminated carbon di-  
20 oxide, in the event of unintended release after sequestration, would enhance the greenhouse effect in a known manner.

A preferred embodiment of the process according to the invention is characterized in that carbon dioxide is separated from the residual gas stream RG3, giving a carbon dioxide-rich stream CG3 and a residual gas stream RG4. The carbon dioxide is preferably separated by membrane separation from the residual gas stream RG3, in order to obtain the carbon dioxide-rich stream CG3 and the residual gas stream RG4.  
25

In one example of the process according to the invention, gases present in the residual gas stream RG4 are utilized as fuel gases for heating in the autothermal reforming step of step c).

30 The carbon dioxide-rich stream CG3 is preferably supplied to the residual gas stream RG1 for cryogenic carbon dioxide separation in step (f). This increases the

yield of utilizable carbon dioxide and reduces the amount of carbon dioxide actually emitted to a minimum.

A preferred embodiment of the process according to the invention is characterized in that the residual gas stream RG1, for cryogenic carbon dioxide separation in step (f),  
5 is subjected to at least one compression step and at least one cooling step, giving the carbon dioxide-rich stream CG1 at least partly in the form of a condensed carbon dioxide stream. The cryogenic carbon dioxide separation is preferably conducted under pressure by compression, for example a pressure between 5 and 74 bar, with simultaneous cooling of residual gas stream RG1, preferably to a temperature above  
10 the triple point of carbon dioxide (minus 56°C) or another temperature suitable for the condensation. Under these temperature and pressure conditions, the carbon dioxide partly condenses out, enriching the liquid phase with carbon dioxide and enriching the gas phase with uncondensable gases. Preferably, and to the extent required, step (f) includes multiple compression steps and/or multiple cooling steps, meaning  
15 that the condensation of carbon dioxide out of the residual gas stream RG1 is effected in multiple successive compression and cooling steps.

Preferably, and to the extent required, the residual gas stream RG1 is dried in one or more steps in the course of step (f). A drying step can be performed before a compression step, between two compression steps and/or after a compression step. A  
20 drying step can also be performed before a cooling step, between two cooling steps and/or after a cooling step.

Preferably, and to the extent required, the residual gas stream RG1, in the course of step (f), is subjected to one or more separation steps for removal of condensable constituents such as methanol. A separation step can be performed before a compression step, between two compression steps and/or after a compression step. A  
25 separation step can also be performed before a cooling step, between two cooling steps and/or after a cooling step.

The objects of the invention are also at least partly achieved by a plant, wherein the plant is configured for performance of the process according to the invention.

The objects of the invention are also at least partly achieved by a plant for preparation of hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the plant comprises the following plant components in fluid connection with one another:

- 5 (a) means of providing a feed gas stream FG, wherein the feed gas stream FG comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;
- (b) a first reforming unit, wherein the first reforming unit is configured for reforming at least a portion of the feed gas stream FG in an endothermic reforming step over a reforming catalyst, wherein a synthesis gas stream SG1 is obtainable in the endothermic reforming step, wherein  
10 the synthesis gas stream SG1 comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;
- (c) a second reforming unit, arranged parallel to or downstream of the first reforming unit, wherein  
15 - the second reforming unit, in the case of parallel arrangement to the first reforming unit, is configured for reforming of a portion of the feed gas stream FG in an autothermal reforming step, wherein
- 20 the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst and
- a synthesis gas stream SG2 is obtainable in the autothermal reforming step, and
- 25 the first and second reforming unit, in the case of parallel arrangement, are configured such that the synthesis gas streams SG1 and SG2 can be combined to give a synthesis gas stream SG3,

- the second reforming unit, in the case of arrangement downstream of the first reforming unit, is configured for reforming of at least a portion of the synthesis gas stream SG1 in an autothermal reforming step, wherein
- 5                   the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein
- a synthesis gas stream SG3 is obtainable in the autothermal reforming step, wherein
- 10               the synthesis gas streams SG2 and SG3 comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and
- the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b);
- 15               (d) a converter unit, arranged
- downstream of the first and second reforming unit in the case of parallel arrangement of the first and second reforming unit, or
- 20               - arranged downstream of the second reforming unit in the case of arrangement of the second reforming unit downstream of the first reforming unit, wherein
- the converter unit is configured for conversion of the carbon monoxide present in the synthesis gas stream SG3 with steam to give carbon dioxide and hydrogen, giving a synthesis gas stream SG3, and
- 25               the synthesis gas stream SG3 comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in the converter unit;

(e) a pressure swing adsorption unit, arranged downstream of the converter unit, wherein

5 the pressure swing adsorption unit is configured to separate hydrogen from the synthesis gas stream SG3, wherein a hydrogen-rich stream HG1 and a residual gas stream RG1 are obtainable, wherein the residual gas stream RG1 comprises carbon dioxide, carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, and unreacted methane;

10 (f) a separation unit arranged downstream of the pressure swing adsorption unit, wherein the separation unit is configured for cryogenic separation of carbon dioxide from the residual gas stream RG1 produced in the pressure swing adsorption unit, wherein a carbon dioxide-rich stream CG1 and a residual gas stream RG2 are obtainable, wherein the residual gas stream RG2 comprises carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, carbon dioxide not separated off in the separation unit, and unreacted methane.

20 According to the invention, the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b). The first reforming unit is configured for an endothermic reforming step. The second reforming unit is configured for an autothermal reforming step. The second reforming unit is preferably an autothermal reformer. The second reforming unit is arranged parallel to the first reforming unit or downstream of the first reforming unit.

30 In the case of parallel arrangement to the first reforming unit, the second reforming unit produces a synthesis gas stream SG2 that can be combined with the synthesis gas stream SG1 from the first reforming unit. The synthesis gas stream SG2 is preferably utilized directly for heating in the first reforming unit, meaning that the heat present in the synthesis gas stream SG2 is utilized directly for heating in the first reforming unit. What is meant by "directly" in this connection is that the heat present

in the synthesis gas stream SG2 is not transferred to a further heat transport medium. The heat present in the synthesis gas stream SG2 is accordingly utilized for production of the synthesis gas stream SG1 in the endothermic process in the first reforming unit.

- 5 In the case of arrangement downstream of the first reforming unit, the second reforming unit produces a synthesis gas stream SG3. The synthesis gas stream SG3 is preferably utilized directly for heating in the first reforming unit, meaning that the heat present in the synthesis gas stream SG3 is utilized directly for heating in the first reforming unit. What is meant by "directly" in this connection is that the heat
- 10 present in the synthesis gas stream SG3 is not transferred to a further heat transport medium. The heat present in the synthesis gas stream SG3 is accordingly utilized for production of the synthesis gas stream SG1 in the endothermic process in the first reforming unit.

## Working examples

The invention is elucidated in detail hereinafter by two inventive working examples and one noninventive comparative example in conjunction with three drawings, where the working examples and the drawings do not mean any restriction of the invention.

The figures show:

- Figure 1 a block flow diagram of a process or plant according to the prior art,
- Figure 2 a block flow diagram of a first alternative of a process according to the invention or of a plant according to the invention with parallel arrangement of the reforming units for the endothermic and autothermal reforming steps,
- Figure 3 a block flow diagram of a second alternative of a process according to the invention or of a plant according to the invention with series arrangement of the reforming units for the endothermic and autothermal reforming steps.

Figure 1 shows a highly simplified block flow diagram of a process or plant according to the prior art, as disclosed, for example, in US 2015/0321914. A feed gas stream FG is introduced into an autothermal reforming unit 100 and converted to a synthesis gas stream SG1. Synthesis gas stream SG1 is subsequently introduced into a converter unit 101, which results in reaction of carbon monoxide present in synthesis gas stream SG1 with steam to give carbon dioxide and hydrogen. Hydrogen-enriched synthesis gas stream SG2 is subsequently introduced into a pressure swing adsorption unit 102 in order to separate hydrogen from the synthesis gas stream SG2 with high purity. Hydrogen separated from the pressure swing adsorption unit 102 is discharged from the pressure swing adsorption unit 102 in the form of a hydrogen-rich stream HG1. A hydrogen-depleted residual gas stream RG1 is likewise drawn off from the pressure swing adsorption unit 102 and introduced into a separation unit 103. In the separation unit 103, carbon dioxide is separated out in high purity by

means of multiple compression and cooling steps and drying steps, and drawn off from the separation unit in the form of a carbon dioxide-rich stream CG1. Carbon dioxide-rich stream CG1 still contains significant residual amounts of methane that can optionally be removed by distillation of the carbon dioxide-rich stream CG1 (not shown). The resulting pure carbon dioxide product is suitable for the sequestration of carbon dioxide or for further use, for example the synthesis of methanol by reaction with hydrogen produced from an electrolysis stream. A highly carbon dioxide-depleted residual gas stream RG2 is also drawn off from the separation unit 103 and introduced into a membrane unit 104. A hydrogen-rich stream HG2 which is enriched with hydrogen compared to residual gas stream RG2 is produced by membrane separation in membrane unit 104 and drawn off from the membrane unit 104. In addition, a residual gas stream RG3 depleted of hydrogen compared to residual gas stream RG2 is produced and drawn off from the membrane unit 104. Hydrogen-rich stream HG2, for further use, can optionally either be recycled to the pressure adsorption unit 102 to increase the hydrogen yield or can be used as fuel gas in the autothermal reforming unit 100.

Table 1 below shows a material balance of a simulation of a process according to Figure 1. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 1: Material balance in comparative example**

|                                |        | FG    | SG1   | SG2   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperature                    | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Pressure                       | bar    | 51    | 47    | 43    | 43    | 2     | 20    | 30    | 30    | 3     |
| Molar flow rate                | kmol/h | 3869  | 16768 | 14272 | 8923  | 5349  | 2570  | 2750  | 1841  | 729   |
| CO <sub>2</sub>                | mol%   | 0.77  | 6.46  | 24.57 | 0.00  | 65.57 | 29.69 | 99.77 | 33.77 | 19.39 |
| CO                             | mol%   | 0.00  | 15.77 | 0.97  | 0.00  | 2.58  | 5.38  | 0.00  | 1.84  | 14.33 |
| H <sub>2</sub>                 | mol%   | 0.00  | 46.88 | 71.04 | 99.99 | 22.75 | 47.35 | 0.00  | 61.96 | 10.44 |
| N <sub>2</sub>                 | mol%   | 0.54  | 0.12  | 0.15  | 0.00  | 0.38  | 0.80  | 0.00  | 0.19  | 2.32  |
| CH <sub>4</sub>                | mol%   | 94.31 | 2.17  | 2.55  | 0.00  | 6.81  | 13.93 | 0.23  | 2.24  | 43.44 |
| C <sub>2</sub> H <sub>6</sub>  | mol%   | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol%   | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol%   | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| H <sub>2</sub> O               | mol%   | 0.00  | 28.57 | 0.52  | 0.00  | 1.38  | 1.78  | 0.00  | 0.00  | 6.28  |
| Methanol                       | mol%   | 0.00  | 0.00  | 0.17  | 0.00  | 0.46  | 0.92  | 0.00  | 0.00  | 3.24  |
| Ar                             | mol%   | 0.00  | 0.02  | 0.03  | 0.00  | 0.08  | 0.16  | 0.00  | 0.00  | 0.55  |

The specific carbon dioxide emission of the process according to the process of Figure 1 with the material balance according to table 1 is 0.140 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced.

Rather than the autothermal reforming unit 100, it is also possible, as likewise disclosed in US 2015/0321914, to use an endothermic reforming unit. More particularly, the endothermic reforming unit may be a steam reformer known to the person skilled in the art. In the case of use of a steam reformer, the specific carbon dioxide emission, at 0.396 kg of CO<sub>2</sub> per standard cubic metre of hydrogen produced, is several times higher than in the case of use of an autothermal reformer.

Figure 2 shows a highly simplified block flow diagram of a process or plant in a first example of the invention (Example 1) with a parallel arrangement of the reforming units. A feed gas stream FG is divided into two substreams. A first substream of the feed gas stream FG is introduced into an endothermic reforming unit 200 (first reforming unit, configured for an endothermic reforming step). A second substream of the feed gas stream FG is introduced into an autothermal reforming unit 201 (second reforming unit, configured for an autothermal reforming step). In the endothermic reforming unit 200, the first substream of the feed gas stream FG is converted to a synthesis gas stream SG1. In the autothermal reforming unit 201, the second substream of the feed gas stream FG is converted to a synthesis gas stream SG2. The heat generated in the autothermal reforming step of the autothermal reforming unit

201 is utilized for heating in the endothermic reforming step in the endothermic reforming unit 200, indicated by the heat flow 202. The second synthesis gas stream SG2 is preferably utilized directly for heating in the endothermic reforming step in the endothermic reforming unit 200, meaning that the heat present in the second synthesis gas stream SG2 is utilized without transfer to a further heat transport medium for heating in the endothermic reforming step in the endothermic reforming unit 201.

The synthesis gas streams SG1 and SG2 that are produced by the endothermic reforming unit 200 and the autothermal reforming unit 201 are combined to give a mixed synthesis gas stream SG3 which is introduced into a converter unit 203, as a result of which carbon monoxide present in the synthesis gas stream SG3 is reacted with steam to give carbon dioxide and hydrogen. Hydrogen-enriched synthesis gas stream SG4 is subsequently introduced into a pressure swing adsorption unit 204 in order to separate hydrogen from the synthesis gas stream SG4 with high purity. Hydrogen separated from the pressure swing adsorption unit 204 is discharged from the pressure swing adsorption unit 204 in the form of a hydrogen-rich stream HG1. A hydrogen-depleted first residual gas stream RG1 is likewise drawn off from the pressure swing adsorption unit 204 and introduced into a separation unit 205. In the separation unit 205, carbon dioxide is separated out in high purity by means of multiple compression and cooling steps and drying steps, and drawn off from the separation unit 205 in the form of a carbon dioxide-rich stream CG1. Carbon dioxide-rich stream CG1 still contains significant residual amounts of methane that can optionally be removed by distillation of the carbon dioxide-rich stream CG1 (not shown). The resulting pure carbon dioxide product is suitable for the sequestration of carbon dioxide or for further use, for example the synthesis of methanol by reaction with hydrogen produced from electrolysis.

A highly carbon dioxide-depleted residual gas stream RG2 is also drawn off from the separation unit 205 and introduced into a membrane unit 206. A hydrogen-rich stream HG2 which is enriched with hydrogen compared to the residual gas stream RG2 is produced by membrane separation in membrane unit 206 and drawn off from the membrane unit 206. In addition, a residual gas stream RG3 depleted of hydrogen compared to the residual gas stream RG2 is produced and drawn off from the membrane unit 206. The hydrogen-rich stream HG2, for further use, can optionally either

be recycled to the pressure adsorption unit 204 to increase the overall hydrogen yield of the process or can be used as fuel gas in the autothermal reforming unit 201.

Table 2 below shows a material balance of a simulation of the first example of a process according to the invention as per Figure 2. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 2: Material balance of Example 1**

|                                |        | FG    | SG3   | SG4   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperature                    | °C     | 40    | 958   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Pressure                       | bar    | 51    | 47    | 42    | 41    | 2     | 20    | 20    | 40    | 5     |
| Molar flow rate                | kmol/h | 3252  | 15139 | 12476 | 8923  | 5400  | 2671  | 2729  | 1847  | 824   |
| CO <sub>2</sub>                | mol%   | 0.77  | 6.07  | 22.93 | 0.00  | 64.40 | 28.32 | 99.71 | 33.36 | 17.01 |
| CO                             | mol%   | 0.00  | 13.96 | 0.88  | 0.00  | 2.70  | 5.46  | 0.00  | 1.93  | 13.36 |
| H <sub>2</sub>                 | mol%   | 0.00  | 47.34 | 72.13 | 99.99 | 22.53 | 45.54 | 0.00  | 61.74 | 9.24  |
| N <sub>2</sub>                 | mol%   | 0.54  | 0.12  | 0.14  | 0.00  | 0.38  | 0.78  | 0.00  | 0.20  | 2.08  |
| CH <sub>4</sub>                | mol%   | 94.31 | 2.65  | 3.21  | 0.00  | 8.37  | 16.63 | 0.29  | 2.77  | 47.69 |
| C <sub>2</sub> H <sub>6</sub>  | mol%   | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol%   | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol%   | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| H <sub>2</sub> O               | mol%   | 0.00  | 29.85 | 0.53  | 0.00  | 1.23  | 2.49  | 0.00  | 0.00  | 8.07  |
| Methanol                       | mol%   | 0.00  | 0.00  | 0.15  | 0.00  | 0.34  | 0.69  | 0.00  | 0.00  | 2.25  |
| Ar                             | mol%   | 0.00  | 0.02  | 0.02  | 0.00  | 0.05  | 0.10  | 0.00  | 0.00  | 0.31  |

The specific carbon dioxide emission of the process according to Figure 2 with the material balance according to table 2 is 0.128 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced. Compared to the comparative example, this corresponds to a reduction in specific carbon dioxide emissions of 9%.

Figure 3 shows a highly simplified block flow diagram of a process or plant in a second example of the invention (Example 2). The process or plant according to Figure 3 differs from the process or plant according to Figure 2 by the series arrangement or connection of the reforming units. The endothermic reforming unit 200 (first reforming unit, configured for an endothermic reforming step) is arranged upstream of the autothermal reforming unit 201 (second reforming unit, configured for an autothermal reforming step) in gas flow direction, and the latter is correspondingly arranged downstream of the endothermic reforming unit 200 in gas flow direction. A feed gas stream FG is introduced into an endothermic reforming unit 200 and converted to a synthesis gas stream SG1. The synthesis gas stream SG1 is converted

to a synthesis gas stream SG3 in the autothermal reforming unit 201. The heat generated in the autothermal reforming step of the autothermal reforming unit 201 is utilized for heating in the endothermic reforming step in the endothermic reforming unit 200, indicated by the heat flow 202. Synthesis gas stream SG3 is preferably  
5 utilized directly for heating in the endothermic reforming step in the endothermic reforming unit 200, meaning that the heat present in synthesis gas stream SG3 is utilized without further transfer to a heat transport medium for heating in the endothermic reforming step in the endothermic reforming unit 200. All the subsequent process steps correspond to Example 1 according to Figure 2.

10

Table 3 below shows a material balance of a simulation of the second example of a process according to the invention as per Figure 3. The simulation was conducted with the aid of the "Aspen Plus" software. The composition of the feed gas stream is reported without added steam.

**Table 3: Material balance of Example 2**

|                                |        | FG    | SG3   | SG4   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperature                    | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Pressure                       | bar    | 51    | 44    | 39    | 39    | 2     | 20    | 20    | 40    | 5     |
| Molar flow rate                | kmol/h | 2540  | 15037 | 11714 | 8923  | 4281  | 4281  | 2242  | 1491  | 549   |
| CO <sub>2</sub>                | mol%   | 0.77  | 5.02  | 20.09 | 0.00  | 66.80 | 66.80 | 99.82 | 34.01 | 21.01 |
| CO                             | mol%   | 0.00  | 11.40 | 0.66  | 0.00  | 2.39  | 2.39  | 0.00  | 1.68  | 14.08 |
| H <sub>2</sub>                 | mol%   | 0.00  | 49.59 | 76.71 | 100.0 | 23.16 | 23.16 | 0.00  | 62.35 | 11.31 |
| N <sub>2</sub>                 | mol%   | 0.54  | 0.09  | 0.12  | 0.00  | 0.39  | 0.39  | 0.00  | 0.19  | 2.50  |
| CH <sub>4</sub>                | mol%   | 94.31 | 1.37  | 1.76  | 0.00  | 5.44  | 5.44  | 0.18  | 1.77  | 36.91 |
| C <sub>2</sub> H <sub>6</sub>  | mol%   | 3.96  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>3</sub> H <sub>8</sub>  | mol%   | 0.39  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| C <sub>4</sub> H <sub>10</sub> | mol%   | 0.03  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  |
| H <sub>2</sub> O               | mol%   | 0.00  | 32.52 | 0.56  | 0.00  | 1.54  | 1.54  | 0.00  | 0.00  | 12.04 |
| Methanol                       | mol%   | 0.00  | 0.00  | 0.10  | 0.00  | 0.27  | 0.27  | 0.00  | 0.00  | 2.08  |
| Ar                             | mol%   | 0.00  | 0.00  | 0.00  | 0.00  | 0.01  | 0.01  | 0.00  | 0.00  | 0.09  |

The specific carbon dioxide emission of the process according to Figure 3 with the material balance according to table 3 is 0.118 kg of CO<sub>2</sub> per standard cubic metre (m<sup>3</sup> (STP)) of hydrogen produced. Compared to the comparative example, this corresponds to a reduction in specific carbon dioxide emission of 15%. In addition, the series arrangement of the reforming units 200 and 201, with regard to the reduction in specific carbon dioxide emission, results in an advantage over the parallel arrangement of the reforming units 200 and 201 according to Figure 2.

### List of reference symbols

|    |     |                                |
|----|-----|--------------------------------|
|    | FG  | feed gas stream                |
|    | SG1 | synthesis gas stream           |
| 5  | SG2 | synthesis gas stream           |
|    | SG3 | synthesis gas stream           |
|    | SG4 | synthesis gas stream           |
|    | HG1 | hydrogen-rich stream           |
|    | HG2 | hydrogen-rich stream           |
| 10 | CG1 | carbon dioxide-rich stream     |
|    | RG1 | residual gas stream            |
|    | RG2 | residual gas stream            |
|    | RG3 | residual gas stream            |
| 15 |     |                                |
|    | 100 | autothermal reforming unit     |
|    | 101 | converter unit                 |
|    | 102 | pressure swing adsorption unit |
|    | 103 | separation unit                |
| 20 | 104 | membrane unit                  |
|    |     |                                |
|    | 200 | endothermic reforming unit     |
|    | 201 | autothermal reforming unit     |
|    | 202 | heat flow                      |
| 25 | 203 | converter unit                 |
|    | 204 | pressure swing adsorption unit |
|    | 205 | separation unit                |
|    | 206 | membrane unit                  |

## Claims

1. Process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the process comprises the following steps:
  - 5 (a) providing a feed gas stream FG, wherein the feed gas stream FG comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;
  - (b) reforming at least a portion of the feed gas stream FG in an endothermic reforming step over a reforming catalyst to give a synthesis gas stream SG1, wherein the synthesis gas stream SG1 comprises hydrogen,  
10 carbon monoxide, carbon dioxide, and unreacted methane;
  - (c) reforming a portion of the feed gas stream FG in an autothermal reforming step to give a synthesis gas stream SG2, and combining the synthesis gas streams SG1 and SG2 to give a synthesis gas stream  
15 SG3, or  
reforming the synthesis gas stream SG1 in an autothermal reforming step to give a synthesis gas stream SG3,  
wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein  
20 the synthesis gas streams SG2 and SG3 comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and wherein  
heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);
  - 25 (d) converting the carbon monoxide present in the synthesis gas stream SG3 with steam to give hydrogen and carbon dioxide to give a synthesis gas stream SG4, wherein the synthesis gas stream SG4 comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);

- 5 (e) separating hydrogen from the synthesis gas stream SG4 by pressure swing adsorption, giving a hydrogen-rich stream HG1 and a residual gas stream RG1, wherein the residual gas stream RG1 comprises carbon dioxide, carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane;
- 10 (e) separating carbon dioxide from the residual gas stream RG1 obtained in step (e) by cryogenic carbon dioxide separation, giving a carbon dioxide-rich stream CG1 and a residual gas stream RG2, wherein the residual gas stream RG2 comprises carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), carbon dioxide not separated off in step (f), and unreacted methane.
- 15 2. Process according to Claim 1, characterized in that hydrogen is separated from the residual gas stream RG2, giving a hydrogen-rich stream HG2 and a residual gas stream RG3.
3. Process according to Claim 2, characterized in that the hydrogen is separated from the residual gas stream RG2 by membrane separation.
- 20 4. Process according to either of Claims 2 and 3, characterized in that the hydrogen-rich stream HG2 is supplied to the synthesis gas stream SG4 for separation of hydrogen by pressure swing adsorption in step (e).
- 25 5. Process according to any of Claims 2 to 4, characterized in that gases present in the hydrogen-rich stream HG2 are utilized as fuel gases for heating in the autothermal reforming step of step c).

6. Process according to any of Claims 1 to 5, characterized in that the carbon dioxide-rich stream CG1 comprises unreacted methane, and the carbon dioxide-rich stream CG1 is subjected to a thermal separation process for separation of methane, giving a carbon dioxide-rich stream CG2.

5

7. Process according to any of Claims 2 to 6, characterized in that carbon dioxide is separated from the residual gas stream RG3, giving a carbon dioxide-rich stream CG3 and a residual gas stream RG4.

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8. Process according to Claim 7, characterized in that the carbon dioxide is separated from the residual gas stream RG3 by membrane separation.

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9. Process according to either of Claims 7 and 8, characterized in that gases present in the residual gas stream RG4 are utilized as fuel gases for heating in the autothermal reforming step of step c).

20

10. Process according to any of Claims 7 to 9, characterized in that the carbon dioxide-rich stream CG3 is supplied to the residual gas stream RG1 for cryogenic carbon dioxide separation in step (f).

25

11. Process according to any of Claims 1 to 10, characterized in that the residual gas stream RG1, for cryogenic carbon dioxide separation in step (f), is subjected to at least one compression step and at least one cooling step, giving the carbon dioxide-rich stream CG1 at least partly in the form of a condensed carbon dioxide stream.

12. Plant configured for performance of the process according to any of Claims 1 to 11.

5 13. Plant for preparation of hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, wherein the plant comprises the following plant components in fluid connection with one another:

(a) means of providing a feed gas stream FG, wherein the feed gas stream FG comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;

10 (b) a first reforming unit, wherein the first reforming unit is configured for reforming at least a portion of the feed gas stream FG in an endothermic reforming step over a reforming catalyst, wherein a synthesis gas stream SG1 is obtainable in the endothermic reforming step, wherein the synthesis gas stream SG1 comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;

15 (c) a second reforming unit, arranged parallel to or downstream of the first reforming unit, wherein

20 - the second reforming unit, in the case of parallel arrangement to the first reforming unit, is configured for reforming of a portion of the feed gas stream FG in an autothermal reforming step, wherein

the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst and

25 a synthesis gas stream SG2 is obtainable in the autothermal reforming step, and

the first and second reforming unit, in the case of parallel arrangement, are configured such that the synthesis gas streams

SG1 and SG2 can be combined to give a synthesis gas stream SG3,

- the second reforming unit, in the case of arrangement downstream of the first reforming unit, is configured for reforming of at least a portion of the synthesis gas stream SG1 in an autothermal reforming step, wherein

the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst, wherein

a synthesis gas stream SG3 is obtainable in the autothermal reforming step, wherein

the synthesis gas streams SG2 and SG3 comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and

the first reforming unit (b) and the second reforming unit (c) are configured such that heat generated in the second reforming unit (c) by the autothermal reforming step is utilizable for heating in the first reforming unit (b);

(d) a converter unit, arranged

- downstream of the first and second reforming unit in the case of parallel arrangement of the first and second reforming unit, or

- arranged downstream of the second reforming unit in the case of arrangement of the second reforming unit downstream of the first reforming unit, wherein

the converter unit is configured for conversion of the carbon monoxide present in the synthesis gas stream SG3 with steam to give carbon dioxide and hydrogen, giving a synthesis gas stream SG3, and

the synthesis gas stream SG3 comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in the converter unit;

5 (e) a pressure swing adsorption unit, arranged downstream of the converter unit, wherein

the pressure swing adsorption unit is configured to separate hydrogen from the synthesis gas stream SG3, wherein a hydrogen-rich stream HG1 and a residual gas stream RG1 are obtainable, wherein the residual gas stream RG1 comprises carbon dioxide, carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, and unreacted methane;

10

(f) a separation unit arranged downstream of the pressure swing adsorption unit, wherein the separation unit is configured for cryogenic separation of carbon dioxide from the residual gas stream RG1 produced in the pressure swing adsorption unit, wherein a carbon dioxide-rich stream CG1 and a residual gas stream RG2 are obtainable, wherein the residual gas stream RG2 comprises carbon monoxide unconverted in the converter unit, hydrogen not separated off in the pressure swing adsorption unit, carbon dioxide not separated off in the separation unit, and unreacted methane.

15

20

## Abstract

The invention relates to a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide. The process comprises one endo-  
5 thermic and one autothermal reforming step for production of a synthesis gas stream, wherein heat generated in the autothermal reforming step is utilized for heating in the endothermic reforming step. The process further comprises a step of converting the synthesis gas stream obtained for enrichment with hydrogen, a step of separating the hydrogen thus prepared by pressure swing adsorption, and a step of separation  
10 of carbon dioxide from the residual gas obtained in the pressure swing adsorption. The reforming units for the endothermal and autothermal reforming steps are arranged parallel to one another or in series.

(Figure 3)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.: Not yet assigned  
Inventors: Sophia SCHMIDT et al.  
Filed: August 11, 2021  
Title: PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND  
SEPARATION OF CARBON DIOXIDE  
TC/A.U.: TBD  
Examiner: TBD  
Docket No.: 2019P00370  
Customer No.: 40582

INFORMATION DISCLOSURE STATEMENT

Commissioner of Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In accordance with the duty of disclosure as set forth in 37 CFR § 1.56, Applicants hereby submit the following information in conformance with 37 CFR §§ 1.97 and 1.98. Pursuant to 37 CFR § 1.98, any non-US patent documents cited on the attached PTO Form 1449 are enclosed. It is respectfully requested that an Examiner-initialed copy of this form be returned to the undersigned.

No fee is due at this time in accordance with 37 CFR § 1.97. However, the Commissioner is hereby authorized to charge any appropriate fees under 37 CFR §§ 1.16, 1.17 and 1.21 that may be required by this paper and to credit any overpayment to Deposit Account No. 01-1375.

Respectfully submitted,

/Elwood L. Haynes/

Date: August 11, 2021

\_\_\_\_\_  
Elwood L. Haynes  
Registration No. 55254

Air Liquide USA LLC  
Intellectual Property Department  
9811 Katy Freeway, Suite 100  
Houston, Texas 77024  
(713) 624-8954 Phone  
(713) 624-8950 Fax

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|                                                                                                                                     |                                  |                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|---------------------------------------------------|
| <b>UTILITY<br/>PATENT APPLICATION<br/>TRANSMITTAL</b><br><br><i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i> | Attorney Docket No.              | 2019P00370                                        |
|                                                                                                                                     | First Named Inventor             | Sophia SCHMIDT                                    |
|                                                                                                                                     | Title                            | Process and Plant for Preparation of Hydrogen ... |
|                                                                                                                                     | Priority Mail Express® Label No. | Via EFS-Web                                       |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>APPLICATION ELEMENTS</b><br><i>See MPEP chapter 600 concerning utility patent application contents.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>ADDRESS TO:</b><br>Commissioner for Patents<br>P.O. Box 1450<br>Alexandria, VA 22313-1450                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 1. <input checked="" type="checkbox"/> <b>Fee Transmittal Form</b><br>(PTO/SB/17 or equivalent)<br>2. <input type="checkbox"/> <b>Applicant asserts small entity status.</b><br>See 37 CFR 1.27<br>3. <input type="checkbox"/> <b>Applicant certifies micro entity status.</b> See 37 CFR 1.29.<br>Applicant must attach form PTO/SB/15A or B or equivalent.<br>4. <input checked="" type="checkbox"/> <b>Specification</b> [Total Pages <u>25</u> ]<br>Both the claims and abstract must start on a new page.<br>(See MPEP § 608.01(a) for information on the preferred arrangement)<br>5. <input checked="" type="checkbox"/> <b>Drawing(s)</b> (35 U.S.C. 113) [Total Sheets <u>3</u> ]<br>6. <b>Inventor's Oath or Declaration</b> [Total Pages _____]<br>(including substitute statements under 37 CFR 1.64 and assignments<br>serving as an oath or declaration under 37 CFR 1.63(e))<br>a. <input type="checkbox"/> Newly executed (original or copy)<br>b. <input type="checkbox"/> A copy from a prior application (37 CFR 1.63(d))<br>7. <input checked="" type="checkbox"/> <b>Application Data Sheet</b> * See note below.<br>See 37 CFR 1.76 (PTO/AIA/14 or equivalent)<br>8. <b>CD-ROM or CD-R</b><br>in duplicate, large table, or Computer Program (Appendix)<br><input type="checkbox"/> Landscape Table on CD<br>9. <b>Nucleotide and/or Amino Acid Sequence Submission</b><br>(if applicable, items a. -- c. are required)<br>a. <input type="checkbox"/> Computer Readable Form (CRF)<br>b. <input type="checkbox"/> Specification Sequence Listing on:<br>i. <input type="checkbox"/> CD-ROM or CD-R (2 copies); or<br>ii. <input type="checkbox"/> Paper<br>c. <input type="checkbox"/> Statements verifying identity of above copies | <b>ACCOMPANYING APPLICATION PAPERS</b><br>10. <input type="checkbox"/> <b>Assignment Papers</b><br>(cover sheet & document(s))<br>Name of Assignee _____<br>11. <input type="checkbox"/> <b>37 CFR 3.73(c) Statement</b> <input type="checkbox"/> <b>Power of Attorney</b><br>(when there is an assignee)<br>12. <input checked="" type="checkbox"/> <b>English Translation Document</b><br>(if applicable)<br>13. <input checked="" type="checkbox"/> <b>Information Disclosure Statement</b><br>(PTO/SB/08 or PTO-1449)<br><input checked="" type="checkbox"/> Copies of citations attached<br>14. <input type="checkbox"/> <b>Preliminary Amendment</b><br>15. <input type="checkbox"/> <b>Return Receipt Postcard</b><br>(MPEP § 503) (Should be specifically itemized)<br>16. <input type="checkbox"/> <b>Certified Copy of Priority Document(s)</b><br>(if foreign priority is claimed)<br>17. <input type="checkbox"/> <b>Nonpublication Request</b><br>Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35<br>or equivalent.<br>18. <input type="checkbox"/> <b>Other:</b> _____<br>_____<br>_____<br>_____ |

\*Note: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 must be included in an Application Data Sheet (ADS).  
 (2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

|                                                                                                                                                        |                    |          |                                   |                 |  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------|-----------------------------------|-----------------|--|
| <b>19. CORRESPONDENCE ADDRESS</b>                                                                                                                      |                    |          |                                   |                 |  |
| <input checked="" type="checkbox"/> The address associated with Customer Number: <u>40582</u> OR <input type="checkbox"/> Correspondence address below |                    |          |                                   |                 |  |
| Name                                                                                                                                                   |                    |          |                                   |                 |  |
| Address                                                                                                                                                |                    |          |                                   |                 |  |
| City                                                                                                                                                   | State              | Zip Code |                                   |                 |  |
| Country                                                                                                                                                | Telephone          | Email    |                                   |                 |  |
| Signature                                                                                                                                              | /Elwood L. Haynes/ |          | Date                              | August 11, 2021 |  |
| Name (Print/Type)                                                                                                                                      | Elwood L. Haynes   |          | Registration No. (Attorney/Agent) | 55254           |  |

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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|                                                                                                                                                                                  |      |                          |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------------------------|-----------------|
| <b>FEE TRANSMITTAL</b>                                                                                                                                                           |      | <b>Complete if known</b> |                 |
|                                                                                                                                                                                  |      | Application Number       |                 |
|                                                                                                                                                                                  |      | Filing Date              | August 11, 2021 |
| <input type="checkbox"/> Applicant asserts small entity status. See 37 CFR 1.27.                                                                                                 |      | First Named Inventor     | Sophia SCHMIDT  |
| <input type="checkbox"/> Applicant certifies micro entity status. See 37 CFR 1.29. Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously. |      | Examiner Name            |                 |
|                                                                                                                                                                                  |      | Art Unit                 |                 |
| TOTAL AMOUNT OF PAYMENT                                                                                                                                                          | (\$) | Practitioner Docket No.  | 2019P00370      |

**METHOD OF PAYMENT** (check all that apply)
☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): \_\_\_\_\_

☒ Deposit Account Deposit Account Number: 01-1375 Deposit Account Name: Air Liquide

For the above-identified deposit account, the Director is hereby authorized to (check all that apply):

☒ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**
☒ Charge any additional fee(s) or underpayment of fee(s) ☐ Credit any overpayment of fee(s) under 37 CFR 1.16 and 1.17
**WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.**FEE CALCULATION****1. BASIC FILING, SEARCH, AND EXAMINATION FEES (U = undiscounted fee; S = small entity fee; M = micro entity fee)**

| Application Type | FILING FEES |        |        | SEARCH FEES |        |        | EXAMINATION FEES |        |        | Fees Paid (\$) |
|------------------|-------------|--------|--------|-------------|--------|--------|------------------|--------|--------|----------------|
|                  | U (\$)      | S (\$) | M (\$) | U (\$)      | S (\$) | M (\$) | U (\$)           | S (\$) | M (\$) |                |
| Utility          | 320         | 160*   | 80     | 700         | 350    | 175    | 800              | 400    | 200    | \$1820         |
| Design           | 220         | 110    | 55     | 160         | 80     | 40     | 640              | 320    | 160    |                |
| Plant            | 220         | 110    | 55     | 440         | 220    | 110    | 660              | 330    | 165    |                |
| Reissue          | 320         | 160    | 80     | 700         | 350    | 175    | 2,320            | 1,160  | 580    |                |
| Provisional      | 300         | 150    | 75     | 0           | 0      | 0      |                  | 0      | 0      |                |

\* The \$150 small entity status filing fee for a utility application is further reduced to \$75 for a small entity status applicant who files the application via EFS-Web.

**2. EXCESS CLAIM FEES**

| Fee Description                                                        | Undiscounted Fee (\$) | Small Entity Fee (\$) | Micro Entity Fee (\$) |
|------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
| Each claim over 20 (including Reissues)                                | 100                   | 50                    | 25                    |
| Each independent claim over 3 (including Reissues)                     | 480                   | 240                   | 120                   |
| Multiple dependent claims                                              | 860                   | 430                   | 215                   |
| <b>Total Claims</b>                                                    |                       |                       |                       |
| 13 - 20 or HP = 0 x 100 = 0                                            |                       |                       |                       |
| HP = highest number of total claims paid for, if greater than 20.      |                       |                       |                       |
| <b>Indep. Claims</b>                                                   |                       |                       |                       |
| 2 - 3 or HP = 0 x 480 = 0                                              |                       |                       |                       |
| HP = highest number of independent claims paid for, if greater than 3. |                       |                       |                       |

**3. APPLICATION SIZE FEE**

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is \$420 (\$210 for small entity) (\$105 for micro entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

| Total Sheets                                                | Extra Sheets | Number of each additional 50 or fraction thereof | Fee (\$) | Fee Paid (\$) |
|-------------------------------------------------------------|--------------|--------------------------------------------------|----------|---------------|
| 3 - 100 = 0 / 50 = 0 (round up to a whole number) x 420 = 0 |              |                                                  |          |               |

**4. OTHER FEE(S)**

Non-English specification, \$140 fee (\$70 for small entity) (\$35 for micro entity)

Non-electronic filing fee under 37 CFR 1.16(t) for a utility application, \$400 fee (\$200 small or micro entity)

Other (e.g., late filing surcharge): Late Declarations 160

|                     |                    |                                         |                          |
|---------------------|--------------------|-----------------------------------------|--------------------------|
| <b>SUBMITTED BY</b> |                    |                                         |                          |
| Signature           | /Elwood L. Haynes/ | Registration No. (Attorney/Agent) 55254 | Telephone (713) 624-8954 |
| Name (Print/Type)   | Elwood L. Haynes   | Date August 11, 2021                    |                          |

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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IPR2025-01173, -01174, Topsoe Ex. 1002

Page 68 of 203

|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------------|------------------------------------------------------------------------|
| <b>INFORMATION DISCLOSURE CITATION</b><br>(USE SEVERAL SHEETS IF NECESSARY)                                                                                                                                                              |          |                                                                                                                                                                                                                                                                |                  | <b>Complete if Known</b> |                                                                        |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  | Application Number       |                                                                        |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  | Filing Date              |                                                                        |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  | First Named Inventor     |                                                                        |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  | Art Unit                 |                                                                        |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  | Examiner Name            |                                                                        |
| Sheet                                                                                                                                                                                                                                    | 1        | of                                                                                                                                                                                                                                                             | 1                | Attorney Docket Number   |                                                                        |
| 2019P00370                                                                                                                                                                                                                               |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
| <b>U.S. PATENT DOCUMENTS</b>                                                                                                                                                                                                             |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Document Number                                                                                                                                                                                                                                                | Publication Date | Name                     | Pages Column, Lines Where Relevant Passages or Relevant Figures Appear |
|                                                                                                                                                                                                                                          | A1       | US 2015 0141535                                                                                                                                                                                                                                                | 2015-05-21       | KRESNYAK                 |                                                                        |
|                                                                                                                                                                                                                                          | A2       | US 2015 0321914                                                                                                                                                                                                                                                | 2015-11-12       | DARDE et al.             |                                                                        |
| <b>FOREIGN PATENT DOCUMENTS</b>                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Document Number                                                                                                                                                                                                                                                | Publication Date | Name                     | Pages Column, Lines Where Relevant Passages or Relevant Figures Appear |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
| <b>NON PATENT LITERATURE DOCUMENTS</b>                                                                                                                                                                                                   |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published |                  |                          |                                                                        |
|                                                                                                                                                                                                                                          | C1       | AASBERG-PETERSEN, K. et al., Natural gas to synthesis gas – catalysts and catalytic processes, Journal of Natural Gas Science and Engineering, Elsevier, Amsterdam, NL, Vol. 3, No. 2, March 28, 2011                                                          |                  |                          |                                                                        |
|                                                                                                                                                                                                                                          | C2       | WISMANN, S.T. et al. Electrified methane reforming: a compact approach to greener industrial hydrogen production, Science 364, 2019, 756-759                                                                                                                   |                  |                          |                                                                        |
|                                                                                                                                                                                                                                          | C3       | European Search Report for corresponding EP 20020366, January 18, 2021                                                                                                                                                                                         |                  |                          |                                                                        |
| Examiner                                                                                                                                                                                                                                 |          |                                                                                                                                                                                                                                                                | Date Considered  |                          |                                                                        |
| EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. |          |                                                                                                                                                                                                                                                                |                  |                          |                                                                        |

| Electronic Patent Application Fee Transmittal |          |                                                                                |        |                      |
|-----------------------------------------------|----------|--------------------------------------------------------------------------------|--------|----------------------|
| Application Number:                           |          |                                                                                |        |                      |
| Filing Date:                                  |          |                                                                                |        |                      |
| Title of Invention:                           |          | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |        |                      |
| First Named Inventor/Applicant Name:          |          | Sophia SCHMIDT                                                                 |        |                      |
| Filer:                                        |          | Elwood L. Haynes/Diana Guzman                                                  |        |                      |
| Attorney Docket Number:                       |          | 2019P00370                                                                     |        |                      |
| Filed as Large Entity                         |          |                                                                                |        |                      |
| Filing Fees for   Utility under 35 USC 111(a) |          |                                                                                |        |                      |
| Description                                   | Fee Code | Quantity                                                                       | Amount | Sub-Total in USD(\$) |
| Basic Filing:                                 |          |                                                                                |        |                      |
| UTILITY APPLICATION FILING                    | 1011     | 1                                                                              | 320    | 320                  |
| UTILITY SEARCH FEE                            | 1111     | 1                                                                              | 700    | 700                  |
| UTILITY EXAMINATION FEE                       | 1311     | 1                                                                              | 800    | 800                  |
| Pages:                                        |          |                                                                                |        |                      |
| Claims:                                       |          |                                                                                |        |                      |
| Miscellaneous-Filing:                         |          |                                                                                |        |                      |
| LATE FILING FEE FOR OATH OR DECLARATION       | 1051     | 1                                                                              | 160    | 160                  |
| Petition:                                     |          |                                                                                |        |                      |
| IPR2025-01173, -01174, Topsoe Ex. 1002        |          |                                                                                |        |                      |

| Description                       | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|-----------------------------------|----------|----------|--------|----------------------|
| Patent-Appeals-and-Interference:  |          |          |        |                      |
| Post-Allowance-and-Post-Issuance: |          |          |        |                      |
| Extension-of-Time:                |          |          |        |                      |
| Miscellaneous:                    |          |          |        |                      |
| Total in USD (\$)                 |          |          |        | 1980                 |

## Electronic Acknowledgement Receipt

|                                             |                                                                                |
|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 43480673                                                                       |
| <b>Application Number:</b>                  | 17399277                                                                       |
| <b>International Application Number:</b>    |                                                                                |
| <b>Confirmation Number:</b>                 | 2532                                                                           |
| <b>Title of Invention:</b>                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
| <b>First Named Inventor/Applicant Name:</b> | Sophia SCHMIDT                                                                 |
| <b>Customer Number:</b>                     | 40582                                                                          |
| <b>Filer:</b>                               | Elwood L. Haynes/Diana Guzman                                                  |
| <b>Filer Authorized By:</b>                 | Elwood L. Haynes                                                               |
| <b>Attorney Docket Number:</b>              | 2019P00370                                                                     |
| <b>Receipt Date:</b>                        | 11-AUG-2021                                                                    |
| <b>Filing Date:</b>                         |                                                                                |
| <b>Time Stamp:</b>                          | 12:06:43                                                                       |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                                    |

### Payment information:

|                                          |                  |
|------------------------------------------|------------------|
| Submitted with Payment                   | yes              |
| Payment Type                             | DA               |
| Payment was successfully received in RAM | \$ 1980          |
| RAM confirmation Number                  | E20218AC07074731 |
| Deposit Account                          | 011375           |
| Authorized User                          | Diana Guzman     |

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

IPR2025-01173, -01174, Topsoe Ex. 1002

37 CFR 1.19 (Document supply fees)  
37 CFR 1.21 (Miscellaneous fees and charges)

# File Listing:

| Document Number | Document Description                                | File Name                                             | File Size(Bytes)/<br>Message Digest      | Multi Part /.zip | Pages (if appl.) |
|-----------------|-----------------------------------------------------|-------------------------------------------------------|------------------------------------------|------------------|------------------|
| 1               |                                                     | 2019P00370_US_2021-08-11_APPLICATION_as_filed_ELH.pdf | 7431113                                  | yes              | 112              |
|                 |                                                     |                                                       | 857238452ec34228e59e399d7cc75d49a2c4efbc |                  |                  |
|                 | Multipart Description/PDF files in .zip description |                                                       |                                          |                  |                  |
|                 | Document Description                                |                                                       | Start                                    | End              |                  |
|                 | Transmittal of New Application                      |                                                       | 1                                        | 1                |                  |
|                 | Fee Worksheet (SB06)                                |                                                       | 2                                        | 2                |                  |
|                 | Application Data Sheet                              |                                                       | 3                                        | 9                |                  |
|                 | Specification                                       |                                                       | 10                                       | 28               |                  |
|                 | Claims                                              |                                                       | 29                                       | 33               |                  |
|                 | Abstract                                            |                                                       | 34                                       | 34               |                  |
|                 | Drawings-only black and white line drawings         |                                                       | 35                                       | 37               |                  |
|                 | Translation of Foreign Priority Documents           |                                                       | 38                                       | 67               |                  |
|                 | Transmittal Letter                                  |                                                       | 68                                       | 68               |                  |
|                 | Information Disclosure Statement (IDS) Form (SB08)  |                                                       | 69                                       | 69               |                  |
|                 | Non Patent Literature                               |                                                       | 70                                       | 106              |                  |
|                 | Non Patent Literature                               |                                                       | 107                                      | 110              |                  |
|                 | Other Reference-Patent/App/Search documents         |                                                       | 111                                      | 112              |                  |
| Warnings:       |                                                     |                                                       |                                          |                  |                  |
| Information:    |                                                     |                                                       |                                          |                  |                  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                      |              |                                                                           |    |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------|---------------------------------------------------------------------------|----|---|
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Fee Worksheet (SB06) | fee-info.pdf | <div>46776</div> <div>0f34de261f51ee78e96506819d8ce3e8bde<br/>e904b</div> | no | 2 |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                      |              |                                                                           |    |   |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                      |              |                                                                           |    |   |
| <b>Total Files Size (in bytes):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                      |              | 7477889                                                                   |    |   |
| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> <b>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</b></p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> <b>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</b></p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> <b>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</b></p> |                      |              |                                                                           |    |   |



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
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www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 17/399,277         | 08/11/2021            | Sophia SCHMIDT        | 2019P00370             |

**CONFIRMATION NO. 2532**

**INFORMAL NOTICE**



40582  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

Date Mailed: 08/24/2021

**INFORMATIONAL NOTICE TO APPLICANT**

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):  
Sophia SCHMIDT  
Teja SCHMID McGUINESS

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at (571) 272-4000 or (571) 272-4200 or 1-888-786-0101.

/cnguyen/

| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                               |                                    |               |                    |                    | Application or Docket Number<br>17/399,277 |                    |                               |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------------|--------------------|--------------------|--------------------------------------------|--------------------|-------------------------------|--|
| <b>APPLICATION AS FILED - PART I</b>                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                    |               |                    |                    |                                            |                    |                               |  |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                               | (Column 2)                         |               | SMALL ENTITY       |                    | OR<br>OTHER THAN SMALL ENTITY              |                    |                               |  |
| FOR                                                                                                                                                                                                                                                                                                                                                                                                        | NUMBER FILED                                                                                                                                                                                                                  | NUMBER EXTRA                       | RATE(\$)      | FEE(\$)            |                    | RATE(\$)                                   | FEE(\$)            |                               |  |
| BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                                                                                                                                                                                                                                                                                                                                 | N/A                                                                                                                                                                                                                           | N/A                                | N/A           |                    |                    | N/A                                        | 320                |                               |  |
| SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                                                                                                                                                                                                                                                                                                                                | N/A                                                                                                                                                                                                                           | N/A                                | N/A           |                    |                    | N/A                                        | 700                |                               |  |
| EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                                                                                                                                                                                                                                                                                                                           | N/A                                                                                                                                                                                                                           | N/A                                | N/A           |                    |                    | N/A                                        | 800                |                               |  |
| TOTAL CLAIMS<br>(37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                                                           | 13                                                                                                                                                                                                                            | minus 20 = *                       |               |                    | OR                 | x 100 =                                    | 0.00               |                               |  |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                                                                                                                                                                                                                                                                                                     | 2                                                                                                                                                                                                                             | minus 3 = *                        |               |                    |                    | x 480 =                                    | 0.00               |                               |  |
| APPLICATION SIZE FEE<br>(37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                   | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                    |               |                    |                    |                                            | 0.00               |                               |  |
| MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                               |                                    |               |                    |                    |                                            | 0.00               |                               |  |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                               |                                    |               | TOTAL              |                    | TOTAL                                      | 1820               |                               |  |
| <b>APPLICATION AS AMENDED - PART II</b>                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                               |                                    |               |                    |                    |                                            |                    |                               |  |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                               | (Column 2)                         |               | (Column 3)         |                    | SMALL ENTITY                               |                    | OR<br>OTHER THAN SMALL ENTITY |  |
| AMENDMENT A                                                                                                                                                                                                                                                                                                                                                                                                | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE(\$)           | ADDITIONAL FEE(\$) |                                            | RATE(\$)           | ADDITIONAL FEE(\$)            |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Total<br>(37 CFR 1.16(i))                                                                                                                                                                                                     | *                                  | Minus **      | =                  |                    | OR                                         | x                  | =                             |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Independent<br>(37 CFR 1.16(h))                                                                                                                                                                                               | *                                  | Minus ***     | =                  |                    | OR                                         | x                  | =                             |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                         |                                    |               |                    |                    | OR                                         |                    |                               |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                               |                                    |               |                    |                    | OR                                         |                    |                               |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               |                                    |               | TOTAL<br>ADD'L FEE |                    | OR                                         | TOTAL<br>ADD'L FEE |                               |  |
| AMENDMENT B                                                                                                                                                                                                                                                                                                                                                                                                | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE(\$)           | ADDITIONAL FEE(\$) |                                            | RATE(\$)           | ADDITIONAL FEE(\$)            |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Total<br>(37 CFR 1.16(i))                                                                                                                                                                                                     | *                                  | Minus **      | =                  |                    | OR                                         | x                  | =                             |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Independent<br>(37 CFR 1.16(h))                                                                                                                                                                                               | *                                  | Minus ***     | =                  |                    | OR                                         | x                  | =                             |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                         |                                    |               |                    |                    | OR                                         |                    |                               |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                               |                                    |               |                    |                    | OR                                         |                    |                               |  |
|                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               |                                    |               | TOTAL<br>ADD'L FEE |                    | OR                                         | TOTAL<br>ADD'L FEE |                               |  |
| * If the entry in column 1 is less than the entry in column 2, write "0" in column 3.<br>** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".<br>*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".<br>The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1. |                                                                                                                                                                                                                               |                                    |               |                    |                    |                                            |                    |                               |  |



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| APPLICATION<br>NUMBER | FILING or<br>371(c) DATE | GRP ART<br>UNIT | FIL FEE REC'D | ATTY. DOCKET NO | TOT CLAIMS | IND CLAIMS |
|-----------------------|--------------------------|-----------------|---------------|-----------------|------------|------------|
| 17/399,277            | 08/11/2021               | 1736            | 1980          | 2019P00370      | 13         | 2          |

**CONFIRMATION NO. 2532**

## FILING RECEIPT



0000000127839649

40582  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

Date Mailed: 08/24/2021

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

**Please verify the accuracy of the data presented on this receipt.** If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

### Inventor(s)

Sophia SCHMIDT, Frankfurt am Main, GERMANY;  
Teja SCHMID McGUINNESS, Frankfurt am Main, GERMANY;

### Applicant(s)

L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude,  
Paris, FRANCE;

**Power of Attorney:** None

### Domestic Applications for which benefit is claimed - None.

*A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.*

**Foreign Applications** (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.)

EUROPEAN PATENT OFFICE (EPO) 20020366.9 08/11/2020 Access Code Provided

**Permission to Access Application via Priority Document Exchange:** Yes

**Permission to Access Search Results:** Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

**If Required, Foreign Filing License Granted:** 08/19/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/399,277**

**Projected Publication Date:** 02/17/2022

**Non-Publication Request:** No

**Early Publication Request:** No

**Title**

PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE

**Preliminary Class**

423

**Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:** No

## **PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative,

page 2 of 4

this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

**LICENSE FOR FOREIGN FILING UNDER**  
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**Title 37, Code of Federal Regulations, 5.11 & 5.15**

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

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No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

---

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.: 17/399,277  
Filing Date: August 11, 2021  
Inventors: Sophia SCHMIDT et al.  
Title: Process and Plant Preparation of Hydrogen and Separation of Carbon Dioxide  
TC/A.U.: 1736  
Examiner: To be assigned  
Docket No.: 2019P00370  
Customer No.: 40582

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

TRANSMITTAL OF DECLARATIONS

Dear Sir:

Submitted herewith are the Declarations in connection with the above-identified application.

No fee is due at this time because the Commissioner has already charged the \$160.00 37 CFR 1.16(f) fee to Deposit Account No. 01-1375 on August 11, 2021. The Commissioner is hereby authorized to charge any additional fees, which may be required in connection with this paper, or credit any overpayment to Deposit Account No. 01-1375.

Respectfully submitted,

/Elwood L. Haynes/

Date: September 13, 2021

Elwood L. Haynes, Reg. No. 55254

Air Liquide USA LLC  
9811 Katy Freeway, Suite 100  
Houston, Texas 77024  
Phone (713) 624-8954  
(713) 624-8950 Fax

Certificate of EFS-Web Transmission

I hereby certify that this correspondence is being transmitted via the U.S. Patent and Trademark Office Electronic Filing System (EFS-Web) to the USPTO on September 13, 2021.

Name: Neva M. Dare      Signature: /Neva M. Dare/

# DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

|                    |                                                                            |
|--------------------|----------------------------------------------------------------------------|
| Title of Invention | PROCESS AND PLANT PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
|--------------------|----------------------------------------------------------------------------|

As the below named inventor, I hereby declare that:

This declaration is directed to: ☐ The attached application, or ☒ United States application or PCT international application number 17/399,277 filed on August 11, 2021.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

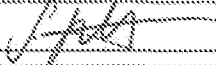
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

**WARNING:**

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

**LEGAL NAME OF INVENTOR**

Inventor: Sophia SCHMIDT Date (Optional): 31.08.21

Signature: 

Note: An application data sheet (PTO/IAA/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/IB/IAI01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN  
APPLICATION DATA SHEET (37 CFR 1.76)****Title of  
Invention**PROCESS AND PLANT PREPARATION OF HYDROGEN AND SEPARATION OF  
CARBON DIOXIDE

As the below named inventor, I hereby declare that:

This declaration  
is directed to:

The attached application, or

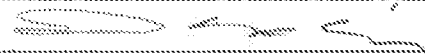
United States application or PCT international application number 17/399,277filed on August 11, 2021.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001  
by fine or imprisonment of not more than five (5) years, or both.**WARNING:**

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

**LEGAL NAME OF INVENTOR**Inventor: Teja SCHMID McGUINNESSDate (Optional): 2021-08-13Signature: 

Note: An application data sheet (PTO/AIA/14 or equivalent), including naming the entire inventive entity, must accompany this form.  
Use an additional PTO/SB/AIA01 form for each additional inventor.

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## Electronic Acknowledgement Receipt

|                                             |                                                                                |
|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 43743633                                                                       |
| <b>Application Number:</b>                  | 17399277                                                                       |
| <b>International Application Number:</b>    |                                                                                |
| <b>Confirmation Number:</b>                 | 2532                                                                           |
| <b>Title of Invention:</b>                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
| <b>First Named Inventor/Applicant Name:</b> | Sophia SCHMIDT                                                                 |
| <b>Customer Number:</b>                     | 40582                                                                          |
| <b>Filer:</b>                               | Elwood L. Haynes/Neva Dare                                                     |
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| <b>Attorney Docket Number:</b>              | 2019P00370                                                                     |
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### File Listing:

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|-----------------|----------------------|------------------------------------------------|---------------------------------------------------|------------------|------------------|
| 1               | Transmittal Letter   | 2019P00370_US_Transmittal_of_Declarations_.pdf | 72175<br>c47e958bd107e7aee9af506f5c892c4ade7aed89 | no               | 1                |

### Warnings:

IPR2025-01173, -01174, Topsoe Ex. 1002

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| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                           |                                               |                                              |        |   |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                           |                                               | 7150795daecb415e898247c3171dd08d29<br>1ac5ac |        |   |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                           |                                               |                                              |        |   |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                           |                                               |                                              |        |   |
| <b>Total Files Size (in bytes):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                           |                                               |                                              | 368631 |   |
| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> <b>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</b></p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> <b>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</b></p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> <b>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</b></p> |                           |                                               |                                              |        |   |

## Bescheinigung

Die angehefteten  
Unterlagen stimmen mit der  
als ursprünglich eingereicht  
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## Certificate

The attached documents are  
exact copies of the text in  
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## Attestation

Les documents joints à la  
présente attestation sont  
conformes au texte,  
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initialement déposé, de la  
demande de brevet  
européen qui est spécifiée à  
la page suivante.

**Patentanmeldung Nr.**

**Patent application No.**

**Demande de brevet n°**

20020366.9 / EP20020366

The organisation code and number of your priority application, to be used for filing abroad under the Paris Convention, is EP20020366.

Der Präsident des Europäischen Patentamts;  
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets  
p.o.



V. Joseph

IPR2025-01173, -01174, Topsoe Ex. 1002

Anmeldung Nr:  
Application no.: 20020366.9  
Demande no. :

Anmeldetag:  
Date of filing: 11.08.20  
Date de dépôt :

Anmelder / Applicant(s) / Demandeur(s):

L'AIR LIQUIDE, SOCIÉTÉ ANONYME POUR L'ÉTUDE ET  
L'EXPLOITATION DES PROCÉDÉS GEORGES CLAUDE  
75, quai d'Orsay  
75007 Paris/FR

Bezeichnung der Erfindung / Title of the invention / Titre de l'invention:

(Falls die Bezeichnung der Erfindung nicht angegeben ist, oder falls die Anmeldung in einer Nicht-Amtssprache des EPA eingereicht wurde, siehe Beschreibung bezüglich ursprünglicher Bezeichnung.

If no title is shown, or if the application has been filed in a non-EPO language, please refer to the description for the original title.

Si aucun titre n'est indiqué, ou si la demande a été déposée dans une langue autre qu'une langue officielle de l'OEB, se référer à la description pour le titre original.)

Verfahren und Anlage zur Herstellung von Wasserstoff und Abscheidung von Kohlendioxid

In Anspruch genommene Priorität(en) / Priority(Priorities) claimed / Priorité(s) revendiquée(s)  
Staat/Tag/Aktenzeichen / State/Date/File no. / Pays/Date/Numéro de dépôt:

Am Anmeldetag benannte Vertragsstaaten / Contracting States designated at date of filing / Etats contractants désignés lors du dépôt:

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11. August 2020 / StefSta

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AIR LIQUIDE-Aktenzeichen: 2019P00370 EP

10                    **Verfahren und Anlage zur Herstellung von Wasserstoff und Abscheidung von Kohlendioxid**

**Gebiet der Erfindung**

15    Die Erfindung betrifft ein Verfahren zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf und zur Abscheidung von Kohlendioxid. Die Erfindung betrifft ferner eine Anlage zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf und zur Abscheidung von Kohlendioxid.

20    **Stand der Technik**

Die global produzierte Wasserstoffmenge wird heute auf 70 Mt pro Jahr geschätzt, wobei der größte Teil davon durch endotherme Reformierung von Erdgas mit Dampf an einem Reformierungskatalysator auf Nickelbasis erzeugt wird. Bei diesem als Dampfreformierung (*steam methane reforming* – SMR) bezeichneten Prozess reagiert hauptsächlich Methan und Wasserdampf zu einem Gemisch aus hauptsächlich Wasserstoff, Kohlenmonoxid und Kohlendioxid. Der Dampfreformierungsprozess weist einen großen Kohlendioxidfußabdruck auf, da für jede Tonne produzierten Wasserstoffs circa 9 Tonnen Kohlendioxid emittiert werden. Berechnungen zufolge trägt die Dampfreformierung von Erdgas alleine mit einem Anteil von 1,5 % zu den  
25  
30 global verursachten Kohlendioxidemissionen bei (Wisman et al., Science 364, 756-759, 2019).

Wasserstoff wird auch durch autotherme Reformierung (*autothermal reforming* – ATR) von Erdgas hergestellt. Von der Dampfreformierung unterscheidet sich die autotherme Reformierung dadurch, dass dem endothermen Reformierungsschritt ein exothermer partieller Oxidationsschritt vorangeht, welcher die für den nachfolgenden endothermen, katalytischen Schritt nötige Reaktionswärme liefert. Für die partielle Oxidation wird in der Regel Luft oder Sauerstoff, beispielsweise aus einer Luftzerlegungsanlage, als Oxidationsmedium verwendet. Ferner erfordert die ATR einen Brenner, welcher mit Hilfe eines Brenngases die erforderliche Aktivierungsenergie für die partielle Oxidation zur Verfügung stellt. Das Resultat dieser beiden Reaktionsschritte, der partiellen Oxidation von Methan und der anschließenden endothermen katalytischen Reformierung des Zwischenprodukts mit Dampf, ist ebenfalls ein hauptsächlich Wasserstoff, Kohlenmonoxid und Kohlendioxid aufweisendes Synthesegas.

Um die genannten Prozesse umweltfreundlicher zu gestalten, wurden in der Vergangenheit Verfahren entwickelt, um das bei der SMR oder ATR erzeugte Kohlendioxid als möglichst reines Kohlendioxidprodukt aus dem primär erzeugten Synthesegasgemisch abzutrennen. Dafür stehen Gaswäscheverfahren auf Basis von physikalischer oder chemischer Absorption in Absorptionsmitteln wie Methanol oder Aminen, sowie die tiefkalte flüssige Abscheidung und Reinigung des Kohlendioxids durch Kompression, Kondensation und Destillation zur Verfügung. Das in großen Mengen in Absorptionsmitteln absorbierte und anschließend wieder desorbierte oder bei niedrigen Temperaturen durch Kondensation abgeschiedene Kohlendioxid kann jedoch häufig keiner sinnvollen weiteren industriellen Verwendung zugeführt werden. Häufig bleibt daher nur die Möglichkeit, das nicht verwendbare Kohlendioxid langfristig zu speichern, um es nicht in die Atmosphäre gelangen zu lassen. Die Kombination aus Abscheidung (durch Gaswäsche oder Kondensation) und Speicherung von Kohlendioxid wird auch als Sequestrierung oder CCS (*carbon capture and storage*) bezeichnet.

Es ist daher erforderlich bekannte Prozesse zur Herstellung von Wasserstoff dergestalt zu verbessern, dass von vorneherein geringere Mengen an Kohlendioxid pro Tonne produzierten Wasserstoffs generiert werden.

US 2015/0321914 A1 offenbart ein Verfahren, in dem ein primär durch Dampfreformierung oder autotherme Reformierung erzeugtes Synthesegas durch Konvertierung des im primär erzeugten Synthesegas enthaltenen Kohlenmonoxid mit Dampf zu Kohlendioxid und Wasserstoff umgesetzt wird (Wassergas-Shift-Reaktion). Aus dem mit Kohlendioxid und Wasserstoff angereicherten konvertierten Synthesegas wird anschließend mit Hilfe einer Druckwechseladsorptionseinheit Wasserstoff abgetrennt. Das an Wasserstoff verarmte, jedoch noch kohlendioxidreiche Restgas wird anschließend in einer als kryogene Reinigungseinheit (*cryogenic purification unit* – CPU) bezeichneten Vorrichtung behandelt, um Kohlendioxid in möglichst reiner Form aus dem Restgas abzuscheiden und zu verflüssigen. Das verflüssigte Kohlendioxid kann anschließend einer Lagerung zugeführt oder für Industrie- oder Verbrauchszwecke verwendet werden.

## Beschreibung der Erfindung

Allgemein ist es eine Aufgabe der vorliegenden Erfindung, die vorgenannten Nachteile des Standes der Technik zu überwinden.

5

Insbesondere besteht eine Aufgabe der vorliegenden Erfindung darin, bekannte Verfahren so zu modifizieren, dass die pro Gewichtseinheit produzierten Wasserstoffs gebildete Menge Kohlendioxid reduziert wird.

- 10      Insbesondere besteht eine Aufgabe der vorliegenden Erfindung darin, die Kohlendioxidemissionen von Verfahren zu reduzieren, welche autotherme Reformierung von Methan mit tiefkalter Kohlendioxidabscheidung kombinieren.

- 15      Ein Beitrag zur mindestens teilweisen Erfüllung mindestens einer der obigen Aufgaben wird durch die unabhängigen Ansprüche geleistet. Die abhängigen Ansprüche stellen bevorzugte Ausführungsformen bereit, die zur mindestens teilweisen Erfüllung mindestens einer der Aufgaben beitragen. Bevorzugte Ausgestaltungen von Bestandteilen einer erfindungsgemäßen Kategorie sind, soweit zutreffend, ebenso bevorzugt für gleichnamige oder entsprechende Bestandteile einer jeweils anderen erfindungsgemäßen Kategorie.
- 20

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25

Die Aufgaben der Erfindung werden zumindest teilweise gelöst durch ein Verfahren zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf, sowie zur Abscheidung von Kohlendioxid, wobei das Verfahren die folgenden Schritte umfasst:

- 30            (a) Bereitstellen eines Einsatzgasstroms FG, wobei der Einsatzgasstrom FG eine Kohlenwasserstoffkomponente und Dampf umfasst, wobei die Kohlenwasserstoffkomponente zumindest Methan umfasst;

- 5 (b) Reformieren zumindest eines Teils des Einsatzgasstroms FG in einem endothermen Reformierungsschritt an einem Reformierungskatalysator zu einem Synthesegasstrom SG1, wobei der Synthesegasstrom SG1 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthält;
- 10 (c) Reformieren eines Teils des Einsatzgasstroms FG in einem autothermen Reformierungsschritt zu einem Synthesegasstrom SG2 und Zusammenführen der Synthesegasströme SG1 und SG2 zu einem Synthesegasstrom SG3, oder
- 15 Reformieren des Synthesegasstroms SG1 in einem autothermen Reformierungsschritt zu einem Synthesegasstrom SG3, wobei der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst, wobei
- 20 die Synthesegasströme SG2 und SG3 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthalten, und wobei durch den autothermen Reformierungsschritt erzeugte Wärme zum Heizen im endothermen Reformierungsschritt gemäß Schritt (b) genutzt wird;
- 25 (d) Konvertieren des im Synthesegasstrom SG3 enthaltenen Kohlenmonoxid mit Dampf zu Wasserstoff und Kohlendioxid zu einem Synthesegasstrom SG4, wobei der Synthesegasstrom SG4 Wasserstoff, Kohlendioxid, nicht reagiertes Methan sowie in Schritt (d) nicht konvertiertes Kohlenmonoxid enthält;
- 30 (e) Abtrennen von Wasserstoff aus dem Synthesegasstrom SG4 durch Druckwechseladsorption, wobei ein wasserstoffreicher Strom HG1 sowie ein Restgasstrom RG1 erhalten werden, wobei der Restgasstrom RG1 Kohlendioxid, in Schritt (d) nicht konvertiertes Kohlenmonoxid, in Schritt (e) nicht abgetrennten Wasserstoff sowie nicht reagiertes Methan enthält;
- (f) Abtrennen von Kohlendioxid aus dem in Schritt (e) erzeugten Restgasstrom RG1 durch tiefkalte Kohlendioxid-Abscheidung, wobei ein kohlendioxidreicher Strom CG1 sowie ein Restgasstrom RG2 erhalten werden, wobei der Restgasstrom RG2 in Schritt (d) nicht konvertiertes

Kohlenmonoxid, in Schritt (e) nicht abgetrennten Wasserstoff, in Schritt (f) nicht abgetrenntes Kohlendioxid sowie nicht reagiertes Methan enthält.

5 Gegenüber aus dem Stand der Technik bekannten Verfahren zeichnet sich das erfindungsgemäße Verfahren dadurch aus, dass gemäß den Schritten (b) und (c) eine Kombination aus endothermem und autothermem Reformierungsschritt zum Einsatz kommt, und durch den autothermen Reformierungsschritt erzeugte Wärme zum Heizen im endothermen Reformierungsschritt gemäß Schritt (b) genutzt wird. Der autotherme Reformierungsschritt wird in einer autothermen Reformierungseinheit (autothermer Reformier) durchgeführt. Der endotherme Reformierungsschritt wird in einer endothermen Reformierungseinheit durchgeführt (endothermer Reformier, beispielsweise Dampfreformier). Dadurch werden die spezifischen Kohlendioxidemissionen im Hinblick auf den Gesamtprozess überraschenderweise signifikant gesenkt. Unter „spezifischen Kohlendioxidemissionen“ wird die Masse an gebildetem CO<sub>2</sub> verstanden, die pro Normkubikmeter produziertem Wasserstoff über den Gesamtprozess gebildet wird. Die spezifischen Kohlendioxidemissionen können beispielsweise in kg CO<sub>2</sub> / Nm<sup>3</sup> Wasserstoff angegeben werden.

10 Im endothermen Reformierungsschritt gemäß Schritt (b) wird das Einsatzgas FG durch Zufuhr von Wärme an einem geeigneten Katalysator zum Synthesegas SG1 umgesetzt. Bei dem Katalysator handelt es sich beispielsweise um einen dem Fachmann bekannten Nickel-Katalysator. Die für den endothermen Reformierungsschritt zum Ablauf der Reformierungsreaktion erforderliche Wärme wird zumindest teilweise, vorzugsweise vollständig durch im autothermen Reformierungsschritt gebildete Wärme geliefert. Je nach Anordnung der Reformierungseinheiten wird das Einsatzgas FG teilweise oder vollständig in die Reformierungseinheit des endothermen Reformierungsschritts eingeschleust und zum Synthesegas SG1 umgesetzt.

25 Der autotherme Reformierungsschritt gemäß Schritt (c) umfasst einen Schritt einer partiellen Oxidation des Einsatzgasstroms FG und einen nachfolgenden endothermen Reformierungsschritt mit Dampf zur Umsetzung des Einsatzgasstroms FG zum Synthesegasstrom SG2 oder zum Synthesegasstrom SG3. Der Schritt der partiellen Oxidation des autothermen Reformierungsschritts erfordert die Zufuhr eines Oxidationsmittels wie Luft, reinen Sauerstoff oder mit Sauerstoff angereicherter Luft. Das

Oxidationsmittel wird üblicherweise über einen Brenner in den autothermen Reform-  
er eingeschleust. Die partielle Oxidation des Einsatzgasstroms FG zum Syntheseg-  
asstrom SG2 oder zum Synthesegasstrom SG3 im Rahmen des autothermen Re-  
formierungsschritts ist eine exotherme Reaktion. Die dadurch erzeugte Abwärme  
5 wird für den „endothermen Teil“ des autothermen Reformierungsschritts genutzt. Der  
autotherme Reformierungsschritt ist so ausgelegt, dass in Summe, über beide Re-  
aktionsstufen (partielle Oxidation und endotherme Reformierung) genügend Wärme  
erzeugt wird, welche zum Beheizen des endothermen Reformierungsschritts zur Um-  
setzung des Einsatzgases FG zum Synthesegas SG1 nutzbar ist.

- 10 Das erfindungsgemäße Verfahren beinhaltet zwei durch Schritt (c) definierte Alter-  
nativen.

Gemäß der ersten Alternative wird ein Teil des Einsatzgasstroms FG im endother-  
men Reformierungsschritt zum Synthesegasstrom SG1 reformiert. Ein weiterer Teil  
des Einsatzgasstroms FG, vorzugsweise der verbleibende Teil des Einsatz-  
15 gasstroms FG, wird im autothermen Reformierungsschritt zum Synthesegasstrom  
SG2 reformiert. Die Synthesegasströme SG2 und SG3 werden anschließend zu ei-  
nem Synthesegasstrom SG3 kombiniert. Daraus ergibt sich eine parallele Anordnung  
oder Verschaltung der Reformierungseinheiten für den endothermen Reformierungs-  
schritt und für den autothermen Reformierungsschritt.

- 20 Gemäß der zweiten Alternative des erfindungsgemäßen Verfahrens wird das Ein-  
satzgas FG vollständig in die Reformierungseinheit des endothermen Reformie-  
rungsschritt eingeschleust und zum Synthesegasstrom SG1 umgesetzt. Dabei wird  
das Einsatzgas FG nur teilweise zum Synthesegas SG1 umgesetzt, das heißt es  
verbleibt ein vergleichsweise hoher Anteil an Methan und gegebenenfalls anderen  
25 reformierbaren Kohlenwasserstoffkomponenten im Synthesegas SG1. Diese verblei-  
bende Menge wird anschließend im autothermen Reformierungsschritt zum Synthe-  
segas SG3 reformiert. Daraus ergibt sich eine serielle Anordnung oder Verschaltung  
der Reformierungseinheiten für den endothermen Reformierungsschritt und für den  
autothermen Reformierungsschritt, wobei der autotherme Reformierungsschritt auf  
30 den endothermen Reformierungsschritt folgt. Mit anderen Worten, die Reformie-

rungseinheit für den autothermen Reformierungsschritt ist in Gasflussrichtung strom-  
abwärts zur Reformierungseinheit für den endothermen Reformierungsschritt ange-  
ordnet.

Vorzugsweise wird der im autothermen Reformierungsschritt erzeugte Synthese-  
gasstrom, das heißt der Synthesegasstrom SG2 bei paralleler Anordnung der Refor-  
mierungseinheiten oder der Synthesegasstrom SG3 bei serieller Anordnung der Re-  
formierungseinheiten, direkt für die Übertragung von Wärme im endothermen Refor-  
mierungsschritt genutzt. Der Synthesegasstrom SG2 und/oder der Synthese-  
gasstrom SG3 weisen dabei vorzugsweise eine Temperatur von 750 bis 1100 °C auf.

Der Einsatzgasstrom FG weist zumindest eine Kohlenwasserstoffkomponente auf,  
die mit Wasserdampf, zu einem Synthesegas SG1, SG2, SG3 oder SG4 reformierbar  
ist. Das Synthesegas weist zumindest Wasserstoff, Kohlenmonoxid und Kohlendi-  
oxid als Produktkomponenten auf. Der Einsatzgasstrom FG weist zumindest Methan  
als Kohlenwasserstoffkomponente auf. Weitere höhere analoge Kohlenwasserstoffe  
wie beispielsweise Ethan, Propan oder Butan können im Einsatzgasstrom FG vor-  
handen sein.

Ein Einsatzgas kann zunächst in einem sogenannten Vorreformer behandelt werden,  
um höhere Kohlenwasserstoffe mit Dampf zu kurzkettigen Kohlenwasserstoffen um-  
zuwandeln, insbesondere mit dem Zweck den Methan-Anteil im Einsatzgasstrom FG  
zu erhöhen. Der Zweck des Vorreformers besteht somit allgemein darin, Kohlenwas-  
serstoffe mit mindestens zwei Kohlenstoffatomen in Kohlenmonoxid, Wasserstoff  
und Methan umzuwandeln. Ein in einem Vorreformer behandelter Einsatzgasstrom  
FG kann somit bereits bestimmte Mengen an Kohlenmonoxid und Wasserstoff ent-  
halten.

Der durch die Kombination aus autothermem und endothermem Reformierungs-  
schritt gebildete Synthesegasstrom SG3 wird einem Konvertierungsschritt (d) zuge-  
führt. In diesem Konvertierungsschritt wird im Synthesegasstrom SG3 enthaltenes  
Kohlenmonoxid mit Wasser durch die sogenannte Wassergas-Shift-Reaktion an ei-  
nem geeigneten Katalysator zu Wasserstoff und Kohlendioxid umgesetzt. Vor Ein-  
schleusen in Schritt (d) wird das Synthesegas SG3 abgekühlt. Davon abhängig ob  
es sich gemäß Schritt (d) um eine sogenannte Niedrigtemperatur-Shift oder eine

Hochtemperatur-Shift handelt, wird das Synthesegas SG3 vor Einschleusen in Schritt (d) mehr oder weniger stark abgekühlt.

Der durch den Konvertierungsschritt (d) gebildete Synthesegasstrom SG4 ist mit Wasserstoff und Kohlendioxid angereichert und an Kohlenmonoxid verarmt. Synthesegasstrom SG4 wird nachfolgend einem Trennschritt (e) unterzogen, in dem weitgehend reiner Wasserstoff aus dem Synthesegasstrom SG4 durch Druckwechseladsorption (*pressure swing adsorption*, PSA) erzeugt wird. Der durch die Druckwechseladsorption erhaltene wasserstoffreiche Strom HG1 weist regelmäßig einen Wasserstoffgehalt von mindestens 95 mol-%, vorzugsweise von mindestens 99 mol-%, weiter bevorzugt von mindestens 99,5 mol-% und weiter bevorzugt von mindestens 99,9 mol-% auf. Das an Wasserstoff verarmte Nebenprodukt des Druckwechseladsorptionsschritts, der Restgasstrom RG1, ist im Vergleich zum Synthesegasstrom SG4 stark an Wasserstoff verarmt und stark mit Kohlendioxid angereichert. Es enthält ferner nicht in Schritt (d) konvertiertes Kohlenmonoxid und nicht in den Schritten (b) und (c) konvertiertes Methan. Durch das Vorhandensein von Gasen mit hohem Heizwert (Methan, Kohlenmonoxid und Wasserstoff) kann es verfahrenintern oder –extern als Brennstoff verwendet werden.

Zur Abtrennung von Kohlendioxid aus dem Restgasstrom RG1 wird dieser einer tiefkalten Kohlendioxid-Abscheidung gemäß Schritt (f) unterzogen, wodurch ein kohlendioxidreicher Strom CG1 sowie ein weiterer Restgasstrom RG2 erhalten werden. Der Trennschritt (f) erfordert die teilweise Kondensation des im Restgasstrom RG1 enthaltenen Kohlendioxid, und zur Erzielung einer bestimmten Reinheit nachfolgend und optional die Destillation des kohlendioxidreichen Stroms CG1. Die tiefkalte Kohlendioxid-Abscheidung wird vorzugsweise bei einer Temperatur von weniger als 35 °C durchgeführt, oder weniger als 20 °C, oder weniger als 0 °C, oder weniger als – 20 °C, oder weniger als – 40 °C, oder weniger als – 50 °C, oder weniger als – 55 °C. Die tiefkalte Kohlendioxid-Abscheidung wird ferner vorzugsweise bei einer Temperatur von mehr als – 60 °C durchgeführt.

Der Synthesegasstrom SG1 kann auch als erster Synthesegasstrom bezeichnet werden, der Synthesegasstrom SG2 als zweiter Synthesegasstrom und so weiter. Dies trifft *mutatis mutandis* auf alle weiteren im Rahmen dieser Offenbarung nummerierten Fluidströme RG, CG und HG zu.

Eine bevorzugte Ausführungsform des erfindungsgemäßen Verfahrens ist dadurch gekennzeichnet, dass aus dem Restgasstrom RG2 Wasserstoff abgetrennt wird, wobei ein wasserstoffreicher Strom HG2 und ein Restgasstrom RG3 erhalten werden. Der Restgasstrom RG2 weist regelmäßig, trotz des vorangegangenen Trennschritts  
5 durch Druckwechseladsorption, größere Mengen an Restwasserstoff von bis zu 50 mol-% auf. Es ist daher vorteilhaft, den Restgasstrom 2 einem weiteren Trennschritt zur Abtrennung oder zumindest Anreicherung von Wasserstoff zuzuführen. Vorzugsweise wird der Wasserstoff aus dem Restgasstrom RG2 durch Membrantrennung abgetrennt.

10 In einem Beispiel des erfindungsgemäßen Verfahrens wird der wasserstoffreiche Strom HG2 dem Synthesegasstrom SG4 zum Abtrennen von Wasserstoff durch Druckwechseladsorption gemäß Schritt (e) zugeführt. Insbesondere Membrantrennverfahren weisen keine ausreichende Selektivität auf, um aus dem Restgasstrom RG2 einen Wasserstoffstrom mit hoher Reinheit, beispielsweise von mehr als 99  
15 mol-%, zu gewinnen. Da ein zweiter Druckwechseladsorptionsschritt im Sinne einer zweiten Druckwechseladsorptionsvorrichtung zu aufwändig und teuer wäre, wird der wasserstoffreiche Strom HG2 in vorteilhafter Weise Schritt (e) zugeführt, wodurch die Wasserstoff-Ausbeute bezogen auf den Gesamtprozess erhöht wird.

Alternativ werden im wasserstoffreichen Strom HG2 enthaltene Gase als Brenngase  
20 zum Heizen im autothermen Reformierungsschritt gemäß Schritt c) genutzt. Für den autothermen Reformierungsschritt muss das Einsatzgas FG angewärmt werden, was beispielsweise mittels einer befeuerten Heizeinheit erfolgen kann. Die befeuerte Heizeinheit kann zumindest teilweise mit Hilfe der im wasserstoffreichen Strom HG2 enthaltenen Gase, welche einen hohen Heizwert aufweisen, insbesondere Kohlen-  
25 monoxid, Methan und Wasserstoff beheizt werden, um die Wärmeintegration des Prozesses zu verbessern.

Eine bevorzugte Ausführungsform des erfindungsgemäßen Verfahrens ist dadurch gekennzeichnet, dass der kohlendioxidreiche Strom CG1 nicht reagiertes Methan umfasst, und der kohlendioxidreiche Strom CG1 einem thermischen Trennverfahren  
30 zur Abtrennung von Methan unterzogen wird, wobei ein kohlendioxidreicher Strom CG2 erhalten wird. Der kohlendioxidreiche Strom kann als Ergebnis der tiefkalten Kohlendioxidabscheidung signifikante Mengen Methan enthalten, beispielsweise bis

zu 0,2 mol-% Methan, oder bis zu 0,5 mol-% Methan. Durch einen weiteren Schritt, welcher ein thermisches Trennverfahren beinhaltet, kann der Kohlendioxidgehalt des kohlendioxidreichen Stroms CG1 weiter erhöht werden. Bei dem thermischen Trennverfahren handelt es sich vorzugsweise um eine Destillation. Dadurch kann ein weit-

5 gehend reines Kohlendioxidprodukt erhalten werden, welches einfacher einer ökologisch sinnvollen Valorisierung zugeführt werden kann als ein mit Methan verunreinigtes Kohlendioxidprodukt. So kann reines Kohlendioxid beispielsweise mit Elektrolyse-Wasserstoff im richtigen Verhältnis gemischt als Synthesegas zur Methanol-

10 Produktion eingesetzt werden. Auch bei der Sequestrierung des Kohlendioxids hat ein reines Kohlendioxidprodukt Vorteile, da insbesondere mit Methan verunreinigtes Kohlendioxid bei unbeabsichtigter Freisetzung nach Sequestrierung den Treibhauseffekt bekanntermaßen verstärken würde.

Eine bevorzugte Ausführungsform des erfindungsgemäßen Verfahrens ist dadurch gekennzeichnet, dass aus dem Restgasstrom RG3 Kohlendioxid abgetrennt wird,

15 wobei ein kohlendioxidreicher Strom CG3 und ein Restgasstrom RG4 erhalten werden. Vorzugsweise wird das Kohlendioxid aus dem Restgasstrom RG3 durch Membrantrennung abgetrennt, um den kohlendioxidreichen Strom CG3 und den Restgasstrom RG4 zu erhalten.

In einem Beispiel des erfindungsgemäßen Verfahrens werden im Restgasstrom RG4

20 enthaltene Gase als Brenngase zum Heizen im autothermen Reformierungsschritt gemäß Schritt c) genutzt.

Der kohlendioxidreiche Strom CG3 wird vorzugsweise dem Restgasstrom RG1 zur tiefkalten Kohlendioxid-Abscheidung gemäß Schritt (f) zugeführt. Dadurch wird die Ausbeute an verwertbarem Kohlendioxid gesteigert und die Menge an tatsächlich

25 emittiertem Kohlendioxid auf ein Minimum reduziert.

Eine bevorzugte Ausführungsform des erfindungsgemäßen Verfahrens ist dadurch gekennzeichnet, dass der Restgasstrom RG1 zur tiefkalten Kohlendioxid-Abscheidung gemäß Schritt (f) zumindest einem Verdichtungsschritt sowie zumindest einem Abkühlschritt unterzogen wird, wobei der kohlendioxidreiche Strom CG1 zumindest

30 teilweise als kondensierter Kohlendioxidstrom erhalten wird. Die tiefkalte Kohlendioxid-Abscheidung wird vorzugsweise unter Druck durch Kompression durchgeführt,

beispielsweise einem Druck zwischen 5 und 74 bar, wobei Restgasstrom RG1 gleichzeitig vorzugsweise auf eine Temperatur oberhalb des Tripelpunkt des Kohlendioxid (minus 56 °C) oder eine andere für die Kondensation geeignete Temperatur abgekühlt wird. Unter diesen Temperatur- und Druckbedingungen kondensiert das Kohlendioxid teilweise aus, wobei die Flüssigphase mit Kohlendioxid angereichert wird und die Gasphase mit nicht kondensierbaren Gasen angereichert wird. Vorzugsweise und soweit erforderlich beinhaltet Schritt (f) mehrere Verdichtungsschritte und/oder mehrere Abkühlschritte, das heißt die Kondensation von Kohlendioxid aus dem Restgasstrom RG1 erfolgt in mehreren hintereinandergeschalteten Kompressions- und Abkühlschritten.

Vorzugsweise und soweit erforderlich wird der Restgasstrom RG1 im Rahmen von Schritt (f) in einem oder mehreren Schritten getrocknet. Ein Trocknungsschritt kann vor einem Kompressionsschritt, zwischen zwei Kompressionsschritten und/oder nach einem Kompressionsschritt durchgeführt werden. Ein Trocknungsschritt kann ferner vor einem Abkühlschritt, zwischen zwei Abkühlschritten und/oder nach einem Abkühlschritt durchgeführt werden.

Vorzugsweise und soweit erforderlich wird der Restgasstrom RG1 im Rahmen von Schritt (f) zur Entfernung kondensierbarer Bestandteile wie Methanol einem oder mehreren Abscheideschritten unterzogen. Ein Abscheideschritt kann vor einem Kompressionsschritt, zwischen zwei Kompressionsschritten und/oder nach einem Kompressionsschritt durchgeführt werden. Ein Abscheideschritt kann ferner vor einem Abkühlschritt, zwischen zwei Abkühlschritten und/oder nach einem Abkühlschritt durchgeführt werden.

Die Aufgaben der Erfindung werden ferner zumindest teilweise gelöst durch eine Anlage, wobei die Anlage zur Durchführung des erfindungsgemäßen Verfahrens konfiguriert ist.

Die Aufgaben der Erfindung werden ferner zumindest teilweise gelöst durch eine Anlage zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf, sowie zur Abscheidung von Kohlendioxid, wobei die Anlage folgende miteinander in Fluidverbindung stehende Anlagenkomponenten umfasst:

- (a) Mittel zum Bereitstellen eines Einsatzgasstroms FG, wobei der Einsatzgasstrom FG eine Kohlenwasserstoffkomponente und Dampf umfasst, wobei die Kohlenwasserstoffkomponente zumindest Methan umfasst;
- 5 (b) eine erste Reformierungseinheit, wobei die erste Reformierungseinheit zum Reformieren zumindest eines Teils des Einsatzgasstroms FG in einem endothermen Reformierungsschritt an einem Reformierungskatalysator konfiguriert ist, wobei in dem endothermen Reformierungsschritt ein Synthesegasstrom SG1 erhältlich ist, wobei der
- 10 Synthesegasstrom SG1 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthält;
- (c) eine zweite Reformierungseinheit, angeordnet parallel oder stromabwärts zur ersten Reformierungseinheit, wobei
- 15 - die zweite Reformierungseinheit bei paralleler Anordnung zur ersten Reformierungseinheit zum Reformieren eines Teils des Einsatzgasstroms FG in einem autothermen Reformierungsschritt konfiguriert ist, wobei
- 20 der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst und
- 25 in dem autothermen Reformierungsschritt ein Synthesegasstrom SG2 erhältlich ist, und
- die erste und die zweite Reformierungseinheit bei paralleler Anordnung so konfiguriert sind, dass die Synthesegasströme SG1 und SG2 zu einem Synthesegasstrom SG3 zusammenführbar sind,
- 30 - die zweite Reformierungseinheit bei Anordnung stromabwärts zur ersten Reformierungseinheit zum Reformieren zumindest eines Teils des Synthesegasstroms SG1 in einem autothermen Reformierungsschritt konfiguriert ist, wobei
- der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst, wobei

in dem autothermen Reformierungsschritt ein Synthesegasstrom SG3 erhältlich ist, wobei

die Synthesegasströme SG2 und SG3 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthalten, und

5 die erste Reformierungseinheit (b) und die zweite Reformierungseinheit (c) so konfiguriert sind, dass durch den autothermen Reformierungsschritt in der zweiten Reformierungseinheit (c) erzeugte Wärme zum Heizen in der ersten Reformierungseinheit (b) nutzbar ist;

(d) eine Konvertiereinheit, angeordnet

10 - stromabwärts zur ersten und zweiten Reformierungseinheit bei paralleler Anordnung der ersten und der zweiten Reformierungseinheit, oder

- angeordnet stromabwärts zur zweiten Reformierungseinheit bei Anordnung der zweiten Reformierungseinheit stromabwärts zur

15 ersten Reformierungseinheit, wobei

die Konvertiereinheit zum Konvertieren des im Synthesegasstrom SG3 enthaltenen Kohlenmonoxid mit Dampf zu Kohlendioxid und Wasserstoff konfiguriert ist, wobei ein Synthesegasstrom SG3 erhältlich ist, und

20 der Synthesegasstrom SG3 Wasserstoff, Kohlendioxid, nicht reagiertes Methan sowie in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid enthält;

(e) eine Druckwechseladsorptionseinheit, angeordnet stromabwärts zur Konvertiereinheit, wobei

25 die Druckwechseladsorptionseinheit zum Abtrennen von Wasserstoff aus dem Synthesegasstrom SG3 konfiguriert ist, wobei ein wasserstoffreicher Strom HG1 sowie ein Restgasstrom RG1 erhältlich sind, wobei der Restgasstrom RG1 Kohlendioxid, in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid, in der Druckwechseladsorptionseinheit nicht abgetrennten Wasserstoff sowie nicht reagiertes Methan

30 enthält;

(f) eine Abscheideeinheit, angeordnet stromabwärts zur Druckwechseladsorptionseinheit, wobei die Abscheideeinheit zum tiefkalten Ab-

5 trennen von Kohlendioxid aus dem in der Druckwechseladsorptionseinheit erzeugten Restgasstrom RG1 konfiguriert ist, wobei ein kohlendioxidreicher Strom CG1 sowie ein Restgasstrom RG2 erhältlich sind, wobei der Restgasstrom RG2 in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid, in der Druckwechseladsorptionseinheit nicht abgetrennten Wasserstoff, in der Abscheideeinheit nicht abgetrenntes Kohlendioxid sowie nicht reagiertes Methan enthält.

10 Erfindungsgemäß sind die erste Reformierungseinheit (b) und die zweite Reformierungseinheit (c) so konfiguriert, dass durch den autothermen Reformierungsschritt in der zweiten Reformierungseinheit (c) erzeugte Wärme zum Heizen in der ersten Reformierungseinheit (b) nutzbar ist. Die erste Reformierungseinheit ist für einen endothermen Reformierungsschritt konfiguriert. Die zweite Reformierungseinheit ist für einen autothermen Reformierungsschritt konfiguriert. Vorzugsweise ist die zweite  
15 Reformierungseinheit ein autothermer Reformer. Die zweite Reformierungseinheit ist parallel zur ersten Reformierungseinheit angeordnet oder stromabwärts (downstream) zur ersten Reformierungseinheit angeordnet.

Bei paralleler Anordnung zur ersten Reformierungseinheit wird in der zweiten Reformierungseinheit ein Synthesegasstrom SG2 erzeugt, welcher mit dem Synthesegasstrom SG1 der ersten Reformierungseinheit zusammenführbar ist. Vorzugsweise  
20 wird der Synthesegasstrom SG2 unmittelbar zum Heizen in der ersten Reformierungseinheit genutzt, das heißt die im Synthesegasstrom SG2 enthaltene Wärme wird unmittelbar zum Heizen in der ersten Reformierungseinheit genutzt. „Unmittelbar“ bedeutet in diesem Zusammenhang, dass die im Synthesegasstrom SG2 enthaltene Wärme nicht auf ein weiteres Wärmetransportmedium übertragen wird. Die  
25 in Synthesegasstrom SG2 enthaltene Wärme wird demnach zum Erzeugen des Synthesegasstroms SG1 im endothermen Prozess der ersten Reformierungseinheit genutzt.

Bei Anordnung stromabwärts zur ersten Reformierungseinheit wird in der zweiten  
30 Reformierungseinheit ein Synthesegasstrom SG3 erzeugt. Vorzugsweise wird der Synthesegasstrom SG3 unmittelbar zum Heizen in der ersten Reformierungseinheit

genutzt, das heißt die im Synthesegasstrom SG3 enthaltene Wärme wird unmittelbar zum Heizen in der ersten Reformierungseinheit genutzt. „Unmittelbar“ bedeutet in diesem Zusammenhang, dass die im Synthesegasstrom SG3 enthaltene Wärme nicht auf ein weiteres Wärmetransportmedium übertragen wird. Die in Synthesegasstrom SG3 enthaltene Wärme wird demnach zum Erzeugen des Synthesegasstroms SG1 im endothermen Prozess der ersten Reformierungseinheit genutzt.

## Ausführungsbeispiele

Die Erfindung wird im Folgenden durch zwei erfindungsgemäße Ausführungsbeispiele sowie ein nicht erfindungsgemäßes Vergleichsbeispiel in Verbindung mit drei Zeichnungen näher erläutert, wobei die Ausführungsbeispiele und die Zeichnungen  
5 keine Beschränkung der Erfindung bedeuten.

Es zeigen

10      Figur 1      ein Blockfließbild eines Verfahrens oder einer Anlage nach dem Stand der Technik,

15      Figur 2      ein Blockfließbild einer ersten Alternative eines erfindungsgemäßen Verfahrens oder einer erfindungsgemäßen Anlage mit paralleler Anordnung der Reformierungseinheiten für den endothermen und den autothermen Reformierungsschritt,

20      Figur 3      ein Blockfließbild einer zweiten Alternative eines erfindungsgemäßen Verfahrens oder einer erfindungsgemäßen Anlage mit serieller Anordnung der Reformierungseinheiten für den endothermen und den autothermen Reformierungsschritt.

Figur 1 zeigt ein stark vereinfachtes Blockfließbild eines Verfahrens oder einer Anlage gemäß dem Stand der Technik, wie beispielsweise in der US 2015/0321914 offenbart. Ein Einsatzgasstrom FG wird in eine autotherme Reformierungseinheit 100  
25 eingeschleust und zu einem Synthesegasstrom SG1 umgesetzt. Synthesegasstrom SG1 wird nachfolgend in eine Konvertiereinheit 101 eingeschleust, wodurch in Synthesegasstrom SG1 enthaltenes Kohlenmonoxid mit Wasserdampf zu Kohlendioxid und Wasserstoff umgesetzt wird. Mit Wasserstoff angereicherter Synthesegasstrom SG2 wird nachfolgend in eine Druckwechseladsorptionseinheit 102 eingeschleust,  
30 um Wasserstoff aus dem Synthesegasstrom SG2 mit hoher Reinheit abzutrennen. Aus der Druckwechseladsorptionseinheit 102 abgetrennter Wasserstoff wird in Form eines wasserstoffreichen Stroms HG1 aus der Druckwechseladsorptionseinheit 102 ausgeschleust. Ebenfalls wird ein an Wasserstoff verarmter Restgasstrom RG1 aus

der Druckwechseladsorptionseinheit 102 abgezogen und in eine Abscheideeinheit 103 eingeschleust. In der Abscheideeinheit 103 wird Kohlendioxid durch mehrere Kompressions- und Abkühlschritte sowie Trocknungsschritte in hoher Reinheit abgeschieden und als kohlendioxidreicher Strom CG1 aus der Abscheideeinheit abgezogen. Kohlendioxidreicher Strom CG1 enthält noch signifikante Restmengen Methan, die optional durch Destillation des kohlendioxidreichen Stroms CG1 entfernbare sind (nicht gezeigt). Das resultierende reine Kohlendioxidprodukt eignet sich für die Sequestrierung des Kohlendioxids oder für eine Weiterverwendung, beispielsweise die Synthese von Methanol durch Umsetzung mit aus Elektrolysestrom erzeugtem Wasserstoff. Aus der Abscheideeinheit 103 wird auch ein stark an Kohlendioxid verarmter Restgasstrom RG2 abgezogen und in eine Membraneinheit 104 eingeschleust. Durch Membrantrennung wird in Membraneinheit 104 ein gegenüber Restgasstrom RG2 mit Wasserstoff angereicherter wasserstoffreicher Strom HG2 erzeugt und aus der Membraneinheit 104 abgezogen. Ferner wird ein gegenüber Restgasstrom RG2 an Wasserstoff verarmter Restgasstrom RG3 erzeugt und aus der Membraneinheit 104 abgezogen. Wasserstoffreicher Strom HG2 kann zur weiteren Verwendung optional entweder zur Druckadsorptionseinheit 102 zur Steigerung der Wasserstoffausbeute zurückgeführt werden oder als Brenngas in der autothermen Reformierungseinheit 100 verwendet werden.

Die nachfolgende Tabelle 1 zeigt eine Materialbilanz einer Simulation eines Verfahrens gemäß Figur 1. Die Simulation wurde mit Hilfe der Software „Aspen Plus“ durchgeführt. Die Zusammensetzung des Einsatzgasstroms ist ohne Dampfzusatz angegeben.

**Tabelle 1: Materialbilanz Vergleichsbeispiel**

|                                |        | FG    | SG1   | SG2   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperatur                     | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Druck                          | bar    | 51    | 47    | 43    | 43    | 2     | 20    | 30    | 30    | 3     |
| Stoffmen-<br>gen-<br>strom     | kmol/h | 3869  | 16768 | 14272 | 8923  | 5349  | 2570  | 2750  | 1841  | 729   |
| CO <sub>2</sub>                | mol-%  | 0,77  | 6,46  | 24,57 | 0,00  | 65,57 | 29,69 | 99,77 | 33,77 | 19,39 |
| CO                             | mol-%  | 0,00  | 15,77 | 0,97  | 0,00  | 2,58  | 5,38  | 0,00  | 1,84  | 14,33 |
| H <sub>2</sub>                 | mol-%  | 0,00  | 46,88 | 71,04 | 99,99 | 22,75 | 47,35 | 0,00  | 61,96 | 10,44 |
| N <sub>2</sub>                 | mol-%  | 0,54  | 0,12  | 0,15  | 0,00  | 0,38  | 0,80  | 0,00  | 0,19  | 2,32  |
| CH <sub>4</sub>                | mol-%  | 94,31 | 2,17  | 2,55  | 0,00  | 6,81  | 13,93 | 0,23  | 2,24  | 43,44 |
| C <sub>2</sub> H <sub>6</sub>  | mol-%  | 3,96  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>3</sub> H <sub>8</sub>  | mol-%  | 0,39  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>4</sub> H <sub>10</sub> | mol-%  | 0,03  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| H <sub>2</sub> O               | mol-%  | 0,00  | 28,57 | 0,52  | 0,00  | 1,38  | 1,78  | 0,00  | 0,00  | 6,28  |
| Methanol                       | mol-%  | 0,00  | 0,00  | 0,17  | 0,00  | 0,46  | 0,92  | 0,00  | 0,00  | 3,24  |
| Ar                             | mol-%  | 0,00  | 0,02  | 0,03  | 0,00  | 0,08  | 0,16  | 0,00  | 0,00  | 0,55  |

Die spezifische Kohlendioxidemission des Verfahrens gemäß dem Verfahren der Figur 1 mit der Materialbilanz entsprechend Tabelle 1 liegt bei 0,140 kg CO<sub>2</sub> pro Normkubikmeter (Nm<sup>3</sup>) erzeugten Wasserstoffs.

Anstatt der autothermen Reformierungseinheit 100 kann auch, wie ebenfalls in der US 2015/0321914 offenbart, eine endotherme Reformierungseinheit verwendet werden. Insbesondere kann es sich bei der endothermen Reformierungseinheit um einen dem Fachmann bekannten Dampfpreformer handeln. Im Falle der Verwendung eines Dampfreformers liegt die spezifische Kohlendioxid-Emission mit 0,396 kg CO<sub>2</sub> pro Normkubikmeter erzeugten Wasserstoffs mehrfach höher als bei Verwendung eines autothermen Reformers.

Figur 2 zeigt ein stark vereinfachtes Blockfließbild eines Verfahrens oder einer Anlage gemäß einem ersten Beispiel der Erfindung (Beispiel 1) mit paralleler Anordnung der Reformierungseinheiten. Ein Einsatzgasstrom FG wird auf zwei Teilströme aufgeteilt. Ein erster Teilstrom des Einsatzgasstroms FG wird in eine endotherme Reformierungseinheit 200 (erste Reformierungseinheit, konfiguriert für einen endothermen Reformierungsschritt) eingeschleust. Ein zweiter Teilstrom des Einsatzgasstroms FG wird in eine autotherme Reformierungseinheit 201 (zweite Reformierungseinheit, konfiguriert für einen autothermen Reformierungsschritt) eingeschleust. In der endothermen Reformierungseinheit 200 wird der erste Teilstrom des

Einsatzgasstroms FG zu einem Synthesegasstrom SG 1 umgesetzt. In der autothermen Reformierungseinheit 201 wird der zweite Teilstrom des Einsatzgasstroms FG zu einem Synthesegasstrom SG2 umgesetzt. Die im autothermen Reformierungsschritt der autothermen Reformierungseinheit 201 erzeugte Wärme wird zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 200 genutzt, angezeigt durch den Wärmestrom 202. Vorzugsweise wird der zweite Synthesegasstrom SG2 unmittelbar zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 200 genutzt, das heißt die im zweiten Synthesegasstrom SG2 enthaltene Wärme wird ohne Übertragung auf ein weiteres Wärmetransportmedium zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 201 genutzt.

Die durch die endotherme Reformierungseinheit 200 und die autotherme Reformierungseinheit 201 erzeugten Synthesegasströme SG1 und SG2 werden zusammengeführt zu einem gemischten Synthesegasstrom SG3, welcher in eine Konvertiereinheit 203 eingeschleust wird, wodurch in Synthesegasstrom SG3 enthaltenes Kohlenmonoxid mit Wasserdampf zu Kohlendioxid und Wasserstoff umgesetzt wird. Mit Wasserstoff angereicherter Synthesegasstrom SG4 wird nachfolgend in eine Druckwechseladsorptionseinheit 204 eingeschleust, um Wasserstoff aus dem Synthesegasstrom SG4 mit hoher Reinheit abzutrennen. Aus der Druckwechseladsorptionseinheit 204 abgetrennter Wasserstoff wird in Form eines wasserstoffreichen Stroms HG1 aus der Druckwechseladsorptionseinheit 204 ausgeschleust. Ebenfalls wird ein an Wasserstoff verarmter erster Restgasstrom RG1 aus der Druckwechseladsorptionseinheit 204 abgezogen und in eine Abscheideeinheit 205 eingeschleust. In der Abscheideeinheit 205 wird Kohlendioxid durch mehrere Kompressions- und Abkühlsschritte sowie Trocknungsschritte in hoher Reinheit abgeschieden und als kohlendioxidreicher Strom CG1 aus der Abscheideeinheit 205 abgezogen. Kohlendioxidreicher Strom CG1 enthält noch signifikante Restmengen Methan, die optional durch Destillation des kohlendioxidreichen Stroms CG1 entfernenbar sind (nicht gezeigt). Das resultierende reine Kohlendioxidprodukt eignet sich für die Sequestrierung des Kohlendioxids oder für eine Weiterverwendung, beispielsweise die Synthese von Methanol durch Umsetzung mit aus Elektrolyse erzeugtem Wasserstoff.

Aus der Abscheideeinheit 205 wird auch ein stark an Kohlendioxid verarmter Restgasstrom RG2 abgezogen und in eine Membraneinheit 206 eingeschleust. Durch Membrantrennung wird in Membraneinheit 206 ein gegenüber dem Restgasstrom RG2 ein mit Wasserstoff angereicherter wasserstoffreicher Strom HG2 erzeugt und aus der Membraneinheit 206 abgezogen. Ferner wird ein gegenüber dem Restgasstrom RG2 ein an Wasserstoff verarmter Restgasstrom RG3 erzeugt und aus der Membraneinheit 206 abgezogen. Der wasserstoffreiche Strom HG2 kann zur weiteren Verwendung optional entweder zur Druckadsorptionseinheit 204 zur Steigerung der Gesamtwasserstoffausbeute des Prozesses zurückgeführt werden oder als Brenngas in der autothermen Reformierungseinheit 201 verwendet werden.

Die nachfolgende Tabelle 2 zeigt eine Materialbilanz einer Simulation des ersten Beispiels eines erfindungsgemäßen Verfahrens gemäß Figur 2. Die Simulation wurde mit Hilfe der Software „Aspen Plus“ durchgeführt. Die Zusammensetzung des Einsatzgasstroms ist ohne Dampfzusatz angegeben.

**Tabelle 2: Materialbilanz Beispiel 1**

|                                |        | FG    | SG3   | SG4   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperatur                     | °C     | 40    | 958   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Druck                          | bar    | 51    | 47    | 42    | 41    | 2     | 20    | 20    | 40    | 5     |
| Stoffmengenstrom               | kmol/h | 3252  | 15139 | 12476 | 8923  | 5400  | 2671  | 2729  | 1847  | 824   |
| CO <sub>2</sub>                | mol-%  | 0,77  | 6,07  | 22,93 | 0,00  | 64,40 | 28,32 | 99,71 | 33,36 | 17,01 |
| CO                             | mol-%  | 0,00  | 13,96 | 0,88  | 0,00  | 2,70  | 5,46  | 0,00  | 1,93  | 13,36 |
| H <sub>2</sub>                 | mol-%  | 0,00  | 47,34 | 72,13 | 99,99 | 22,53 | 45,54 | 0,00  | 61,74 | 9,24  |
| N <sub>2</sub>                 | mol-%  | 0,54  | 0,12  | 0,14  | 0,00  | 0,38  | 0,78  | 0,00  | 0,20  | 2,08  |
| CH <sub>4</sub>                | mol-%  | 94,31 | 2,65  | 3,21  | 0,00  | 8,37  | 16,63 | 0,29  | 2,77  | 47,69 |
| C <sub>2</sub> H <sub>6</sub>  | mol-%  | 3,96  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>3</sub> H <sub>8</sub>  | mol-%  | 0,39  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>4</sub> H <sub>10</sub> | mol-%  | 0,03  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| H <sub>2</sub> O               | mol-%  | 0,00  | 29,85 | 0,53  | 0,00  | 1,23  | 2,49  | 0,00  | 0,00  | 8,07  |
| Methanol                       | mol-%  | 0,00  | 0,00  | 0,15  | 0,00  | 0,34  | 0,69  | 0,00  | 0,00  | 2,25  |
| Ar                             | mol-%  | 0,00  | 0,02  | 0,02  | 0,00  | 0,05  | 0,10  | 0,00  | 0,00  | 0,31  |

Die spezifische Kohlendioxidemission des Verfahrens gemäß Figur 2 mit der Materialbilanz entsprechend Tabelle 2 liegt bei 0,128 kg CO<sub>2</sub> pro Normkubikmeter (Nm<sup>3</sup>) erzeugten Wasserstoffs. Gegenüber dem Vergleichsbeispiel entspricht dies einer Reduktion der spezifischen Kohlendioxidemissionen von 9 %.

Figur 3 zeigt ein stark vereinfachtes Blockfließbild eines Verfahrens oder einer Anlage gemäß einem zweiten Beispiel der Erfindung (Beispiel 2). Das Verfahren oder die Anlage gemäß Figur 3 unterscheidet sich vom Verfahren oder der Anlage gemäß

- 5 Die endotherme Reformierungseinheit 200 (erste Reformierungseinheit, konfiguriert für einen endothermen Reformierungsschritt) ist in Gasflussrichtung stromaufwärts (upstream) zur autothermen Reformierungseinheit 201 (zweite Reformierungseinheit, konfiguriert für einen autothermen Reformierungsschritt) angeordnet, welche
- 10 entsprechend in Gasflussrichtung stromabwärts (downstream) zur endothermen Reformierungseinheit 200 angeordnet ist. Ein Einsatzgasstrom FG wird in eine endotherme Reformierungseinheit 200 eingeschleust und zu einem Synthesegasstrom SG1 umgesetzt. Der Synthesegasstrom SG1 wird in der autothermen Reformierungseinheit 201 zu einem Synthesegasstrom SG3 umgesetzt. Die im autothermen Reformierungsschritt der autothermen Reformierungseinheit 201 erzeugte Wärme
- 15 wird zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 200 genutzt, angezeigt durch den Wärmestrom 202. Vorzugsweise wird Synthesegasstrom SG3 unmittelbar zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 200 genutzt, das heißt die in Synthesegasstrom SG3 enthaltene Wärme wird ohne weitere Übertragung auf ein Wärmetransportmedium zum Heizen im endothermen Reformierungsschritt der endothermen Reformierungseinheit 200 genutzt. Alle folgenden Prozessschritte entsprechen Beispiel 1 gemäß Figur 2.
- 20

- Die nachfolgende Tabelle 3 zeigt eine Materialbilanz einer Simulation des zweiten
- 25 Beispiels eines erfindungsgemäßen Verfahrens gemäß Figur 3. Die Simulation wurde mit Hilfe der Software „Aspen Plus“ durchgeführt. Die Zusammensetzung des Einsatzgasstroms ist ohne Dampfzusatz angegeben.

**Tabelle 3: Materialbilanz Beispiel 2**

|                                |        | FG    | SG3   | SG4   | HG1   | RG1   | RG2   | CG1   | HG2   | RG3   |
|--------------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Temperatur                     | °C     | 40    | 975   | 40    | 40    | 40    | 40    | 40    | 40    | 40    |
| Druck                          | bar    | 51    | 44    | 39    | 39    | 2     | 20    | 20    | 40    | 5     |
| Stoffmen-<br>gen-<br>strom     | kmol/h | 2540  | 15037 | 11714 | 8923  | 4281  | 4281  | 2242  | 1491  | 549   |
| CO <sub>2</sub>                | mol-%  | 0,77  | 5,02  | 20,09 | 0,00  | 66,80 | 66,80 | 99,82 | 34,01 | 21,01 |
| CO                             | mol-%  | 0,00  | 11,40 | 0,66  | 0,00  | 2,39  | 2,39  | 0,00  | 1,68  | 14,08 |
| H <sub>2</sub>                 | mol-%  | 0,00  | 49,59 | 76,71 | 100,0 | 23,16 | 23,16 | 0,00  | 62,35 | 11,31 |
| N <sub>2</sub>                 | mol-%  | 0,54  | 0,09  | 0,12  | 0,00  | 0,39  | 0,39  | 0,00  | 0,19  | 2,50  |
| CH <sub>4</sub>                | mol-%  | 94,31 | 1,37  | 1,76  | 0,00  | 5,44  | 5,44  | 0,18  | 1,77  | 36,91 |
| C <sub>2</sub> H <sub>6</sub>  | mol-%  | 3,96  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>3</sub> H <sub>8</sub>  | mol-%  | 0,39  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| C <sub>4</sub> H <sub>10</sub> | mol-%  | 0,03  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  | 0,00  |
| H <sub>2</sub> O               | mol-%  | 0,00  | 32,52 | 0,56  | 0,00  | 1,54  | 1,54  | 0,00  | 0,00  | 12,04 |
| Methanol                       | mol-%  | 0,00  | 0,00  | 0,10  | 0,00  | 0,27  | 0,27  | 0,00  | 0,00  | 2,08  |
| Ar                             | mol-%  | 0,00  | 0,00  | 0,00  | 0,00  | 0,01  | 0,01  | 0,00  | 0,00  | 0,09  |

Die spezifische Kohlendioxidemission des Verfahrens gemäß Figur 3 mit der Materialbilanz entsprechend Tabelle 3 liegt bei 0,118 kg CO<sub>2</sub> pro Normkubikmeter (Nm<sup>3</sup>) erzeugten Wasserstoffs. Gegenüber dem Vergleichsbeispiel entspricht dies einer Reduktion der spezifischen Kohlendioxidemission von 15 %. Ferner ergibt sich durch die serielle Anordnung der Reformierungseinheiten 200 und 201 im Hinblick auf die Reduktion der spezifischen Kohlendioxidemission ein Vorteil gegenüber der parallelen Anordnung der Reformierungseinheiten 200 und 201 gemäß Figur 2.

## Bezugszeichenliste

|    |     |                                 |
|----|-----|---------------------------------|
|    | FG  | Einsatzgasstrom                 |
|    | SG1 | Synthesegasstrom                |
| 5  | SG2 | Synthesegasstrom                |
|    | SG3 | Synthesegasstrom                |
|    | SG4 | Synthesegasstrom                |
|    | HG1 | Wasserstoffreicher Strom        |
|    | HG2 | Wasserstoffreicher Strom        |
| 10 | CG1 | Kohlendioxidreicher Strom       |
|    | RG1 | Restgasstrom                    |
|    | RG2 | Restgasstrom                    |
|    | RG3 | Restgasstrom                    |
| 15 |     |                                 |
|    | 100 | autotherme Reformierungseinheit |
|    | 101 | Konvertiereinheit               |
|    | 102 | Druckwechseladsorptionseinheit  |
|    | 103 | Abscheideeinheit                |
| 20 | 104 | Membraneinheit                  |
|    |     |                                 |
|    | 200 | Endotherme Reformierungseinheit |
|    | 201 | Autotherme Reformierungseinheit |
|    | 202 | Wärmestrom                      |
| 25 | 203 | Konvertiereinheit               |
|    | 204 | Druckwechseladsorptionseinheit  |
|    | 205 | Abscheideeinheit                |
|    | 206 | Membraneinheit                  |

30

## Patentansprüche

1. Verfahren zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf, sowie zur Abscheidung von Kohlendioxid, wobei  
5 das Verfahren die folgenden Schritte umfasst:

(a) Bereitstellen eines Einsatzgasstroms FG, wobei der Einsatzgasstrom FG eine Kohlenwasserstoffkomponente und Dampf umfasst, wobei die Kohlenwasserstoffkomponente zumindest Methan umfasst;

10 (b) Reformieren zumindest eines Teils des Einsatzgasstroms FG in einem endothermen Reformierungsschritt an einem Reformierungskatalysator zu einem Synthesegasstrom SG1, wobei der Synthesegasstrom SG1 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthält;

15 (c) Reformieren eines Teils des Einsatzgasstroms FG in einem autothermen Reformierungsschritt zu einem Synthesegasstrom SG2 und Zusammenführen der Synthesegasströme SG1 und SG2 zu einem Synthesegasstrom SG3, oder

20 Reformieren des Synthesegasstroms SG1 in einem autothermen Reformierungsschritt zu einem Synthesegasstrom SG3, wobei der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst, wobei

25 die Synthesegasströme SG2 und SG3 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthalten, und wobei durch den autothermen Reformierungsschritt erzeugte Wärme zum Heizen im endothermen Reformierungsschritt gemäß Schritt (b) genutzt wird;

30 (d) Konvertieren des im Synthesegasstrom SG3 enthaltenen Kohlenmonoxid mit Dampf zu Wasserstoff und Kohlendioxid zu einem Synthesegasstrom SG4, wobei der Synthesegasstrom SG4 Wasserstoff, Kohlendioxid, nicht reagiertes Methan sowie in Schritt (d) nicht konvertiertes Kohlenmonoxid enthält;

- (e) Abtrennen von Wasserstoff aus dem Synthesegasstrom SG4 durch Druckwechseladsorption, wobei ein wasserstoffreicher Strom HG1 sowie ein Restgasstrom RG1 erhalten werden, wobei der Restgasstrom RG1 Kohlendioxid, in Schritt (d) nicht konvertiertes Kohlenmonoxid, in Schritt (e) nicht abgetrennten Wasserstoff sowie nicht reagiertes Methan enthält;
- (f) Abtrennen von Kohlendioxid aus dem in Schritt (e) erzeugten Restgasstrom RG1 durch tiefkalte Kohlendioxid-Abscheidung, wobei ein kohlendioxidreicher Strom CG1 sowie ein Restgasstrom RG2 erhalten werden, wobei der Restgasstrom RG2 in Schritt (d) nicht konvertiertes Kohlenmonoxid, in Schritt (e) nicht abgetrennten Wasserstoff, in Schritt (f) nicht abgetrenntes Kohlendioxid sowie nicht reagiertes Methan enthält.
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass aus dem Restgasstrom RG2 Wasserstoff abgetrennt wird, wobei ein wasserstoffreicher Strom HG2 und ein Restgasstrom RG3 erhalten werden.
3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, dass der Wasserstoff aus dem Restgasstrom RG2 durch Membrantrennung abgetrennt wird.
4. Verfahren nach einem der Ansprüche 2 und 3, dadurch gekennzeichnet, dass der wasserstoffreiche Strom HG2 dem Synthesegasstrom SG4 zum Abtrennen von Wasserstoff durch Druckwechseladsorption gemäß Schritt (e) zugeführt wird.
5. Verfahren nach einem der Ansprüche 2 bis 4, dadurch gekennzeichnet, dass im wasserstoffreichen Strom HG2 enthaltene Gase als Brenngase zum Heizen im autothermen Reformierungsschritt gemäß Schritt c) genutzt werden.
6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, dass der kohlendioxidreiche Strom CG1 nicht reagiertes Methan umfasst, und der kohlendioxidreiche Strom CG1 einem thermischen Trennverfahren zur Abtrennung von Methan unterzogen wird, wobei ein kohlendioxidreicher Strom

CG2 erhalten wird.

- 5 7. Verfahren nach einem der Ansprüche 2 bis 6, dadurch gekennzeichnet, dass aus dem Restgasstrom RG3 Kohlendioxid abgetrennt wird, wobei ein kohlendioxidreicher Strom CG3 und ein Restgasstrom RG4 erhalten werden.
8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, dass das Kohlendioxid aus dem Restgasstrom RG3 durch Membrantrennung abgetrennt wird.
- 10 9. Verfahren nach einem der Ansprüche 7 bis 8, dadurch gekennzeichnet, dass im Restgasstrom RG4 enthaltene Gase als Brenngase zum Heizen im autothermen Reformierungsschritt gemäß Schritt c) genutzt werden.
- 15 10. Verfahren nach einem der Ansprüche 7 bis 9, dadurch gekennzeichnet, dass der kohlendioxidreiche Strom CG3 dem Restgasstrom RG1 zur tiefkalten Kohlendioxid-Abscheidung gemäß Schritt (f) zugeführt wird.
- 20 11. Verfahren nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, dass der Restgasstrom RG1 zur tiefkalten Kohlendioxid-Abscheidung gemäß Schritt (f) zumindest einem Verdichtungsschritt sowie zumindest einem Abkühlschritt unterzogen wird, wobei der kohlendioxidreiche Strom CG1 zumindest teilweise als kondensierter Kohlendioxidstrom erhalten wird.
- 25 12. Anlage, konfiguriert zur Durchführung des Verfahrens nach einem der Ansprüche 1 bis 11.
- 30 13. Anlage zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf, sowie zur Abscheidung von Kohlendioxid, wobei die Anlage folgende miteinander in Fluidverbindung stehende Anlagenkomponenten umfasst:
- (a) Mittel zum Bereitstellen eines Einsatzgasstroms FG, wobei der Einsatzgasstrom FG eine Kohlenwasserstoffkomponente und Dampf umfasst, wobei die Kohlenwasserstoffkomponente zumindest Methan umfasst;

(b) eine erste Reformierungseinheit, wobei die erste Reformierungseinheit zum Reformieren zumindest eines Teils des Einsatzgasstroms FG in einem endothermen Reformierungsschritt an einem Reformierungskatalysator konfiguriert ist, wobei in dem endothermen Reformierungsschritt ein Synthesegasstrom SG1 erhältlich ist, wobei der Synthesegasstrom SG1 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthält;

(c) eine zweite Reformierungseinheit, angeordnet parallel oder stromabwärts zur ersten Reformierungseinheit, wobei

- die zweite Reformierungseinheit bei paralleler Anordnung zur ersten Reformierungseinheit zum Reformieren eines Teils des Einsatzgasstroms FG in einem autothermen Reformierungsschritt konfiguriert ist, wobei der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst und in dem autothermen Reformierungsschritt ein Synthesegasstrom SG2 erhältlich ist, und die erste und die zweite Reformierungseinheit bei paralleler Anordnung so konfiguriert sind, dass die Synthesegasströme SG1 und SG2 zu einem Synthesegasstrom SG3 zusammenführbar sind,
- die zweite Reformierungseinheit bei Anordnung stromabwärts zur ersten Reformierungseinheit zum Reformieren zumindest eines Teils des Synthesegasstroms SG1 in einem autothermen Reformierungsschritt konfiguriert ist, wobei der autotherme Reformierungsschritt exotherme partielle Oxidation umfasst und endotherme Reformierung mit Dampf an einem Reformierungskatalysator umfasst, wobei in dem autothermen Reformierungsschritt ein Synthesegasstrom SG3 erhältlich ist, wobei

die Synthesegasströme SG2 und SG3 Wasserstoff, Kohlenmonoxid, Kohlendioxid, sowie nicht reagiertes Methan enthalten, und

die erste Reformierungseinheit (b) und die zweite Reformierungseinheit (c) so konfiguriert sind, dass durch den autothermen Reformierungsschritt in der zweiten Reformierungseinheit (c) erzeugte Wärme zum Heizen in der ersten Reformierungseinheit (b) nutzbar ist;

(d) eine Konvertiereinheit, angeordnet

- stromabwärts zur ersten und zweiten Reformierungseinheit bei paralleler Anordnung der ersten und der zweiten Reformierungseinheit, oder
- angeordnet stromabwärts zur zweiten Reformierungseinheit bei Anordnung der zweiten Reformierungseinheit stromabwärts zur ersten Reformierungseinheit, wobei

die Konvertiereinheit zum Konvertieren des im Synthesegasstrom SG3 enthaltenen Kohlenmonoxid mit Dampf zu Kohlendioxid und Wasserstoff konfiguriert ist, wobei ein Synthesegasstrom SG3 erhältlich ist, und

der Synthesegasstrom SG3 Wasserstoff, Kohlendioxid, nicht reagiertes Methan sowie in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid enthält;

(e) eine Druckwechseladsorptionseinheit, angeordnet stromabwärts zur Konvertiereinheit, wobei

die Druckwechseladsorptionseinheit zum Abtrennen von Wasserstoff aus dem Synthesegasstrom SG3 konfiguriert ist, wobei ein wasserstoffreicher Strom HG1 sowie ein Restgasstrom RG1 erhältlich sind, wobei der Restgasstrom RG1 Kohlendioxid, in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid, in der Druckwechseladsorptionseinheit nicht abgetrennten Wasserstoff sowie nicht reagiertes Methan enthält;

(f) eine Abscheideeinheit, angeordnet stromabwärts zur Druckwechseladsorptionseinheit, wobei die Abscheideeinheit zum tiefkalten Abtrennen von Kohlendioxid aus dem in der Druckwechseladsorptionseinheit erzeugten Restgasstrom RG1 konfiguriert ist, wobei ein kohlendioxidreicher Strom CG1 sowie ein Restgasstrom RG2 erhältlich sind, wobei der Restgasstrom RG2 in der Konvertiereinheit nicht konvertiertes Kohlenmonoxid, in der Druckwechseladsorptionseinheit

nicht abgetrennten Wasserstoff, in der Abscheideeinheit nicht abgetrenntes Kohlendioxid sowie nicht reagiertes Methan enthält.

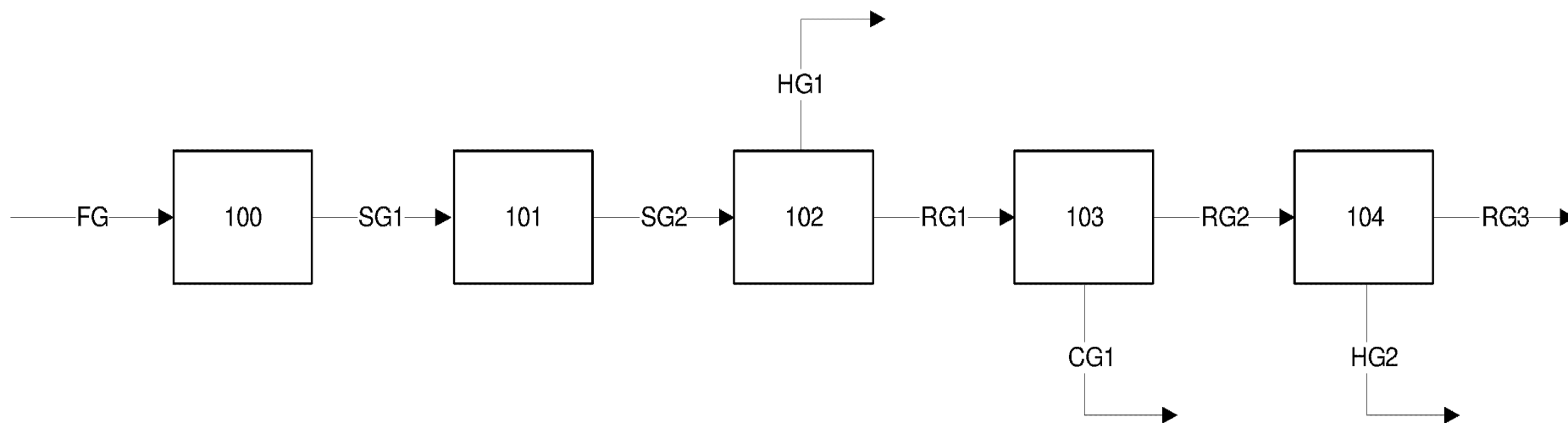
## Zusammenfassung

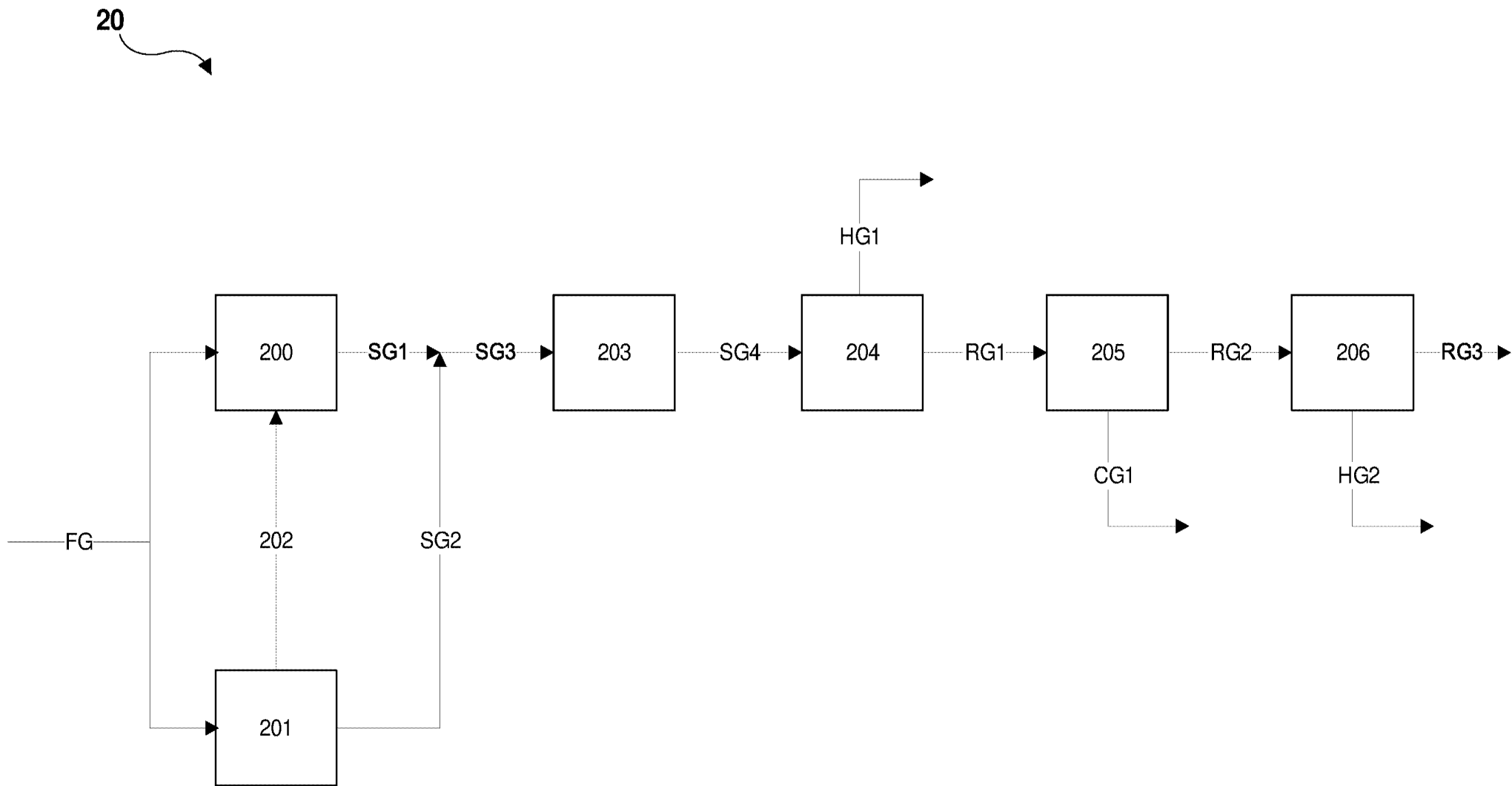
Die Erfindung betrifft ein Verfahren zur Herstellung von Wasserstoff durch Reformieren von Kohlenwasserstoffen mit Dampf, sowie zur Abscheidung von Kohlendioxid.

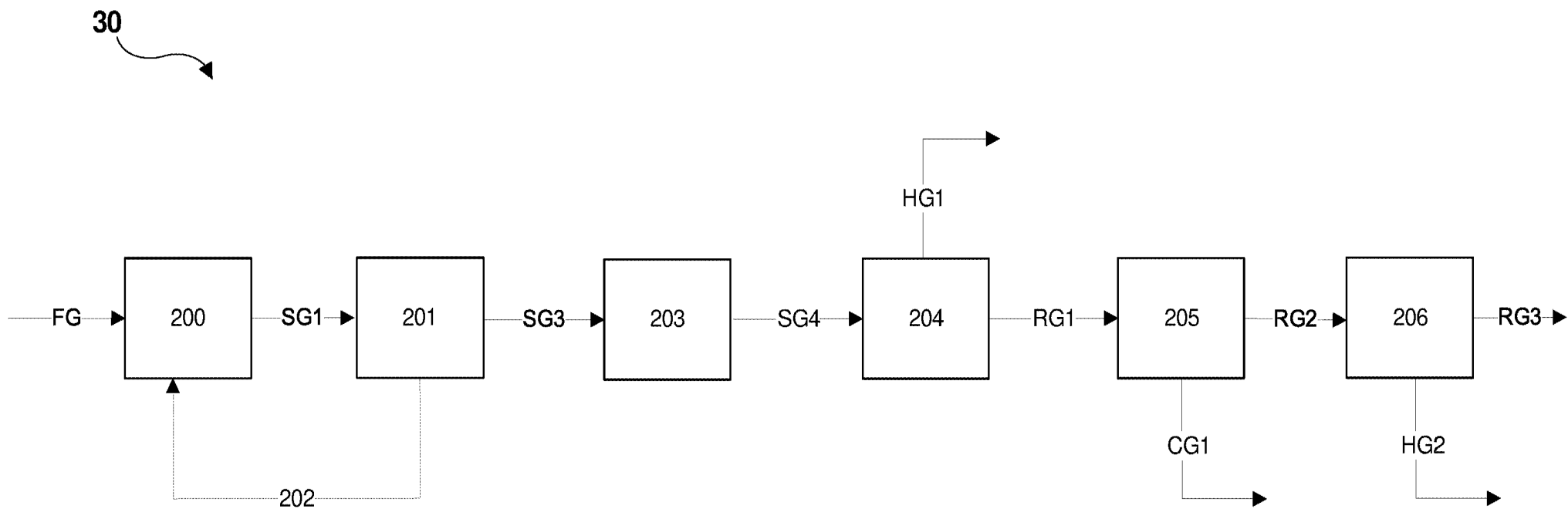
- 5 Das Verfahren umfasst einen endothermen und einen autothermen Reformierungsschritt zur Erzeugung eines Synthesegasstroms, wobei im autothermen Reformierungsschritt erzeugte Wärme zum Heizen im endothermen Reformierungsschritt genutzt wird. Das Verfahren umfasst ferner einen Schritt zum Konvertieren des erhaltenen Synthesegasstroms zur Anreicherung mit Wasserstoff, einen Schritt zur Ab-
- 10 trennung des so hergestellten Wasserstoffs durch Druckwechselabsorption sowie einen Schritt einer Abscheidung von Kohlendioxid aus dem bei der Druckwechselabsorption anfallenden Restgas. Die Reformierungseinheiten für den endothermen und den autothermen Reformierungsschritt sind parallel zueinander oder in Serie angeordnet.

- 15 (Figur 3)

10







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|                                                                                                    |                        |                 |
|----------------------------------------------------------------------------------------------------|------------------------|-----------------|
| <b>TRANSMITTAL<br/>FORM</b><br><br><i>(to be used for all correspondence after initial filing)</i> | Application Number     | 17/399,277      |
|                                                                                                    | Filing Date            | August 11, 2021 |
|                                                                                                    | First Named Inventor   | Sophia SCHMIDT  |
|                                                                                                    | Art Unit               |                 |
|                                                                                                    | Examiner Name          |                 |
| Total Number of Pages in This Submission                                                           | Attorney Docket Number | 2019P00370      |

| ENCLOSURES (Check all that apply)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Fee Transmittal Form<br><input type="checkbox"/> Fee Attached<br><input type="checkbox"/> Amendment/Reply<br><input type="checkbox"/> After Final<br><input type="checkbox"/> Affidavits/declaration(s)<br><input type="checkbox"/> Extension of Time Request<br><input type="checkbox"/> Express Abandonment Request<br><input type="checkbox"/> Information Disclosure Statement<br><br><input type="checkbox"/> Certified Copy of Priority Document(s)<br><input type="checkbox"/> Reply to Missing Parts/<br>Incomplete Application<br><input type="checkbox"/> Reply to Missing Parts<br>under 37 CFR 1.52 or 1.53 | <input type="checkbox"/> Drawing(s)<br><input type="checkbox"/> Licensing-related Papers<br><input type="checkbox"/> Petition<br><input type="checkbox"/> Petition to Convert to a<br>Provisional Application<br><input type="checkbox"/> Power of Attorney, Revocation<br>Change of Correspondence Address<br><input type="checkbox"/> Terminal Disclaimer<br><input type="checkbox"/> Request for Refund<br><input type="checkbox"/> CD, Number of CD(s) _____<br><input type="checkbox"/> Landscape Table on CD | <input type="checkbox"/> After Allowance Communication to TC<br><input type="checkbox"/> Appeal Communication to Board<br>of Appeals and Interferences<br><input type="checkbox"/> Appeal Communication to TC<br>(Appeal Notice, Brief, Reply Brief)<br><input type="checkbox"/> Proprietary Information<br><input type="checkbox"/> Status Letter<br><input checked="" type="checkbox"/> Other Enclosure(s) (please identify<br>below):<br><br><div style="text-align: center;">Corrected ADS</div> |
| <div style="border: 1px solid black; padding: 2px;">Remarks</div><br>Corrected ADS is submitted to correct the spelling of inventor Teja Schmid McGuinness' last name.                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

| SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT |                    |          |       |
|--------------------------------------------|--------------------|----------|-------|
| Firm Name                                  | Air Liquide        |          |       |
| Signature                                  | /Elwood L. Haynes/ |          |       |
| Printed name                               | Elwood L. Haynes   |          |       |
| Date                                       | October 11, 2021   | Reg. No. | 55254 |

| CERTIFICATE OF TRANSMISSION/MAILING                                                                                                                                                                                                                                                                           |                |      |                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------|------------------|
| I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below: |                |      |                  |
| Signature                                                                                                                                                                                                                                                                                                     | /Diana Guzman/ |      |                  |
| Typed or printed name                                                                                                                                                                                                                                                                                         | Diana Guzman   | Date | October 11, 2021 |

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                |                        |            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                | Attorney Docket Number | 2019P00370 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                | Application Number     |            |
| Title of Invention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |
| The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.<br>This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application. |                                                                                |                        |            |

**Secrecy Order 37 CFR 5.2:**

|                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.) |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Inventor Information:**

|                                                                                                                                                                                 |                   |                                          |                    |               |                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------|--------------------|---------------|------------------------|
| <b>Inventor 1</b>                                                                                                                                                               |                   |                                          |                    |               | <a href="#">Remove</a> |
| <b>Legal Name</b>                                                                                                                                                               |                   |                                          |                    |               |                        |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b> | <b>Middle Name</b>                       | <b>Family Name</b> | <b>Suffix</b> |                        |
|                                                                                                                                                                                 | Sophia            |                                          | SCHMIDT            |               |                        |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                   |                                          |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Frankfurt am Main | <b>Country of Residence <sup>i</sup></b> | DE                 |               |                        |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                   |                                          |                    |               |                        |
| <b>Address 1</b>                                                                                                                                                                |                   | Air Liquide IP Dept.                     |                    |               |                        |
| <b>Address 2</b>                                                                                                                                                                |                   | 9811 Katy Freeway, Suite 100             |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Houston           | <b>State/Province</b>                    | TX                 |               |                        |
| <b>Postal Code</b>                                                                                                                                                              | 77024             | <b>Country <sup>i</sup></b>              | US                 |               |                        |
| <b>Inventor 2</b>                                                                                                                                                               |                   |                                          |                    |               | <a href="#">Remove</a> |
| <b>Legal Name</b>                                                                                                                                                               |                   |                                          |                    |               |                        |
| <b>Prefix</b>                                                                                                                                                                   | <b>Given Name</b> | <b>Middle Name</b>                       | <b>Family Name</b> | <b>Suffix</b> |                        |
|                                                                                                                                                                                 | Teja              |                                          | SCHMIDT-McGUINNESS | McGUINNESS    |                        |
| <b>Residence Information (Select One)</b> <input type="radio"/> US Residency <input checked="" type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |                   |                                          |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Frankfurt am Main | <b>Country of Residence <sup>i</sup></b> | DE                 |               |                        |
| <b>Mailing Address of Inventor:</b>                                                                                                                                             |                   |                                          |                    |               |                        |
| <b>Address 1</b>                                                                                                                                                                |                   | Air Liquide IP Dept.                     |                    |               |                        |
| <b>Address 2</b>                                                                                                                                                                |                   | 9811 Katy Freeway, Suite 100             |                    |               |                        |
| <b>City</b>                                                                                                                                                                     | Houston           | <b>State/Province</b>                    | TX                 |               |                        |
| <b>Postal Code</b>                                                                                                                                                              | 77024             | <b>Country <sup>i</sup></b>              | US                 |               |                        |
| All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the <b>Add</b> button.                                     |                   |                                          |                    |               |                        |

**Correspondence Information:**

IPR2025-01173, -01174, Topsoe Ex. 1002

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

Enter either Customer Number or complete the Correspondence Information section below.  
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence information of this application.

|                 |                            |                                          |                                             |
|-----------------|----------------------------|------------------------------------------|---------------------------------------------|
| Customer Number | 40582                      |                                          |                                             |
| Email Address   | IP-USOffice@airliquide.com | <input type="button" value="Add Email"/> | <input type="button" value="Remove Email"/> |

### Application Information:

|                                         |                                                                                |                                           |                          |
|-----------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------|--------------------------|
| Title of the Invention                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                                           |                          |
| Attorney Docket Number                  | 2019P00370                                                                     | Small Entity Status Claimed               | <input type="checkbox"/> |
| Application Type                        | Nonprovisional                                                                 |                                           |                          |
| Subject Matter                          | Utility                                                                        |                                           |                          |
| Total Number of Drawing Sheets (if any) | 3                                                                              | Suggested Figure for Publication (if any) | 3                        |

### Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

|                                                        |                          |                                            |
|--------------------------------------------------------|--------------------------|--------------------------------------------|
| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country |
|                                                        |                          |                                            |

### Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

### Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

|                    |                                                  |                                              |                                                         |
|--------------------|--------------------------------------------------|----------------------------------------------|---------------------------------------------------------|
| Please Select One: | <input checked="" type="radio"/> Customer Number | <input type="radio"/> US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) |
| Customer Number    | 40582                                            | IPR2025-01173, -01174, Topsoe Ex. 1002       |                                                         |

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

### Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

|                                                                                                                       |                 |                          |                                    |
|-----------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------|------------------------------------|
| Prior Application Status                                                                                              |                 |                          | <a href="#">Remove</a>             |
| Application Number                                                                                                    | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
|                                                                                                                       |                 |                          |                                    |
| Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> button. |                 |                          |                                    |

### Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

|                                                                                                        |                      |                          |                                          |
|--------------------------------------------------------------------------------------------------------|----------------------|--------------------------|------------------------------------------|
| Application Number                                                                                     | Country <sup>i</sup> | Filing Date (YYYY-MM-DD) | <a href="#">Remove</a>                   |
| 20020366.9                                                                                             | EP                   | 2020-08-11               | Access Code <sup>i</sup> (if applicable) |
|                                                                                                        |                      |                          | D3A6                                     |
| Additional Foreign Priority Data may be generated within this form by selecting the <b>Add</b> button. |                      |                          |                                          |

### Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.<br>NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA. |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

|                                           |                                                                                |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> | Attorney Docket Number                                                         | 2019P00370 |
|                                           | Application Number                                                             |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |            |

## Applicant Information:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                                                                        |       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                           |                                                                        |       |
| <b>Applicant 1</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                           |                                                                        |       |
| If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. |                                                                                           |                                                                        |       |
| <input type="button" value="Clear"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                                                                        |       |
| <input checked="" type="radio"/> Assignee                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <input type="radio"/> Legal Representative under 35 U.S.C. 117                            | <input type="radio"/> Joint Inventor                                   |       |
| <input type="radio"/> Person to whom the inventor is obligated to assign.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                           | <input type="radio"/> Person who shows sufficient proprietary interest |       |
| If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                           |                                                                        |       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                                                                        |       |
| Name of the Deceased or Legally Incapacitated Inventor: <input type="text"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                                                                        |       |
| If the Applicant is an Organization check here. <input checked="" type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                           |                                                                        |       |
| Organization Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude |                                                                        |       |
| <b>Mailing Address Information For Applicant:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                           |                                                                        |       |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 75, Quai d'Orsay                                                                          |                                                                        |       |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                           |                                                                        |       |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Paris                                                                                     | State/Province                                                         |       |
| Country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | FR                                                                                        | Postal Code                                                            | 75007 |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           | Fax Number                                                             |       |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                           |                                                                        |       |
| Additional Applicant Data may be generated within this form by selecting the Add button.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           |                                                                        |       |

## Assignee Information including Non-Applicant Assignee Information:

|                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

|        |            |             |             |        |
|--------|------------|-------------|-------------|--------|
| Prefix | Given Name | Middle Name | Family Name | Suffix |
|        |            |             |             |        |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

|                      |  |  |                |  |
|----------------------|--|--|----------------|--|
| Address 1            |  |  |                |  |
| Address 2            |  |  |                |  |
| City                 |  |  | State/Province |  |
| Country <sup>i</sup> |  |  | Postal Code    |  |
| Phone Number         |  |  | Fax Number     |  |
| Email Address        |  |  |                |  |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

**Signature:**

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

|            |                    |           |        |                     |            |
|------------|--------------------|-----------|--------|---------------------|------------|
| Signature  | /Elwood L. Haynes/ |           |        | Date (YYYY-MM-DD)   | 2021-08-11 |
| First Name | Elwood L.          | Last Name | Haynes | Registration Number | 55254      |

Additional Signature may be generated within this form by selecting the Add button.

|                                           |                                                                                |                        |            |
|-------------------------------------------|--------------------------------------------------------------------------------|------------------------|------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                                | Attorney Docket Number | 2019P00370 |
|                                           |                                                                                | Application Number     |            |
| Title of Invention                        | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                        |            |

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

## Electronic Acknowledgement Receipt

|                                             |                                                                                |
|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 43994199                                                                       |
| <b>Application Number:</b>                  | 17399277                                                                       |
| <b>International Application Number:</b>    |                                                                                |
| <b>Confirmation Number:</b>                 | 2532                                                                           |
| <b>Title of Invention:</b>                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
| <b>First Named Inventor/Applicant Name:</b> | Sophia SCHMIDT                                                                 |
| <b>Customer Number:</b>                     | 40582                                                                          |
| <b>Filer:</b>                               | Elwood L. Haynes/Diana Guzman                                                  |
| <b>Filer Authorized By:</b>                 | Elwood L. Haynes                                                               |
| <b>Attorney Docket Number:</b>              | 2019P00370                                                                     |
| <b>Receipt Date:</b>                        | 11-OCT-2021                                                                    |
| <b>Filing Date:</b>                         | 11-AUG-2021                                                                    |
| <b>Time Stamp:</b>                          | 11:21:27                                                                       |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                                    |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name                                               | File Size(Bytes)/<br>Message Digest                    | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|---------------------------------------------------------|--------------------------------------------------------|------------------|------------------|
| 1               |                      | 2019P00370_US_2021-10-11_CORRECTED_ADS_as_filed_ELH.pdf | 305621<br>f9cfcbc36547419982fb90916b945adf92ca<br>d012 | yes              | 8                |

IPR2025-01173, -01174, Topsoe Ex. 1002

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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Multipart Description/PDF files in .zip description |        |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Document Description                                | Start  | End |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Transmittal Letter                                  | 1      | 1   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Application Data Sheet                              | 2      | 8   |
| Warnings:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                     |        |     |
| Information:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                     |        |     |
| Total Files Size (in bytes):                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                     | 305621 |     |
| <p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                                     |        |     |



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| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 17/399,277         | 08/11/2021            | Sophia SCHMIDT        | 2019P00370             |

**CONFIRMATION NO. 2532**

## PUBLICATION NOTICE



\*OC000000131897054\*

40582  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

**Title:**PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE

**Publication No.**US-2022-0048768-A1

**Publication Date:**02/17/2022

## NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at [www.uspto.gov](http://www.uspto.gov). The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

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www.uspto.gov

| APPLICATION NO.                                                                                                 | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------------------------------------------------------------------------------------------------------|-------------|----------------------|---------------------|------------------|
| 17/399,277                                                                                                      | 08/11/2021  | Sophia SCHMIDT       | 2019P00370          | 2532             |
| 40582                                                                                                           | 7590        | 10/12/2022           | EXAMINER            |                  |
| American Air Liquide<br>Intellectual Property Department<br>9811 Katy Freeway<br>Suite 100<br>Houston, TX 77024 |             |                      | IQBAL, SYED TAHA    |                  |
|                                                                                                                 |             |                      | ART UNIT            | PAPER NUMBER     |
|                                                                                                                 |             |                      | 1736                |                  |
|                                                                                                                 |             |                      | NOTIFICATION DATE   | DELIVERY MODE    |
|                                                                                                                 |             |                      | 10/12/2022          | ELECTRONIC       |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

IP-USOffice@airliquide.com  
Justin.Murray@airliquide.com  
Neva.Dare-c@airliquide.com



## **DETAILED ACTION**

### ***Notice of Pre-AIA or AIA Status***

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

### ***Claim Rejections - 35 USC § 112***

The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claim 13 is rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor (or for applications subject to pre-AIA 35 U.S.C. 112, the applicant), regards as the invention.

The term “is obtainable” used throughout the claim is indefinite. It is unclear if the syngas is required to be obtained this way or this would just be an available option for obtaining the syngas. The proper terminology would be “obtained”. Similarly the term “utilizable” is indefinite because it creates doubt whether the autothermal step is utilized to heat the first unit or is just an available option.

### ***Allowable Subject Matter***

Claims 1-12 are allowed.

Claim 13 would be allowable if rewritten or amended to overcome the rejection(s) under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), 2nd paragraph, set forth in this Office action.

The following is an examiner's statement of reasons for allowance:

Regarding claims 1, 12 and 13, US 20150321914 teaches a method of converting hydrocarbons (Abstracts). However, there is no teaching or suggestion regarding a first endothermic reforming unit configured to be heated by a second autothermal reforming unit nor is there for a plant comprising same.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

### ***Conclusion***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to SYED TAHA IQBAL whose telephone number is (571)270-5857. The examiner can normally be reached M-F; 7-5.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Keith Walker can be reached on (571) 272-3458. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: <https://patentcenter.uspto.gov>. Visit <https://www.uspto.gov/patents/apply/patent-center> for more information about Patent Center and <https://www.uspto.gov/patents/docx> for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/SYED T IQBAL/  
Examiner, Art Unit 1736

/STEVEN J BOS/  
Primary Examiner, Art Unit 1736

|                                          |                                       |  |                                                              |             |
|------------------------------------------|---------------------------------------|--|--------------------------------------------------------------|-------------|
| <b><i>Notice of References Cited</i></b> | Application/Control No.<br>17/399,277 |  | Applicant(s)/Patent Under<br>Reexamination<br>SCHMIDT et al. |             |
|                                          | Examiner<br>SYED T IQBAL              |  | Art Unit<br>1736                                             | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Name            | CPC Classification | US Classification |
|---|---|--------------------------------------------------|-----------------|-----------------|--------------------|-------------------|
| * | A | US-20150141535-A1                                | 05-2015         | Kresnyak; Steve | C10K1/32           | 208/97            |
| * | B | US-20150321914-A1                                | 11-2015         | DARDE; Arthur   | C01B5/00           | 422/162           |
|   | C |                                                  |                 |                 |                    |                   |
|   | D |                                                  |                 |                 |                    |                   |
|   | E |                                                  |                 |                 |                    |                   |
|   | F |                                                  |                 |                 |                    |                   |
|   | G |                                                  |                 |                 |                    |                   |
|   | H |                                                  |                 |                 |                    |                   |
|   | I |                                                  |                 |                 |                    |                   |
|   | J |                                                  |                 |                 |                    |                   |
|   | K |                                                  |                 |                 |                    |                   |
|   | L |                                                  |                 |                 |                    |                   |
|   | M |                                                  |                 |                 |                    |                   |

**FOREIGN PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Country | Name | CPC Classification |
|---|---|--------------------------------------------------|-----------------|---------|------|--------------------|
|   | N |                                                  |                 |         |      |                    |
|   | O |                                                  |                 |         |      |                    |
|   | P |                                                  |                 |         |      |                    |
|   | Q |                                                  |                 |         |      |                    |
|   | R |                                                  |                 |         |      |                    |
|   | S |                                                  |                 |         |      |                    |
|   | T |                                                  |                 |         |      |                    |

**NON-PATENT DOCUMENTS**

| * |   | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|-------------------------------------------------------------------------------------------|
|   | U |                                                                                           |
|   | V |                                                                                           |
|   | W |                                                                                           |
|   | X |                                                                                           |

\*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)  
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

|                                                                                                          |                                              |                                                                  |
|----------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b>Search Notes</b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                          | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

| CPC - Searched*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------|
| Symbol                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Date       | Examiner   |
| C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR<br>C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR<br>C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR<br>B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR<br>B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR<br>C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151<br>OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR<br>C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR<br>C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR<br>C01B2203/0838 | 10/05/2022 | Syed Iqbal |

| CPC Combination Sets - Searched* |      |          |
|----------------------------------|------|----------|
| Symbol                           | Date | Examiner |
|                                  |      |          |

| US Classification - Searched* |          |      |          |
|-------------------------------|----------|------|----------|
| Class                         | Subclass | Date | Examiner |
|                               |          |      |          |

\* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

| Search Notes                               |            |            |
|--------------------------------------------|------------|------------|
| Search Notes                               | Date       | Examiner   |
| class subclass                             | 10/05/2022 | Syed Iqbal |
| inventor name search                       | 10/05/2022 | Syed Iqbal |
| EPO, JPO and Derwent                       | 10/05/2022 | Syed Iqbal |
| Google Patents and Google Scholar searched | 10/05/2022 | Syed Iqbal |
| iq.ip.com                                  | 10/05/2022 | Syed Iqbal |

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| /SYED T IQBAL/<br>Examiner, Art Unit 1736 |  |
|-------------------------------------------|--|

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|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b><i>Search Notes</i></b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                                 | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

| Interference Search |                       |      |          |
|---------------------|-----------------------|------|----------|
| US Class/CPC Symbol | US Subclass/CPC Group | Date | Examiner |
|                     |                       |      |          |

|                                           |  |
|-------------------------------------------|--|
| /SYED T IQBAL/<br>Examiner, Art Unit 1736 |  |
|-------------------------------------------|--|

| Publication Number | Application Number | Title          | Priority Date - | Application Da | Publication Da |
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|----------------|-----------------|----------------|------------|------------|------------|
| EP2944606A1    | EP14305713      | Process for ge | 5/15/2014  | 5/15/2014  | 11/18/2015 |
| WO2019162236A1 | PCTEP2019053986 | Gas processin  | 2/20/2018  | 2/18/2019  | 8/29/2019  |
| CA2888117A1    | CA2888117       | Method for p   | 12/13/2012 | 10/31/2013 | 6/19/2014  |
| EP3755655A1    | EP19705524      | Gas processin  | 2/20/2018  | 2/18/2019  | 12/30/2020 |

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## PE2E SEARCH - Search History (Prior Art)

| Ref # | Hits | Search Query                                                                                                                                                                                                                                                                                                                                                                                                                                                   | DBs               | Default Operator | Plurals | British Equivalents | Time Stamp          |
|-------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|---------|---------------------|---------------------|
| L1    | 21   | ((SCHMIDT-Sophia) (SCHMID-McGUIINESS-Teja)).inv.                                                                                                                                                                                                                                                                                                                                                                                                               | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 10:55 AM |
| L2    | 1    | ((SCHMIDT-Sophia) (SCHMID-McGUIINESS-Teja)).inv. AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)                                                                                                                                                                                                                                                                                                                                            | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 01:56 PM |
| L3    | 55   | (pressure WITH swing) AND (water WITH gas WITH shift) AND (heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)                                                                                                                                                                                                                                                                              | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 03:33 PM |
| L4    | 47   | (C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 05:36 PM |

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |    |    |    |                        |
|----|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L5 | 10 | <p>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND (pressure WITH<br/>swing) AND (water<br/>WITH gas WITH shift)<br/>AND (heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME<br/>autothermal)</p> <p>(C01B3/40 OR<br/>B01D53/047 OR<br/>C01B3/48 OR<br/>C01B2203/0233 OR<br/>C01B2203/0244 OR<br/>C01B2203/0405 OR<br/>C01B2203/042 OR<br/>C01B2203/046 OR<br/>C01B2203/1058 OR<br/>C01B2203/1241 OR<br/>B01D53/002 OR<br/>C01B32/50 OR<br/>B01D53/22 OR<br/>B01D2256/16 OR<br/>B01D2257/504 OR<br/>C01B2203/0283 OR<br/>C01B2203/043 OR<br/>C01B2203/0475 OR<br/>C01B2203/147 OR<br/>Y02C20/40 OR<br/>Y02P20/151 OR<br/>C01B3/56 OR<br/>C01B3/38 OR<br/>C01B3/503 OR<br/>C01B3/506 OR<br/>C01B2203/0261 OR<br/>C01B2203/0811 OR<br/>C01B2203/1235 OR<br/>C01B3/382 OR<br/>F25J3/067 OR<br/>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND (pressure WITH<br/>swing) AND (water<br/>WITH gas WITH shift)<br/>AND (endotherm\$4<br/>WITH heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME</p> | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>06:41 PM |
|----|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                        |    |    |    |                        |
|----|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----|----|----|------------------------|
| L6 | 10 | autothermal)<br>(pressure WITH swing)<br>AND (water WITH gas<br>WITH shift) AND<br>(endotherm\$4 WITH<br>heat WITH transfer<br>SAME reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                                                                                                                                                                                                     | (US-PGPUB; USPAT)      | OR | ON | ON | 2022/10/05<br>06:43 PM |
| L7 | 0  | (pressure WITH swing)<br>AND (water WITH gas<br>WITH shift) AND<br>(endotherm\$4 WITH<br>heat WITH transfer<br>SAME reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                                                                                                                                                                                                                     | (EPO; JPO;<br>DERWENT) | OR | ON | ON | 2022/10/05<br>06:43 PM |
| L8 | 0  | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND (pressure WITH | (EPO; JPO;<br>DERWENT) | OR | ON | ON | 2022/10/05<br>06:43 PM |

|     |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                     |    |    |    |                     |
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| L9  | 0 | swing) AND (water WITH gas WITH shift) AND (endotherm\$4 WITH heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)<br>(C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR C01B2203/0838).cpc.<br>AND (pressure WITH swing) AND (water WITH gas WITH shift) AND ( heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal) | (EPO; JPO; DERWENT) | OR | ON | ON | 2022/10/05 06:43 PM |
| L10 | 4 | (C01B3/40 OR B01D53/047 OR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (EPO; JPO; DERWENT) | OR | ON | ON | 2022/10/05 06:43 PM |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |    |    |    |                        |
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| L11 | 34 | C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)<br>(C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>06:44 PM |
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|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L12 | 449 | Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal) NOT L6<br><br>(C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heating SAME<br>reform\$4 SAME | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:57 PM |
|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |    |    |    |                        |
|-----|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L13 | 59 | <p>endothrm\$4) AND (reform\$4 SAME<br/>endothrm\$4) AND (reform\$4 SAME<br/>autothermal) NOT L6</p> <p>(C01B3/40 OR<br/>B01D53/047 OR<br/>C01B3/48 OR<br/>C01B2203/0233 OR<br/>C01B2203/0244 OR<br/>C01B2203/0405 OR<br/>C01B2203/042 OR<br/>C01B2203/046 OR<br/>C01B2203/1058 OR<br/>C01B2203/1241 OR<br/>B01D53/002 OR<br/>C01B32/50 OR<br/>B01D53/22 OR<br/>B01D2256/16 OR<br/>B01D2257/504 OR<br/>C01B2203/0283 OR<br/>C01B2203/043 OR<br/>C01B2203/0475 OR<br/>C01B2203/147 OR<br/>Y02C20/40 OR<br/>Y02P20/151 OR<br/>C01B3/56 OR<br/>C01B3/38 OR<br/>C01B3/503 OR<br/>C01B3/506 OR<br/>C01B2203/0261 OR<br/>C01B2203/0811 OR<br/>C01B2203/1235 OR<br/>C01B3/382 OR<br/>F25J3/067 OR<br/>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND ( heating SAME<br/>reform\$4 SAME<br/>endothrm\$4 WITH<br/>autothrm\$4) AND<br/>(reform\$4 SAME<br/>endothrm\$4) AND<br/>(reform\$4 SAME<br/>autothermal) NOT L6</p> | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:57 PM |
| L14 | 57 | <p>(autothrm\$4 SAME<br/>partial WITH oxidation)<br/>AND ( heating SAME<br/>reform\$4 SAME<br/>endothrm\$4 WITH<br/>autothrm\$4) AND<br/>(reform\$4 SAME<br/>endothrm\$4) AND<br/>(reform\$4 SAME<br/>autothermal) NOT L6</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:58 PM |
| L15 | 5  | ((SCHMIDT-Sophia)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05             |

|  |  |                                                 |  |  |  |  |          |
|--|--|-------------------------------------------------|--|--|--|--|----------|
|  |  | (SCHMID-McGUIINESS-Teja)).inv. AND autotherm\$4 |  |  |  |  | 08:00 PM |
|--|--|-------------------------------------------------|--|--|--|--|----------|

## PE2E SEARCH - Search History (Interference)

| Ref # | Hits | Search Query                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | DBs               | Default Operator | Plurals | British Equivalents | Time Stamp             |
|-------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|---------|---------------------|------------------------|
| N1    | 161  | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal) | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05<br>06:43 PM |
| N2    | 1    | ((SCHMIDT-Sophia)<br>(SCHMID-McGUIINESS-Teja)).inv. AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05<br>06:43 PM |

|  |  |              |  |  |  |  |  |
|--|--|--------------|--|--|--|--|--|
|  |  | autothermal) |  |  |  |  |  |
|--|--|--------------|--|--|--|--|--|

| <b>INFORMATION DISCLOSURE CITATION</b><br>(USE SEVERAL SHEETS IF NECESSARY)                                                                                                                                                              |          |                                                                                                                                                                                                                                                                |                                      | <b>Complete if Known</b>                                  |                                                                        |   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------------------------------------------|------------------------------------------------------------------------|---|
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      | Application Number                                        |                                                                        |   |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      | Filing Date                                               |                                                                        |   |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      | First Named Inventor                                      |                                                                        |   |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      | Art Unit                                                  |                                                                        |   |
| Sheet <b>1</b> of <b>1</b>                                                                                                                                                                                                               |          |                                                                                                                                                                                                                                                                |                                      | Examiner Name<br>Attorney Docket Number <b>2019P00370</b> |                                                                        |   |
| <b>U.S. PATENT DOCUMENTS</b>                                                                                                                                                                                                             |          |                                                                                                                                                                                                                                                                |                                      |                                                           |                                                                        |   |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Document Number                                                                                                                                                                                                                                                | Publication Date                     | Name                                                      | Pages Column, Lines Where Relevant Passages or Relevant Figures Appear |   |
|                                                                                                                                                                                                                                          | A1       | US 2015 0141535                                                                                                                                                                                                                                                | 2015-05-21                           | KRESNYAK                                                  |                                                                        |   |
|                                                                                                                                                                                                                                          | A2       | US 2015 0321914                                                                                                                                                                                                                                                | 2015-11-12                           | DARDE et al.                                              |                                                                        |   |
| <b>FOREIGN PATENT DOCUMENTS</b>                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      |                                                           |                                                                        |   |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Document Number                                                                                                                                                                                                                                                | Publication Date                     | Name                                                      | Pages Column, Lines Where Relevant Passages or Relevant Figures Appear | T |
|                                                                                                                                                                                                                                          |          |                                                                                                                                                                                                                                                                |                                      |                                                           |                                                                        |   |
| <b>NON PATENT LITERATURE DOCUMENTS</b>                                                                                                                                                                                                   |          |                                                                                                                                                                                                                                                                |                                      |                                                           |                                                                        |   |
| Examiner Initials                                                                                                                                                                                                                        | Cite No. | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published |                                      |                                                           |                                                                        | T |
|                                                                                                                                                                                                                                          | C1       | AASBERG-PETERSEN, K. et al., Natural gas to synthesis gas – catalysts and catalytic processes, Journal of Natural Gas Science and Engineering, Elsevier, Amsterdam, NL, Vol. 3, No. 2, March 28, 2011                                                          |                                      |                                                           |                                                                        |   |
|                                                                                                                                                                                                                                          | C2       | WISMANN, S.T. et al. Electrified methane reforming: a compact approach to greener industrial hydrogen production, Science 364, 2019, 756-759                                                                                                                   |                                      |                                                           |                                                                        |   |
|                                                                                                                                                                                                                                          | C3       | European Search Report for corresponding EP 20020366, January 18, 2021                                                                                                                                                                                         |                                      |                                                           |                                                                        |   |
| Examiner<br><b>/SYED T IQBAL/</b>                                                                                                                                                                                                        |          |                                                                                                                                                                                                                                                                | Date Considered<br><b>10/05/2022</b> |                                                           |                                                                        |   |
| EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. |          |                                                                                                                                                                                                                                                                |                                      |                                                           |                                                                        |   |

Form PTO-08a/b Facsimile  
(also form PTO-1449)

US Patent and Trademark Office  
US Dept. of Commerce

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------|-----|---------------------------|--|---------------------------------------|--|---------------------|--|
| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                               |                                                                                          |                                                                                                                                                                                                                               |       | Application or Docket Number<br>17/399,277 |     | Filing Date<br>08/11/2021 |  | <input type="checkbox"/> To be Mailed |  |                     |  |
| ENTITY: <input checked="" type="checkbox"/> LARGE <input type="checkbox"/> SMALL <input type="checkbox"/> MICRO                 |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
| <b>APPLICATION AS FILED - PART I</b>                                                                                            |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 |                                                                                          | (Column 1)                                                                                                                                                                                                                    |       | (Column 2)                                 |     |                           |  |                                       |  |                     |  |
| FOR                                                                                                                             |                                                                                          | NUMBER FILED                                                                                                                                                                                                                  |       | NUMBER EXTRA                               |     | RATE (\$)                 |  | FEE (\$)                              |  |                     |  |
| <input type="checkbox"/> BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                             |                                                                                          | N/A                                                                                                                                                                                                                           |       | N/A                                        |     | N/A                       |  |                                       |  |                     |  |
| <input type="checkbox"/> SEARCH FEE<br>(37 CFR 1.16(k), (i), or (m))                                                            |                                                                                          | N/A                                                                                                                                                                                                                           |       | N/A                                        |     | N/A                       |  |                                       |  |                     |  |
| <input type="checkbox"/> EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                       |                                                                                          | N/A                                                                                                                                                                                                                           |       | N/A                                        |     | N/A                       |  |                                       |  |                     |  |
| TOTAL CLAIMS<br>(37 CFR 1.16(i))                                                                                                |                                                                                          | minus 20 = *                                                                                                                                                                                                                  |       |                                            |     | x \$100 =                 |  |                                       |  |                     |  |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                          |                                                                                          | minus 3 = *                                                                                                                                                                                                                   |       |                                            |     | x \$480 =                 |  |                                       |  |                     |  |
| <input type="checkbox"/> APPLICATION SIZE FEE (37 CFR 1.16(s))                                                                  |                                                                                          | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |       |                                            |     |                           |  |                                       |  |                     |  |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                      |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                       |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     | TOTAL                     |  |                                       |  |                     |  |
| <b>APPLICATION AS AMENDED - PART II</b>                                                                                         |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 |                                                                                          | (Column 1)                                                                                                                                                                                                                    |       | (Column 2)                                 |     | (Column 3)                |  |                                       |  |                     |  |
| <b>AMENDMENT</b>                                                                                                                | 01/12/2023                                                                               | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              |       | HIGHEST NUMBER PREVIOUSLY PAID FOR         |     | PRESENT EXTRA             |  | RATE (\$)                             |  | ADDITIONAL FEE (\$) |  |
|                                                                                                                                 | Total<br>(37 CFR 1.16(i))                                                                | * 12                                                                                                                                                                                                                          | Minus | ** 20                                      | = 0 |                           |  | x \$100 =                             |  | 0                   |  |
|                                                                                                                                 | Independent<br>(37 CFR 1.16(h))                                                          | * 1                                                                                                                                                                                                                           | Minus | *** 3                                      | = 0 |                           |  | x \$480 =                             |  | 0                   |  |
|                                                                                                                                 | <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                           |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 | <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  | TOTAL ADD'L FEE                       |  | 0                   |  |
|                                                                                                                                 |                                                                                          | (Column 1)                                                                                                                                                                                                                    |       | (Column 2)                                 |     | (Column 3)                |  |                                       |  |                     |  |
| <b>AMENDMENT</b>                                                                                                                |                                                                                          | CLAIMS REMAINING AFTER AMENDMENT                                                                                                                                                                                              |       | HIGHEST NUMBER PREVIOUSLY PAID FOR         |     | PRESENT EXTRA             |  | RATE (\$)                             |  | ADDITIONAL FEE (\$) |  |
|                                                                                                                                 | Total<br>(37 CFR 1.16(i))                                                                | *                                                                                                                                                                                                                             | Minus | **                                         | =   |                           |  | x \$0 =                               |  |                     |  |
|                                                                                                                                 | Independent<br>(37 CFR 1.16(h))                                                          | *                                                                                                                                                                                                                             | Minus | ***                                        | =   |                           |  | x \$0 =                               |  |                     |  |
|                                                                                                                                 | <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                           |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 | <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
|                                                                                                                                 |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  | TOTAL ADD'L FEE                       |  |                     |  |
| * If the entry in column 1 is less than the entry in column 2, write "0" in column 3.                                           |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  | LIE                                   |  |                     |  |
| ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".                                       |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  | /TERRA T WOODLAND/                    |  |                     |  |
| *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".                                        |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |
| The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1. |                                                                                          |                                                                                                                                                                                                                               |       |                                            |     |                           |  |                                       |  |                     |  |

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Application No.: 17/399,277  
Inventors: Sophia SCHMIDT et al.  
Filed: August 11, 2021  
Title: PROCESS AND PLANT FOR PREPARATION OF  
HYDROGEN AND SEPARATION OF CARBON DIOXIDE  
TC/A.U.: 1736  
Examiner: Syed Taha IQBAL  
Docket No.: 2019P00370  
Customer No.: 40582

**REPLY**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In response to the Non-Final Office Action dated October 12, 2022, having an extended time for response set to expire on January 12, 2023, Applicants respectfully request reconsideration of the present application in view of the following amendments and/or remarks:

**Amendments to the Claims** begin on page 2 of this paper.

**Remarks** begin on page 5 of this paper.

## **Amendments to the Claims**

This listing of claims will replace the originally filed claims in the application.

### **Listing of Claims:**

1. (Previously presented) A process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, comprising:
  - (a) providing a feed gas stream, wherein the feed gas stream comprises a hydrocarbon component and steam, wherein the hydrocarbon component comprises at least methane;
  - (b) reforming at least a portion of the feed gas stream in an endothermic reforming step over a reforming catalyst thereby producing a first synthesis gas stream, wherein the first synthesis gas stream comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;
  - (c) reforming a portion of the feed gas stream in an autothermal reforming step thereby producing a second synthesis gas stream, and combining the first synthesis gas stream and the second synthesis gas stream thereby producing a third synthesis gas stream, or  
reforming the first synthesis gas stream in an autothermal reforming step thereby producing a third synthesis gas stream,  
wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst,  
wherein the second synthesis gas stream and the third synthesis gas stream comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and  
wherein heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);
  - (d) converting the carbon monoxide present in the third synthesis gas stream with steam thereby producing hydrogen and carbon dioxide thereby producing a fourth synthesis gas stream, wherein the fourth synthesis gas stream comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);

(e) separating hydrogen from the fourth synthesis gas stream by pressure swing adsorption, thereby producing a first hydrogen-rich stream and a first residual gas stream, wherein the first residual gas stream comprises carbon dioxide, carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane;

(f) separating carbon dioxide from the first residual gas stream obtained in step (e) by cryogenic carbon dioxide separation, thereby producing a first carbon dioxide-rich stream and a second residual gas stream RG2, wherein the second residual gas stream comprises carbon monoxide unconverted in step (d), hydrogen not separated off in step (e), carbon dioxide not separated off in step (f), and unreacted methane.

2. (Previously presented) The process according to Claim 1, wherein hydrogen is separated from the second residual gas stream, thereby producing a second hydrogen-rich stream and a third residual gas stream.

3. (Previously presented) The process according to Claim 2, wherein the hydrogen is separated from the second residual gas stream by membrane separation.

4. (Previously presented) The process according to Claim 2, wherein the second hydrogen-rich stream is supplied to the fourth synthesis gas stream for separation of hydrogen by pressure swing adsorption in step (e).

5. (Previously presented) The process according to Claim 2, wherein gases present in the second hydrogen-rich stream are utilized as fuel gases for heating in the autothermal reforming step of step c).

6. (Previously presented) The process according to Claim 1, wherein the first carbon dioxide-rich stream comprises unreacted methane, and the first carbon dioxide-rich stream is subjected to a thermal separation process for separation of methane, thereby producing a second carbon dioxide-rich stream.

7. (Previously presented) The process according to Claim 2, wherein carbon dioxide is separated from the third residual gas stream, thereby producing a third carbon dioxide-rich stream and a fourth residual gas stream.
8. (Previously presented) The process according to Claim 7, wherein the carbon dioxide is separated from the third residual gas stream by membrane separation.
9. (Previously presented) The process according to Claim 7, wherein gases present in the fourth residual gas stream are utilized as fuel gases for heating in the autothermal reforming step of step c).
10. (Previously presented) The process according to Claim 7, wherein the third carbon dioxide-rich stream is supplied to the first residual gas stream for cryogenic carbon dioxide separation in step (f).
11. (Previously presented) The process according to Claim 1, wherein the first residual gas stream, for cryogenic carbon dioxide separation in step (f), is subjected to at least one compression step and at least one cooling step, thereby producing the first carbon dioxide-rich stream at least partly in the form of a condensed carbon dioxide stream.
12. (Previously presented) A plant configured for performance of the process according to Claim 1.
13. (Cancelled)

## REMARKS / ARGUMENTS

In complete response to the Non-Final Office Action dated October 12, 2022 on the above identified application, reconsideration is respectfully requested. Claims 16-30 are pending in this application. With this reply, claim 13 has been cancelled without prejudice..

Applicant has thoroughly reviewed the cited references and respectfully submits that the present invention is distinguishable over the prior art references cited by the Office Action and in support presents the following arguments.

### Claim Rejection under 35 U.S.C. § 112

Claim 13 is rejected under 35 U.S.C. 112 as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor regards as the invention. Claims 13 has been cancelled, thereby rendering this rejection moot.

### Allowable Subject Matter

Applicants acknowledge with appreciation that claims 1–12 are allowable.

## CONCLUSION

Accordingly, it is believed that the present application now stands in condition for allowance. Early notice to this effect is earnestly solicited. Should the Examiner believe a telephone call would expedite the prosecution of the application, he is invited to call the undersigned attorney at the number listed below.

Respectfully submitted,

Date: **January 12, 2023**

/Elwood L. Haynes/

Elwood L. Haynes

Registration No. 55,254

Air Liquide USA LLC  
Intellectual Property Department  
9811 Katy Freeway, Suite 100  
Houston, Texas 77024  
(713) 624-8954 Phone  
(713) 624-8950 Fax

#### CERTIFICATE OF TRANSMISSION UNDER 37 CFR 1.8

I hereby certify that this correspondence is being electronically transmitted to the USPTO via EFS-Web on January 12, 2023.

/Diana Guzman/

Diana Guzman

## Electronic Acknowledgement Receipt

|                                             |                                                                                |
|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 47364259                                                                       |
| <b>Application Number:</b>                  | 17399277                                                                       |
| <b>International Application Number:</b>    |                                                                                |
| <b>Confirmation Number:</b>                 | 2532                                                                           |
| <b>Title of Invention:</b>                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
| <b>First Named Inventor/Applicant Name:</b> | Sophia SCHMIDT                                                                 |
| <b>Customer Number:</b>                     | 40582                                                                          |
| <b>Filer:</b>                               | Elwood L. Haynes/Diana Guzman                                                  |
| <b>Filer Authorized By:</b>                 | Elwood L. Haynes                                                               |
| <b>Attorney Docket Number:</b>              | 2019P00370                                                                     |
| <b>Receipt Date:</b>                        | 12-JAN-2023                                                                    |
| <b>Filing Date:</b>                         | 11-AUG-2021                                                                    |
| <b>Time Stamp:</b>                          | 18:39:55                                                                       |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                                    |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name                                                               | File Size(Bytes)/<br>Message Digest                | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|-------------------------------------------------------------------------|----------------------------------------------------|------------------|------------------|
| 1               |                      | 2019P00370_US_2023-01-12_RESPONSE_TO_OA_dtd_2022-10-12_as_filed_ELH.pdf | 105294<br>2d519d6f2583c10ecd5724de97e8b0ed3bc9fce7 | yes              | 5                |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Multipart Description/PDF files in .zip description             |        |     |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Document Description                                            | Start  | End |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Amendment/Request for Reconsideration-After Non-Final Rejection | 1      | 1   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Claims                                                          | 2      | 4   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Applicant Arguments/Remarks Made in an Amendment                | 5      | 5   |
| Warnings:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                 |        |     |
| Information:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                 |        |     |
| Total Files Size (in bytes):                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                 | 105294 |     |
| <p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                                                 |        |     |



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## NOTICE OF ALLOWANCE AND FEE(S) DUE

40582 7590 02/03/2023  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

|                  |              |
|------------------|--------------|
| EXAMINER         |              |
| IQBAL, SYED TAHA |              |
| ART UNIT         | PAPER NUMBER |

1736

DATE MAILED: 02/03/2023

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 17/399,277      | 08/11/2021  | Sophia SCHMIDT       | 2019P00370          | 2532             |

TITLE OF INVENTION: PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE

| APPLN. TYPE    | ENTITY STATUS | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|---------------|---------------|---------------------|----------------------|------------------|------------|
| nonprovisional | UNDISCOUNTED  | \$1200        | \$0.00              | \$0.00               | \$1200           | 05/03/2023 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

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For purposes of this notice, small entity fees are 40% the amount of undiscounted fees, and micro entity fees are 20% the amount of undiscounted fees.

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III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

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| _____<br>(Signature)             |
| _____<br>(Date)                  |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 17/399,277      | 08/11/2021  | Sophia SCHMIDT       | 2019P00370          | 2532             |

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| nonprovisional | UNDISCOUNTED  | \$1200        | \$0.00              | \$0.00               | \$1200           | 05/03/2023 |

| EXAMINER         | ART UNIT | CLASS-SUBCLASS |
|------------------|----------|----------------|
| IQBAL, SYED TAHA | 1736     | 423-653000     |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

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☐ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,

1 \_\_\_\_\_

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2 \_\_\_\_\_

3 \_\_\_\_\_

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government4a. Fees submitted: ☐ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies \_\_\_\_\_

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5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29☐ Applicant asserting small entity status. See 37 CFR 1.27☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature \_\_\_\_\_

Date \_\_\_\_\_

Typed or printed name \_\_\_\_\_

Registration No. \_\_\_\_\_



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| APPLICATION NO.                                                                                                 | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------------------------------------------------------------------------------------------------------|-------------|----------------------|---------------------|------------------|
| 17/399,277                                                                                                      | 08/11/2021  | Sophia SCHMIDT       | 2019P00370          | 2532             |
| 40582                                                                                                           | 7590        | 02/03/2023           | EXAMINER            |                  |
| American Air Liquide<br>Intellectual Property Department<br>9811 Katy Freeway<br>Suite 100<br>Houston, TX 77024 |             |                      | IQBAL, SYED TAHA    |                  |
|                                                                                                                 |             |                      | ART UNIT            | PAPER NUMBER     |
|                                                                                                                 |             |                      | 1736                |                  |
| DATE MAILED: 02/03/2023                                                                                         |             |                      |                     |                  |

## Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

## OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

### Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an issued patent, or a trademark registration.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

|                               |                                      |                                       |                                 |
|-------------------------------|--------------------------------------|---------------------------------------|---------------------------------|
| <b>Notice of Allowability</b> | <b>Application No.</b><br>17/399,277 | <b>Applicant(s)</b><br>SCHMIDT et al. |                                 |
|                               | <b>Examiner</b><br>SYED T IQBAL      | <b>Art Unit</b><br>1736               | <b>AIA (FITF) Status</b><br>Yes |

**-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--**

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to the amendment of 01/12/2023.  
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on \_\_\_\_\_.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on \_\_\_\_\_; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1-12. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see [http://www.uspto.gov/patents/init\\_events/pph/index.jsp](http://www.uspto.gov/patents/init_events/pph/index.jsp) or send an inquiry to [PPHfeedback@uspto.gov](mailto:PPHfeedback@uspto.gov).

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

**Certified copies:**

a) ☒ All      b) ☐ Some\*      c) ☐ None of the:

1. ☒ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.

3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

\* Certified copies not received: \_\_\_\_\_.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.  
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.  
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date \_\_\_\_\_.

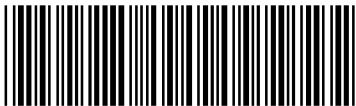
**Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

|                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. <input type="checkbox"/> Notice of References Cited (PTO-892)<br>2. <input type="checkbox"/> Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____<br>3. <input type="checkbox"/> Examiner's Comment Regarding Requirement for Deposit of Biological Material _____<br>4. <input type="checkbox"/> Interview Summary (PTO-413), Paper No./Mail Date. _____ | 5. <input type="checkbox"/> Examiner's Amendment/Comment<br>6. <input type="checkbox"/> Examiner's Statement of Reasons for Allowance<br>7. <input type="checkbox"/> Other _____ |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                   |
|-------------------------------------------|---------------------------------------------------|
| /SYED T IQBAL/<br>Examiner, Art Unit 1736 | /STEVEN J BOS/<br>Primary Examiner, Art Unit 1736 |
|-------------------------------------------|---------------------------------------------------|

|                                                                                                                  |                                              |                                                                  |
|------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b>Issue Classification</b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                                  | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

| CPC    |   |      |   |      |      |            |
|--------|---|------|---|------|------|------------|
| Symbol |   |      |   |      | Type | Version    |
| C01B   | / | 3    | / | 40   | F    | 2013-01-01 |
| B01D   | / | 53   | / | 047  | I    | 2013-01-01 |
| C01B   | / | 3    | / | 48   | I    | 2013-01-01 |
| C01B   | / | 2203 | / | 0233 | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 0244 | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 0405 | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 042  | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 046  | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 1058 | A    | 2013-01-01 |
| C01B   | / | 2203 | / | 1241 | A    | 2013-01-01 |

| CPC Combination Sets |   |  |   |      |     |
|----------------------|---|--|---|------|-----|
| Symbol               |   |  |   | Type | Set |
|                      | / |  | / |      |     |

|                                                                          |                           |                                    |                             |
|--------------------------------------------------------------------------|---------------------------|------------------------------------|-----------------------------|
| / SYED T IQBAL/<br>Examiner, Art Unit 1736<br>(Assistant Examiner)       | 23 January 2023<br>(Date) | <b>Total Claims Allowed:</b><br>12 |                             |
| / STEVEN J BOS/<br>Primary Examiner, Art Unit 1736<br>(Primary Examiner) | 24 January 2023<br>(Date) | O.G. Print Claim(s)<br>1           | O.G. Print Figure<br>Fig. 2 |

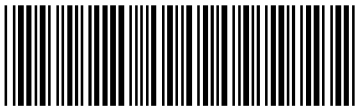
|                                                                                                                         |                                              |                                                                  |
|-------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b><i>Issue Classification</i></b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                                         | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

|                                     |   |    |       |
|-------------------------------------|---|----|-------|
| <b>INTERNATIONAL CLASSIFICATION</b> |   |    |       |
| <b>CLAIMED</b>                      |   |    |       |
| C01B3/40                            | / | 3  | / 40  |
| B01D53/047                          | / | 53 | / 047 |
| C01B3/48                            | / | 3  | / 48  |
| <b>NON-CLAIMED</b>                  |   |    |       |
|                                     | / |    | /     |

|                                   |                 |
|-----------------------------------|-----------------|
| <b>US ORIGINAL CLASSIFICATION</b> |                 |
| <b>CLASS</b>                      | <b>SUBCLASS</b> |
|                                   |                 |

|                            |                                          |  |  |  |  |
|----------------------------|------------------------------------------|--|--|--|--|
| <b>CROSS REFERENCES(S)</b> |                                          |  |  |  |  |
| <b>CLASS</b>               | <b>SUBCLASS (ONE SUBCLASS PER BLOCK)</b> |  |  |  |  |
|                            |                                          |  |  |  |  |

|                                                                         |                           |                                    |                             |
|-------------------------------------------------------------------------|---------------------------|------------------------------------|-----------------------------|
| /SYED T IQBAL/<br>Examiner, Art Unit 1736<br>(Assistant Examiner)       | 23 January 2023<br>(Date) | <b>Total Claims Allowed:</b><br>12 |                             |
| /STEVEN J BOS/<br>Primary Examiner, Art Unit 1736<br>(Primary Examiner) | 24 January 2023<br>(Date) | O.G. Print Claim(s)<br>1           | O.G. Print Figure<br>Fig. 2 |

|                                                                                                                  |                                              |                                                                  |
|------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b>Issue Classification</b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                                  | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

|                                                                                                                                                                                              |          |       |          |       |          |       |          |       |          |       |          |       |          |       |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------|----------|-------|----------|-------|----------|-------|----------|-------|----------|-------|----------|-------|----------|
| <input checked="" type="checkbox"/> Claims renumbered in the same order as presented by applicant <input type="checkbox"/> CPA <input type="checkbox"/> T.D. <input type="checkbox"/> R.1.47 |          |       |          |       |          |       |          |       |          |       |          |       |          |       |          |
| <b>CLAIMS</b>                                                                                                                                                                                |          |       |          |       |          |       |          |       |          |       |          |       |          |       |          |
| Final                                                                                                                                                                                        | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
|                                                                                                                                                                                              |          |       |          |       |          |       |          |       |          |       |          |       |          |       |          |
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|                                                                                                                                                                                              |          |       |          |       |          |       |          |       |          |       |          |       |          |       |          |
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|                                                                         |                           |                                    |                             |
|-------------------------------------------------------------------------|---------------------------|------------------------------------|-----------------------------|
| /SYED T IQBAL/<br>Examiner, Art Unit 1736<br>(Assistant Examiner)       | 23 January 2023<br>(Date) | <b>Total Claims Allowed:</b><br>12 |                             |
| /STEVEN J BOS/<br>Primary Examiner, Art Unit 1736<br>(Primary Examiner) | 24 January 2023<br>(Date) | O.G. Print Claim(s)<br>1           | O.G. Print Figure<br>Fig. 2 |

|                                                                                                          |                                              |                                                                  |
|----------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b>Search Notes</b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                          | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

| CPC - Searched*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------|
| Symbol                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Date       | Examiner   |
| C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR<br>C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR<br>C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR<br>B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR<br>B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR<br>C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151<br>OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR<br>C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR<br>C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR<br>C01B2203/0838 | 10/05/2022 | Syed Iqbal |

| CPC Combination Sets - Searched* |      |          |
|----------------------------------|------|----------|
| Symbol                           | Date | Examiner |
|                                  |      |          |

| US Classification - Searched* |          |      |          |
|-------------------------------|----------|------|----------|
| Class                         | Subclass | Date | Examiner |
|                               |          |      |          |

\* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

| Search Notes                               |            |            |
|--------------------------------------------|------------|------------|
| Search Notes                               | Date       | Examiner   |
| class subclass                             | 10/05/2022 | Syed Iqbal |
| inventor name search                       | 10/05/2022 | Syed Iqbal |
| EPO, JPO and Derwent                       | 10/05/2022 | Syed Iqbal |
| Google Patents and Google Scholar searched | 10/05/2022 | Syed Iqbal |
| iq.ip.com                                  | 10/05/2022 | Syed Iqbal |
| updated search                             | 01/23/2023 | Syed Iqbal |

|                                           |  |
|-------------------------------------------|--|
| /SYED T IQBAL/<br>Examiner, Art Unit 1736 |  |
|-------------------------------------------|--|

|                                                                                                                 |                                              |                                                                  |
|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------|
| <b><i>Search Notes</i></b><br> | <b>Application/Control No.</b><br>17/399,277 | <b>Applicant(s)/Patent Under Reexamination</b><br>SCHMIDT et al. |
|                                                                                                                 | <b>Examiner</b><br>SYED T IQBAL              | <b>Art Unit</b><br>1736                                          |

| Interference Search |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |            |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------|
| US Class/CPC Symbol | US Subclass/CPC Group                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Date       | Examiner   |
|                     | C01B3/40 OR B01D53/047 OR C01B3/48 OR<br>C01B2203/0233 OR C01B2203/0244 OR<br>C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR<br>B01D53/002 OR C01B32/50 OR B01D53/22 OR<br>B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR<br>C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR<br>C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR<br>F25J3/067 OR F25J3/08 OR C01B2203/0833 OR C01B2203/0838 | 01/23/2023 | Syed Iqbal |
|                     | inventor name search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 01/23/2023 | Syed Iqbal |

|                                            |  |
|--------------------------------------------|--|
| / SYED T IQBAL/<br>Examiner, Art Unit 1736 |  |
|--------------------------------------------|--|

| Publication Number | Application Number | Title          | Priority Date - | Application Da | Publication Da |
|--------------------|--------------------|----------------|-----------------|----------------|----------------|
| KR20220020778A     | KR20210103672A     | Process and p  | 8/11/2020       | 8/6/2021       | 2/21/2022      |
| CN114074920A       | CN202110894117A    | Method and s   | 8/11/2020       | 8/4/2021       | 2/22/2022      |
| EP3954650A1        | EP20020366         | Method and s   | 8/11/2020       | 8/11/2020      | 2/16/2022      |
| WO2006042986A1     | PCTFR2005050818    | Method for pi  | 10/20/2004      | 10/6/2005      | 4/27/2006      |
| FR2876683A1        | FR0452377          | Process for pr | 10/20/2004      | 10/20/2004     | 4/21/2006      |
| EP3828132A1        | EP19020665         | Method and s   | 11/26/2019      | 11/26/2019     | 6/2/2021       |
| ES2711529T3        | ES09808776         | High pressure  | 8/21/2008       | 8/19/2009      | 5/6/2019       |
| CA2734874C         | CA2734874          | Systems and p  | 8/21/2008       | 8/19/2009      | 10/11/2016     |
| US20220267147      | US17677805         | Gas reformer   | 2/22/2021       | 2/22/2022      | 8/25/2022      |
| WO2022178439A1     | PCTUS2022017352    | Improved gas   | 2/22/2021       | 2/22/2022      | 8/25/2022      |
| CA2734874A1        | CA2734874          | Systems and p  | 8/21/2008       | 8/19/2009      | 2/25/2010      |
| DE102012112705A1   | DE102012112705     | Process for pr | 12/20/2012      | 12/20/2012     | 6/26/2014      |
| CA2647909A1        | CA2647909          | Carbon dioxid  | 4/3/2006        | 3/28/2007      | 11/1/2007      |
| CA2647909C         | CA2647909          | Carbon dioxid  | 4/3/2006        | 3/28/2007      | 3/24/2015      |
| US20070232706      | US11395137         | Carbon dioxid  | 4/3/2006        | 4/3/2006       | 10/4/2007      |
| US20150323248      | US14410903         | Process for re | 4/7/2012        | 5/3/2013       | 11/12/2015     |
| EP2682364A1        | EP12174867         | Process for re | 7/4/2012        | 7/4/2012       | 1/8/2014       |
| US7871457          | US11395137         | Carbon dioxid  | 4/3/2006        | 4/3/2006       | 1/18/2011      |
| EP2356068A2        | EP09808776         | Systems and p  | 8/21/2008       | 8/19/2009      | 8/17/2011      |
| WO2010022162A2     | PCTUS2009054332    | Systems and p  | 8/21/2008       | 8/19/2009      | 2/25/2010      |
| US20170057819      | US15144675         | Systems and p  | 8/21/2008       | 5/2/2016       | 3/2/2017       |
| WO2007123673A1     | PCTUS2007007898    | Carbon dioxid  | 4/3/2006        | 3/28/2007      | 11/1/2007      |
| US20100047160      | US12544099         | Systems and p  | 8/21/2008       | 8/19/2009      | 2/25/2010      |
| EP2004307A1        | EP07754418         | Carbon dioxid  | 4/3/2006        | 3/28/2007      | 12/24/2008     |
| RU2516527C2        | RU2011110497       | Systems and r  | 8/21/2008       | 8/19/2009      | 5/20/2014      |
| WO2014005745A1     | PCTEP2013059281    | Process for re | 7/4/2012        | 5/3/2013       | 1/9/2014       |
| EP2931654B1        | EP13805447         | Method for pi  | 12/13/2012      | 10/31/2013     | 10/5/2016      |
| FR2999555A1        | FR1262001          | Process for hy | 12/13/2012      | 12/13/2012     | 6/20/2014      |
| CN113795460A       | CN202080032748A    | ATR-based hy   | 5/2/2019        | 4/22/2020      | 12/14/2021     |
| WO2014091097A1     | PCTFR2013052611    | Method for pi  | 12/13/2012      | 10/31/2013     | 6/19/2014      |
| EP2931654A1        | EP13805447         | Method for pi  | 12/13/2012      | 10/31/2013     | 10/21/2015     |
| FR2999556A1        | FR1262002          | Process for hy | 12/13/2012      | 12/13/2012     | 6/20/2014      |
| EP2356068B1        | EP09808776         | Process for pr | 8/21/2008       | 8/19/2009      | 11/14/2018     |
| JP2012511493A      | JP2011540196A      | Integrated ga  | 12/11/2008      | 12/10/2009     | 5/24/2012      |
| US9327972          | US12544099         | Systems and p  | 8/21/2008       | 8/19/2009      | 5/3/2016       |
| WO2014091098A1     | PCTFR2013052613    | Method for pi  | 12/13/2012      | 10/31/2013     | 6/19/2014      |
| KR20090015041A     | KR20087026815A     | Carbon dioxid  | 4/3/2006        | 10/31/2008     | 2/11/2009      |
| EP2931655A1        | EP13805448         | Method for pi  | 12/13/2012      | 10/31/2013     | 10/21/2015     |
| EP2931655B1        | EP13805448         | Method for pi  | 12/13/2012      | 10/31/2013     | 7/6/2016       |
| JP5677659B2        | JP2011540196A      | Integrated ga  | 12/11/2008      | 12/10/2009     | 2/25/2015      |
| WO2015173290A1     | PCTEP2015060565    | Process for ge | 5/15/2014       | 5/13/2015      | 11/19/2015     |
| CA2889078A1        | CA2889078          | Method for pi  | 12/13/2012      | 10/31/2013     | 6/19/2014      |
| US20210155478      | US17102593         | Process and p  | 11/26/2019      | 11/24/2020     | 5/27/2021      |
| WO2021175662A1     | PCTEP2021054441    | Hydrogen anc   | 3/6/2020        | 2/23/2021      | 9/10/2021      |
| IN202117049549A    | IN202117049549     | Atr-based hyc  | 5/2/2019        | 10/29/2021     | 3/4/2022       |
| AU768779B2         | AU5765499          | Process for pr | 9/16/1998       | 9/14/1999      | 1/8/2004       |

|                |                 |                |            |            |            |
|----------------|-----------------|----------------|------------|------------|------------|
| EP2944606A1    | EP14305713      | Process for ge | 5/15/2014  | 5/15/2014  | 11/18/2015 |
| WO2019162236A1 | PCTEP2019053986 | Gas processin  | 2/20/2018  | 2/18/2019  | 8/29/2019  |
| CA2888117A1    | CA2888117       | Method for p   | 12/13/2012 | 10/31/2013 | 6/19/2014  |
| EP3755655A1    | EP19705524      | Gas processin  | 2/20/2018  | 2/18/2019  | 12/30/2020 |

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| Publication Number | Application Number | Title         | Priority Date | Application Date | Publication Date |
|--------------------|--------------------|---------------|---------------|------------------|------------------|
| KR20220020778A     | KR20210103672A     | Process and   | 8/11/2020     | 8/6/2021         | 2/21/2022        |
| CN114074920A       | CN202110894117A    | Method and    | 8/11/2020     | 8/4/2021         | 2/22/2022        |
| EP3954650A1        | EP20020366         | Method and    | 8/11/2020     | 8/11/2020        | 2/16/2022        |
| WO2006042986A1     | PCTFR2005050818    | Method for p  | 10/20/2004    | 10/6/2005        | 4/27/2006        |
| FR2876683A1        | FR0452377          | Process for p | 10/20/2004    | 10/20/2004       | 4/21/2006        |
| EP4098610A1        | EP21020287         | Method and    | 5/31/2021     | 5/31/2021        | 12/7/2022        |
| EP3828132A1        | EP19020665         | Method and    | 11/26/2019    | 11/26/2019       | 6/2/2021         |
| WO2022229838A1     | PCTIB2022053855    | Process for p | 4/27/2021     | 4/26/2022        | 11/3/2022        |
| ES2711529T3        | ES09808776         | High pressur  | 8/21/2008     | 8/19/2009        | 5/6/2019         |
| CA2734874C         | CA2734874          | Systems and   | 8/21/2008     | 8/19/2009        | 10/11/2016       |
| EP4098609A1        | EP21020286         | Method and    | 5/31/2021     | 5/31/2021        | 12/7/2022        |
| US20220267147      | US17677805         | Gas reformer  | 2/22/2021     | 2/22/2022        | 8/25/2022        |
| WO2022178439A1     | PCTUS2022017352    | Improved ga   | 2/22/2021     | 2/22/2022        | 8/25/2022        |
| CA2734874A1        | CA2734874          | Systems and   | 8/21/2008     | 8/19/2009        | 2/25/2010        |
| DE102012112705A1   | DE102012112705     | Process for p | 12/20/2012    | 12/20/2012       | 6/26/2014        |
| CA2647909A1        | CA2647909          | Carbon dioxi  | 4/3/2006      | 3/28/2007        | 11/1/2007        |
| CA2647909C         | CA2647909          | Carbon dioxi  | 4/3/2006      | 3/28/2007        | 3/24/2015        |
| US20070232706      | US11395137         | Carbon dioxi  | 4/3/2006      | 4/3/2006         | 10/4/2007        |
| US20150323248      | US14410903         | Process for r | 4/7/2012      | 5/3/2013         | 11/12/2015       |
| EP2682364A1        | EP12174867         | Process for r | 7/4/2012      | 7/4/2012         | 1/8/2014         |
| US7871457          | US11395137         | Carbon dioxi  | 4/3/2006      | 4/3/2006         | 1/18/2011        |
| EP2356068A2        | EP09808776         | Systems and   | 8/21/2008     | 8/19/2009        | 8/17/2011        |
| WO2010022162A2     | PCTUS2009054332    | Systems and   | 8/21/2008     | 8/19/2009        | 2/25/2010        |
| US20170057819      | US15144675         | Systems and   | 8/21/2008     | 5/2/2016         | 3/2/2017         |
| WO2007123673A1     | PCTUS2007007898    | Carbon dioxi  | 4/3/2006      | 3/28/2007        | 11/1/2007        |
| US20100047160      | US12544099         | Systems and   | 8/21/2008     | 8/19/2009        | 2/25/2010        |
| EP2004307A1        | EP07754418         | Carbon dioxi  | 4/3/2006      | 3/28/2007        | 12/24/2008       |
| RU2516527C2        | RU2011110497       | Systems and   | 8/21/2008     | 8/19/2009        | 5/20/2014        |
| WO2014005745A1     | PCTEP2013059281    | Process for r | 7/4/2012      | 5/3/2013         | 1/9/2014         |
| EP2931654B1        | EP13805447         | Method for p  | 12/13/2012    | 10/31/2013       | 10/5/2016        |
| FR2999555A1        | FR1262001          | Process for h | 12/13/2012    | 12/13/2012       | 6/20/2014        |
| CN113795460A       | CN202080032748A    | ATR-based h   | 5/2/2019      | 4/22/2020        | 12/14/2021       |
| WO2014091097A1     | PCTFR2013052611    | Method for p  | 12/13/2012    | 10/31/2013       | 6/19/2014        |
| EP2931654A1        | EP13805447         | Method for p  | 12/13/2012    | 10/31/2013       | 10/21/2015       |
| FR2999556A1        | FR1262002          | Process for h | 12/13/2012    | 12/13/2012       | 6/20/2014        |
| JP2012511493A      | JP2011540196A      | Integrated g  | 12/11/2008    | 12/10/2009       | 5/24/2012        |
| EP2356068B1        | EP09808776         | Process for p | 8/21/2008     | 8/19/2009        | 11/14/2018       |
| US9327972          | US12544099         | Systems and   | 8/21/2008     | 8/19/2009        | 5/3/2016         |
| WO2014091098A1     | PCTFR2013052613    | Method for p  | 12/13/2012    | 10/31/2013       | 6/19/2014        |
| KR20090015041A     | KR20087026815A     | Carbon dioxi  | 4/3/2006      | 10/31/2008       | 2/11/2009        |
| EP2931655A1        | EP13805448         | Method for p  | 12/13/2012    | 10/31/2013       | 10/21/2015       |
| EP2931655B1        | EP13805448         | Method for p  | 12/13/2012    | 10/31/2013       | 7/6/2016         |
| JP5677659B2        | JP2011540196A      | Integrated g  | 12/11/2008    | 12/10/2009       | 2/25/2015        |
| WO2015173290A1     | PCTEP2015060565    | Process for g | 5/15/2014     | 5/13/2015        | 11/19/2015       |
| WO2022253460A1     | PCTEP2022025240    | Process and   | 5/31/2021     | 5/24/2022        | 12/8/2022        |
| CA2889078A1        | CA2889078          | Method for p  | 12/13/2012    | 10/31/2013       | 6/19/2014        |

|                 |                 |              |            |            |           |
|-----------------|-----------------|--------------|------------|------------|-----------|
| US20210155478   | US17102593      | Process and  | 11/26/2019 | 11/24/2020 | 5/27/2021 |
| IN202117049549A | IN202117049549  | Atr-based hy | 5/2/2019   | 10/29/2021 | 3/4/2022  |
| EP4114792A1     | EP21708180      | Hydrogen an  | 3/6/2020   | 2/23/2021  | 1/11/2023 |
| WO2021175662A1  | PCTEP2021054441 | Hydrogen an  | 3/6/2020   | 2/23/2021  | 9/10/2021 |

## Bibliographic Data

Application No: 17/399,277

Foreign Priority claimed: ☒ Yes ☐ No

35 USC 119 (a-d) conditions met: ☒ Yes ☐ No ☐ Met After Allowance

Verified and Acknowledged:

/SYED T IQBAL/

Examiner's Signature

Initials

Title:

PROCESS AND PLANT FOR PREPARATION OF HYDROGEN  
AND SEPARATION OF CARBON DIOXIDE

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| FILING or 371(c) DATE | CLASS | GROUP ART UNIT | ATTORNEY DOCKET NO. |
|-----------------------|-------|----------------|---------------------|
| 08/11/2021            | 423   | 1736           | 2019P00370          |
| <b>RULE</b>           |       |                |                     |

### APPLICANTS

L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude, Paris, FRANCE

### INVENTORS

Sophia SCHMIDT, Frankfurt am Main, GERMANY

Teja SCHMID McGUIINESS, Frankfurt am Main, GERMANY

### CONTINUING DATA

### FOREIGN APPLICATIONS

EPO EP20020366.9 08/11/2020

### IF REQUIRED, FOREIGN LICENSE GRANTED\*\*

08/19/2021

### STATE OR COUNTRY

GERMANY

### ADDRESS

American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024  
UNITED STATES

### FILING FEE RECEIVED

\$1,980

## PE2E SEARCH - Search History (Prior Art)

| Ref # | Hits | Search Query                                                                                                                                                                                                                                                                                                                                                                                                                                                   | DBs               | Default Operator | Plurals | British Equivalents | Time Stamp          |
|-------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|---------|---------------------|---------------------|
| L1    | 21   | ((SCHMIDT-Sophia) (SCHMID-McGUIINESS-Teja)).inv.                                                                                                                                                                                                                                                                                                                                                                                                               | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 10:55 AM |
| L2    | 1    | ((SCHMIDT-Sophia) (SCHMID-McGUIINESS-Teja)).inv. AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)                                                                                                                                                                                                                                                                                                                                            | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 01:56 PM |
| L3    | 55   | (pressure WITH swing) AND (water WITH gas WITH shift) AND (heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)                                                                                                                                                                                                                                                                              | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 03:33 PM |
| L4    | 47   | (C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05 05:36 PM |

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |    |    |    |                        |
|----|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L5 | 10 | <p>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND (pressure WITH<br/>swing) AND (water<br/>WITH gas WITH shift)<br/>AND (heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME<br/>autothermal)</p> <p>(C01B3/40 OR<br/>B01D53/047 OR<br/>C01B3/48 OR<br/>C01B2203/0233 OR<br/>C01B2203/0244 OR<br/>C01B2203/0405 OR<br/>C01B2203/042 OR<br/>C01B2203/046 OR<br/>C01B2203/1058 OR<br/>C01B2203/1241 OR<br/>B01D53/002 OR<br/>C01B32/50 OR<br/>B01D53/22 OR<br/>B01D2256/16 OR<br/>B01D2257/504 OR<br/>C01B2203/0283 OR<br/>C01B2203/043 OR<br/>C01B2203/0475 OR<br/>C01B2203/147 OR<br/>Y02C20/40 OR<br/>Y02P20/151 OR<br/>C01B3/56 OR<br/>C01B3/38 OR<br/>C01B3/503 OR<br/>C01B3/506 OR<br/>C01B2203/0261 OR<br/>C01B2203/0811 OR<br/>C01B2203/1235 OR<br/>C01B3/382 OR<br/>F25J3/067 OR<br/>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND (pressure WITH<br/>swing) AND (water<br/>WITH gas WITH shift)<br/>AND (endotherm\$4<br/>WITH heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME</p> | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>06:41 PM |
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|----|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----|----|----|------------------------|
| L6 | 10 | autothermal)<br>(pressure WITH swing)<br>AND (water WITH gas<br>WITH shift) AND<br>(endotherm\$4 WITH<br>heat WITH transfer<br>SAME reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                                                                                                                                                                                                     | (US-PGPUB; USPAT)      | OR | ON | ON | 2022/10/05<br>06:43 PM |
| L7 | 0  | (pressure WITH swing)<br>AND (water WITH gas<br>WITH shift) AND<br>(endotherm\$4 WITH<br>heat WITH transfer<br>SAME reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                                                                                                                                                                                                                     | (EPO; JPO;<br>DERWENT) | OR | ON | ON | 2022/10/05<br>06:43 PM |
| L8 | 0  | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND (pressure WITH | (EPO; JPO;<br>DERWENT) | OR | ON | ON | 2022/10/05<br>06:43 PM |

|     |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                     |    |    |    |                     |
|-----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----|----|----|---------------------|
| L9  | 0 | swing) AND (water WITH gas WITH shift) AND (endotherm\$4 WITH heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)<br>(C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR C01B2203/0838).cpc.<br>AND (pressure WITH swing) AND (water WITH gas WITH shift) AND ( heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal) | (EPO; JPO; DERWENT) | OR | ON | ON | 2022/10/05 06:43 PM |
| L10 | 4 | (C01B3/40 OR B01D53/047 OR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (EPO; JPO; DERWENT) | OR | ON | ON | 2022/10/05 06:43 PM |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |    |    |    |                        |
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| L11 | 34 | C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)<br>(C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>06:44 PM |
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|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L12 | 449 | Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal) NOT L6<br><br>(C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heating SAME<br>reform\$4 SAME | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:57 PM |
|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                   |    |    |    |                        |
|-----|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| L13 | 59 | <p>endothrm\$4) AND (reform\$4 SAME<br/>endothrm\$4) AND (reform\$4 SAME<br/>autothermal) NOT L6</p> <p>(C01B3/40 OR<br/>B01D53/047 OR<br/>C01B3/48 OR<br/>C01B2203/0233 OR<br/>C01B2203/0244 OR<br/>C01B2203/0405 OR<br/>C01B2203/042 OR<br/>C01B2203/046 OR<br/>C01B2203/1058 OR<br/>C01B2203/1241 OR<br/>B01D53/002 OR<br/>C01B32/50 OR<br/>B01D53/22 OR<br/>B01D2256/16 OR<br/>B01D2257/504 OR<br/>C01B2203/0283 OR<br/>C01B2203/043 OR<br/>C01B2203/0475 OR<br/>C01B2203/147 OR<br/>Y02C20/40 OR<br/>Y02P20/151 OR<br/>C01B3/56 OR<br/>C01B3/38 OR<br/>C01B3/503 OR<br/>C01B3/506 OR<br/>C01B2203/0261 OR<br/>C01B2203/0811 OR<br/>C01B2203/1235 OR<br/>C01B3/382 OR<br/>F25J3/067 OR<br/>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND ( heating SAME<br/>reform\$4 SAME<br/>endothrm\$4 WITH<br/>autothrm\$4) AND<br/>(reform\$4 SAME<br/>endothrm\$4) AND<br/>(reform\$4 SAME<br/>autothermal) NOT L6</p> | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:57 PM |
| L14 | 57 | <p>(autothrm\$4 SAME<br/>partial WITH oxidation)<br/>AND ( heating SAME<br/>reform\$4 SAME<br/>endothrm\$4 WITH<br/>autothrm\$4) AND<br/>(reform\$4 SAME<br/>endothrm\$4) AND<br/>(reform\$4 SAME<br/>autothermal) NOT L6</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>07:58 PM |
| L15 | 5  | ((SCHMIDT-Sophia)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05             |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                   |    |    |    |                                 |
|-----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|---------------------------------|
| L16 | 60 | (SCHMID-McGUIINESS-Teja)).inv. AND autotherm\$4<br>(C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR C01B2203/0838).cpc. AND ( heating SAME reform\$4 SAME endotherm\$4 WITH autotherm\$4) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal) NOT L6 | (US-PGPUB; USPAT) | OR | ON | ON | 08:00 PM<br>2023/01/23 08:13 PM |
| L17 | 57 | (autotherm\$4 SAME partial WITH oxidation) AND ( heating SAME reform\$4 SAME endotherm\$4 WITH autotherm\$4) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal) NOT L6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23 08:13 PM             |
| L18 | 6  | ((SCHMIDT-Sophia) (SCHMID-                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23 08:13 PM             |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |    |    |    |                     |
|-----|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|---------------------|
| L19 | 10 | McGUIINESS-Teja)).inv. AND autotherm\$4<br>(pressure WITH swing) AND (water WITH gas WITH shift) AND (endotherm\$4 WITH heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME autothermal)                                                                                                                                                                                                                                                                                                                                                                                                                                           | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23 08:13 PM |
| L20 | 47 | (C01B3/40 OR B01D53/047 OR C01B3/48 OR C01B2203/0233 OR C01B2203/0244 OR C01B2203/0405 OR C01B2203/042 OR C01B2203/046 OR C01B2203/1058 OR C01B2203/1241 OR B01D53/002 OR C01B32/50 OR B01D53/22 OR B01D2256/16 OR B01D2257/504 OR C01B2203/0283 OR C01B2203/043 OR C01B2203/0475 OR C01B2203/147 OR Y02C20/40 OR Y02P20/151 OR C01B3/56 OR C01B3/38 OR C01B3/503 OR C01B3/506 OR C01B2203/0261 OR C01B2203/0811 OR C01B2203/1235 OR C01B3/382 OR F25J3/067 OR F25J3/08 OR C01B2203/0833 OR C01B2203/0838).cpc. AND (pressure WITH swing) AND (water WITH gas WITH shift) AND (heat WITH transfer SAME reform\$4 SAME autothermal) AND (reform\$4 SAME endotherm\$4) AND (reform\$4 SAME | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23 08:13 PM |

|     |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |    |    |    |                        |
|-----|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----|----|----|------------------------|
| L21 | 10 | autothermal)<br>(C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND (pressure WITH<br>swing) AND (water<br>WITH gas WITH shift)<br>AND (endotherm\$4<br>WITH heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal) | (US-PGPUB; USPAT)      | OR | ON | ON | 2023/01/23<br>08:13 PM |
| L22 | 4  | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | (EPO; JPO;<br>DERWENT) | OR | ON | ON | 2023/01/23<br>08:13 PM |

|  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |  |  |  |  |
|--|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|--|--|
|  |  | C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal) |  |  |  |  |  |
|--|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|--|--|

## PE2E SEARCH - Search History (Interference)

| Ref # | Hits | Search Query                                                                                                                                                                                                                                                                                                                                                                                               | DBs               | Default Operator | Plurals | British Equivalents | Time Stamp             |
|-------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|---------|---------------------|------------------------|
| N1    | 161  | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR | (US-PGPUB; USPAT) | OR               | ON      | ON                  | 2022/10/05<br>06:43 PM |

|    |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                   |    |    |    |                        |
|----|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
|    |     | C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR<br>F25J3/08 OR<br>C01B2203/0833 OR<br>C01B2203/0838).cpc.<br>AND ( heat WITH<br>transfer SAME<br>reform\$4 SAME<br>autothermal) AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                |                   |    |    |    |                        |
| N2 | 1   | ((SCHMIDT-Sophia<br>(SCHMID-<br>McGUIINESS-<br>Teja)).inv. AND<br>(reform\$4 SAME<br>endotherm\$4) AND<br>(reform\$4 SAME<br>autothermal)                                                                                                                                                                                                                                                                                                                                                                                                             | (US-PGPUB; USPAT) | OR | ON | ON | 2022/10/05<br>06:43 PM |
| N3 | 162 | (C01B3/40 OR<br>B01D53/047 OR<br>C01B3/48 OR<br>C01B2203/0233 OR<br>C01B2203/0244 OR<br>C01B2203/0405 OR<br>C01B2203/042 OR<br>C01B2203/046 OR<br>C01B2203/1058 OR<br>C01B2203/1241 OR<br>B01D53/002 OR<br>C01B32/50 OR<br>B01D53/22 OR<br>B01D2256/16 OR<br>B01D2257/504 OR<br>C01B2203/0283 OR<br>C01B2203/043 OR<br>C01B2203/0475 OR<br>C01B2203/147 OR<br>Y02C20/40 OR<br>Y02P20/151 OR<br>C01B3/56 OR<br>C01B3/38 OR<br>C01B3/503 OR<br>C01B3/506 OR<br>C01B2203/0261 OR<br>C01B2203/0811 OR<br>C01B2203/1235 OR<br>C01B3/382 OR<br>F25J3/067 OR | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23<br>08:13 PM |

|    |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                   |    |    |    |                        |
|----|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----|----|----|------------------------|
| N4 | 162 | <p>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND ( heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME<br/>autothermal)</p> <p>(C01B3/40 OR<br/>B01D53/047 OR<br/>C01B3/48 OR<br/>C01B2203/0233 OR<br/>C01B2203/0244 OR<br/>C01B2203/0405 OR<br/>C01B2203/042 OR<br/>C01B2203/046 OR<br/>C01B2203/1058 OR<br/>C01B2203/1241 OR<br/>B01D53/002 OR<br/>C01B32/50 OR<br/>B01D53/22 OR<br/>B01D2256/16 OR<br/>B01D2257/504 OR<br/>C01B2203/0283 OR<br/>C01B2203/043 OR<br/>C01B2203/0475 OR<br/>C01B2203/147 OR<br/>Y02C20/40 OR<br/>Y02P20/151 OR<br/>C01B3/56 OR<br/>C01B3/38 OR<br/>C01B3/503 OR<br/>C01B3/506 OR<br/>C01B2203/0261 OR<br/>C01B2203/0811 OR<br/>C01B2203/1235 OR<br/>C01B3/382 OR<br/>F25J3/067 OR<br/>F25J3/08 OR<br/>C01B2203/0833 OR<br/>C01B2203/0838).cpc.<br/>AND ( heat WITH<br/>transfer SAME<br/>reform\$4 SAME<br/>autothermal) AND<br/>(reform\$4 SAME<br/>endotherm\$4) AND<br/>(reform\$4 SAME<br/>autothermal)</p> | (US-PGPUB; USPAT) | OR | ON | ON | 2023/01/23<br>08:13 PM |
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|-----------------------|--------------------------|-----------------|---------------|-----------------|------------|------------|
| 17/399,277            | 08/11/2021               | 1736            | 1980          | 2019P00370      | 13         | 2          |

40582

American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

CONFIRMATION NO. 2532

UPDATED FILING RECEIPT



0000000056106717

Date Mailed: 04/19/2023

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

**Please verify the accuracy of the data presented on this receipt.** If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

## Inventor(s)

Sophia SCHMIDT, Frankfurt am Main, GERMANY;  
Teja SCHMID McGUINNESS, Frankfurt am Main, GERMANY;

## Applicant(s)

L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude,  
Paris, FRANCE;

**Power of Attorney:** None

## Domestic Applications for which benefit is claimed - None.

*A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.*

**Foreign Applications** (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.)

EUROPEAN PATENT OFFICE (EPO) 20020366.9 08/11/2020 Access Code Provided

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Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

**If Required, Foreign Filing License Granted:** 08/19/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/399,277**

**Projected Publication Date:** 02/17/2022

**Non-Publication Request:** No

**Early Publication Request:** No

**Title**

PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE

**Preliminary Class**

423

**Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:** No

## **PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

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| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 17/399,277         | 08/11/2021            | Sophia SCHMIDT        | 2019P00370             |

**CONFIRMATION NO. 2532**

40582  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

**37 CFR 1.48(f)**  
**ACKNOWLEDGEMENT LETTER**



\*OC000000056106716\*

Date Mailed: 04/19/2023

**NOTICE OF ACCEPTANCE OF REQUEST UNDER 37 CFR 1.48(f)**

This is in response to the applicant's request under 37 CFR 1.48(f) submitted on 10/11/2021.

The request under 37 CFR 1.48(f) to correct the inventorship, to correct or update the name of an inventor, or to correct the order of names of joint inventors is accepted.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at (571) 272-4000 or (571) 272-4200 or 1-888-786-0101.

/mnguyen/

## PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

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|                |                         |
|----------------|-------------------------|
| Diana Guzman   | (Typed or printed name) |
| /Diana Guzman/ | (Signature)             |
| May 2, 2023    | (Date)                  |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 17/399,277      | 08/11/2021  | Sophia SCHMIDT       | 2019P00370          | 2532             |

TITLE OF INVENTION: PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE

| APPL. TYPE     | ENTRY STATUS | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|---------------|---------------------|----------------------|------------------|------------|
| nonprovisional | UNDISCOUNTED | \$1200        | \$0.00              | \$0.00               | \$1200           | 05/03/2023 |

| EXAMINER         | ART. UNIT | CLASS-SUBCLASS |
|------------------|-----------|----------------|
| IQBAL, SYED TAHA | 1736      | 423-653000     |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363):

☐ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1. Elwood L. Haynes

2.

3.

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: CITY and STATE OR COUNTRY

L'Air Liquide, Société Anonyme pour l'Etude et  
l'Exploitation des Procédés Georges Claude

Paris, France

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies

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5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Elwood L. Haynes/

Date May 2, 2023

Typed or printed name Elwood L. Haynes

Registration No. 55254

## Electronic Patent Application Fee Transmittal

|                                                    |                                                                                |                 |               |                             |
|----------------------------------------------------|--------------------------------------------------------------------------------|-----------------|---------------|-----------------------------|
| <b>Application Number:</b>                         | 17399277                                                                       |                 |               |                             |
| <b>Filing Date:</b>                                | 11-Aug-2021                                                                    |                 |               |                             |
| <b>Title of Invention:</b>                         | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |                 |               |                             |
| <b>First Named Inventor/Applicant Name:</b>        | Sophia SCHMIDT                                                                 |                 |               |                             |
| <b>Filer:</b>                                      | Elwood L. Haynes/Diana Guzman                                                  |                 |               |                             |
| <b>Attorney Docket Number:</b>                     | 2019P00370                                                                     |                 |               |                             |
| Filed as Large Entity                              |                                                                                |                 |               |                             |
| <b>Filing Fees for Utility under 35 USC 111(a)</b> |                                                                                |                 |               |                             |
| <b>Description</b>                                 | <b>Fee Code</b>                                                                | <b>Quantity</b> | <b>Amount</b> | <b>Sub-Total in USD(\$)</b> |
| <b>Basic Filing:</b>                               |                                                                                |                 |               |                             |
| <b>Pages:</b>                                      |                                                                                |                 |               |                             |
| <b>Claims:</b>                                     |                                                                                |                 |               |                             |
| <b>Miscellaneous-Filing:</b>                       |                                                                                |                 |               |                             |
| <b>Petition:</b>                                   |                                                                                |                 |               |                             |
| <b>Patent-Appeals-and-Interference:</b>            |                                                                                |                 |               |                             |
| <b>Post-Allowance-and-Post-Issuance:</b>           |                                                                                |                 |               |                             |
| UTILITY APPL ISSUE FEE                             | 1501                                                                           | 1               | 1200          | 1200                        |

| Description        | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|--------------------|----------|----------|--------|----------------------|
| Extension-of-Time: |          |          |        |                      |
| Miscellaneous:     |          |          |        |                      |
| Total in USD (\$)  |          |          |        | 1200                 |

## Electronic Acknowledgement Receipt

|                                             |                                                                                |
|---------------------------------------------|--------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 47940685                                                                       |
| <b>Application Number:</b>                  | 17399277                                                                       |
| <b>International Application Number:</b>    |                                                                                |
| <b>Confirmation Number:</b>                 | 2532                                                                           |
| <b>Title of Invention:</b>                  | PROCESS AND PLANT FOR PREPARATION OF HYDROGEN AND SEPARATION OF CARBON DIOXIDE |
| <b>First Named Inventor/Applicant Name:</b> | Sophia SCHMIDT                                                                 |
| <b>Customer Number:</b>                     | 40582                                                                          |
| <b>Filer:</b>                               | Elwood L. Haynes/Diana Guzman                                                  |
| <b>Filer Authorized By:</b>                 | Elwood L. Haynes                                                               |
| <b>Attorney Docket Number:</b>              | 2019P00370                                                                     |
| <b>Receipt Date:</b>                        | 02-MAY-2023                                                                    |
| <b>Filing Date:</b>                         | 11-AUG-2021                                                                    |
| <b>Time Stamp:</b>                          | 17:56:38                                                                       |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                                    |

### Payment information:

|                                          |                  |
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| Submitted with Payment                   | yes              |
| Payment Type                             | DA               |
| Payment was successfully received in RAM | \$ 1200          |
| RAM confirmation Number                  | E202352H57518143 |
| Deposit Account                          | 011375           |
| Authorized User                          | Diana Guzman     |

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

IPR2025-01173, -01174, Topsoe Ex. 1002

37 CFR 1.19 (Document supply fees)  
37 CFR 1.20 (Post Issuance fees)  
37 CFR 1.21 (Miscellaneous fees and charges)

### File Listing:

| Document Number | Document Description        | File Name                                                       | File Size(Bytes)/<br>Message Digest     | Multi Part /.zip | Pages (if appl.) |
|-----------------|-----------------------------|-----------------------------------------------------------------|-----------------------------------------|------------------|------------------|
| 1               | Issue Fee Payment (PTO-85B) | 2019P00370_US_2023-05-02_ISSUE_FEE_TRANSMITTAL_as_filed_ELH.pdf | 333175                                  | no               | 1                |
|                 |                             |                                                                 | 31d48604000701d10617fcade2ba0fc090ebf9f |                  |                  |

### Warnings:

### Information:

|   |                      |              |                                          |    |   |
|---|----------------------|--------------|------------------------------------------|----|---|
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 37985                                    | no | 2 |
|   |                      |              | b940b15825f7ed1a5de1f0e27ebc2979988b2665 |    |   |

### Warnings:

### Information:

|                                     |        |
|-------------------------------------|--------|
| <b>Total Files Size (in bytes):</b> | 371160 |
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### New Applications Under 35 U.S.C. 111

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

### National Stage of an International Application under 35 U.S.C. 371

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

### New International Application Filed with the USPTO as a Receiving Office

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| APPLICATION NO. | ISSUE DATE | PATENT NO. | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|------------|------------|---------------------|------------------|
| 17/399,277      | 06/13/2023 | 11673805   | 2019P00370          | 2532             |

40582 7590 05/24/2023  
American Air Liquide  
Intellectual Property Department  
9811 Katy Freeway  
Suite 100  
Houston, TX 77024

## ISSUE NOTIFICATION

The projected patent number and issue date are specified above. The patent will issue electronically. The electronically issued patent is the official patent grant pursuant to 35 U.S.C. § 153. The patent may be accessed on or after the issue date through Patent Center at <https://patentcenter.uspto.gov/>. The patent will be available in both the public and the private sides of Patent Center. Further assistance in electronically accessing the patent, or about Patent Center, is available by calling the Patent Electronic Business Center at 1-888-217-9197.

The USPTO is implementing electronic patent issuance with a transition period, during which period the USPTO will mail a ceremonial paper copy of the electronic patent grant to the correspondence address of record. Additional copies of the patent (i.e., certified and presentation copies) may be ordered for a fee from the USPTO's Certified Copy Center at <https://certifiedcopycenter.uspto.gov/index.html>. The Certified Copy Center may be reached at (800)972-6382.

### **Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)** (application filed on or after May 29, 2000)

The Patent Term Adjustment is 1 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Patents Stakeholder Experience (OPSE), Stakeholder Support Division (SSD) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional inventors):

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Teja SCHMID McGuinness, Frankfurt am Main, GERMANY;

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

L'Air Liquide, Société Anonyme pour l'Etude et l'Exploitation des Procédés Georges Claude, Paris, FRANCE;

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| APPLICATION NO. | ISSUE DATE | PATENT NO. |
|-----------------|------------|------------|
| 17/399,277      | 13-JUN-23  | 11673805   |

American Air Liquide Intellectual Property Department  
9811 Katy Freeway Suite 100  
Houston, TX 77024

### EGRANT NOTIFICATION

Your electronic patent grant (eGrant) is now available, which can be accessed via Patent Center at <https://patentcenter.uspto.gov>

The electronic patent grant is the official patent grant under 35 U.S.C. 153. For more information, please visit <https://www.uspto.gov/electronicgrants>