

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TOPSOE, INC.,
Petitioner

v.

L'AIR LIQUIDE, SOCIÉTÉ ANONYME POUR L'ETUDE ET
L'EXPLOITATION DES PROCÉDÉS GEORGES CLAUDE,
Patent Owner

U.S. Patent No. 11,673,805

Filed: August 11, 2021

Issued: June 13, 2023

Inventors: Schmidt, *et al.*

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

Inter Partes Review No. IPR2025-01174

PETITION FOR *INTER PARTES* REVIEW

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EXHIBITS CITED

Exhibit	Description
1001	U.S. Patent No. 11,673,805 to Schmidt et al. (“the ’805 patent”)
1002	File History of U.S. Patent No. 11,673,805
1003	Declaration of Prof. Dr. Harald Klein
1004	Curriculum Vitae of Prof. Dr. Harald Klein
1005	RESERVED
1006	Martin <i>et al.</i> , (2019) “Progress Update on the Allam Cycle: Commercialization of NET Power and the NET Power Demonstration Facility” " by Scott Martin, et al as presented at the 14th Greenhouse Gas Control Technologies Conference (October 21st – 25th, 2018). Available at SSRN: https://ssrn.com/abstract=3366370 uploaded and downloadable April 11, 2019 (“Martin”)
1007	RESERVED
1008	RESERVED
1009	RESERVED
1010	Cotton, B. (2019) “Clean Hydrogen. Part 1: Hydrogen from Natural Gas Through Cost Effective CO ₂ Capture”, dated March 15, 2019, The Chemical Engineer website, available from https://www.thechemicalengineer.com/features/clean-hydrogen-part-1-hydrogen-from-natural-gas-through-cost-effective-co2-capture/ , for download, Published by Institution of Chemical Engineers (Rugby, UK) (“Cotton”)

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1011	Patwardhan et al. (2013) “Optimised hydrogen production by steam reforming: part 2”; Digital Refining article 1000841, dated PTQ Q3 2013, available for download from http://www.digitalrefining.com/article/1000841 (“Patwardhan”)
1012	Elsevier Signed Declaration (SSR posting) for Martin et al. EX1006
1013	SSRN Cover for Martin et al. EX1006
1014	U.S. Patent Publication No. 2009/0298957 to Gauthier et al. (“Gauthier”)
1015	U.S. Patent Publication No. 2019/0135626 to Rafati et al. (“Rafati”)
1016	Appl, M. (1997) Ammonia Methanol Hydrogen Carbon Monoxide, Modern Production Technologies, A Review; published by Nitrogen-The Journal of the World Nitrogen and Methanol Industries, an imprint of British Sulphur Publishing, a division of CRU Publishing Ltd. (London, England) (“Appl”)
1017	Aasberg-Petersen et al. (2011) “Natural gas to synthesis gas – Catalysts and catalytic processes,” J. Natural Gas Science and Engineering, 3:423-459 (“Aasberg-Petersen”)
1018	Technology Handbook (Air Liquide, Engineering and Construction. Ed.) February 2018, version 2, available for download at https://www.scribd.com/document/386431469/Air-Liquide-Technology-Handbook-March-2018 , 108 pages (“Technology Handbook”)
1019	Riquarts et al. (1985) “Gas separation using pressure swing absorption plants,” in Linde Reports on Science and Technology, No. 40, (LindeAktiengesellschaft), ISSN:0942-5268 (“Riquarts”)

Exhibit	Description
1020	Xu et al. (2014) “An Improved CO ₂ Separation and Purification System Based on Cryogenic Separation and Distillation Theory,” <i>Energies</i> (ISSN 1996-1073), 7, 3484-3502; MDPI (Basel, CH) doi:10.3390/en7053484 (“Xu”)
1021	Keshavarz et al. (2019) “Cryogenic CO ₂ Capture,” in <i>Sustainable Agriculture Reviews</i> 38, (Inamuddin et al., Eds.), ISBN 978-3-030-29337-6 (eBook), Springer Nature Switzerland AG (“Keshavarz”)
1022	RESERVED
1023	RESERVED
1024	U.S. Patent Application No. 2012/0291484 to Terrien et al. (“Terrien”)
1025	Munford Declaration
1026	K. Aasberg-Petersen et al. (2004) “Synthesis gas production for FT synthesis,” Chapter 4 in <i>Studies in Surface Science and Catalysis</i> , vol 152, pages 258-405 (“Aasberg-Petersen II”)
1027	J. R. Rostrup-Nielsen (1993) “Production of Synthesis Gas,” <i>Catalysis Today</i> , volume 18, pages 305-324
1028	J. R. Rostrup-Nielsen (2002) “Syngas in perspective,” <i>Catalysis Today</i> , volume 71, pages 243-247

LISTING OF THE CHALLENGED CLAIMS

<i>Reference</i>	<i>Claim 1</i>
1.pre	A process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide, comprising:
1.1	(a) providing a feed gas stream,
1.1.1	wherein the feed gas stream comprises a hydrocarbon component and steam,
1.1.2	wherein the hydrocarbon component comprises at least methane;
1.2	(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,
1.2.1	wherein the first synthesis gas stream comprises hydrogen, carbon monoxide, carbon dioxide, and unreacted methane;
1.3	(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,
1.3.1	wherein the autothermal reforming step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst,
1.3.2	wherein the second synthesis gas stream and the third synthesis gas stream comprise hydrogen, carbon monoxide, carbon dioxide, and unreacted methane, and
1.3.3	wherein heat generated by the autothermal reforming step is utilized for heating in the endothermic reforming step of step (b);
1.4	(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,
1.4.1	wherein the fourth synthesis gas stream comprises hydrogen, carbon dioxide, unreacted methane, and carbon monoxide unconverted in step (d);

1.5	(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,
1.5.1	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;
1.6	(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,
1.6.1	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.
<i>Reference</i>	<i>Claim 2</i>
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.
<i>Reference</i>	<i>Claim 3</i>
3	The process according to claim 2, wherein the hydrogen is separated from the second residual gas stream by membrane separation.
<i>Reference</i>	<i>Claim 4</i>
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).
<i>Reference</i>	<i>Claim 5</i>
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).
<i>Reference</i>	<i>Claim 6</i>

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.
<i>Reference</i>	<i>Claim 11</i>
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.
<i>Reference</i>	<i>Claim 12</i>
12	A plant configured for performance of the process according to claim 1.

I. INTRODUCTION

Pursuant to 35 U.S.C. §§311–319 and 37 C.F.R. §42.100 et seq., Topsoe, Inc. (“Petitioner”) requests *inter partes* review of claims 1–6, 11, and 12 of U.S. Patent No. 11,673,805 (“the ’805 patent,” EX1001), currently assigned to L’Air Liquide, Société Anonyme pour l’Etude et l’Exploitation des Procédés Georges Claude. (“Patent Owner”). Claims 1–6, 11, and 12 of the ’805 patent are unpatentable under 35 U.S.C. §§102 and 103 for anticipation and for obviousness in view of prior art.

The ’805 patent specification is directed to a process for preparing hydrogen from hydrocarbon gases while separating carbon dioxide (CO₂). The ’805 patent states a goal of reducing CO₂ emissions and describes use of an endothermic reforming step and an autothermal reforming step including two different arrangements—one serial, one parallel—whereby heat generated from the autothermal reforming is used for heating the endothermic reforming step.

During prosecution, claims were allowed because the examiner believed this use of autothermal reforming to heat an endothermic reforming step to be novel. EX1002, p.136. However, the examiner was unaware of prior art references that disclose such arrangement of endothermic and autothermal reforming steps, including both series and parallel configurations, for hydrogen production with CO₂ separation. The remaining aspects of the ’805 patent claims include well-

known steps, such as using pressure swing adsorption (PSA) to separate hydrogen and cryogenic CO₂ separation, and the natural physical characteristics of gases in the process. As shown by the references cited herein, therefore, the process claimed in the '805 patent merely recites a known dual reforming arrangement with already established separation processes, and therefore, should not have been allowed to issue.

II. COMPLIANCE WITH REQUIREMENTS OF AN INTER PARTES REVIEW PETITION

A. Grounds for Standing (§ 42.104(a))

Pursuant to 37 C.F.R. §42.104(a), Petitioner certifies that U.S. Patent No. 11,673,805 (EX1001) is available for *inter partes* review and that Petitioner is not barred or estopped from requesting *inter partes* review of the claims of the '805 patent on the grounds identified in this petition.

B. Fee for *Inter Partes* Review (§42.15(a))

This Petition is accompanied by the fees set forth in 37 C.F.R. §42.15(a). Please charge or credit Deposit Account No. 12-1216 with any shortage or overpayment of fees associated with this Petition.

C. Mandatory Notices (§42.8(b))

1. Real Parties-In-Interest (§42.8(b)(1))

Petitioner certifies that the real parties-in-interest of this Petition are Topsoe, Inc. and Topsoe A/S.

2. Related Matters (§42.8(b)(2))

The '805 patent is the subject of another request for inter partes review concurrently filed by the Petitioner at Inter Partes Review No. IPR2025-01173. Petitioner is unaware of any litigation or other P.T.A.B. proceedings involving the '805 patent.

3. Lead and Back-Up Counsel (§42.8(b)(3))

Petitioner designates the following counsel:

Lead Counsel: Aaron R. Feigelson, Reg. No. 59,022

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Pursuant to 37 C.F.R. §42.10(b), Petitioners have filed a power of attorney with the above designation of counsel.

4. Service Information (§42.8(b)(4))

Petitioner provides the following service information for designated counsel. Petitioners further consent to electronic service by email at the email addresses of the counsel provided below.

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III. IDENTIFICATION OF CHALLENGE AND RELIEF REQUESTED

Petitioner challenges claims 1–6, 11 and 12 of the '805 patent and requests that these claims be found unpatentable and cancelled on the following grounds:

<u>Ground</u>	<u>Statutory Basis</u>	<u>Claims</u>
1	Obvious under 35 U.S.C. §103 in view of Martin and Rafati	1, 6, 11–12
2	Obvious under 35 U.S.C. §103 in view of Martin and Rafati in further view of Gauthier	2-4, 6
3	Obvious under 35 U.S.C. §103 in view of Martin and Rafati and in further view of Terrien	2-5

IV. BACKGROUND AND OVERVIEW OF THE '805 PATENT

The '805 patent entitled, "Process And Plant For Preparation Of Hydrogen And Separation Of Carbon Dioxide," was filed on August 11, 2021, issued on June 13, 2023 and claims priority to EP20020366, filed August 11, 2020. EX1001, p.1.

A. Summary of the '805 Patent Written Description

The '805 patent describes a process for making hydrogen from hydrocarbons, particularly methane, where emission levels of CO₂ are reduced. EX1001, col.2, ln.30–34. The process includes reforming a hydrocarbon feed gas (FG) with steam to form carbon monoxide (CO), CO₂, and hydrogen (synthesis gas, SG1, SG2, SG3). *Id.*, col.4, ln.53–55. The process uses water gas shift reaction to convert CO generated from reforming into CO₂ and additional hydrogen (*Id.*, col.5, ln.4–9), to produce a hydrogen-enriched synthesis gas stream (SG4) (*Id.*, col.5, ln.15–17). Hydrogen is separated from the SG4 using pressure swing adsorption (PSA) to produce a hydrogen-rich stream (HG1) and a residual gas stream containing CO₂ (RG1). *Id.*, col.12, ln.1–7. CO₂ is cryogenically separated from RG1 to produce a CO₂-enriched stream (CG1) and a second residual gas stream depleted of CO₂ (RG2). *Id.*, col.12, ln.7–12. CG1 is optionally separated to remove unreacted methane. *Id.*, col.12, ln.12–14. RG2 is optionally separated

generating additional hydrogen-rich streams (e.g., HG2) and residual gas streams (e.g., RG3). *Id.*, col.12, ln.20–33.

Fig.1 of the '805 patent “shows a highly simplified block flow diagram of a process or plant according to the prior art” (*Id.*, col.9, ln.40–41):

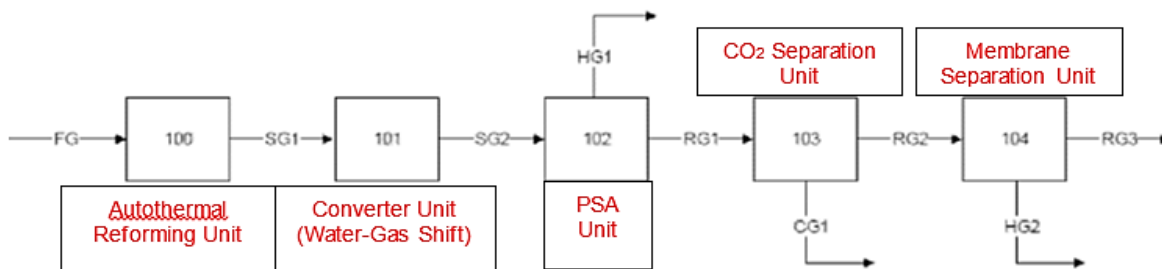
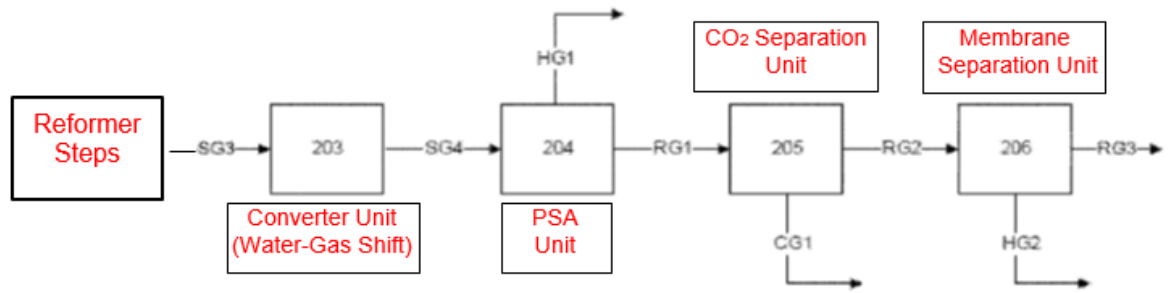


Fig. 1, annotated

The prior art process of Fig. 1 includes an ATR step (100) and a Water-Gas Shift (WGS) Conversion step (101) to generate hydrogen-enriched synthesis gas (SG2) from which hydrogen is separated by a PSA process (102) to produce HG1 and RG1. *Id.*, col.9, ln.42–col.10, ln.15. CO₂ is separated from RG1 to produce CO₂-enriched gas (CG1) and RG2 in a CO₂ separation step (103). *Id.*, col.10, ln.15–26. Hydrogen membrane separation unit (104) separates hydrogen from RG2 to produce HG2 and RG3 (104). *Id.*, col.10, ln.26–38.

Figs. 2 and 3 of the '805 patent illustrate the process of the invention. In Figs. 2 and 3 the processes after the reforming step to produce SG3 are the same as in prior art Fig. 1, *Id.*, col.12, ln.1–15, 20–29; col.13, ln.22–23; EX1003, ¶¶43–44:



Figs. 2 and 3, excerpt, annotated

The reforming step to produce SG3 has two alternative configurations: a series configuration (A) and a parallel configuration (B), as shown below in Figs. 3 and 2, respectively. In both configurations, heat generated in an ATR step is transferred to an endothermic reforming step. EX1001, col.11, ln.28–31, col.13, ln.13–22; EX1003, ¶¶45–46.

Series Configuration:

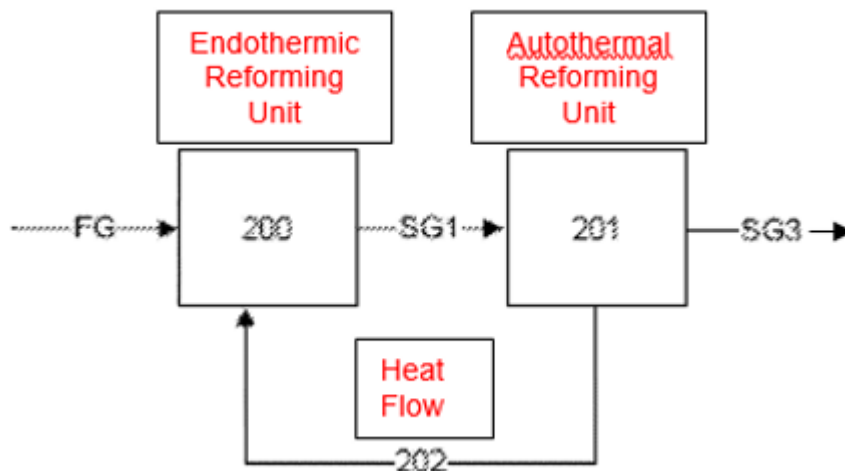


Fig. 3, excerpt, annotated

Parallel Configuration:

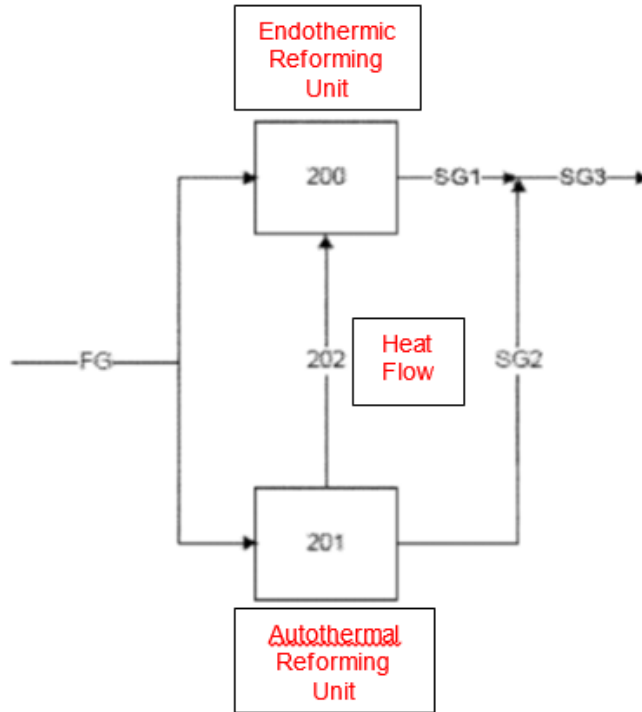


Fig. 2, excerpt, annotated

The '805 patent includes material balance simulations in Tables 2 and 3 which purportedly show a surprising reduction in specific CO₂ emissions for series and parallel reformer configurations. EX1001, col.3, ln.42–44, col.12, ln.34–64, col.13, ln.25–59; Table 1, col.11, ln.1–4; EX1003, ¶47. However, the simulation values in Tables 2 and 3 indicate clear discrepancies and errors, including inaccurate mass balances, and therefore do not support the '805 patent's assertions. EX1001, col.13, ln.42–44; EX1003, ¶¶48–49.

B. Prosecution History of the '805 Patent (EX1002)

The '805 patent was filed as U.S. application no. 17/399,277 on August 11, 2021, claiming priority to European application 20020366, filed August 11, 2020 (the “critical date”), and presented 13 claims. In an Office Action dated October 12, 2022, claims 1–12 were allowed and claim 13 was rejected as indefinite. The applicant responded on January 12, 2023 canceling claim 13. A Notice of Allowance was mailed on February 3, 2023 allowing claims 1–12, wherein the examiner referred to US20150321914 (U.S. national stage of Darde (EX1007)) stating:

“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.” EX1002, p.136.

V. OVERVIEW OF THE PRIOR ART

A. “Progress Update on the Allam Cycle” to Martin et al. (“Martin”)

Martin (EX1006) is an article entitled, “Progress Updated on the Allam Cycle: Commercialization of NET Power and the NET Power Demonstration Facility,” presented at the 14th International Conference on Greenhouse Gas

Control Technologies, GHGT-14, in October 2018 in Melbourne, Australia.

Martin was uploaded to the electronic journal SSRN and posted in that journal on April 11, 2019 as indicated on the SSRN website entry page (EX1013) for Martin as part of the Proceedings of the conference noted above. The article was indexed, searchable and downloadable from the SSRN journal on the posted date. EX1012, ¶¶12; EX1025, ¶¶7–10. In addition, records kept in the ordinary course of business by SSRN, as well as citations in subsequent articles, indicate that the Martin reference was in fact downloaded and thus publicly accessible prior to the critical date for the '805 patent. EX1012, ¶¶8–11; EX1013; EX1025, ¶¶13–17. Because Martin was published and publicly accessible no later than April 2019, Martin is prior art under 35 U.S.C. §102(a)(1)(AIA).

Martin describes a combination reforming process for the generation of hydrogen and carbon capture from natural gas. EX1006, p.11–12. Martin provides a simplified block flow diagram of the process, as shown in annotated Figure 7 below:

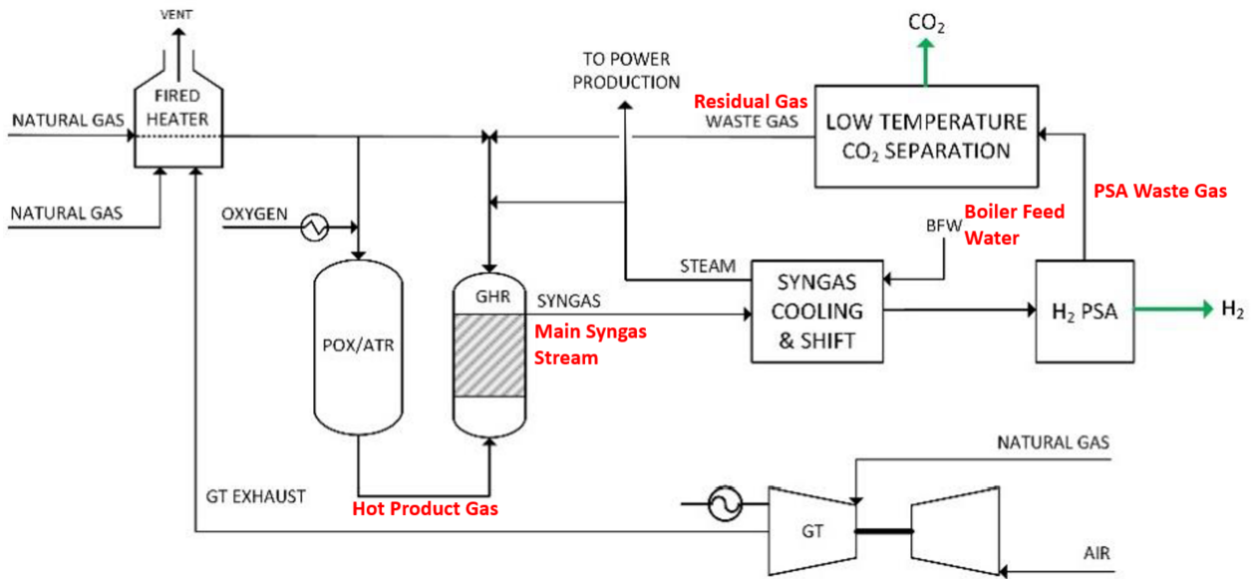


Figure 7, annotated

Martin details the process steps and gas stream flows of the dual reformer arranged in parallel, as depicted in Figure 7. EX1006, p.11–12; EX1003, ¶72.

Martin further describes downstream conversion of CO to CO₂ via syngas shifting and cooling steps, hydrogen separation using a PSA, and cryogenic CO₂ separation. EX1006, p.11–12; EX1003, ¶72. Finally, to maximize process efficiency and CO₂ capture, Martin describes that residual gas from the CO₂ separation and purification system can be recycled back to the reforming reactors. EX1006, p.11–12; EX1003, ¶72.

Thus, before August 2020, skilled artisans understood that generation of hydrogen from hydrocarbons and separation of CO₂ could be accomplished through reforming a feed gas stream using an ATR component in parallel

configuration with a GHR component, converting CO to CO₂, separating hydrogen by PSA, and separating CO₂ through a low temperature removal system. EX1003, ¶¶71-72.

B. U.S. Patent Publication No. 2019/0135626 to Rafati et al. (“Rafati”)

Rafati (EX1015) is a U.S. patent publication that published on May 9, 2019 from U.S. Patent Application No. 16/185,188, filed on November 9, 2018. Rafati is a publication under 35 U.S.C. §122(b). Because Rafati published and was effectively filed prior to the critical date for the ’805 patent, Rafati is prior art under 35 U.S.C. §102(a)(1)(AIA).

Rafati describes a method for the production and separation of hydrogen and CO₂ from hydrocarbon fuel streams in the presence of steam using two-stage reforming processes. EX1015, ¶¶[0014], [0016], [0114]. Specifically, Rafati discusses certain advantages of using a dual reformer with GHR and ATR reactors, arranged in series or parallel, where exhaust from the ATR provides heat for the endothermic reactions in the GHR. EX1015, ¶[0016]; EX1003, ¶¶83-84.

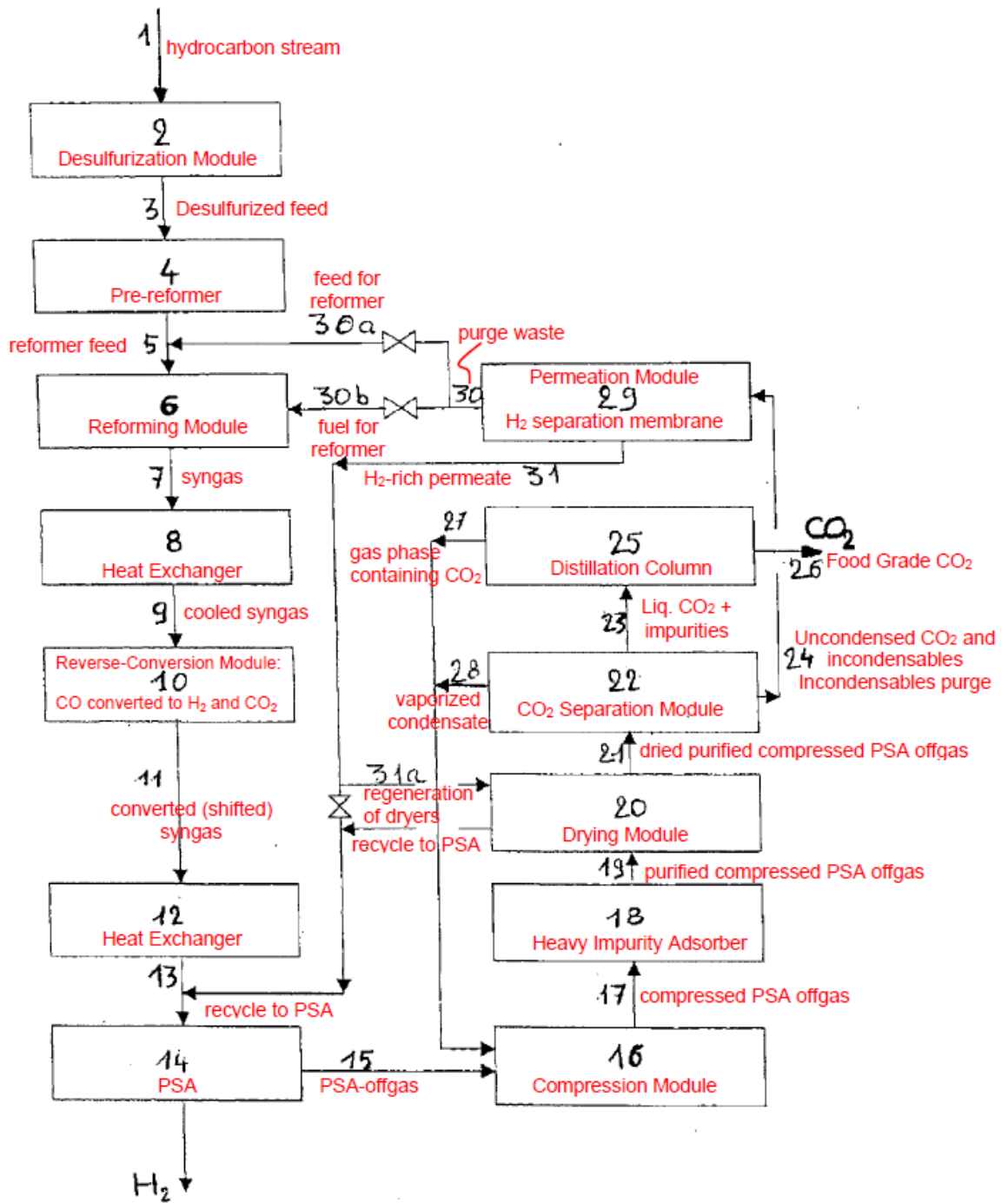
Thus, before the critical date, artisans having a goal of enhancing H₂ yield from a hydrocarbon source would have known the advantages of implementing a dual reforming process. EX1003, ¶¶83-84.

¶87. Rafati also discloses that the process optionally comprises pre-heating feed streams to increase efficiency. EX1015, ¶[0019]; EX1003, ¶88. Thus, before the critical date, skilled artisans understood the reactions and compositions of streams present at each stage of the process for producing H₂ and separating CO₂ wherein said process implements a dual reforming system, a CO conversion step, a PSA separating step, a cryogenic CO₂ separating step, and an optional pre-heating step. EX1003, ¶87-88.

C. U.S. Patent Publication No. US2009/0298957 to Gauthier et al. (“Gauthier”)

Gauthier (EX1014) is a U.S. Patent Publication that published on December 3, 2009 from U.S. application 11/719,248, filed December 22, 2008. Because Gauthier is a publication under §122(b), and published prior to the critical date of the ’805 patent, Gauthier is prior art under 35 U.S.C. §102(a)(1)(AIA).

Gauthier describes a method for producing hydrogen and CO₂ from hydrocarbons. EX1014, Abstract. For example, Figure 1 illustrates a method of separating H₂ from shifted synthesis gas using a PSA (14). EX1014, ¶¶[0137]–[0159].



EX1014, Figure 1, annotated

Gauthier provides detail on the process steps and gas stream flows as depicted in Figure 1, including cryogenic CO₂ separation followed by distillation to remove impurities from CO₂. EX1014, ¶¶[0143]–[0147]; EX1003, ¶¶90-91.

Gauthier further discloses that a purge gas from cryogenic separation is treated in a permeation module to generate H₂-rich permeate. EX1014, ¶¶[0149]–[0150]; EX1003, ¶90. Gauthier further provides processes for recycle, including recycle to an ATR. EX1014, ¶¶[0075], [0152]; EX1003, ¶92.

**D. U.S. Patent Publication No. 2012/0291484 to Terrien et al.
 (“Terrien”)**

Terrien (EX1024) is a U.S. patent publication, published November 22, 2012, corresponding to U.S. application 13/169,241, filed June 27, 2011. Terrien published pursuant to §122(b) prior to the critical date. Terrien is therefore prior art under 35 U.S.C. §102(a)(2)(AIA).

Terrien describes methods for recovery of hydrogen and CO₂ from a syngas stream from gas reforming, including by recycling hydrogen-rich permeates, as exemplified in FIG.5. EX1024, ¶¶[0018], [0020]–[0021], [0074]–[0075], [0077]–[0078]; EX1003, ¶¶94-97.

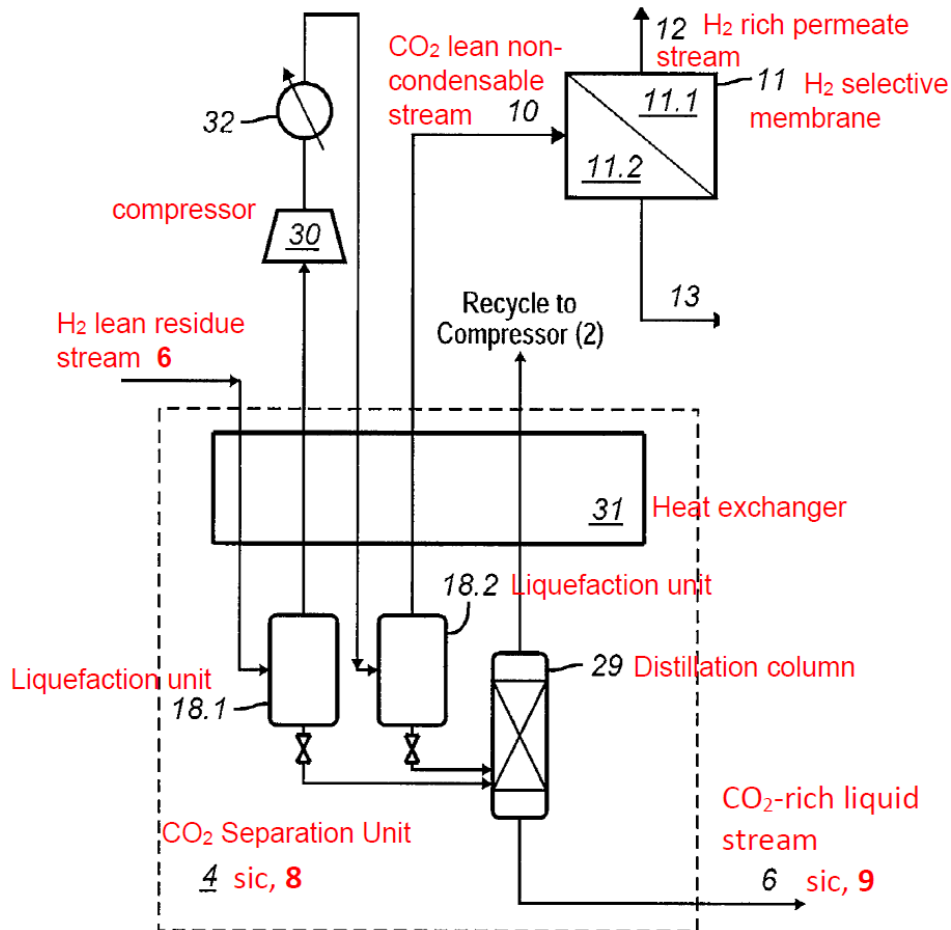


FIG. 4, excerpt, annotated

Terrien discloses use of an ATR to generate the gas input for the process unit (0), compositions of the syngas, and use of cryogenic CO₂ separation.

EX1024, ¶¶[0019], [0069], [0075], [0077]; EX1003, ¶¶99–100.

Terrien discloses recycling hydrogen-rich streams for use as feeds to process steps, including to a PSA and/or fuel in the reforming process, to improve

efficiency of hydrogen and CO₂ recovery. EX1024, ¶¶[0077]–[0078]; EX1003, ¶¶101–103.

VI. LEVEL OF ORDINARY SKILL IN THE ART

A person of ordinary skill in the art (“POSA”) at the critical date would have possessed at least: (1) 3-5 years of experience with steam reforming of methane, partial oxidation, water gas shift process and synthesis gas separation, and (2) a graduate degree in chemical engineering (M.Sc. level). EX1003, ¶15.

VII. HOW THE CHALLENGED CLAIMS ARE TO BE CONSTRUED

In an *inter partes* review, claims “shall be construed using the same claim construction standard that would be used to construe the claim in a civil action.” 37 C.F.R. §42.100; *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312–13 (Fed. Cir. 2005) (*en banc*).

All other claim elements take on a plain and ordinary meaning, as would be understood by a POSA. At present, Petitioner submits that no term of the ’805 patent claims requires a construction outside of its plain and ordinary meaning.

VIII. DETAILED EXPLANATION OF GROUNDS FOR CHALLENGE

Claims 1–6, 11 and 12 of the '805 patent are unpatentable under 35 U.S.C. §103 as obvious over the cited references. In support of the proposed grounds, this Petition is accompanied by the Declaration of Dr. Harald Klein (EX1003), an expert in processes and systems for steam reforming and synthesis gas production with over 25 years of experience in the industry. EX1003, ¶¶3–10.

A. **Ground 1: Claims 1, 6 and 11–12 are Obvious Over Martin and Rafati**

Claims 1, 6 and 11–12 would have been obvious to a POSA based on the combination of Martin and Rafati. EX1003, Section XI.E. As shown below, the combination discloses all the elements of claims 1, 6 and 11–12.

1. **Motivation to Combine, Reasonable Expectation of Success**

Martin alone discloses embodiments within the scope of claims 1, 6, and 11–12 detailing all the process steps of hydrogen production, CO₂ separation, and CO₂ purification of the '805 patent, including the claimed sequence of said steps. EX1006, p.11–12. Patent Owner may contend that the teachings of Martin are not sufficiently detailed, and a POSA could not rely on Martin alone to arrive at the claimed invention. However, to the extent Martin lacks sufficient teaching, there are several reasons why a POSA would have been motivated to supplement the process of Martin with the details disclosed in Rafati.

First, Martin and Rafati describe the same parallel dual reforming configuration with the same combination of downstream CO conversion and H₂/CO₂ separation processes to address complementary aspects of the same problem—producing H₂ while maximizing process efficiency and reducing CO₂ emissions. EX1003, ¶¶318–319.

Indeed, both Martin and Rafati provide detailed discussion around the benefits of using a dual reforming system to increase H₂ yield and improve CO₂ capture. EX1003, ¶320. For example, Rafati states:

An advantage of the two reactor configuration is that the yield of H₂+CO from hydrocarbon feed is maximized, and all CO₂ formed in the reactions is contained within the high-pressure system.

EX1015, ¶[0115]. Martin similarly explains that downstream separation of CO₂ is “more facile” when a combination of partial oxidation and steam methane reforming reactors are used as compared to a single SMR process:

[A] two-stage high pressure syngas generation system utilizing a combination of partial oxidation and steam methane reforming reactors [allows for] all CO₂ generated due to the reforming reactions [to be] contained within the high pressure syngas loop which makes the downstream separation of CO₂ more facile.

EX1006, p.11.

Second, a POSA would have known at the time of the invention that a parallel arrangement of a GHR with an ATR for H₂ production, with heat transfer from the ATR to the GHR, would provide the benefits of saving on natural gas as fuel at the expense of steam production. EX1003, ¶321. For example, Patwardhan (EX1011) acknowledges “[n]ew process schemes such as the autothermal reformer and the gas-heated reformer in series or parallel combination with SMR or ATR are gaining prominence, as they offer potential in reducing energy consumption and flue gas emissions.” *See*, EX1011, p.6. Patwardhan reports numerical simulations showing significant reductions in “relative flue gas emission, CO₂ %” of approximately 5% are achievable via a GHR and ATR reformer configuration with heat exchange with downstream H₂ purification using PSA. *See*, EX1011, Table 3, p.5–6. The simulations reported in Patwardhan demonstrate that a POSA would be motivated to combine the teaching of Martin and Rafati to achieve the reduced energy consumption and flue gas emission reported in Patwardhan EX1003, ¶¶321–323.

Moreover, a POSA would reasonably expect success in combining the teachings of Martin with Rafati to achieve predictable results due to the compatibility of process conditions and reagents of the methods and technologies described therein.

A POSA reviewing both references would have recognized that the details of Rafati could be integrated into the framework of Martin to yield predictable results. EX1003, ¶¶322–325, 366–368.

For example, each of the individual reforming steps recited in Martin and Rafati could be combined with no change in their respective functions. EX1003, ¶367. The parallel configuration of the reforming systems of Martin and Rafati both function to enhance the generation of syngas with the goal of improving efficiency by using the heat from the PDX/ATR process to drive the endothermic reforming reactions of the GHR, as shown in the excerpts below.

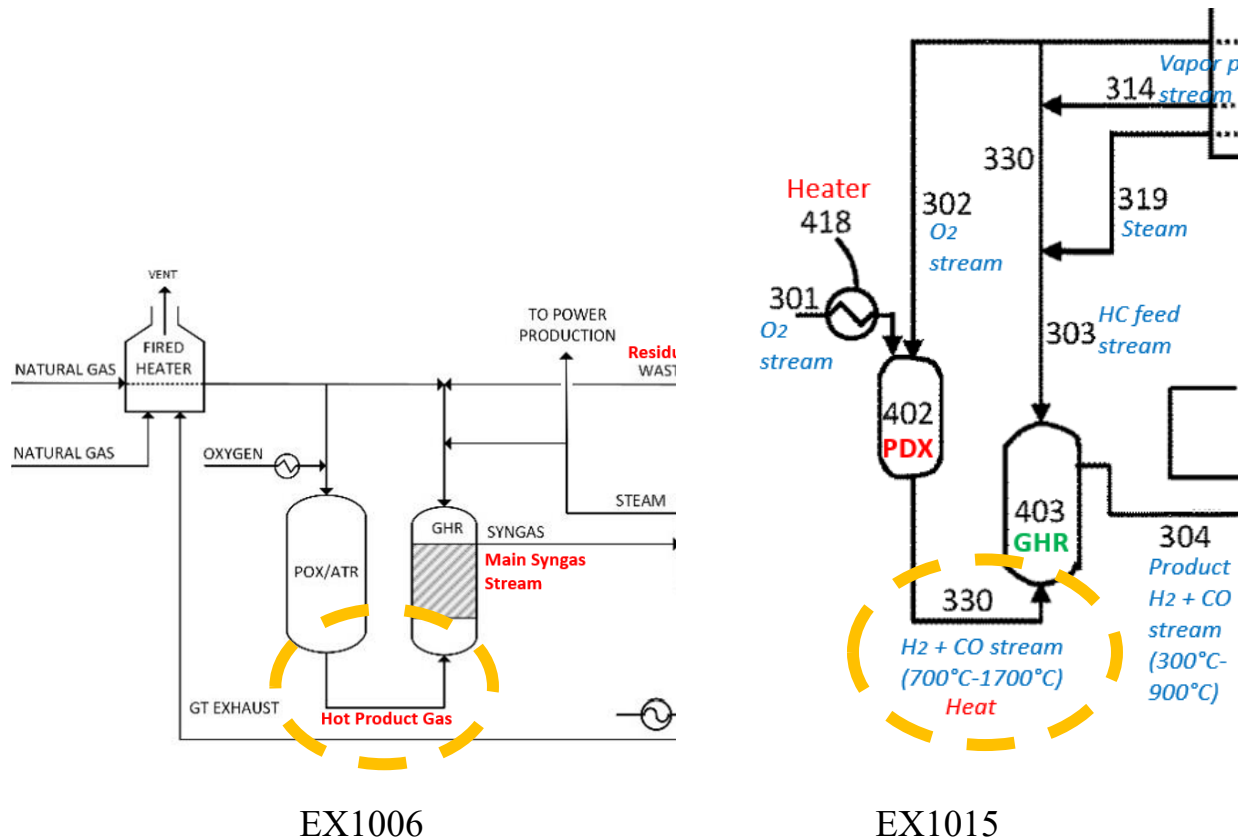
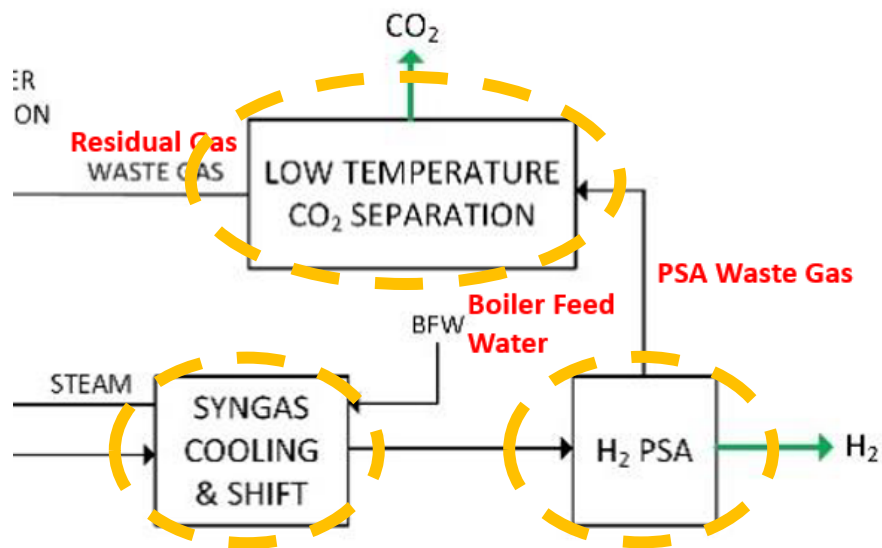


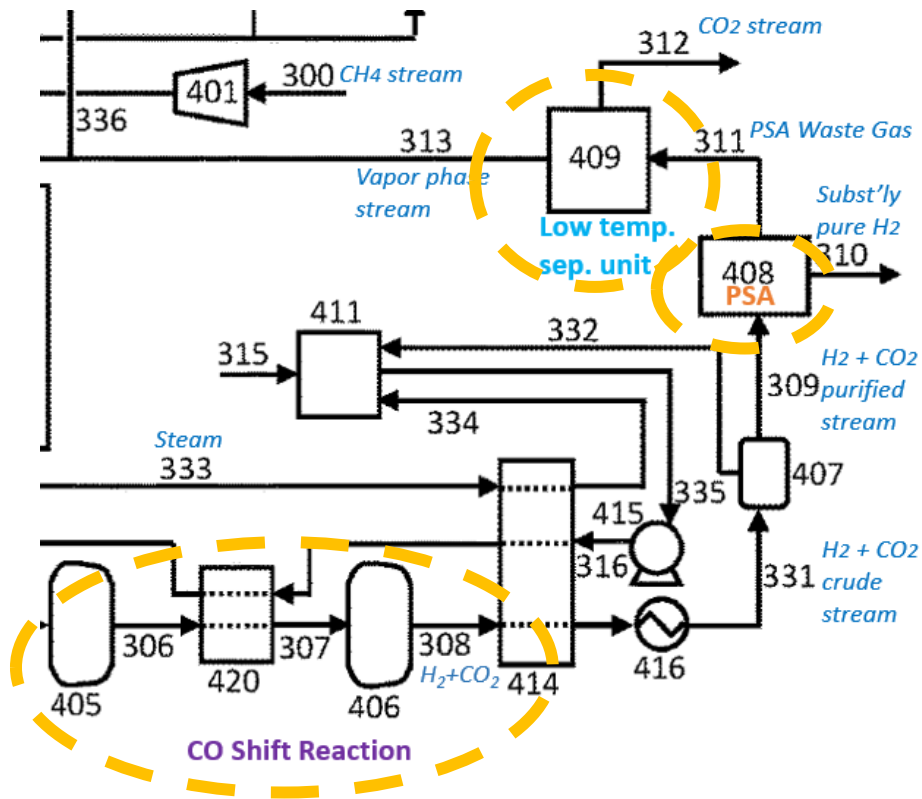
Figure 7, excerpt, annotated

FIG. 2, excerpt, annotated

Furthermore, both Martin and Rafati describe the same combination of devices, in the same order, for downstream CO conversion (CO Shift Reactor) as well as H₂/CO₂ separation (H₂ PSA unit positioned upstream of a low temperature CO₂ separation unit), as shown in the excerpts below. EX1003, ¶368.



EX1006, Figure 7, excerpt, annotated



EX1015, FIG. 2, excerpt, annotated

Thus, a POSA would have reasonably expected that supplementing the process of Martin with the teachings of Rafati would successfully lead to claim 1 of the '805 patent. EX1003, ¶¶325, 366-368. To the extent of inconsistencies between Martin and Rafati, if any, it is noted that absolute predictability of success is not required to demonstrate a reasonable expectation of success. *Pfizer, Inc. v. Apotex, Inc.*, 480 F.3d 1348, 1364 (Fed. Cir. 2007) (“the expectation of success need only be reasonable, not absolute”).

The rationale described above also applies to claims 6 and 11–12, as these claims recite nothing more than the application of methods known in the prior art,

and a POSA would have had a reasonable expectation of success in combining Martin with Rafati. Accordingly, claims 1, 6, and 11–12 were obvious over Martin in view of Rafati.

2. Martin and Rafati Combine to Disclose the Limitations of the Claims

(a) Element 1.pre: Preamble

Martin discloses a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of CO₂. EX1003, ¶¶327–328. See, Figure 7 below:

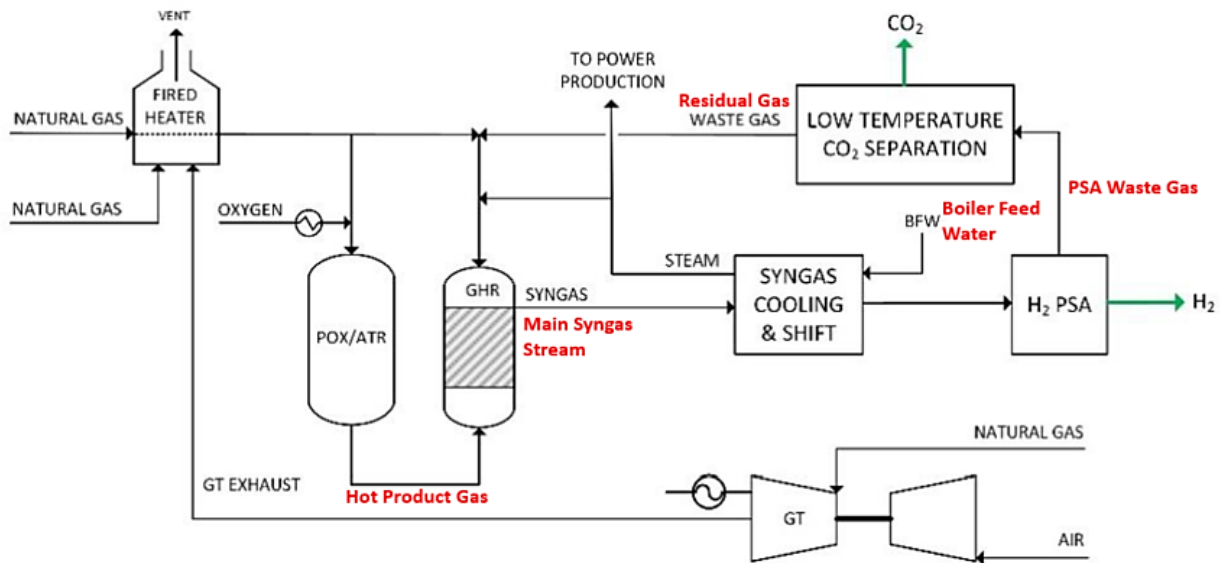


Figure 7, annotated

Martin describes Figure 7 as a “Simplified block flow diagram of 8RH2 process for hydrogen generation with carbon capture.” EX1006, p.12. Figure 7 shows the reforming of hydrocarbons (natural gas) using steam and “LOW

TEMPERATURE CO₂ SEPARATION.” *Id.* Martin further describes another steam methane reforming process for reforming of hydrocarbons using steam in order to produce hydrogen, as shown in Figure 6 below:

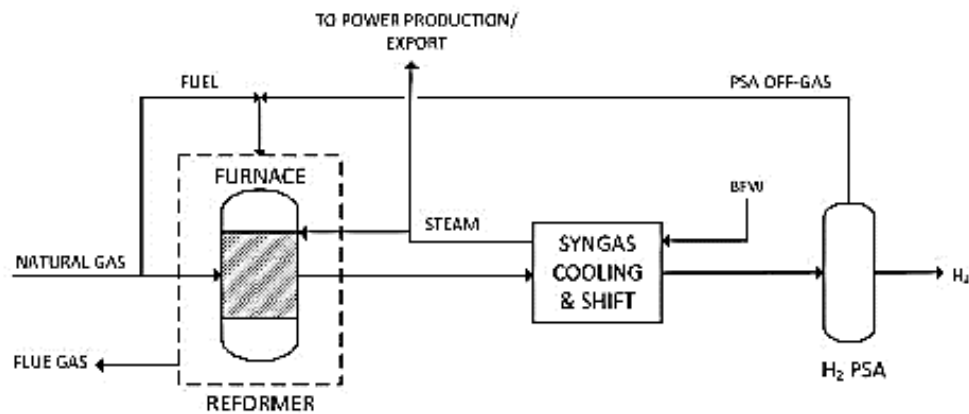


Figure 6

(b) Element 1.1: providing a feed gas stream

Martin discloses providing a feed gas stream. EX1006, p.12; EX1003, ¶329. For example, Martin describes, “[i]n the combined reforming concept, natural gas is partially oxidized in an oxygen deficient environment,” and depicts the natural gas first going through a fired heater, thereby generating a feed gas stream, as shown in the excerpt from Figure 7 below. EX1006, p.12.

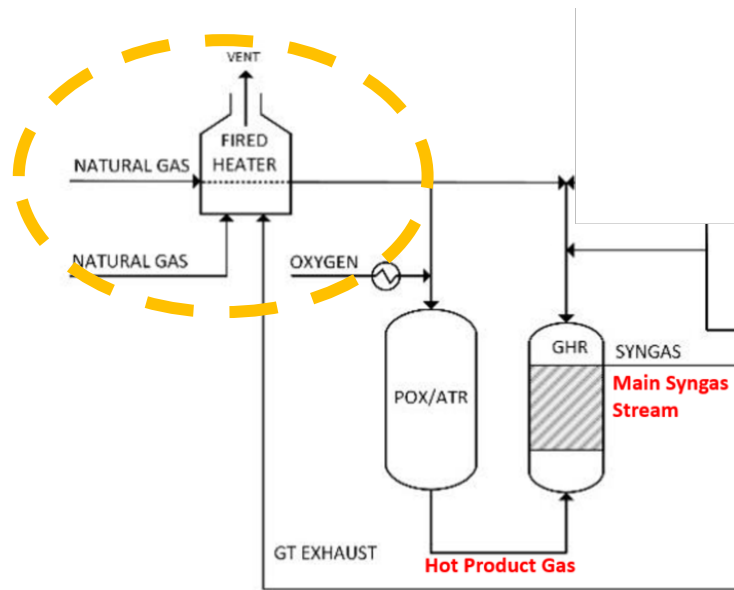


Figure 7, excerpt, annotated

(c) Element 1.1.1: hydrocarbon component and steam

Martin discloses the feed gas stream comprises a hydrocarbon component and steam. EX1006, p.12; EX1003, ¶¶330–332. Martin explicitly discloses natural gas in the feed gas stream, which a POSA would recognize as containing a hydrocarbon component. EX1003, ¶¶28, 331.

Martin further discloses the inclusion of steam in the feed gas stream. Martin expressly notes that “[t]he hot product gas...drives the steam methane reforming reactions within the GHR tubes.” EX1006, p.12. Moreover, a POSA would have understood that a steam methane reforming process in a GHR reformer necessarily requires that steam be present in the input stream. EX1003, ¶¶35–36, 331–332.

To the extent Martin may not explicitly disclose such a composition of a feed gas stream, Rafati describes an embodiment wherein a “steam stream 319 passes through the heat exchanger 412 before combining with methane stream 303 for entry into the GHR 403” as shown in FIG. 2, below. EX1015, ¶[0128]. Therefore, the addition of steam to the methane stream 303 via steam stream 319, as described in Rafati, is equivalent to the '805 patent's feed gas stream comprising a hydrocarbon component and steam. EX1003, ¶332.

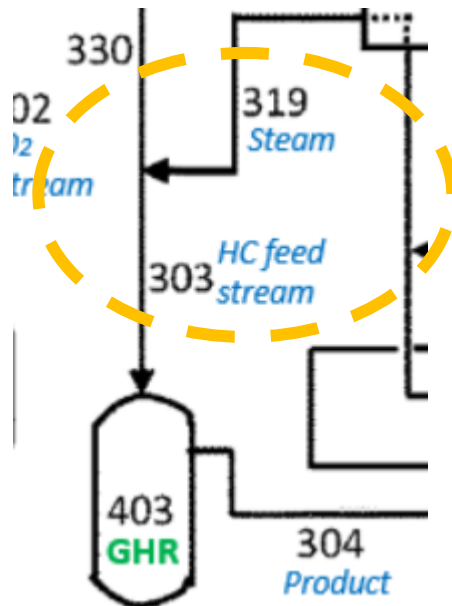


FIG. 2, excerpt, annotated

(d) Element 1.1.2: methane

Martin discloses a feed gas stream with a hydrocarbon component containing methane. EX1006, p.12; EX1003, ¶¶333–334. Martin explicitly

discloses natural gas in the feed gas stream, which necessarily contains methane.

EX1003, ¶28.

To the extent Martin may not explicitly disclose such a composition of a feed gas stream, Rafati expressly recites the hydrocarbon component may comprise methane. EX1015, ¶[0124] (“The example embodiment of FIG. 2 is described in relation to the use of methane as the hydrocarbon.”); EX1003, ¶334.

(e) Element 1.2: endothermic reforming step

Martin discloses 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. EX1006, p.12; EX1003, ¶335. Martin describes that at least a portion of the natural gas is reformed in an endothermic reforming step and passed through a catalyst bed (in the GHR, see Figure 7). EX1006, p.12. It is well understood in the art that a typical GHR reforming process comprises an endothermic reforming step and a reforming catalyst to produce a syngas stream from feed gas. EX1003, ¶¶36, 335. The output from the GHR is a syngas stream, as depicted in Figure 7. Thus, the GHR of Martin is equivalent to the endothermic reforming step of the '805 patent.

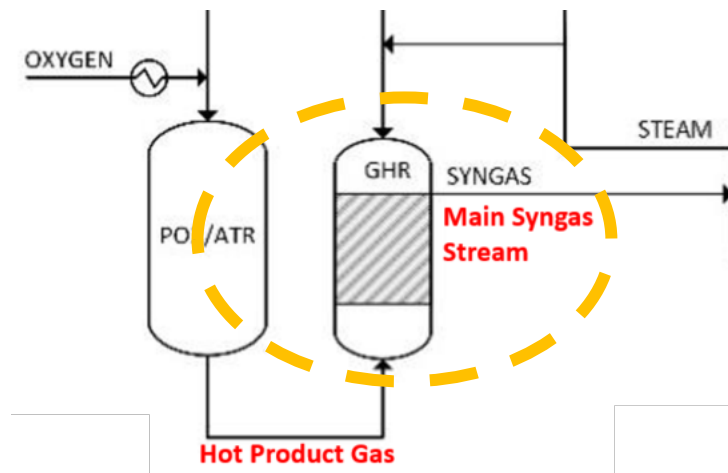


Figure 7, excerpt, annotated

Rafati similarly teaches element 1.2 by disclosing an endothermic reforming step over a reforming catalyst using a GHR to produce a syngas stream. EX1015, ¶[0114] (“A favorable configuration uses a vertical gas heated reformer (GHR) with catalyst filled open ended tubes hanging from a single tube sheet at the top of the vessel, with the product $H_2 + CO$ leaving the reformer tubes.”).

(f) Element 1.2.1: first synthesis gas

Martin discloses, at least inherently, a first synthesis gas stream comprising hydrogen, CO, CO_2 , and unreacted methane. EX1006, p.12; EX1003, ¶[336, 338–339.

To the extent Martin may not explicitly disclose such components of a synthesis gas stream, Rafati discloses an embodiment wherein a product stream having hydrogen and CO exits the GHR. EX1015, ¶[0114] (“A favorable configuration uses a vertical gas heated reformer (GHR) with catalyst filled open

ended tubes hanging from a single tube sheet at the top of the vessel, with the product H₂+CO leaving the reformer tubes.”); EX1003, ¶337. Moreover, Rafati describes the sequence of chemical reactions that occur during the whole hydrogen production process, including the presence of CH₄ and CO₂ after the steam reforming step. EX1015, ¶[0116]. Therefore, the GHR product stream of Rafati, which includes hydrogen, CO, CO₂, and unreacted methane, is equivalent to that of the first synthesis gas stream of the ’805 patent. *Id.*

Both Martin’s and Rafati’s GHRs would also naturally result in the production of unreacted methane and CO₂. As the steam reforming reaction is in equilibrium, both methane and steam are present in the output of the reaction, as well as the H₂, CO and CO₂ product gases. EX1003, ¶¶28–30, 338–339.

Thus, to the extent Martin and Rafati may not expressly disclose the components of the first synthesis gas stream as including the gases enumerated in the claim, both references nevertheless disclose such components of gases as a natural result of the GHR processes described. *Arbutus Biopharma Corp. v. ModernaTx, Inc.*, 65 F.4th 656, 662 (Fed. Cir. 2023) (“[I]nherent anticipation requires ‘merely that the disclosure of the prior art is sufficient to show that the natural result flowing from the operation as taught in the prior art would result in the claimed product.’”).

(g) Element 1.3: reforming in an ATR step

Martin discloses 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. EX1006, p.12; EX1003, ¶340. Martin discloses an autothermal reforming step in, e.g., a POX/ATR reformer. EX1006, p.12, Figure 7. Martin shows the output of the POX/ATR—a second synthesis gas stream as a hot product gas—feeding the GHR. *Id.* Martin then describes “eventually both syngas streams combines to form the main syngas stream.” *Id.*, p.12. Thus, the main syngas stream of Martin is equivalent to that of the third synthesis gas stream of the '805 patent and necessarily includes hydrogen, CO, CO₂, and unreacted methane as a natural result of the ATR process of Martin. EX1003, ¶340; *Arbutus*, 65 F.4th at 662.

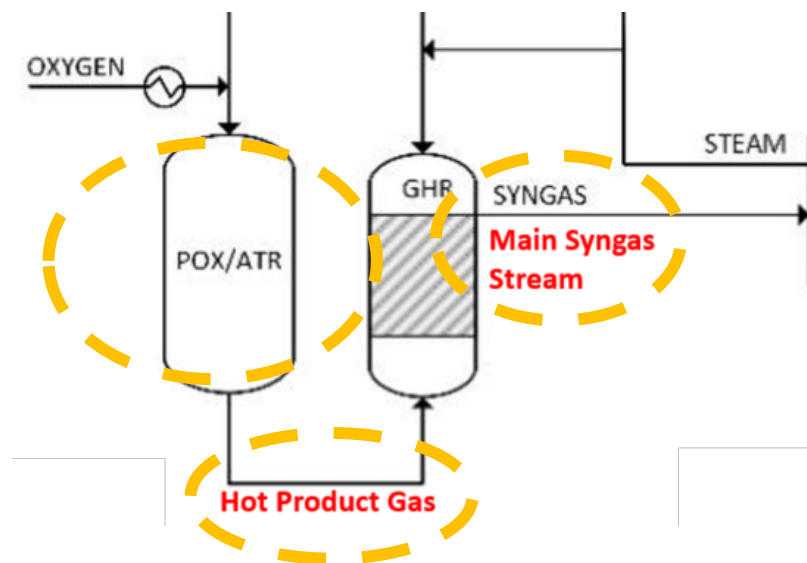


Figure 7, excerpt, annotated

Rafati similarly teaches element 1.3 by disclosing an ATR step and generating a combined product stream. EX1015, ¶¶[0114] (“with the product H₂+CO leaving the reformer tubes and mixing with the product gas from a PDX reactor or an ATR in the base of the GHR, and the total product H₂+CO stream passing through the shell side”), [0125].

(h) Element 1.3.1: exothermic partial oxidation and endothermic reforming

Martin discloses the ATR step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst. EX1006, p.12, Figure 7; EX1003, ¶¶341–342.

Martin discloses the use of an ATR, which by its nature operates in this manner. EX1006, p.12 (“In catalytic variation of partial oxidation, also known as auto-thermal reforming (ATR), the product gas from the partial oxidation section of the reactor is passed through a catalyst bed to enhance syngas generation reactions.”); EX1003, ¶¶28–30, 33–34, 342. This element is similarly taught by Rafati. EX1015, ¶¶[0016], [0066], [0078].

(i) Element 1.3.2: second and third synthesis gas

Martin discloses, at least inherently, the second and third synthesis gas streams comprise hydrogen, CO, CO₂, and unreacted methane. EX1003, ¶¶28–30, 343.

To the extent Martin may not explicitly disclose such compositions of second and third synthesis gas streams, Rafati expressly discloses reforming processes for producing synthesis gases comprising hydrogen, CO, and unreacted methane. Rafati provides, “[t]he steam stream **319** fed to the GHR reactor **403** provides a steam to carbon ratio (carbon combined with hydrogen in the GHR reactor feed) of 6:1 in this case. This high ratio allows 80 bar H₂+CO production pressure with a low quantity of unconverted methane in the total product H₂+CO stream **304**.” EX1015, ¶[0129]; FIG. 2. Thus, Rafati discloses that the product stream from the dual reforming reaction, which is equivalent to the third synthesis gas stream, comprises at least hydrogen, CO, and unreacted methane. EX1003, ¶344. A POSA would have understood that such second and third synthesis gas streams would necessarily include CO₂. EX1003, ¶¶28–30; *Arbutus*, 65 F.4th at 662.

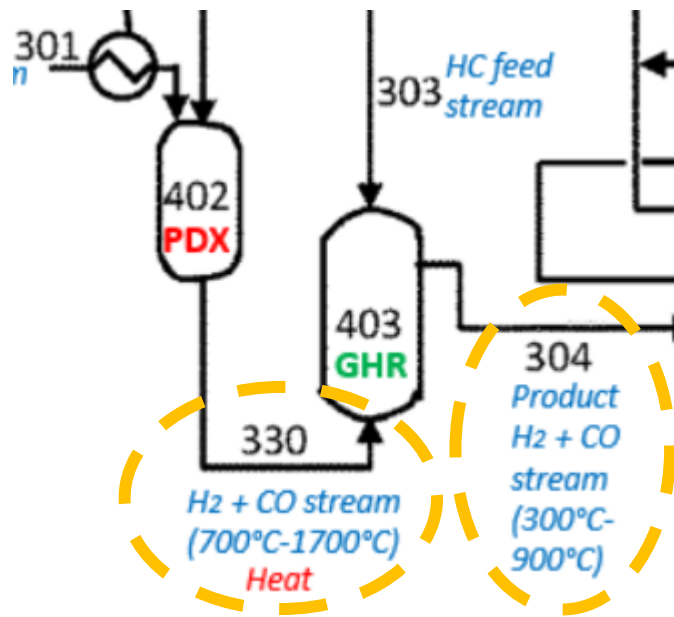


FIG. 2, excerpt, annotated

(j) Element 1.3.3: heat from ATR step

Martin discloses the heat generated by the ATR step is utilized for heating in the endothermic reforming step of step (b). EX1006, p.12, Figure 7; EX1003, ¶345. Martin discloses heat (the hot product gas exiting the ATR) flows to the GHR to provide heat for the initial reaction. EX1006, p.12 (“The hot product gas at 1050-1400 C...drives the steam methane reforming reactions within the GHR tubes.”). Rafati similarly discloses that heat generated by the ATR provides heat for the reforming reactions of the GHR. EX1015, ¶[0016].

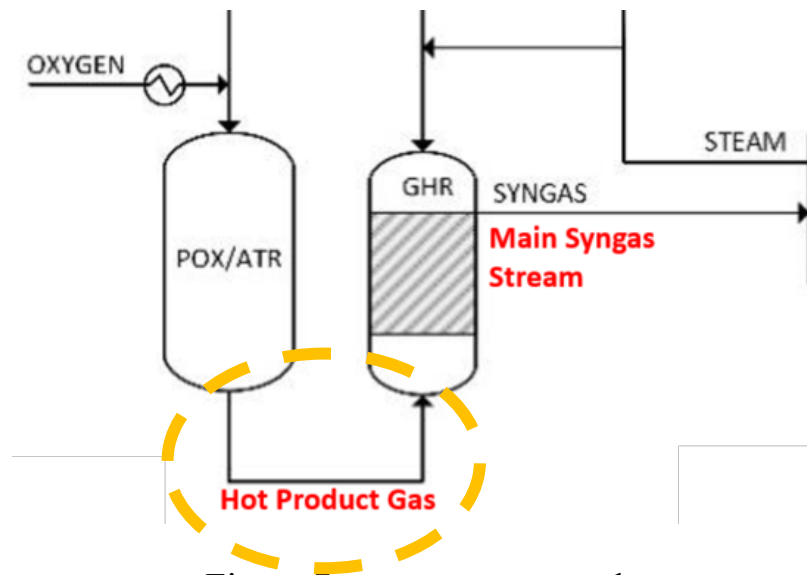


Figure 7, excerpt, annotated

(k) Element 1.4: converting the CO

Martin discloses converting the CO present in the third synthesis gas stream with steam to produce hydrogen and CO₂, thereby disclosing the fourth synthesis gas stream of the '805 Patent. EX1006, p.12, Figure 7; EX1003, ¶¶346–347.

Martin describes using a “SYNGAS COOLING & SHIFT” (Figure 7) to convert CO in the main syngas stream, equivalent to the third gas stream of the '805 patent (*see*, Section VIII.A.2.(g), *supra*), using steam. EX1006, p.12. The result of this shift necessarily produces hydrogen and CO₂ in a fourth synthesis gas stream. EX1003, ¶¶30, 346. Synthesis gas subjected to a WGS reaction undergoes a reversible reaction such that the shifted synthesis gas primarily contains CO₂, CO, H₂, as well as unreacted CH₄ and residual H₂O. *Id.*

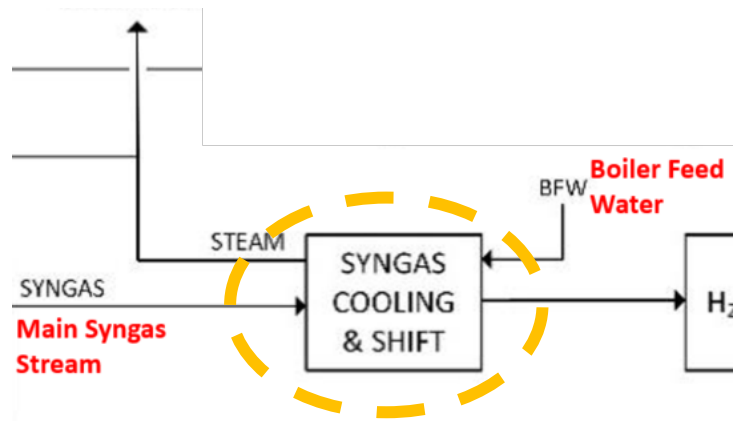


Figure 7, excerpt, annotated

To the extent Martin may not explicitly disclose that the CO conversion step necessarily produces H₂ and CO₂, such products of a CO conversion step are expressly recited in Rafati. EX1015, ¶[0126] (“The product stream comprising H₂+CO is then reacted in at least one reactor to form a stream comprising H₂+CO₂.”). As illustrated in FIG. 2, the total product CO+H₂ stream **305** passes through a first catalyst filled CO shift reactor **405** and a second catalyst filled CO shift reactor **406** in series with respective outlet streams **306** and **308**.”); EX1003, ¶[347.

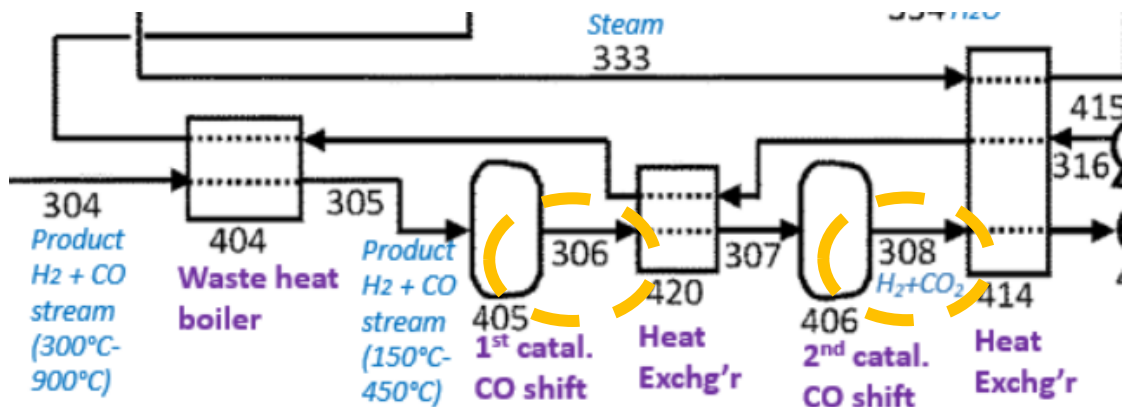


FIG. 2, excerpt, annotated

(I) Element 1.4.1: fourth synthesis gas

Martin discloses, at least inherently, the fourth synthesis gas stream comprises hydrogen, CO₂, unreacted methane, and CO unconverted in step (d). EX1006, p.12; EX1003, ¶¶348–350. Martin discloses “syngas shifting and cooling steps” that necessarily generates a shifted gas comprising hydrogen and CO₂. *See*, Section VIII.A.2.(k), *supra*. Unreacted methane and CO unconverted in step (d) are also necessarily present in the shifted gas. *Id.*

To the extent Martin may not explicitly disclose such compositions of a fourth synthesis gas stream, Rafati expressly discloses that a H₂ + CO stream which undergoes a CO shift reaction step results in a stream comprising H₂ and CO₂, as well as CO and one or more carbon-containing materials. EX1015, ¶[0127] (“The stream **308** comprises H₂+CO₂, but it is understood that any stream described herein as comprising H₂+CO₂ only defines the minimal composition of the stream, and further materials may be present in said stream, such as carbon monoxide and one or more carbon-containing materials.”).

Moreover, Rafati discloses that the crude H₂ + CO₂ stream (**331** of FIG. 2, below) “preferably can contain substantially all of the CO₂ derived from combustion of carbon in the hydrocarbon feed together with water vapor and minor amounts of CO, CH₄, N₂ and Ar.” *Id.* Therefore, Rafati expressly recites each of the components of the fourth synthesis gas stream of the ’805 patent.

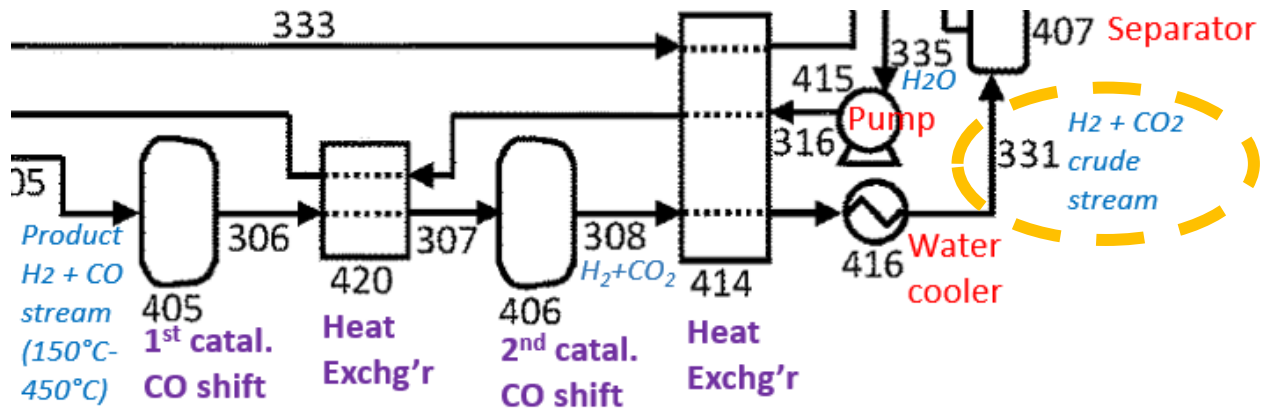


FIG. 2, excerpt, annotated

(m) Element 1.5: separating hydrogen

Martin discloses 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. EX1006, p.12; EX1003, ¶351. Martin exemplifies this step schematically in Figure 7 showing that hydrogen is separated from the synthesis gas stream by “H₂ PSA,” producing a “PSA waste gas” (equivalent to the first residual gas stream of the ’805 patent) as well as a hydrogen stream “H₂” (equivalent to the first hydrogen-rich stream of the ’805 patent. EX1006, p.12, Figure 7.

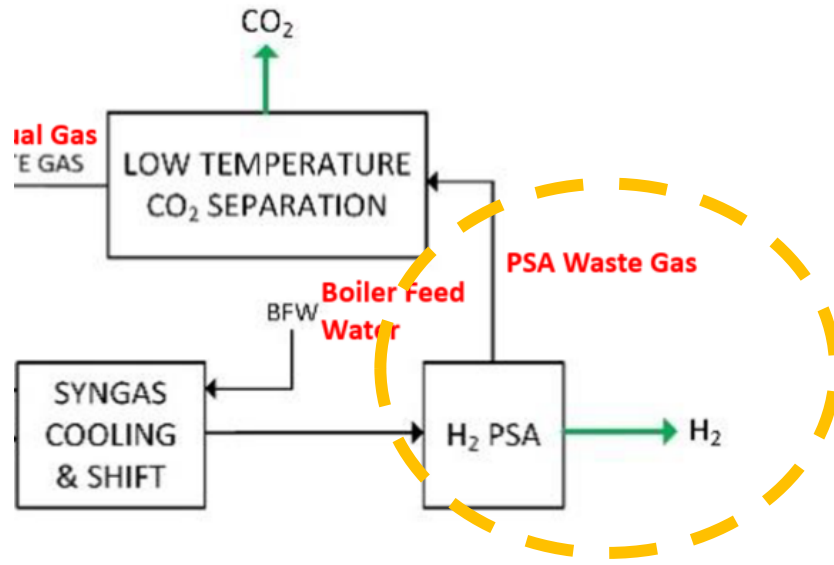


Figure 7, excerpt, annotated

Rafati similarly discloses hydrogen separation by PSA to produce a first hydrogen-rich stream (FIG. 2, “Subst’ly pure H₂”) and a first residual gas stream (FIG. 2, “PSA Waste Gas”). EX1015, ¶[0130], FIG. 2.

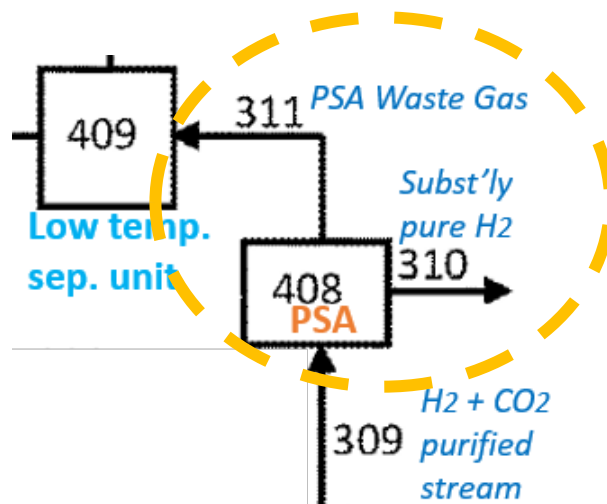


FIG. 2, excerpt, annotated

(n) Element 1.5.1: first residual gas

Martin discloses the first residual gas stream comprises CO₂, CO unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane. EX1006, p.12; EX1003, ¶352. Martin describes that the PSA waste gas “contains about 76% CO₂ (mole basis) which is suitable for processing in a low temperature removal system.” EX1006, p.12; EX1003, ¶352. A POSA would have understood that Martin’s PSA separation step would necessarily produce a residual gas stream having CO₂, unconverted CO, unseparated H₂, and unreacted methane. EX1003, ¶¶39, 352. Thus, the components of the PSA waste gas are equivalent to that of the first residual gas of the ’805 patent and necessarily includes CO₂, unconverted CO, hydrogen not separated and unreacted methane as a natural result of the hydrogen separation process of Martin. EX1003, ¶352; *Arbutus*, 65 F.4th at 662.

To the extent Martin may not explicitly disclose this element, Rafati discloses PSA for producing a substantially pure hydrogen stream (**310** of FIG. 2), which corresponds to the first hydrogen-rich stream of the ’805 patent, and a waste gas (**311** of FIG. 2), which is equivalent to the first residual gas of the ’805 patent, wherein the waste gas “preferably contains all the CO₂ plus CO, H₂, CH₄, Argon, N₂, and traces of water vapor previously in stream **309**.” EX1015, ¶[0131]; EX1003, ¶353.

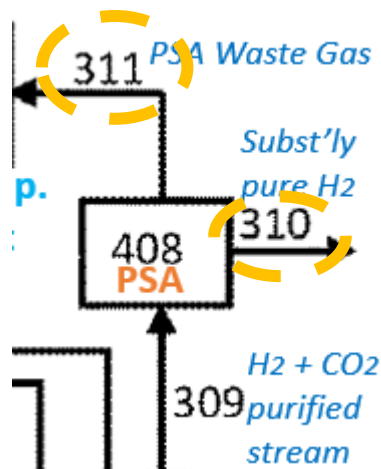


FIG. 2, excerpt, annotated

(o) Element 1.6: separating CO₂

Martin discloses separating CO₂ from the first residual gas stream obtained in step (e) by cryogenic CO₂ separation, thereby producing a first CO₂-rich stream and a second residual gas stream RG2. EX1006, p.12; EX1003, ¶354. Martin discloses the PSA waste gas, which corresponds to the first residual gas stream of the '805 patent, “is suitable for processing in a low temperature removal system. Such a system uses the auto-refrigeration principle to cool down the process stream near CO₂ triple point, and separates and purifies CO₂ product in a distillation column.” *Id.* A POSA would have understood this description to be a cryogenic CO₂ separation process. EX1003, ¶¶40, 354. CO₂ separation generates a CO₂-rich stream, as shown by the green arrow from the “LOW TEMPERATURE CO₂ SEPARATION” portion of Figure 7. EX1006, p.12; EX1003, ¶354. Martin also

discloses that a “WASTE GAS”, which is equivalent to the second residual gas of the '805 patent, is produced from the cryogenic separation process. EX1006, p.12.

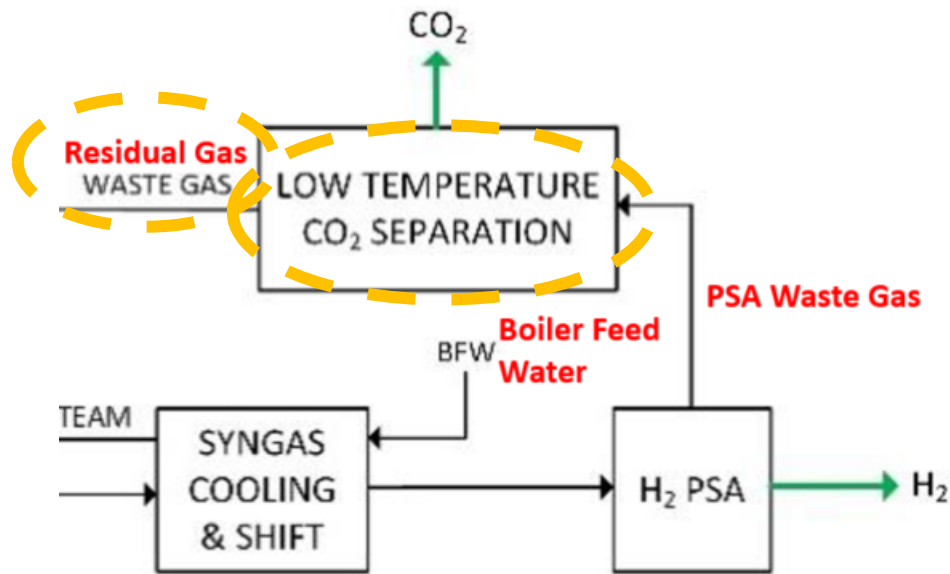


Figure 7, excerpt, annotated

To the extent Martin may not explicitly disclose this element, Rafati expressly discloses that a low temperature separation unit may be a cryogenic separation unit. EX1015, ¶[0131] (“The waste gas stream 311 is then processed in a low temperature separation unit 409 (e.g., a cryogenic separation unit) as otherwise described herein to form a liquid CO₂ product stream.”); EX1003, ¶355.

(p) Element 1.6.1: second residual gas

Martin discloses at least inherently the second residual gas stream comprises CO unconverted in step (d), hydrogen not separated off in step (e), CO₂ not separated off in step (f), and unreacted methane, as these gases are the natural

result of cryogenic CO₂ separation in the process of Martin. EX1003, ¶356;
Arbutus, 65 F.4th at 662.

To the extent Martin may not explicitly disclose this element, Rafati discloses an embodiment comprising a cryogenic CO₂ separation unit for producing a liquid CO₂ product stream (312 of FIG. 2), which corresponds to the '805 patent's first CO₂-rich stream, and a vapor phase stream (313 of FIG. 2), which corresponds to the '805 patent's RG2, comprising the CO₂ remaining after cryogenic CO₂ separation as well as the other components of the PSA waste gas, including CO, H₂, CH₄, Argon, N₂, and traces of water vapor. EX1003, ¶357; EX1015, ¶[0131] (describing the cryogenic separation step is "preferably carried out such that at least 50 mol % of the CO₂ in the waste gas stream 311 is separated into the liquid CO₂ product stream. Separated CO₂ is removed in CO₂ stream 312. The remaining vapor phase materials exit the low temperature separation unit 409 in vapor phase stream 313.").

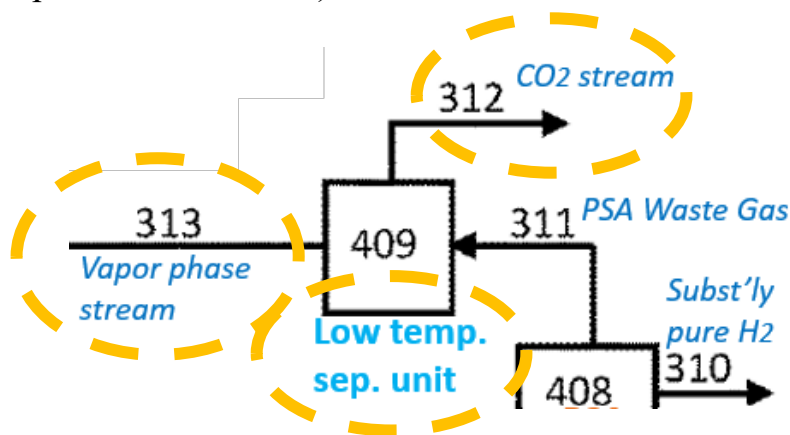


FIG. 2, excerpt, annotated

(q) Element 6: thermal separation of methane from first CO₂ stream

Like claim 1, claim 6 recites nothing more than applying methods known in the prior art. Martin, alone or in combination with Rafati, discloses all elements of claim 6. EX1003, ¶¶358–360.

Martin discloses a process using “LOW TEMPERATURE CO₂ SEPARATION”, which is described as “separat[ing] and purif[ing] CO₂ product in a distillation column.” EX1006, p.12.

To the extent Martin may not explicitly disclose this element, Rafati discloses, “[o]ptionally the liquid CO₂ can be treated in a stripping distillation column to remove dissolved H₂+CO+CH₄ which will be transferred to the vapor phase.” EX1015, ¶[0022].

(r) Element 11: compression step and cooling step

Like claim 1, claim 11 recites nothing more than applying methods known in the prior art. Martin, alone or in combination with Rafati, discloses all elements of claim 11. EX1003, ¶¶361–363.

Martin discloses a process using “LOW TEMPERATURE CO₂ SEPARATION”, which is described as applying “the auto-refrigeration principle to cool down the process stream near CO₂ triple point, and separates and purifies CO₂ product in a distillation column.” EX1006, p.12. Based on this teaching in Martin and the general skill in the art, a POSA would understand to implement

cryogenic CO₂ separation following PSA for hydrogen separation using at least one compression step and at least one cooling step to produce a CO₂-rich stream at least partly in the form of a condensed CO₂ stream. EX1003, ¶363.

To the extent Martin may not explicitly disclose this element, Rafati expressly discloses that condensation and cooling steps, as recited in claim 11, may be steps in cryogenic CO₂ separation. EX1003, ¶363; EX1015, ¶¶[0094] (“The forming of the liquid CO₂ product stream in the cryogenic separation unit can comprise...cooling the waste gas stream comprising CO₂ in at least one heat exchanger to provide the waste gas stream comprising CO₂ as a two phase stream”), [0086] (“The cryogenic separation unit further can comprise: a compressor configured for compressing the waste gas stream comprising CO₂”).

(s) Element 12: plant configured to perform process

Martin and Rafati disclose a plant configured for performance of the hydrogen separation process. EX1006, *passim*; EX1015, ¶[0113] “the present disclosure may refer to a hydrogen plant, and it is understood that such hydrogen

plant refers to the combination of elements necessary to form the hydrogen production system utilized herein”); EX1003, ¶365.

B. Ground 2: Claims 2-4 and 6 are Obvious over Martin in Combination with Rafati and in Further View of Gauthier

Claims 2–4 and 6 would have been obvious to a POSA based on the combination of Martin with Rafati and in further view of Gauthier. EX1003, Section XI.F.

1. Motivation to Combine, Reasonable Expectation of Success

Motivation to combine the teachings of Martin and Rafati in the manner claimed is demonstrated in Section VIII.A.1, *supra*. EX1003, ¶¶316-325.

Similar to Martin and Rafati, Gauthier relates to a process for combined production of hydrogen and CO₂ from synthesis gas generated through reforming of hydrocarbons, including natural gas/methane and shifting the synthesis gas to increase hydrogen in the synthesis gas. EX1014, ¶¶[0001], [0026], [0142]; EX1003, ¶¶370–371. Gauthier also employs a PSA process to separate a first purified hydrogen-rich product stream which is passed to cryogenic CO₂ separation to produce a CO₂-enriched product stream. EX1014, ¶¶[0007], [0183]. Gauthier further teaches additional steps of generating a second hydrogen-rich gas stream using a permeation module (i.e., a H₂ separation membrane, EX1003, ¶39), recycling of the second hydrogen-rich product stream back to the PSA and/or employing the second hydrogen rich product steam as fuel for heating in a

reformer. EX1014, ¶¶[0023]–[0038]; EX1003, ¶371. Gauthier additionally teaches further purification of the CO₂-enriched product stream by distillation to remove light impurities in a distillation step separate from the cryogenic CO₂ separation. EX1014, ¶[0147]; EX1003, ¶371. This additional distillation step is described as providing food grade CO₂. EX1014, ¶[0147]; EX1003, ¶371. Gauthier also includes additional steps recycling residual/waste gases for further capture of H₂ or CO₂ and for use as feed and/or fuel in other parts of the process system. EX1014, ¶¶[0072]–[0075]; EX1003, ¶371.

A POSA would have been motivated to combine the teachings of Gauthier with those of Martin/Rafati because each of the processes are directed to hydrogen production with low CO₂ emissions and incorporate PSA hydrogen separation and cryogenic CO₂ separation. EX1003, ¶¶372–374. The references address the same or similar problems, share common goals, and teach the same or similar solutions to the problems. *Id.* In Gauthier, separated CO₂ is purified and captured as a value-added product of the process (food grade CO₂). EX1014, ¶[0019]. A POSA would have been further motivated to combine the teachings of Gauthier with those of Martin and Rafati to increase the purity and value of products of the combined process and to increase at least the energy efficiency of the combined process by recycling of product gases to feed and/or fuel the reformers in the process. EX1003, ¶¶372–374.

The proposed modifications of the combination of Martin and Rafati with the additional purification and recycling steps as taught in Gauthier would not change the principles of operation of the combined process of Martin and Rafati. Because the processes employ the same feed gases in the same process steps (reforming, WGS, PSA separation, and cryogenic separation), generate the same intermediates (syngas and shifted syngas), and the same products (H₂ and CO₂), a POSA would have recognized that modification using Gauthier's additional methods would not change the principles of operation of a Martin/Rafati process. *Id.*

Because the additional steps of Gauthier, and their function and implementation, were well known and understood in the art, a POSA would have had a reasonable expectation that the additional process steps of Gauthier could be successfully implemented in the combined process of Martin/Rafati and that the desired additional benefits of their implementation would be achieved. *Id.*

With respect to claim 2, a POSA would have been motivated to apply the additional hydrogen separation step as taught by Gauthier to the combined method of Martin/Rafati to increase the yield of the desired hydrogen product by separating an additional hydrogen-rich stream and would have known in view of the teachings of these references how to implement that separation and would have reasonably expected success in that implementation. EX1003, ¶375.

With respect to claim 3, a POSA would have been motivated to employ the membrane hydrogen separation step as taught by Gauthier to the combined method of Martin/Rafati again to increase the yield of the desired hydrogen product by separating an additional hydrogen-rich stream. EX1003, ¶376. The use of a membrane to separate hydrogen from synthesis gas product streams was well known in the art at least by the critical date. EX1003, ¶41. A POSA would have known how to implement the membrane separation in view of what was known in the art and the teachings of the references and would have reasonably expected success in that implementation. EX1003, ¶376.

With respect to claim 4, Gauthier teaches separation of second hydrogen-rich stream using membrane separation and recycling of that stream to a PSA unit. Hydrogen separation/purification by use of membranes and PSA processes was well known in the art at least at the critical date. EX1003, ¶41. A POSA would have been motivated to employ the hydrogen recycling taught by Gauthier to the combined method of Martin/Rafati to increase the yield of the desired hydrogen product, but also to generally increase the efficiency of the entire hydrogen generation process. EX1003, ¶¶41, 377. A POSA would have known how to implement the hydrogen recycling in view of what was known in the art and the teachings of the references and would have reasonably expected success in that implementation. EX1003, ¶377.

With respect to claim 6, Gauthier teaches the further purification of CO₂ that is cryogenically separated from synthesis gas to provide higher value CO₂ product (food grade CO₂). EX1014, ¶[0019]. The further purification is removal of light impurities in the CO₂ by distillation. EX1014, ¶[0147]. As described in the '805 patent, distillation is a thermal separation process for separation of methane. EX1001, col.10, ln.19–22. A POSA would have been motivated to employ the additional purification of CO₂ taught by Gauthier to the combined method of Martin/Rafati to increase the yield and value of the CO₂ product of the process. Specifically, a POSA would have known that cryogenically separated CO₂ as produced in the Martin/Rafati process would contain unreacted or residual methane as a light impurity in view of the feed employed and the processes employed, and that the well-known distillation method of Gauthier could be employed to remove it to generate a value-added product. EX1003, ¶378.

2. Martin and Rafati in further view of Gauthier Disclose the Limitations of Claims 2–4 and 6.

(a) Element 1

The combination of Martin and Rafati teach each feature of claim 1 from which claim 2 depends. Section VIII.A.2, *supra*.

(b) Element 2: hydrogen is separated from the second residual gas stream

The combination of Martin and Rafati in further view of Gauthier teach a hydrogen separation step from the second residual gas stream (RG2), thereby producing a second hydrogen-rich stream (HG2) and a third residual gas stream (RG3). EX1003, ¶¶379–383.

In the '805 patent RG2 is residual gas exiting the cryogenic CO₂ separation unit (205) and is described as being introduced into a membrane unit 206 to separate H₂ and generate HG2 enriched in hydrogen and a third residual gas Stream (RG3). EX1001 col.12, ln.20–29. The combination of Martin and Rafati discloses hydrogen-containing residual gas (from a cryogenic CO₂ separation unit) (“WASTE GAS” EX1006, Figure 7) and vapor phase stream 313 (EX1015, Figure 2), respectively. Residual gas from CO₂ separation (“WASTE GAS”) is recycled “back to the reforming reactors to maximize the process efficiency and CO₂ capture. EX1006, p.12, Figure 7. Stream 313 derives from cryogenic CO₂ removal from stream 311, and “contains all the CO₂ plus CO, H₂, CH₄, Argon, N, and traces of water.” EX1015, ¶[0131]. Stream 313 can be recycled for a variety of uses, and specifically to hydrocarbon feed streams 303. EX1015, ¶[0132]. Martin’s “WASTE GAS” is not expressly described as containing hydrogen, but in view of

the similarities in feed gas and process steps, a POSA would have recognized that it contained hydrogen. EX1003, ¶30; Section VIII.A.2.(o), *supra*.

Gauthier in Figure 1 describes a purge gas mixture **24** from a cryogenic CO₂ separation unit **22** which contains hydrogen. This purge gas is introduced to permeation module **29** to generate a permeate **31** enriched in hydrogen and a purge waste **30** enriched with methane and CO. Purge gas **24** of Gauthier is equivalent to the hydrogen-containing “WASTE GAS”/stream **313** of Martin/Rafati as these products are the natural result of cryogenic CO₂ separation in the process of each reference. EX1003, ¶¶382–383.

WASTE GAS/stream **313**/purge gas **24** of the combination of Martin/Rafati and Gauthier corresponds to the second residual gas stream of the '805 patent. EX1003, ¶383. Permeate **31** and purge gas **30** both resulting from application of Gauthier's additional H₂ separation are equivalent to the second hydrogen-rich stream and the third residual gas stream of the '805 patent, respectively. *Id.* Thus, the combination of Martin and Rafati in view of Gauthier teaches producing a second hydrogen-rich stream and a third residual gas stream as in claim 2 of the '805 Patent. EX1003, ¶¶379–383.

(c) Element 3: membrane separation

The combination of Martin and Rafati in view of Gauthier teaches each feature of claim 2 from which claim 3 depends. Section VIII.B.2(b), *supra*. The

additional features of claim 3 are disclosed by Martin and Rafati in view of Gauthier. EX1003, ¶¶384–386.

In the '805 patent, RG2 exits cryogenic CO₂ separation unit (205) and is described as being introduced into a membrane unit 206 to generate HG2 (“enriched with hydrogen compared to” RG2) and RG3 (“depleted of hydrogen compared to” RG2). EX1001, col.12, ln.20–29.

Gauthier in Figure 1 describes a purge gas mixture 24 from a cryogenic CO₂ separation unit 22 which contains hydrogen. Section VIII.B.2(b), *supra*. Purge gas 24 of Gauthier (equivalent to “WASTE GAS”/stream 313 of Martin/Rafati), is introduced to a permeation module 29 to generate a permeate 31 enriched in hydrogen (EX1014, Figure 1; ¶[0150]) and a purge waste 30 enriched with methane and CO. Purge waste 30 is clearly depleted in hydrogen which is separated by membrane 206 into permeate 31. A permeation module as described in Gauthier is a membrane for hydrogen separation, and permeation module 29 of Gauthier is equivalent to membrane 206 of the '805 patent. EX1003, ¶386.

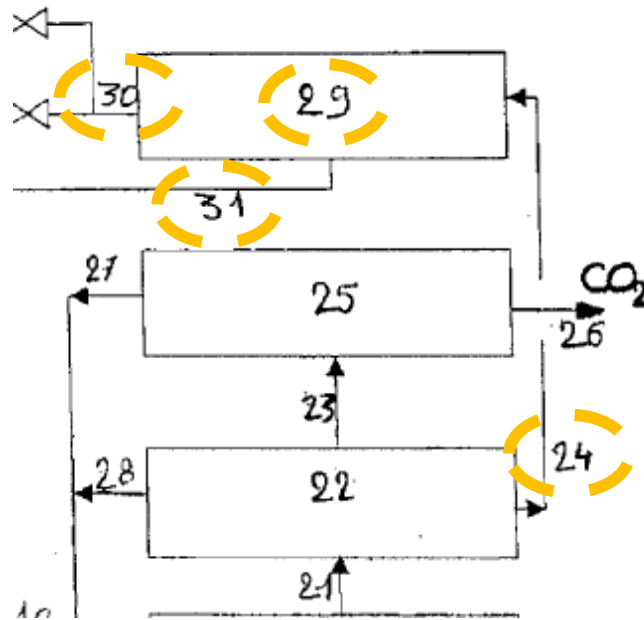


Figure 1, excerpt, annotated

(d) Element 4: the second hydrogen-rich stream is supplied to the fourth synthesis gas stream

The combination of Martin and Rafati in view of Gauthier teaches each feature of claim 2 from which claim 4 depends. Section VIII.B.2(b), *supra*. The additional features of claim 4 are disclosed by Martin and Rafati in view of Gauthier. EX1003, ¶¶387–389.

In the '805 patent, HG2 exits membrane unit 206 (EX1001, Figures 2 and 3) and is optionally recycled to the fourth synthesis gas stream (SG4) which exits converter unit 203 (a WGS unit) and then enters PSA unit 204 to increase overall hydrogen yield. EX1001, col. 11, ln.59–col.12, ln.31.

Further to the description of Section VIII.B.2(c), *supra*, Gauthier's hydrogen-rich permeate **31** is recycled to the synthesis gas stream **13** which enters the hydrogen purification unit **14**, a PSA type unit. EX1014, Figure 1; ¶¶[0151], [0143]. Hydrogen-rich permeate **31** is equivalent to the second hydrogen-rich stream of claim 4 of the '805 patent, stream **13** is equivalent to the fourth synthesis gas stream of claim 4 of the '805 patent and hydrogen purification unit **14** is equivalent to the PSA **204** of the '805 patent. EX1003, ¶389.

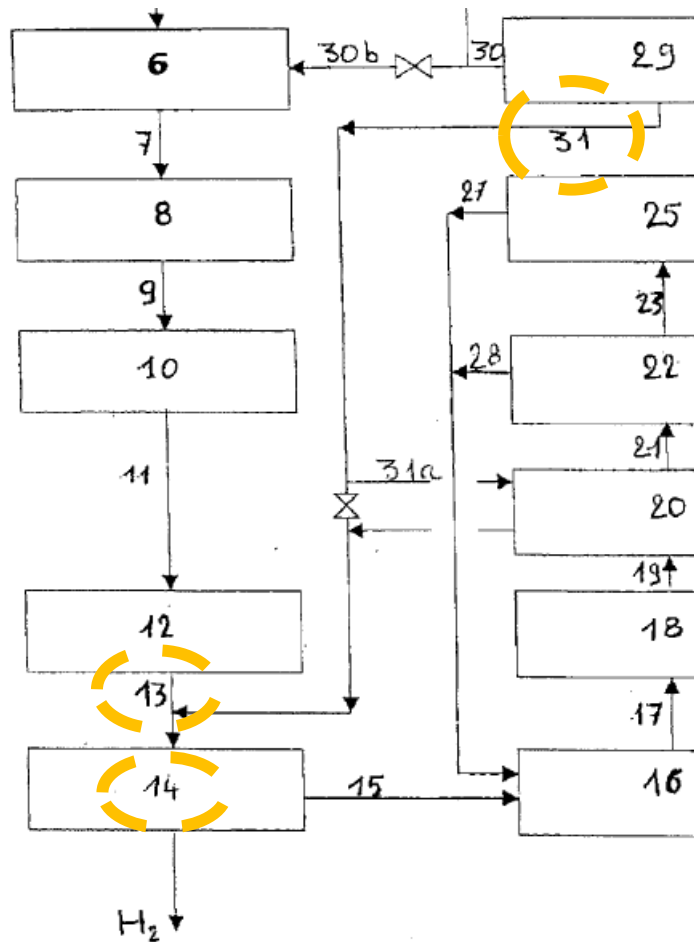


Figure 1, excerpt, annotated

(e) **Element 6: thermal separation of methane from first CO₂ stream**

The combination of Martin and Rafati teaches each element of claim 6 of the '805 patent. Section VIII.A.2.(q), *supra*. Additional features of claim 6 are disclosed by Martin and Rafati in view of Gauthier. EX1003, ¶¶390–393.

The '805 patent states that in a preferred embodiment of the process, “the CO₂-rich stream CG1 comprises unreacted methane, and the CG1 is subjected to a thermal separation process for separation of methane, giving a second CO₂-rich stream CG2.” EX1001, col.6, ln.19–24. The '805 patent states that CG1 contains “significant residual amounts of methane that can optionally be removed by distillation of the carbon dioxide-rich stream CG1.” EX1001, col.12, ln.11–14. The '805 patent states that “the thermal separation process” to remove methane “is preferably a distillation.” EX1001, col.6, ln.30–31. Thus, in the '805 patent distillation of methane from CG1 is a thermal process for separation of methane to generate a second CO₂ stream CG2. EX1003, ¶391.

In Gauthier, Figure 1, steam **23**, which exits the cryogenic CO₂ separation unit **22**, is described as a condensate essentially containing CO₂. EX1014, ¶[0146]. The CO₂ stream exiting cryogenic separation is shown as a green arrow in Martin Figure 7, and as stream **312** in Rafati FIG. 2. CO₂-containing stream **23** is purified by distillation in order to strip it of the light impurities, e.g., CH₄ (EX1003, ¶392),

entrained in the liquid phase (EX1014, ¶[0147]). The condensate **23** is expanded before being fed to the distillation column **25** and a liquid phase **26** consisting of food grade CO₂ is recovered at the bottom of the column. EX1014, ¶[0147]. In view of the similarity of feed gas, process steps and purifications steps in the '805 patent and Gauthier, as well as Martin/Rafati, a POSA would have recognized that stream **23** exiting cryogenic separation unit would contain methane and would recognize that methane is a lighter boiling component (i.e., lower molecular mass) when present in a CO₂ stream that can be removed by distillation as described in Gauthier. EX1003, ¶392.

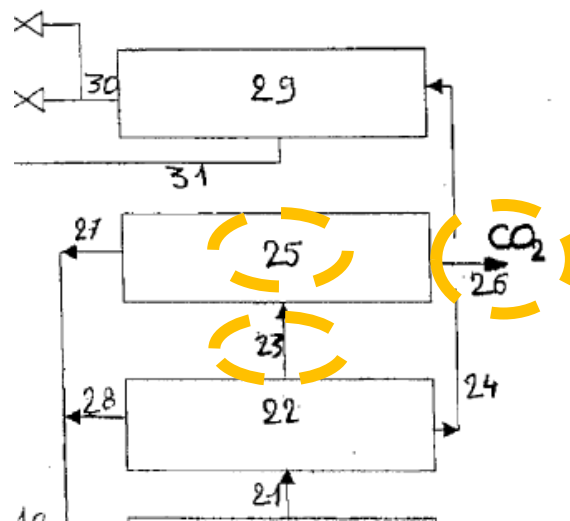


Figure 1, excerpt, annotated

Thus, stream **23** of Gauthier is equivalent to the first CO₂-rich stream comprising unreacted methane of the '805 patent, and stream **26** of Gauthier is equivalent to the second CO₂ stream of increased purity of the '805 patent.

EX1003, ¶393. The distillation column **25** of Gauthier performs a distillation to remove methane from CO₂. Distillation is exemplified in the '805 patent as a “thermal separation process for separation of methane.” EX1001, col.6, ln.22–23. The distillation of Gauthier (implemented in column **25**) is thus equivalent to a thermal separation process for separation of methane. EX1003, ¶393.

C. Ground 3: Claims 2–5 are Obvious Over Martin in Combination with Rafati and in Further View of Terrien

Claims 2–5 would have been obvious to a POSA based on the combination of Martin, with Rafati and in further view of Terrien. EX1003, Section XI.G.

1. Motivation to Combine, Reasonable Expectation of Success

Motivation to combine the teachings of Martin and Rafati in the manner claimed is demonstrated above. Section VIII.A.1, *supra*.

Terrien relates to a process for efficient recovery of hydrogen and CO₂ which, similar to Martin and Rafati, is applied to gas reforming. Terrien teaches additional steps of generating and using hydrogen-rich gas streams as feed into a PSA unit or as fuel for heating in a reformer. EX1024, ¶¶[0016], [0019].

A POSA would have been motivated to implement the additional recycle and purification steps of Terrien to the hydrogen production process of Martin/Rafati to achieve commonly recognized goals of increasing the yield of

hydrogen and CO₂ products, thereby increasing overall energy efficiency of the combined process. EX1003, ¶397.

Modification of the Martin and Rafati process to include aspects of Terrien would not change the principles of operation of the combined process, because the processes employ the same feed gases in the same process steps (reforming, WGS, PSA separation and cryogenic CO₂ separation), generate the same intermediates (syngas and shifted syngas) and the same products (H₂ and CO₂). EX1003, ¶¶398–399.

Indeed, including additional process steps/process units of Terrien with those of Martin/Rafati merely represents the combination of known overlapping methods to achieve their well-understood functions. EX1003, ¶¶398–399; *Wyers v. Master Lock Co.*, 616 F.3d 1231, 1242–43 (Fed. Cir. 2010).

2. Martin and Rafati in view of Terrien Disclose the Limitations of Claims 2–5.

(a) Element 1

The combination of Martin and Rafati teach each feature of claim 1 from which claim 2 depends. Section VIII.A.1, *supra*.

(b) Element 2: hydrogen is separated from the second residual gas stream

The combination of Martin and Rafati generates hydrogen-containing residual gas (from a cryogenic CO₂ separation unit) “WASTE GAS” (Figure 7) and

vapor phase stream **313** (FIG. 2), respectively. Section VIII.B.2.(b), *supra*;
EX1003, ¶406.

Terrien in FIG. 5 describes a CO₂ lean non-condensable stream **10** from a CO₂ separation unit **8** which, in view of the compression/liquefaction and distillation steps described, and the components and process flow illustrated in Terrien FIGs. 2-4, can be a cryogenic CO₂ separation unit. EX1024, ¶¶[0037]–[0038]; EX1003, ¶407. Stream **10** from cryogenic CO₂ separation includes hydrogen because it is passed to H₂ selective membrane **11** for separation of hydrogen to generate hydrogen-rich permeate **12** and a second hydrogen lean residual stream **13**. EX1024, ¶¶[0041]–[0042]; EX1003, ¶¶407-408.

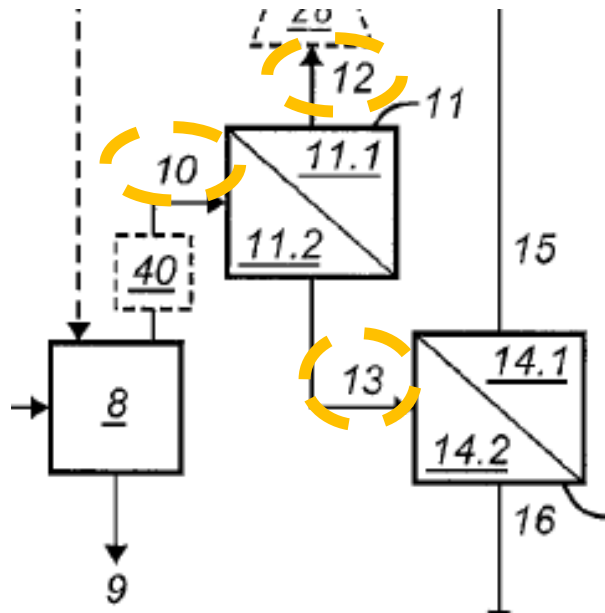


Figure 5, excerpt, annotated

Thus, hydrogen-rich permeate **12** of Terrien is equivalent to the second hydrogen-rich stream of the '805 patent. Indeed, the "WASTE GAS" (Figure 7) of Martin, vapor phase stream **313** (FIG. 2) of Rafati, and lean-condensable stream **10** of Terrien are all equivalent to the second residual gas stream of the '805 patent. EX1003, ¶408. Additionally, the hydrogen-lean residual stream **13** of Terrien is equivalent to the third residual gas stream of the '805 patent. *Id.* Thus, the combination of Martin and Rafati in view of Terrien teaches producing a second hydrogen-rich stream and a third residual gas stream as recited in the '805 patent.

(c) Element 3: membrane separation.

The combination of Martin and Rafati in view of Terrien teach each element of claim 2 from which claim 3 depends. Section VIII.C.2.(b), *supra*. The additional features of claim 3 are disclosed by Martin and Rafati in view of Terrien. EX1003, ¶409.

The CO₂ lean non-condensable stream **10** of Terrien is equivalent to RG2 of the '805 patent, hydrogen rich permeate **12** of Terrien is equivalent to HG2 of the '805 patent and second hydrogen-lean residual stream **13** of Terrien is equivalent to RG3 of the '805 patent. Section VIII.C.2.(b), *supra*; EX1003, ¶411. In Terrien FIG. 5, stream **10** is passed to H₂ selective membrane **11** to generate hydrogen-rich permeate **12**. The H₂ selective membrane **11** of Terrien is equivalent to the membrane unit **206** of the '805 patent because it is also used for hydrogen

separation of a residual gas from cryogenic separation. *Id.* Thus, the combination of Martin and Rafati in view of Terrien teaches producing a second hydrogen-rich stream and a third residual gas stream using membrane separation as recited in claim 3 of the '805 patent. EX1003, ¶¶410–411.

(d) Element 4: the second hydrogen-rich stream is supplied to the fourth synthesis gas stream

The combination of Martin and Rafati in view of Terrien teach each feature of claim 2 from which claim 4 depends. Section VIII.C.2(b), *supra*. The additional features of claim 4 are disclosed in Martin and Rafati in view of Terrien. EX1003, ¶¶412–414.

Terrien in FIG. 5 shows that hydrogen-containing stream **10** from a cryogenic CO₂ separation unit **8** is introduced to H₂ selective membrane **11** to generate hydrogen-rich permeate **12**. EX1024, ¶¶[0019], [0041], [0077]. The hydrogen-rich permeate **12** is recycled to feed gas stream **19** which can be synthesis gas from “a reformer unit/water gas shift unit.” *Id.* Feed gas **19** enters process unit **0** which contains a hydrogen separation unit, specifically a PSA unit. EX1024, ¶[0020]. Hydrogen-rich permeate **12** is equivalent to HG2 of the '805 patent, stream **19** is equivalent to synthesis gas stream SG4 of the '805 patent and process unit **0** contains a PSA unit equivalent to PSA unit **204** of the '805 patent. EX1003, ¶414. Thus, the combination of Martin and Rafati in view of Terrien

teaches supplying the second hydrogen-rich stream to the fourth synthesis gas stream for separation of hydrogen by PSA in step (e) as recited in the '805 patent.

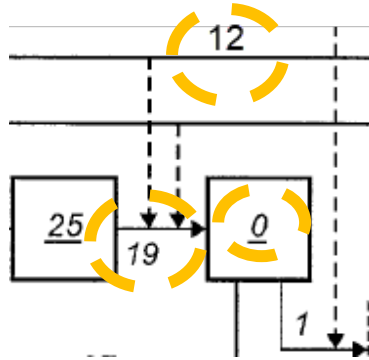


Figure 5, excerpt, annotated

- (e) **Element 5: gases of second hydrogen-rich stream are utilized as fuel gases for heating in the ATR step of step (c).**

The combination of Martin and Rafati in view of Terrien teach each feature of claim 2 from which claim 5 depends. Section VIII.C.2(b), *supra*. The additional features of claim 5 are disclosed in Martin and Rafati in view of Terrien. EX1003, ¶¶415–418.

Terrien teaches recycling of hydrogen-rich streams **27**, **5** and **12** as feed and fuel to improve efficiency of hydrogen and CO₂ recovery in hydrogen generation. EX1024, ¶[0077]. In Terrien FIG. 5, hydrogen-rich permeate **12** is recycled to SMR **23** as feed entering feed stream **22** or directly into the reformer unit as fuel. Terrien provides hydrogen-rich permeate stream **12** is preferably used as fuel to SMR **23** resulting in a boost in CO₂ capture and to minimize natural gas fuel.

EX1024, ¶[0078]. While Terrien exemplifies the use of a SMR in the processes of FIGs. 5 and 6, Terrien teaches that an ATR may also be used to generate feed gas for the purification process. EX1024, ¶[0016]. The teaching of Terrien to employ hydrogen-rich permeate **12** as fuel and that reforming can be accomplished with an ATR would motivate a POSA to employ hydrogen-rich permeate **12** as fuel in an ATR. EX1003, ¶¶417–418. This suggestion is amplified by the teaching in Rafati to use heat generated in the process for pre-heating a fuel stream or a steam feed and by the specific example of including a fired heater to pre-heat natural gas feed entering a parallel configuration of a PDX/ATR with a GHR. EX1015, ¶[0019]. Thus, it was known in the art before the critical date that ATRs could employ fired burners to pre-heat feed entering the ATR to reduce use of methane as fuel. EX1003, ¶¶417–418.

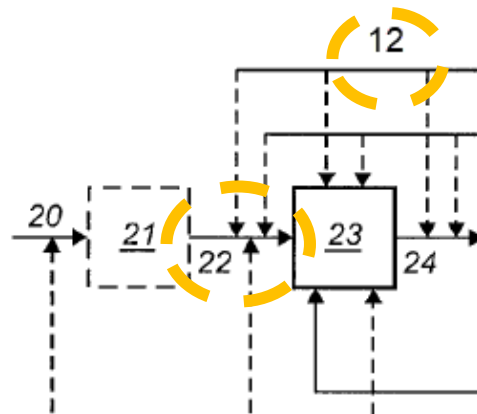


Figure 5, excerpt, annotated

Accordingly, a POSA would have recognized that hydrogen-rich streams generated from hydrocarbon reforming, as in the combination of Martin and Rafati, would be useful for fuel to pre-heat feed entering the ATR therein and would result in the increased efficiency of hydrogen and CO₂ recovery. *Id.* A POSA would have been specifically motivated in view of Terrien's teachings to employ a hydrogen-rich gas stream, generated by removing hydrogen from a residual gas stream from a cryogenic CO₂ separation step (e.g., stream **12**), as fuel to a fired heater for preheating feed entering an ATR in the combination of Martin/Rafati to achieve the benefits taught by Terrien. *Id.* In making these combinations, a POSA would arrive at the process as recited in claim 5 of the '805 patent.

D. No Secondary Considerations

At the institution phase, the Board has repeatedly determined that evidence of secondary considerations should be addressed in a trial where the parties may develop, and the Board may consider, a full record. *See, e.g., Tristar Prods., Inc. v. Choon's Design, LLC*, IPR2015-01883, Paper No. 6 at 26 (PTAB Mar. 9, 2016) (“The issue of secondary considerations is highly fact specific, and at this stage of the proceeding, the record regarding such secondary considerations is incomplete.”).

That is the appropriate course here, given that “the inventions represent[] no more than ‘the predictable use of prior art elements according to their established functions,’” and, thus any secondary considerations do not establish nonobviousness as a matter of law. *Wyers*, 616 F.3d, at 1246 (quoting *KSR Int’l v. Teleflex*, 550 U.S. 398, 417 (2007)); *see, e.g., Leapfrog Enterprises Inc. v. Fisher-Price Inc.*, 485 F.3d 1157, 1162 (Fed. Cir. 2007) (“[G]iven the strength of the prima facie obviousness showing, the evidence on secondary considerations was inadequate to overcome a final conclusion [of obviousness].”).

Additionally, although the ’805 specification characterizes the lowering of CO₂ emissions of the disclosed process as “surprisingly significant” (EX1001, col.3, ln.42–44), it provides insufficient evidence in support of this statement. Indeed, the results recited in the ’805 specification are incomplete and/or appear without basis or explanation. EX1003, ¶¶48-49. For instance, an evaluation of the reported parameters for the material balance simulations provided in Tables 2 and 3 show that they lack elemental carbon balance, as shown by a comparison of the outlet streams and inlet streams, which differ by greater than 20%. *Id.* Thus, the simulations fail to provide credible evidence of unexpected benefits and do not allow for a meaningful comparison with the prior art. *Id.*

IX. CONCLUSION

Based on the foregoing, Petitioner respectfully requests that a Trial be instituted and that claims 1–6 and 11–12 of the '805 patent be canceled as unpatentable under 35 U.S.C. §103(a) for obviousness.

Respectfully submitted,

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The logo for Leydig, featuring the word "Leydig" in a bold, sans-serif font. The letter "y" is stylized with a blue dot above it.

CERTIFICATE OF WORD COUNT COMPLIANCE

Pursuant to 37 C.F.R. § 42.24(d), I hereby certify that this Petition complies with the type-volume limits of 37 C.F.R. § 42.24(a)(1)(i). As calculated by the word count feature of the word-processing system used to prepare this Petition, it contains 10,522 words, excluding the parts of this Petition that are exempted by 37 C.F.R. § 42.24(a) (including a table of contents, a table of authorities, mandatory notices under 37 C.F.R. § 42.8, a certificate of service or word count, and appendix of exhibits or claim listing).

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CERTIFICATE OF SERVICE

I hereby certify that, on July 2, 2025, a true and correct copy of this Petition for *Inter Partes* Review of U.S. Patent No. 11,673,805 under 35 U.S.C. §§ 311-319 and 37 C.F.R. § 42.100 *et Seq.*, including all exhibits thereto, was served in its entirety via Federal Express and/or additionally by electronic mail, upon the following attorneys of record as listed on USPTO Patent Center:

For Patent Owner:

AMERICAN AIR LIQUIDE
Intellectual Property Department
9811 Katy Freeway
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