

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. IPR2025-01173

PETITION FOR *INTER PARTES* REVIEW

Petition 1 of 2

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
II.	COMPLIANCE WITH REQUIREMENTS OF AN INTER PARTES REVIEW PETITION	2
A.	Grounds for Standing (§ 42.104(a)).....	2
B.	Fee for <i>Inter Partes</i> Review (§42.15(a)).....	2
C.	Mandatory Notices (§42.8(b))	3
1.	Real Parties-In-Interest (§42.8(b)(1))	3
2.	Related Matters (§42.8(b)(2)).....	3
3.	Lead and Back-Up Counsel (§42.8(b)(3)).....	3
4.	Service Information (§42.8(b)(4))	3
III.	IDENTIFICATION OF CHALLENGE AND RELIEF REQUESTED	4
IV.	BACKGROUND AND OVERVIEW OF THE '805 PATENT	5
A.	Summary of the '805 Patent Written Description.....	5
B.	Prosecution History of the '805 Patent (EX1002)	9
V.	OVERVIEW OF THE PRIOR ART.....	9
A.	U.S. Patent Publication No. 2023/0119784 to Reinertsen et al. ("Reinertsen")	9
B.	PCT Publication WO2014/091098 to Darde et al. ("Darde").....	12
C.	PCT Publication WO2019/162236 to Rytter et al. ("Rytter")	14
D.	U.S. Patent Publication No. 2012/0291484 to Terrien et al. ("Terrien")	16
VI.	LEVEL OF ORDINARY SKILL IN THE ART.....	19
VII.	HOW THE CHALLENGED CLAIMS ARE TO BE CONSTRUED	19
VIII.	DETAILED EXPLANATION OF GROUNDS FOR CHALLENGE.....	20
A.	Ground 1: Claims 1, 11, and 12 are Anticipated by Reinertsen	20
1.	Element 1.pre: Preamble.....	20
2.	Element 1.1: providing a feed gas stream.....	21
3.	Element 1.1.1: hydrocarbon component and steam.....	22

4.	Element 1.1.2: methane	23
5.	Element 1.2: endothermic reforming step	24
6.	Element 1.2.1: first synthesis gas	25
7.	Element 1.3: reforming in an ATR step	26
8.	Element 1.3.1: exothermic partial oxidation and endothermic reforming	27
9.	Element 1.3.2: second and third synthesis gas	28
10.	Element 1.3.3: heat from ATR step.....	30
11.	Element 1.4: converting the CO	31
12.	Element 1.4.1: fourth synthesis gas	32
13.	Element 1.5: separating hydrogen	33
14.	Element 1.5.1: first residual gas	34
15.	Element 1.6: separating CO ₂	36
16.	Element 1.6.1: second residual gas.....	37
17.	Element 11: compression step and cooling step.....	38
18.	Element 12: plant configured to perform process	39
B.	Ground 2: Claims 1–6, 11, and 12 are Obvious Over Reinertsen and Darde.....	39
1.	Motivation to Combine, Reasonable Expectation of Success ..	40
2.	Reinertsen and Darde Combine to Disclose the Limitations of the Claims	45
(a)	Element 1.pre: Preamble	45
(b)	Element 1.1: providing a feed gas stream	45
(c)	Element 1.1.1: hydrocarbon component and steam	45
(d)	Element 1.1.2: methane	46
(e)	Element 1.2: endothermic reforming step	47
(f)	Element 1.2.1: first synthesis gas	47
(g)	Element 1.3: reforming in an ATR step	47
(h)	Element 1.3.1: exothermic partial oxidation and endothermic reforming	47

(i)	Element 1.3.2: second and third synthesis gas	48
(j)	Element 1.3.3: heat from ATR step.....	48
(k)	Element 1.4: converting the CO	48
(l)	Element 1.4.1: fourth synthesis gas.....	48
(m)	Element 1.5: separating hydrogen	49
(n)	Element 1.5.1: first residual gas	51
(o)	Element 1.6: separating CO ₂	51
(p)	Element 1.6.1: second residual gas	51
(q)	Element 2: hydrogen is separated from the second residual gas stream	52
(r)	Element 3: membrane separation	54
(s)	Element 4: the second hydrogen-rich stream is supplied to the fourth synthesis gas stream	55
(t)	Element 5: gases of second hydrogen-rich stream are utilized as fuel gases for heating in the ATR step of step (c)	56
(u)	Element 6: thermal separation of methane from first CO ₂ stream	57
(v)	Element 11: compression step and cooling step.....	57
(w)	Element 12: plant configured to perform process	58
C.	Ground 3: Claims 1, 6, 11, and 12 are Obvious Over Rytter and Darde	58
1.	Motivation to Combine, Reasonable Expectation of Success ..	58
2.	Rytter and Darde Combine to Disclose the Limitations of the Claims	64
(a)	Element 1.pre: Preamble	64
(b)	Element 1.1: providing a feed gas stream	65
(c)	Element 1.1.1: hydrocarbon component and steam	65
(d)	Element 1.1.2: methane	67
(e)	Element 1.2: endothermic reforming step	67

(f)	Element 1.2.1: first synthesis gas	69
(g)	Element 1.3: reforming in an ATR step	70
(h)	Element 1.3.1: exothermic partial oxidation and endothermic reforming	71
(i)	Element 1.3.2: second and third synthesis gas	72
(j)	Element 1.3.3: heat from ATR step.....	73
(k)	Element 1.4: converting the CO	75
(l)	Element 1.4.1: fourth synthesis gas.....	76
(m)	Element 1.5: separating hydrogen	77
(n)	Element 1.5.1: first residual gas	80
(o)	Element 1.6: separating CO ₂	80
(p)	Element 1.6.1: second residual gas	82
(q)	Element 6: thermal separation of methane from first CO ₂ stream	84
(r)	Element 11: compression step and cooling step.....	84
(s)	Element 12: plant configured to perform process	85
D.	Ground 4: Claims 2-5 are Obvious over Reinertsen in Combination with Darde and in Further View of Terrien	85
1.	Motivation to Combine, Reasonable Expectation of Success ..	85
2.	Reinertsen and Darde in view of Terrien Disclose the Limitations of Claims 2-5.....	86
(a)	Element 1.....	86
(b)	Element 2: hydrogen is separated from the second residual gas stream	87
(c)	Element 3: membrane separation.	87
(d)	Element 4: the second hydrogen-rich stream is supplied to the fourth synthesis gas stream	89
(e)	Element 5: gases of second hydrogen-rich stream are utilized as fuel gases for heating in the ATR step of step (c).	90
E.	No Secondary Considerations.....	91

IX. CONCLUSION93

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Arbutus Biopharma Corp. v. ModernaTx, Inc.,
65 F.4th 656 (Fed. Cir. 2023)26, 30, 33, 35, 38, 70, 73, 77, 80, 84

In re Ethicon, Inc.,
844 F.3d 1344 (Fed. Cir. 2017).....60

KSR Int’l v. Teleflex Inc.,
550 U.S. 398 (2007).....42, 61

Leapfrog Enterprises Inc. v. Fisher-Price Inc.,
485 F.3d 1157 (Fed. Cir. 2007).....91

Motorola, Inc. v. Interdigital Tech. Corp.,
121 F.3d 1461 (Fed. Cir.1997).....43

Phillips v. AWH Corp.,
415 F.3d 1303 (Fed. Cir. 2005).....19

Tristar Prods., Inc. v. Choon’s Design, LLC,
IPR2015-01883, Paper No. 6 (PTAB Mar. 9, 2016)91

Wyers v. Master Lock Co.,
616 F.3d 1231 (Fed. Cir. 2010).....44, 63, 86, 91

Statutes

35 U.S.C. § 1021, 4, 10, 12, 14, 16, 20, 93

35 U.S.C. § 1031, 4, 20, 93

35 U.S.C. § 12210, 12, 14, 16

35 U.S.C. § 325(d).....94

35 U.S.C. § 37412, 14

35 U.S.C. §§ 311-3191, 95

Regulations

37 C.F.R. § 42.10.....3

37 C.F.R. § 42.100.....1, 19, 95

37 C.F.R. § 42.104.....	2
37 C.F.R. § 42.15.....	2
37 C.F.R. § 42.24.....	94
37 C.F.R. § 42.8.....	3, 94

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	U.S. Patent Publication No. 2023/0119784 to Reinertsen et al. (“Reinertsen”)
1006	RESERVED
1007	PCT Publication WO 2014/091098 to Darde et al.
1008	Certified Translation of WO 2014/091098 to Darde et al. (“Darde”)
1009	PCT Publication WO 2019/162236 to Rytter et al. (“Rytter”)
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”)
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”)

Exhibit	Description
1012	RESERVED
1013	RESERVED
1014	RESERVED
1015	RESERVED
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”)
1020	Xu et al. (2014) “An Improved CO ₂ Separation and Purification System Based on Cryogenic Separation and Distillation Theory,”

Exhibit	Description
	Energies (ISSN 1996-1073), 7, 3484-3502; MDPI (Basel, CH) doi:10.3390/en7053484 (“Xu”)
1021	Keshavarz et al. (2019) “Cryogenic CO ₂ Capture,” in Sustainable Agriculture Reviews 38, (Inamuddin et al., Eds.), ISBN 978-3-030-29337-6 (eBook), Springer Nature Switzerland AG (“Keshavarz”)
1022	File history for UK patent application GB2592681 corresponding to UK application 2003317.1, filed March 6, 2020, priority document for U.S. Patent Publication No. 2023/0119784 to Reinertsen et al.
1023	File history for UK patent application GB2592695 corresponding to UK application 2010174.7, filed July 2, 2020, priority document for U.S. Patent Publication No. 2023/0119784 to Reinertsen et al.
1024	U.S. Patent Application No. 2012/0291484 to Terrien et al. (“Terrien”)
1025	RESERVED
1026	K. Aasberg-Petersen et al. (2004) “Synthesis gas production for FT synthesis,” Chapter 4 in Studies in Surface Science and Catalysis, vol 152, pages 258-405 (“Aasberg-Petersen II”)
1027	J. R. Rostrup-Nielsen (1993) “Production of Synthesis Gas,” Catalysis Today, volume 18, pages 305-324
1028	J. R. Rostrup-Nielsen (2002) “Syngas in perspective,” Catalysis Today, 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 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. IPR2025-01174. 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	Anticipation under 35 U.S.C. §102 by Reinertsen	1, 11, 12
2	Obvious under 35 U.S.C. §103 in view of Reinertsen and Darde	1–6, 11, 12
3	Obvious under 35 U.S.C. §103 in view of Rytter and Darde	1, 6, 11, 12

4	Obvious under 35 U.S.C. §103 in view of Reinertsen, Darde, and Terrien	2–5
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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):

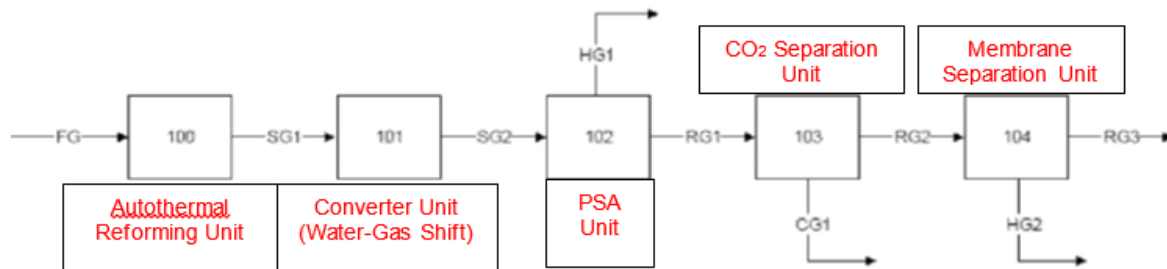
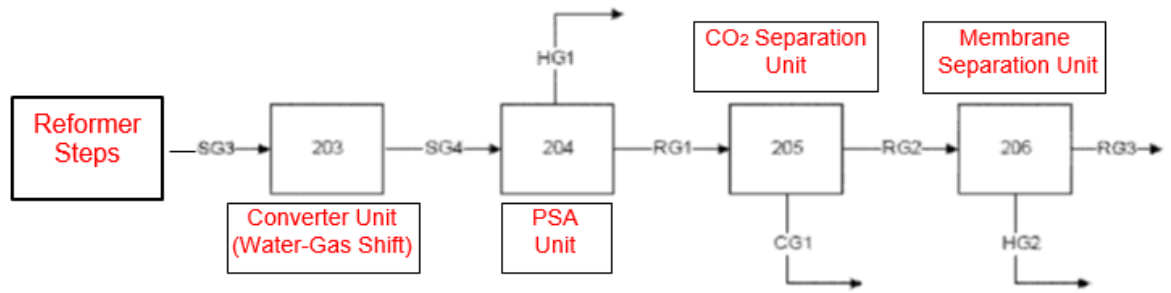


Fig. 1, annotated

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:

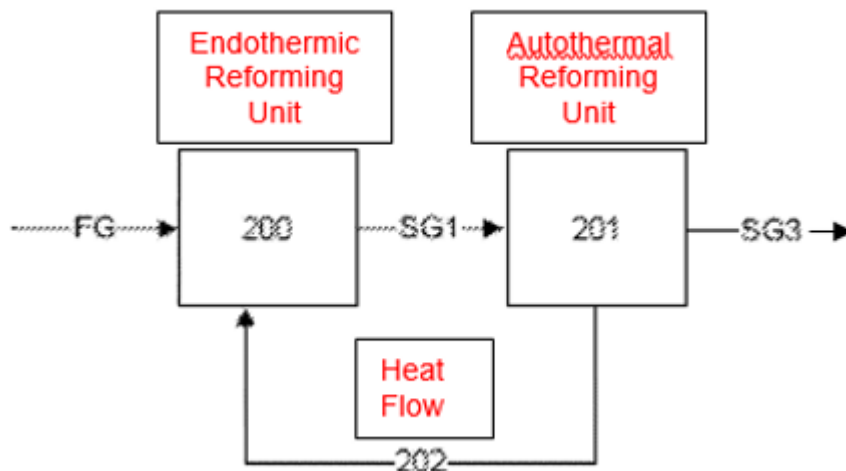


Fig. 3, excerpt, annotated

Parallel Configuration:

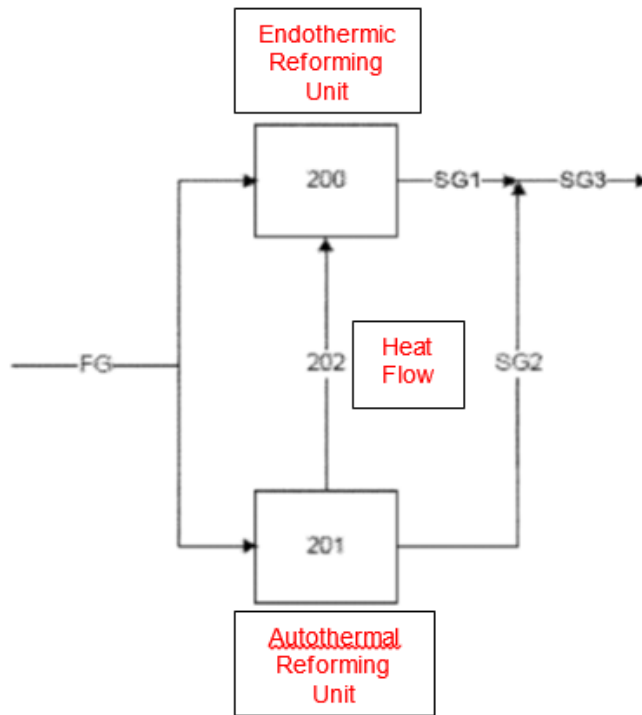


Fig. 2, excerpt, annotated

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. U.S. Patent Publication No. 2023/0119784 to Reinertsen et al. (“Reinertsen”)

Reinertsen (EX1005) is a U.S. patent publication of U.S. application 17/905,448, which is a U.S. National Stage of PCT application PCT/EP2021/054441, filed on February 23, 2021. Reinertsen claims the benefit of

priority to G.B. Patent Application Nos. 2003317.1 (EX1022) and 2010174.7 (EX1023), filed on March 6, 2020 and July 2, 2020, respectively. Because the subject matter of Reinertsen is fully supported by both priority applications (EX1003, ¶¶57, 58, 70), Reinertsen is considered effectively filed under 35 U.S.C. §102(d)(2) as the filing date of the earliest application that describes the subject matter (i.e., July 2, 2020). The relevant subject matter of Reinertsen relied upon is fully supported by both priority applications, as shown herein via parallel citations to G.B. Patent Application Nos. 2003317.1 and 2010174.7 and as further demonstrated and explained in the expert declaration. EX1003, ¶¶57, 58, 70. Because Reinertsen was effectively filed prior to the critical date, and because Reinertsen is a publication under §122(b), Reinertsen is prior art under 35 U.S.C. §102(a)(2)(AIA).

Reinertsen describes a method of producing hydrogen from a hydrocarbon feed gas using a dual reformer, performing a WGS process, and downstream H₂ and CO₂ separation processes to generate streams of H₂, CO₂, and a rest gas. EX1005, Abstract; EX1003, ¶¶59–60.

As shown in Figure 1, Reinertsen describes a dual reformer arranged in a series configuration including a gas-heated reformer (GHR) for an endothermic reforming step and an autothermal reformer (ATR) for an autothermal reforming

step, wherein heat from the ATR provides heat for endothermic reforming.

EX1005, ¶¶[0067], [0070]–[0071], [0074]; EX1003, ¶¶60–65.

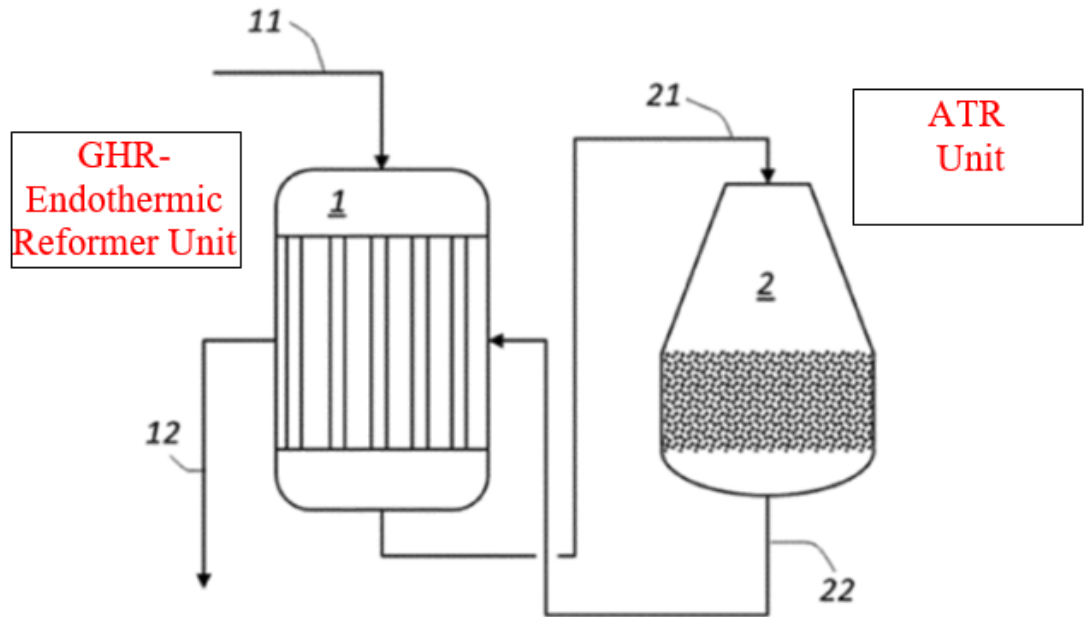
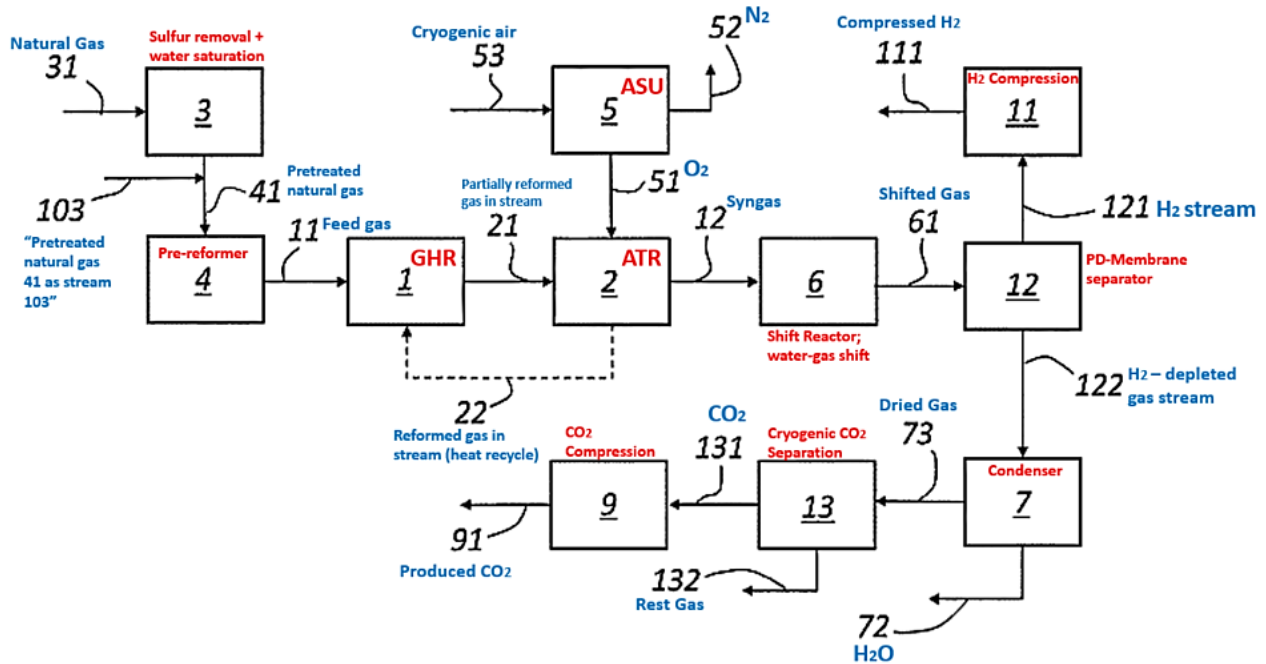


FIGURE 1, annotated

As shown in Figure 4, Reinertsen further describes the dual reformer in combination with shift conversion (a WGS reaction) followed by separating hydrogen by methods including PSA and membranes, and separating CO₂ by methods including cryogenic separation and amine separation. EX1005, FIGs. 1–9, ¶¶[0059], [0063]; EX1003, ¶¶66–69.



EX1005, FIGURE 4, annotated

B. PCT Publication WO2014/091098 to Darde et al. (“Darde”)

Darde is a PCT publication that published on June 19, 2014 from PCT application PCT/FR2013/0552613, filed on October 31, 2013. EX1007. Darde is an international application designating the United States, and thus, according to 35 U.S.C. §374, is a publication under 35 U.S.C. §122(b). Because Darde published and was effectively filed prior to the critical date, Darde is prior art under 35 U.S.C. §§102(a)(1) and (a)(2)(AIA). WO2014/091098 is in French. EX1007. A certified English translation of WO2014/091098 is provided as EX1008. U.S. Publication 2015/0321914, which corresponds to the U.S. national stage of Darde, is referenced in the specification of the '805 patent and was cited during prosecution. EX1001, col.9, ln.40–42; EX1002, p.136. While Darde is cited

C. PCT Publication WO2019/162236 to Rytter et al. (“Rytter”)

Rytter is a PCT publication that published on August 29, 2019 from PCT application PCT/EP2019/053986, which was filed on February 18, 2019. Rytter is an international application designating the U.S., and thus, according to 35 U.S.C. §374, is a publication under 35 U.S.C. §122(b). Because Rytter published and was effectively filed prior to the critical date, Rytter is prior art under 35 U.S.C. §§102(a)(1) and (a)(2)(AIA).

Figure 1 of Rytter illustrates a process including a GHR and an ATR arranged in a series configuration, wherein heat from the ATR step provides heat for endothermic reforming in the GHR. EX1009, p.4, ln.20–24, p.10, ln.23–35, p.15, ln.1–7; EX1003, ¶¶74–76.

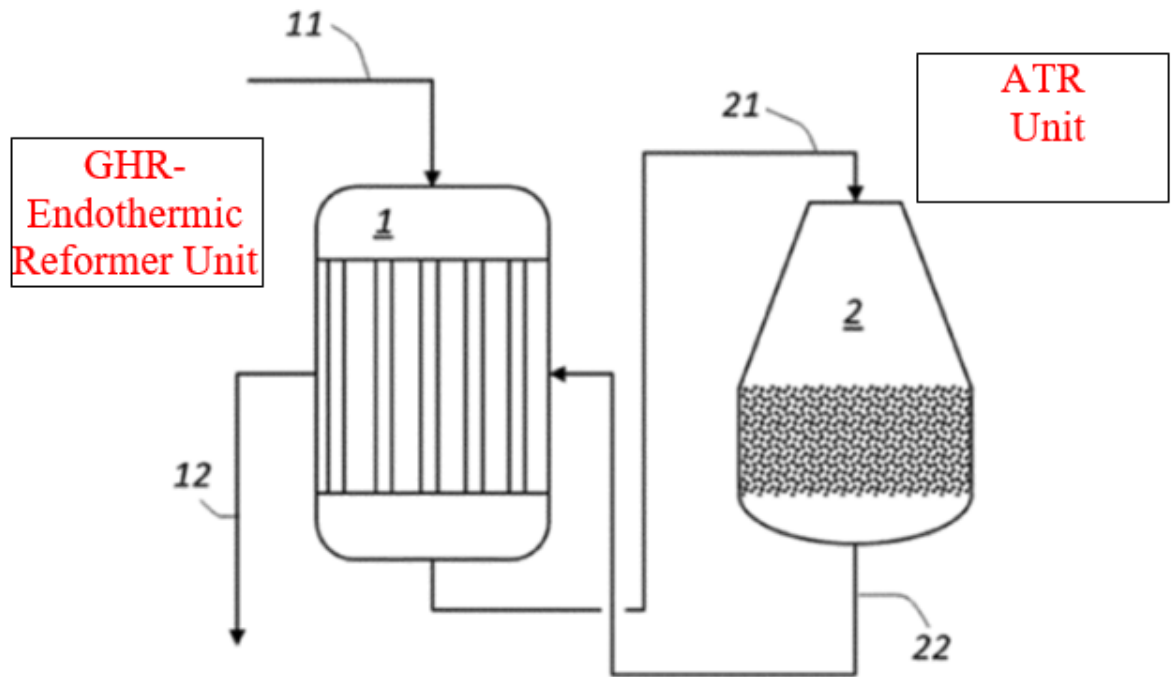


Figure 1, annotated

Figure 3 illustrates a process for production of hydrogen and separation of CO₂ using the combined GHR and ATR of Figure 1 with water shift conversion, hydrogen separation, including PSA and membranes, and CO₂ separation, including cryogenic separation and amine separation. EX1009, p.6, ln.18–23, p.15, ln.9–22; EX1003, ¶77.

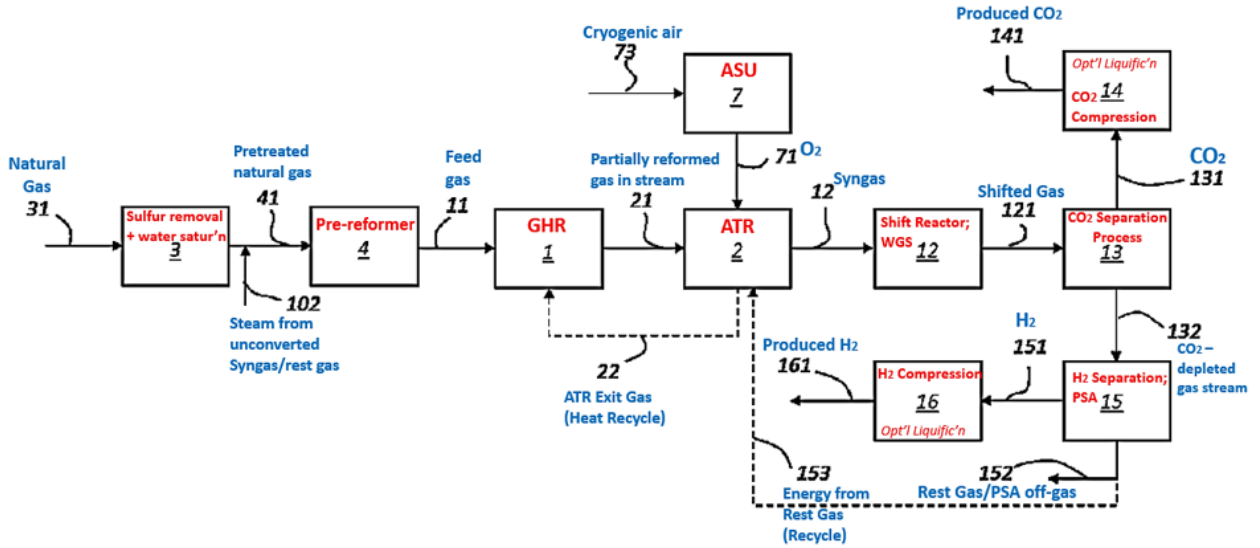


Figure 3, annotated

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.

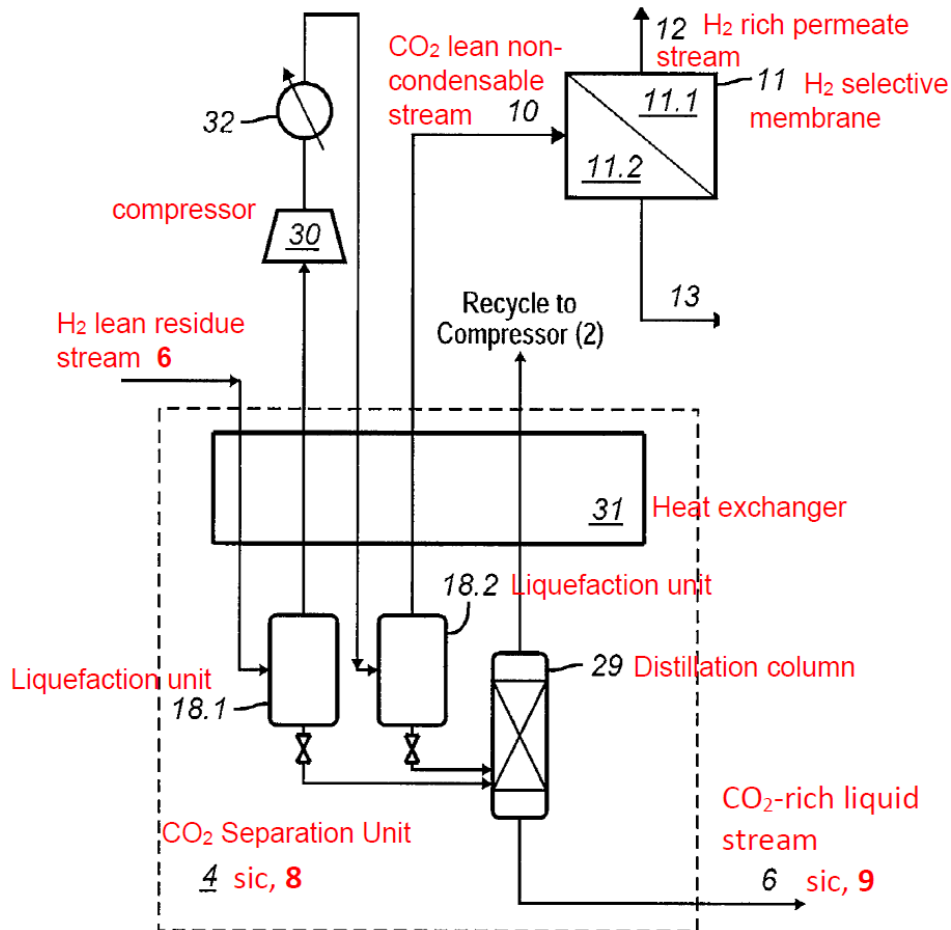


FIG. 4, excerpt, annotated

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. §§102 and 103 as anticipated by and/or 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.

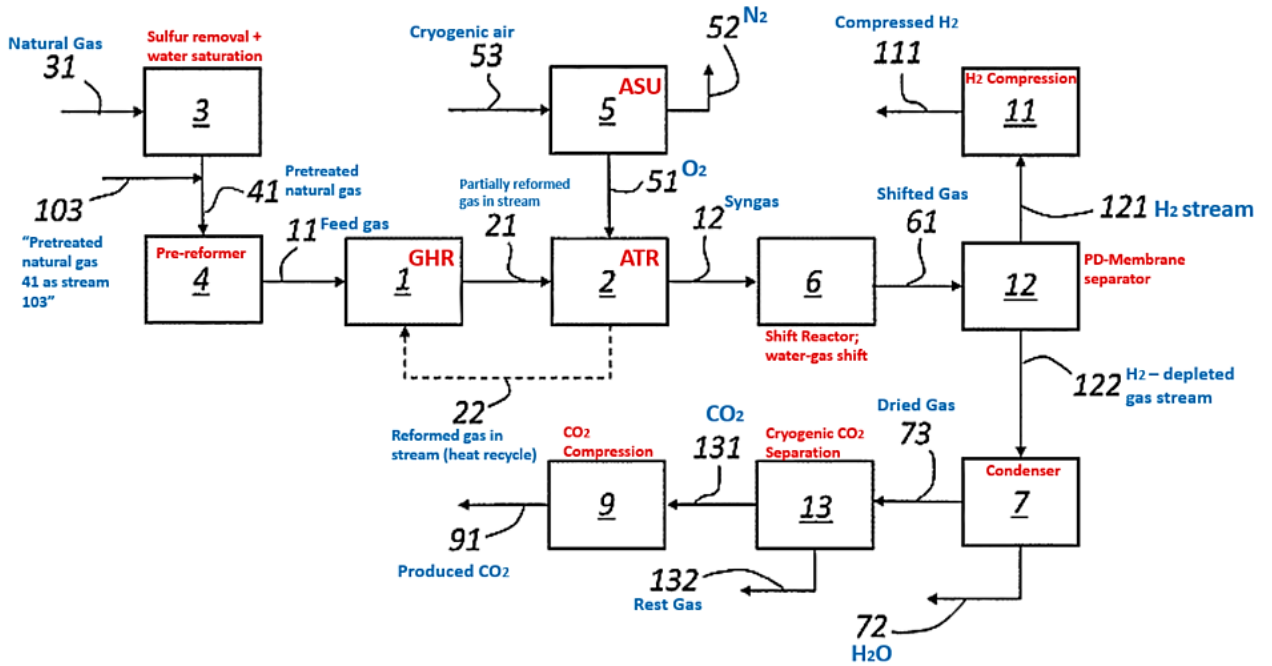
A. Ground 1: Claims 1, 11, and 12 are Anticipated by Reinertsen

Reinertsen discloses all elements of claims 1, 11, and 12, and, therefore, anticipates these claims. EX1003, Section XI.A.

1. Element 1.pre: Preamble

Reinertsen discloses a method for preparing hydrogen by reforming hydrocarbons with steam, and for separation of carbon dioxide. EX1005, FIGURE 4, ¶¶[0005], [0064], [0109]; EX1022, p.4, ln.10–20, p.10, ln.4–9, p.20, ln.24–p.21, ln.2; EX1023, p.4, ln.9–20, p.10, ln.10–15, p.21, ln.5–12; EX1003, ¶¶108–110.

With reference to Figure 4, Reinertsen explains, “FIG. 4 shows a method for production of hydrogen from natural gas with separation of CO₂.” EX1005, ¶[0109]; EX1022, p.20, ln.24–25; EX1023, p.21, ln.5–6.



EX1005, FIGURE 4, annotated

2. Element 1.1: providing a feed gas stream

Reinertsen discloses providing a feed gas stream. EX1005, ¶[0074], FIGURE 4; EX1022, p.12, ln.14–23; EX1023, p.12, ln.20–29; EX1003, ¶¶111–112.

As illustrated in Figure 4, Reinertsen describes a process wherein feed gas 11 is provided.

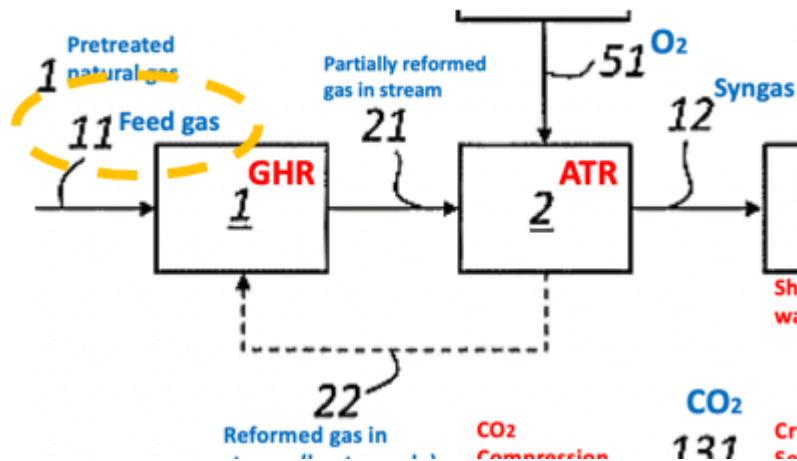


FIGURE 4, excerpt, annotated

Reinertsen explains, “[t]he feed gas 11 first passes through the catalyst in the GHR 1.” EX1005, ¶[0074]; EX1022, p.12, ln.18–22; EX1023, p.12, ln.24–27.

3. Element 1.1.1: hydrocarbon component and steam

Reinertsen discloses feed gas stream comprises a hydrocarbon component and steam. EX1005, Claim 1, ¶¶[0010], [0017], [0067]; EX1022, p.4, ln.30–p.4, ln.4, p.5, ln.17–18, p.10, ln.18–20; EX1023, p.4, ln.26–p.5, ln.2, p.5, ln.17–18, p.10, ln.24–28; EX1003, ¶¶113–115.

Reinertsen discloses, “receiving a feed gas comprising hydrocarbons...”. EX1005, Claim 1; EX1022, Claim 1; EX1023, Claim 1. Reinertsen explains, “the feed gas is a hydrocarbon-rich gaseous stream”. EX1005, ¶[0017]; EX1022, p.5, ln.17; EX1023, p.5, ln.17.

Reinertsen discloses a feed gas comprising steam by describing “saturation of the feed gas with at least water.” EX1005, ¶[0010]; EX1022, p.5, ln.1–2; EX1023, p.4, ln.30–p.5, ln.1. When the water-saturated feed gas is heated, as disclosed by Reinertsen, a POSA would understand that steam is produced and necessarily present within the feed gas stream. EX1003, ¶115. Reinertsen makes this understanding explicit by referring to the chemical reaction of the reforming process “ $\text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + 3\text{H}_2$ ” as “Steam reforming.” EX1005, ¶[0067]; EX1022, p.10, ln.18–20; EX1023, p.10, ln.24–28. Therefore, the components of the feed gas in Reinertsen are equivalent to that of the feed gas stream in the ’805 patent and necessarily includes a hydrocarbon component and steam. EX1003, ¶¶113–115.

4. Element 1.1.2: methane

Reinertsen discloses a feed gas stream with a hydrocarbon component comprising methane. EX1005, ¶[0064]; EX1022, p.10, ln.4–7; EX1023, p.10, ln.10–13; EX1003, ¶¶116–117.

Reinertsen discloses, “[t]he natural gas may be cleaned and pre-treated in a suitable manner so that the gas feed mainly comprises methane after treatment” and further explains, “[t]he pre-treatment may also comprise a pre-reforming process whereby higher hydrocarbons, such as ethane, are converted by steam to methane and CO_2 .” *Id.*

5. Element 1.2: endothermic reforming step

Reinertsen 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. EX1005, ¶¶[0067]–[0068], [0074], FIGURE 4; EX1022, p.10, ln.18–22, p.12, ln.14–23; EX1023, p.10, ln.24–p.11, ln.3, p.12, ln. 20–29; EX1003, ¶¶118–120.

As illustrated by Figure 4, Reinertsen discloses a process wherein feed gas **11** is provided to GHR (**1**) for endothermic reforming.

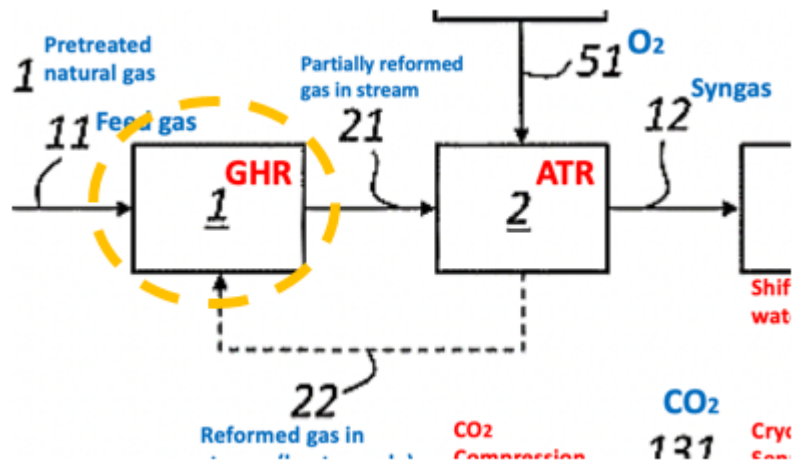


FIGURE 4, excerpt, annotated

Reinertsen explains, “[t]he feed gas **11** first passes through the catalyst in the GHR **1**” to generate “partially reformed gas in stream **21**”. EX1005, ¶[0074]; EX1022, p.12, ln.18–22; EX1023, p.12, ln.24–27. Reinertsen describes the “steam reforming” chemical reaction “ $\text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + 3\text{H}_2$ ” of the feed gas stream

reforming process as being “strongly endothermic.” EX1005, ¶¶[0067]–[0068]; EX1022, p.10, ln.18–22; EX1023, p.10, ln.24–p.11, ln.3. Therefore, the endothermic reforming of the GHR in Reinertsen is equivalent to the endothermic reforming step in the ’805 patent. EX1003, ¶¶118–120.

6. Element 1.2.1: first synthesis gas

Reinertsen discloses a first synthesis gas stream comprising hydrogen, CO, CO₂, and unreacted methane. EX1005, ¶¶[0067], [0074]; EX1022, p.10, ln.18–20, p.12, ln.14–23; EX1023, p.10, ln.24–28, p.12, ln.20–29; EX1003, ¶¶121–123.

As illustrated in Figure 4, Reinertsen discloses producing partially reformed gas stream **21** from endothermic reforming by GHR (**1**).

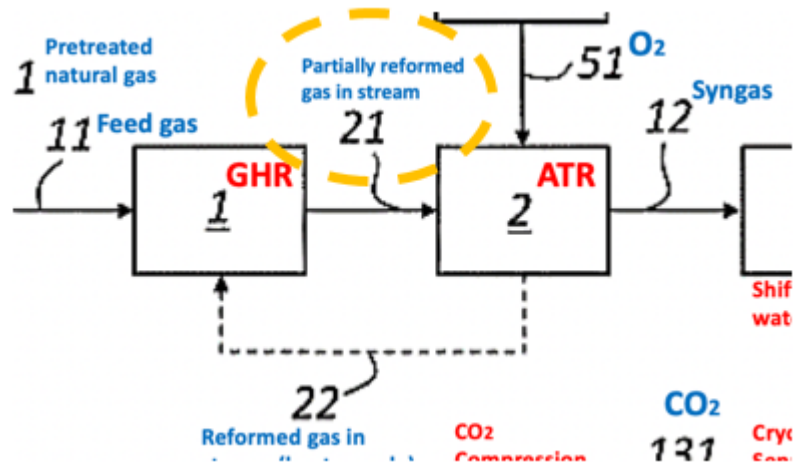
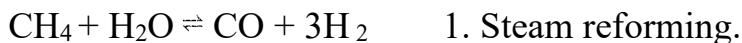


FIGURE 4, excerpt, annotated

Reinertsen describes reversible chemical reactions that occur during the production of synthesis gas including:



EX1005, ¶[0067]; EX1022, p.10, ln.18–20; EX1023, p.10, ln.24–28. The “Steam reforming” reaction is designated an equilibrium reaction (as shown by \rightleftharpoons symbol, above). Therefore, both methane (CH₄) and steam (H₂O) are present in the output of the GHR process, as well as unreacted methane and the H₂, CO and CO₂ product gases. EX1003, ¶¶121–123. Reinertsen explains, “[t]he gas mixture from the reformer reactor contains mainly the gas components CO, H₂, H₂O, CO₂ and some CH₄.” EX1005, ¶[0076]; EX1022, p.12, ln.24–26; EX1023, p.13, ln.3–5.

Therefore, the components of partially reformed gas in stream **21** are equivalent to that of the first synthesis gas stream of the ’805 patent and necessarily includes hydrogen, CO, CO₂, and unreacted methane as a natural result of the GHR process of Reinertsen. EX1003, ¶¶121–123. *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.”).

7. Element 1.3: reforming in an ATR step

Reinertsen discloses reforming the first synthesis gas stream in an ATR step thereby producing a third synthesis gas stream. EX1005, FIGURE 4, ¶¶[0070],

[0074]; EX1022, p.11, ln.10–22, p.12, ln.14–23; EX1023, p.11, ln.17–29, p.12, ln.20–29; EX1003, ¶¶124–126.

As illustrated in Figure 4, Reinertsen discloses providing partially reformed gas in stream (21) to ATR (2) for autothermal reforming.

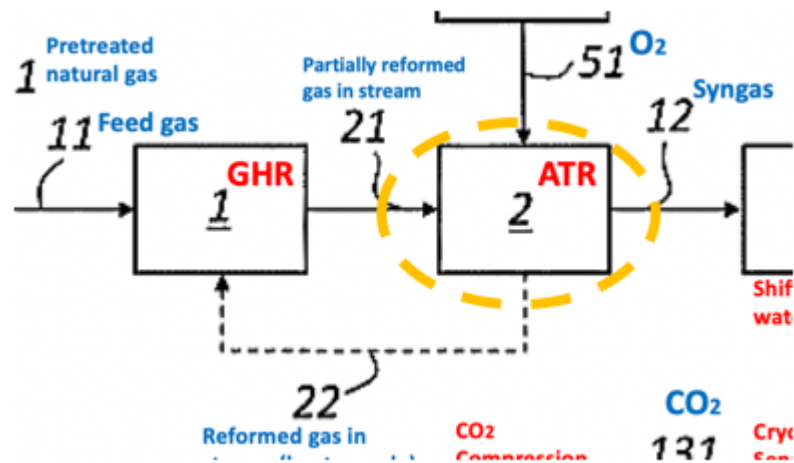


FIGURE 4, excerpt, annotated

Reinertsen explains, “the partially reformed gas in stream 21 passes through the ATR 2”). EX1005, ¶¶[0074]; EX1022, p.12, ln.18–21; EX1023, p.12, ln.24–27. Therefore, the autothermal reforming of the ATR in Reinertsen is equivalent to the autothermal reforming step in the ’805 patent. EX1003, ¶¶124–126.

8. Element 1.3.1: exothermic partial oxidation and endothermic reforming

Reinertsen discloses the ATR step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst. EX1005,

FIGURE 4, ¶¶[0068], [0070]; EX1022, p.10, ln.20–22, p.11, ln.10–22; EX1023, p.11, ln.1–3, p.11, ln.17–29; EX1003, ¶¶127–128.

Reinertsen explains, “[i]n an ATR, ...[t]he energy which is required to operate the endothermic steam reforming reactions is provided by the exothermic reactions between hydrocarbons and/or hydrogen and oxygen...After the combustion chamber the reactions may be driven to equilibrium over a catalyst bed”). EX1005, ¶[0070]; EX1022, p.11, ln.10–22; EX1023, p.11, ln.17–29. Thus, exothermic partial oxidation and endothermic reforming of the ATR in Reinertsen is equivalent to the autothermal reforming step in the ’805 patent. EX1003, ¶¶127–128.

9. Element 1.3.2: second and third synthesis gas

Reinertsen discloses the third² synthesis gas stream comprises hydrogen, CO, CO₂, and unreacted methane. EX1005, ¶[0076]; EX1022, p.12, ln.24–28; EX1023, p.13, ln.3–8; EX1003, ¶¶129–133.

As illustrated in FIGURE 4, Reinertsen discloses producing syngas (12) from autothermal reforming by ATR (2). EX1005, ¶[0103]; EX1022, p.19, ln.5–21; EX1023, p.19, ln.15–31.

² As Reinertsen discloses the serial arrangement of reformers, only the third synthesis gas is referenced.

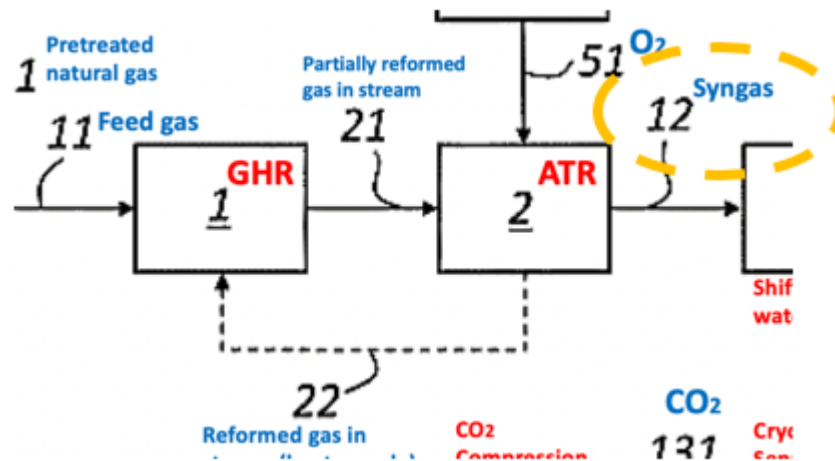
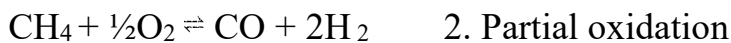
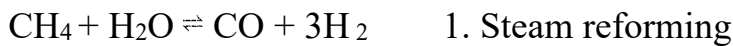


FIGURE 4, excerpt, annotated

Reinertsen describes reversible chemical reactions that occur during the production of synthesis gas including:



EX1005, ¶¶0067]; EX1022, p.10, ln.18–20; EX1023, p.10, ln.24–28. The “Steam reforming” and “Partial oxidation” reactions are designated as equilibrium reactions (as shown by \rightleftharpoons symbol, above). Therefore, CH₄ and steam (H₂O) are present in the output of the ATR process, as well as unreacted methane and the H₂, CO and CO₂ product gases. EX1003, ¶¶129–133. Reinertsen explains, “[t]he gas mixture from the reformer reactor contains mainly the gas components CO, H₂, H₂O, CO₂ and some CH₄.” EX1005, ¶¶0076]; EX1022, p.12, ln.24–28; EX1023, p.13, ln.3–8. Therefore, the components of syngas stream 12 are 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 Reinertsen. EX1003, ¶¶129–133; *Arbutus*, 65 F.4th at 662.

10. Element 1.3.3: heat from ATR step

Reinertsen discloses the heat generated by the ATR step is utilized for heating in the endothermic reforming step of step (b). EX1005, FIGURE 4, ¶¶[0074], [0102]; EX1022, p.12, ln.16–21, p.18, ln.28–ln.29; EX1023, p.12, ln.22–27, p.19, ln.8–9; EX1003, ¶¶134–136.

As illustrated in Figure 4, Reinertsen discloses heat recycle (22) wherein heat generated from the ATR (2) is utilized for heating endothermic reforming in the GHR (1).

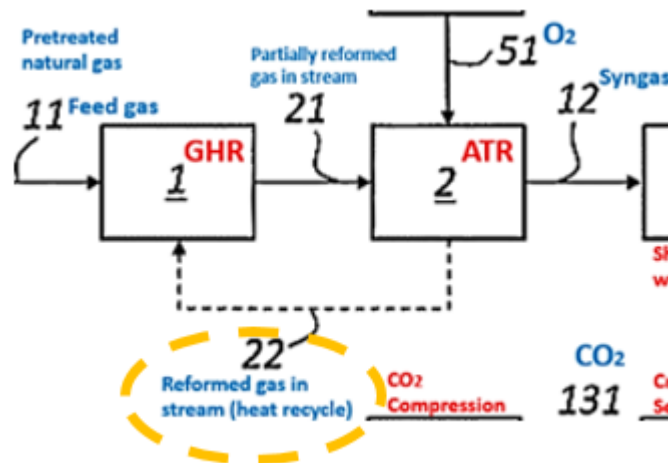


FIGURE 4, excerpt, annotated

Reinertsen discloses, “the reformed gas in stream 22 passes through the heating side of the GHR 1 to provide heat for the initial reaction” and further explains, “[t]he heat recycle 22 is the exit gas from the ATR used to heat the GHR”.

EX1005, ¶¶[0074], [0102]; EX1022, p.12, ln.16–21, p.18, ln.28–29; EX1023, p.12, ln.26–27, p.19, ln.8–9.

11. Element 1.4: converting the CO

Reinertsen discloses converting CO present in third synthesis gas stream with steam thereby producing hydrogen and CO₂ thereby producing a fourth synthesis gas stream. EX1005, ¶¶[0067], [0103]; EX1022, p.10, ln.18–20, p.19, ln.5–21; EX1023, p.10, ln.24–28, p.19, ln.15–31; EX1003, ¶¶137–139.

As shown in Figure 4, Reinertsen describes conversion of the syngas (12) by water gas shift (WGS) in shift reactor (6).

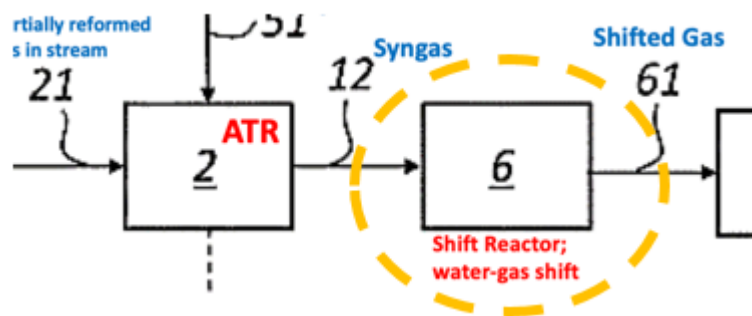


FIGURE 4, excerpt, annotated

Reinertsen discloses that the shift process produces hydrogen and CO₂, which is made explicit by reference to “CO+H₂O ⇌ CO₂+H₂” as the “Shift Reaction”. EX1003, ¶¶137–139; EX1005, ¶¶[0067]; EX1022, p.10, ln.19–20; EX1023, p.10, ln.28. Reinertsen explains, “[t]he produced syngas 12 is shifted to increase the content of hydrogen and CO₂ in one or more shift reactors 6,...to

produce the shifted gas **61**. Steam may be added to the gas mixture before the gas mixture is input into the shift reactor(s) **6**”. EX1005, ¶[0103]; EX1022, p.19, ln.5–9; EX1023, p.19, ln.15–19.

12. Element 1.4.1: fourth synthesis gas

Reinertsen discloses the fourth synthesis gas stream comprises hydrogen, CO₂, unreacted methane, and CO unconverted in step (d). EX1005, Claim 1, ¶[0103]; EX1022, p.19, ln.5–21; EX1023, p.19, ln.15–31; EX1003, ¶¶140–145.

As illustrated in Figure 4, Reinertsen discloses producing shifted gas (**61**) by conversion by WGS in shift reactor (**6**).

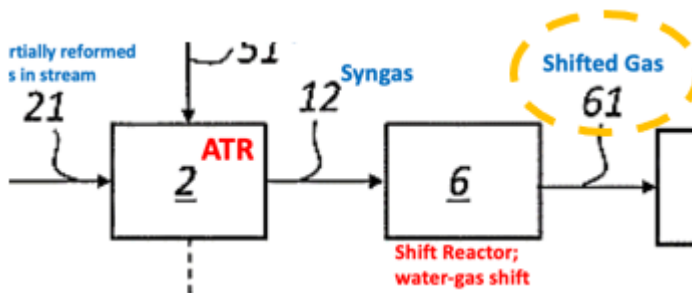


FIGURE 4, excerpt, annotated

Reinertsen describes a “shifted gas comprising hydrogen and carbon dioxide.” EX1005, Claim 1, ¶[0005]; EX1022, Claim 1, p.4, ln.17–18; EX1023, Claim 1, p.4, ln.13–14. Reinertsen designates shift reaction, “CO + H₂O \rightleftharpoons CO₂ + H₂” as an equilibrium reaction (shown by \rightleftharpoons symbol) and, therefore, both CO and H₂O are present in shifted gas (**61**), as well as unreacted methane and the H₂ and

CO₂ product gases.” EX1005, ¶[0067]; EX1022, p.10, ln.18–20; EX1023, p.10, ln.24–28; EX1003, ¶¶140–145. Reinertsen explains with respect to subsequent processing of shifted gas (**61**) “the present mixture of gases, CO, CO₂, and CH₄ are adsorbed, letting the hydrogen pass through at process pressure” and that the downstream rest gas (**132**) “contains remnants of CO and CH₄”, consistent with unreacted methane and unconverted CO being present in shifted gas (**61**). EX1005, ¶¶[0103], [0085]; EX1022, p.19, ln.17–18, p.15, ln.18–20; EX1023, p.19, ln.27–28, p.15, ln.28–30. Thus, the components of shifted gas (**61**) are equivalent to that of the fourth synthesis gas stream of the ’805 and necessarily includes hydrogen, CO₂, unreacted methane and unconverted CO as a natural result of the WGS process of Reinertsen. EX1003, ¶¶140–145; *Arbutus*, 65 F.4th at 662.

13. Element 1.5: separating hydrogen

Reinertsen discloses separating hydrogen from the fourth synthesis gas stream by PSA, thereby producing a first hydrogen-rich stream and a first residual gas stream. EX1005, ¶¶[0012], [0063], [0081], [0085], FIGURE 4, FIGURE 10; EX1022, p.15, ln.9–21; EX1023, p.5, ln.10, p.15, ln.19–31; EX1003, ¶¶146–148.

As illustrated in Figure 4, Reinertsen discloses producing a hydrogen stream **121** by hydrogen separation using a Pd-membrane **12**.

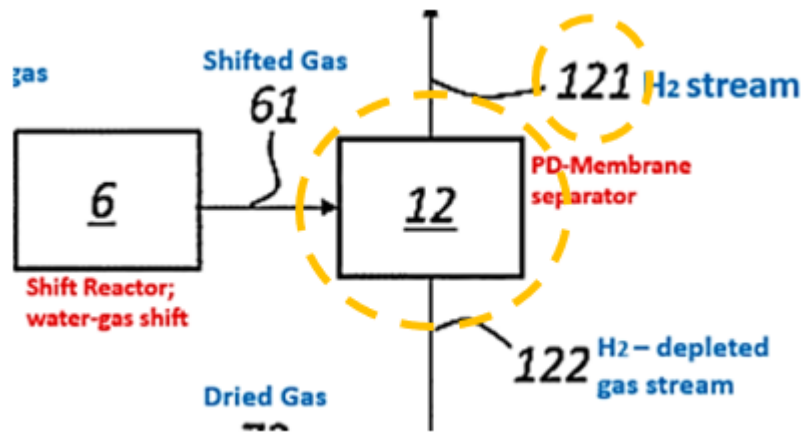


FIGURE 4, excerpt, annotated

However, Reinertsen also explains, “[e]mbodiments may alternatively use PSA to separate hydrogen from the gas output from the WGS reactor.” EX1005, ¶¶[0081], [0085]; EX1022, p.15, ln.14–21; EX1023, p.15, ln.24–31. Moreover, Reinertsen provides “[p]referably, the hydrogen separation process comprises a PSA process.” EX1005, ¶[0012]; EX1023, p.5, ln.10. Therefore, the hydrogen separation in Reinertsen is equivalent to separating hydrogen from the fourth synthesis gas stream to produce the hydrogen rich stream gas stream and residual gas stream as provided in the ’805 patent. EX1003, ¶¶146–148.

14. Element 1.5.1: first residual gas

Reinertsen discloses the first residual gas stream comprises CO₂, CO unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane. EX1005, ¶[0085]; EX1022, p.15, ln.18–19; EX1023, p.15, ln.28–30; EX1003, ¶¶149–150.

As shown in Figure 4, Reinertsen discloses producing H₂-depleted gas stream **122** as a byproduct of hydrogen separation.

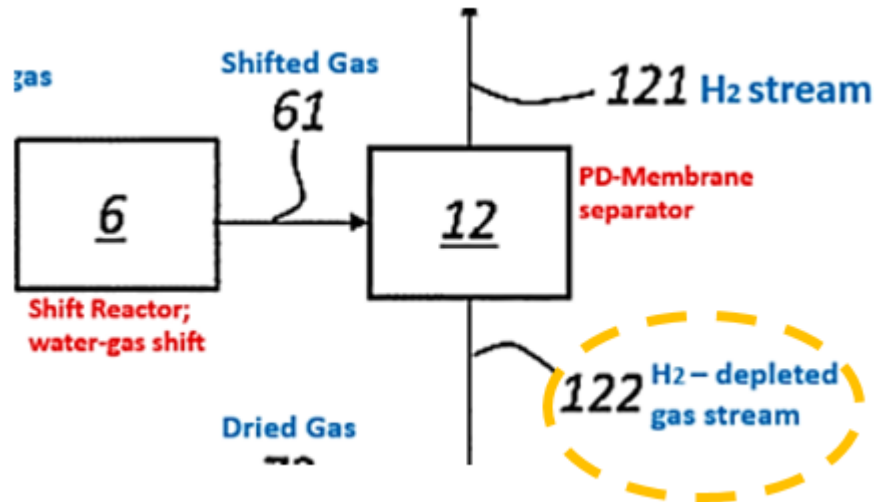


FIGURE 4, excerpt, annotated

Reinertsen explains that in a PSA process a “mixture of gases, CO, CO₂ and CH₄ are adsorbed, letting the hydrogen pass through at process pressure” wherein “[t]he process then swings to low pressure to desorb the adsorbed material”. EX1005, ¶¶0085; EX1022, p.15, ln.18–19; EX1023, p.15, ln.28–30. Therefore, the components of H₂-depleted gas stream **122** 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 Reinertsen. EX1003, ¶¶149–150; *Arbutus*, 65 F.4th at 662.

15. Element 1.6: separating CO₂

Reinertsen 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. EX1005, FIGURE 4, ¶¶[0107], [0110]; EX1022, p.20, ln.12–16, p.21, ln.3–5; EX1023, p.20, ln.23–27, p.21, ln.13–15; EX1003, ¶¶151–153.

As illustrated in Figure 4, Reinertsen discloses the hydrogen depleted residual gas (122) undergoes drying in condenser (7) and cryogenic CO₂ separation (13) to produce CO₂ stream (131).

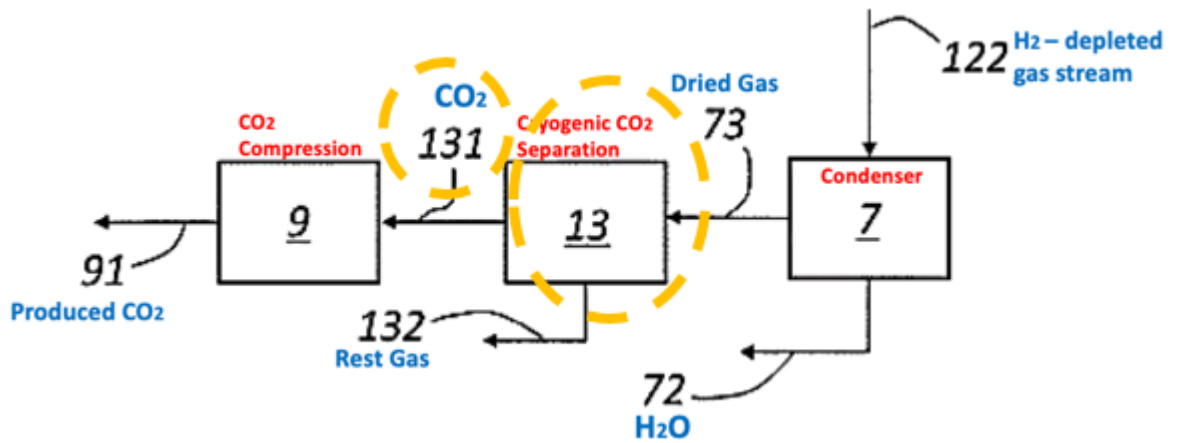


FIGURE 4, excerpt, annotated

Reinertsen explains, “the amine unit 8 of embodiment example 1 is replaced with cryogenic separation 13 of CO₂ 131 from the dried gas 73.” EX1005, ¶¶[0109], [0110]; EX1022, p.21, ln.3–5; EX1023, p.21, ln.13–15. Further, Reinertsen explicitly provides for “separating CO₂ by cryogenic cooling”

(EX1005, ¶[0141], EX1022, p.26, ln.20–25; EX1023, p.26, ln.24–29), and explains, “[t]he CO₂ separation process may be a cryogenic process” (EX1005, ¶[0147]; EX1023, p.27, ln.23). Therefore, cryogenic separation in Reinertsen to produce CO₂ stream (131) is equivalent to producing first CO₂-rich stream of the ’805 patent. EX1003, ¶¶151–153.

16. Element 1.6.1: second residual gas

Reinertsen discloses 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. EX1003, ¶¶154–157. EX1005, ¶¶[0103], [110]; EX1022, p.19, ln.17–18, p.21, ln.4–5; EX1023, p.19, ln.27–28, p.21, ln.14–15.

As illustrated in Figure 4, Reinertsen discloses producing rest gas (132) as a byproduct of cryogenic separation (13).

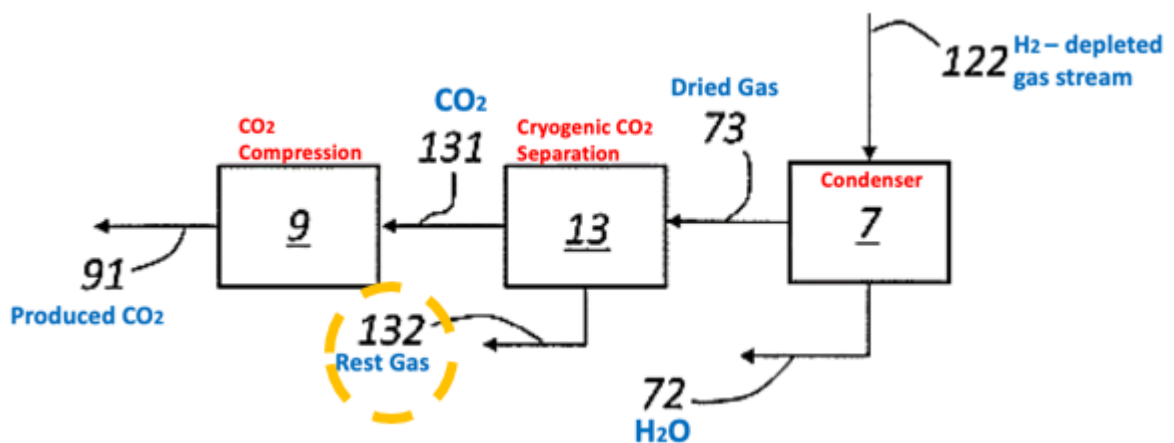


FIGURE 4, excerpt, annotated

Reinertsen describes a process of “cryogenic separation **13** of CO₂ **131** from the dried gas **73**, giving the rest gas **132**.” EX1005, ¶[0110]; EX1022, p.21, ln.4–5; EX1023, p.21, ln.14–15. Reinertsen further describes rest gas **132** as useful “for use in fired heater(s)” consistent with its components including unseparated H₂ and unreacted methane in addition to unconverted CO and unseparated CO₂. *Id.* Therefore, the components of the rest gas **132** are equivalent to the second residual gas stream of the ’805 patent and necessarily includes unconverted CO, hydrogen not separated, CO₂ not separated and unreacted methane as a natural result of the cryogenic CO₂ separation process of Reinertsen. EX1003, ¶¶154–157; *Arbutus*, 65 F.4th at 662.

17. Element 11: compression step and cooling step

Reinertsen discloses the first residual gas stream, for cryogenic CO₂ separation in step (f), is subjected to at least one compression step and at least one cooling step, thereby producing the first CO₂-rich stream at least partly in the form of a condensed CO₂ stream. EX1005, FIGURE 4, ¶¶[0103], [0110]; EX1022, p.19, ln.5–21, p.21, ln.3–5; EX1023, p.19, ln.15–31, p.21, ln.13–15; EX1003, ¶¶158–160.

Reinertsen explains, “embodiments preferably use cryogenic separation to separate CO₂. That is to say, the gas steam is cooled to a temperature, and at a pressure, where CO₂ is liquefied.” EX1005, ¶[0059]; EX1022, p.9, ln.14–16; EX1023, p.9, ln.16–19. Therefore, the cryogenic separation process in Reinertsen

necessarily includes the at least one compression and at least one cooling steps of the '805 patent. EX1003, ¶¶158–160.

18. Element 12: plant configured to perform process

Reinertsen discloses a plant configured for performance of the hydrogen separation process. EX1003, ¶161; EX1005, ¶[0029]; EX1022, p.6, ln.18–19; EX1023, p.6, ln.19–20 (“[T]here is provided a hydrogen production plant arranged to perform the method of the first aspect.”).

B. Ground 2: Claims 1–6, 11, and 12 are Obvious Over Reinertsen and Darde

Claims 1–6, 11, and 12 would have been obvious to a POSA based on the combination of Reinertsen and Darde. EX1003, Section XI.B.

As the basis for allowing these claims, the Patent Office reasoned that US20150321914, the U.S. national stage counterpart of Darde, did not teach or suggest “a first endothermic reforming unit configured to be heated by a second autothermal reforming unit.” EX1002, p.136; Section V.B, *supra*.

Reinertsen, which was not considered during prosecution, discloses this dual reformer configuration, explicitly and in combination with H₂ and CO₂ separation, thereby supplying the key limitation relied upon by the examiner to distinguish over the prior art. *See*, Sections V.A. & VIII.A, *supra*.

As shown by the combination of Reinertsen and Darde, the process claimed in the '805 patent merely recites a known dual reforming arrangement in an already established method of converting hydrocarbons, and therefore, should not have been allowed to issue. EX1003, ¶¶164–172.

1. Motivation to Combine, Reasonable Expectation of Success

A POSA would have been motivated to combine the teachings of Reinertsen and Darde in the manner claimed.

Reinertsen and Darde implement a combination of known gas reforming and separation processes to address a common problem recognized in the art, namely the production of hydrogen with reduced CO₂ emissions. EX1005, ¶[0141]; EX1008, p.7, ln.3–13. Reinertsen acknowledges the problem known in the art of reducing CO₂ emission from gas reforming:

It is known art to reduce the emission of CO₂ from combustion of natural gas, e.g. by gas reforming and shift technology for preparation of a mixture consisting of hydrogen and carbon dioxide. These components are then separated, after which hydrogen may be used in a number of applications...Carbon dioxide has industrial applications but may also be deposited after compression to a desired pressure.

EX1005, ¶[0002]. Similarly, Darde explicitly acknowledges, as essential, that CO₂ generated in gas reforming may be captured to reduce CO₂ emissions:

A second aspect—itself also essential—relating to the hydrogen production facilities concerns the capture of the CO₂ produced by these facilities. Indeed...the demonstration of global warming and of the role that it plays therein has led to ensuring that the CO₂ jointly produced with the hydrogen is captured.

EX1008, p.6, ln.28–33.

To solve this art recognized problem, each of Reinertsen and Darde use a combination of hydrogen separation and CO₂ separation to provide for gas reforming with capture of CO₂. Reinertsen provides processes for hydrogen separation using a Pd-membrane provided upstream of cryogenic CO₂ separation, wherein PSA is disclosed as an alternative for hydrogen separation. EX1005, ¶¶[0012], [0101]–[0109], FIGURE 4, *see also*, Section, VIII.A.13, *supra*. The Patent Owner may nonetheless argue that the specific combination of PSA upstream of cryogenic CO₂ separation is not specifically exemplified in Reinertsen. EX1005, ¶[0012]. However, a POSA would have been motivated to select this option of PSA in view of description in Darde. EX1003, ¶¶168–172.

Darde shows PSA upstream of cryogenic CO₂ separation achieves a “gaseous stream of highly pure (greater than 99%) hydrogen” (EX1008, p.16, ln.7) and an offgas having a high CO₂ content such that “[b]y virtue of this relatively high CO₂ content, the cryogenic CO₂ capture solution may be applied to the PSA

offgas”. EX1008, p.8, ln.10–11. Given that Reinertsen also employs cryogenic separation solution for a gas reforming process, a POSA would have viewed these attributes, disclosed in Darde, as directly applicable to the dual reforming process of Reinertsen. EX1003, ¶¶166–170, 224–227. Therefore, a POSA would have been motivated to select PSA as one of the finite options disclosed in Reinertsen (i.e., PSA and Pd-membrane) to function in its normal and expected way, as demonstrated in Darde, to achieve the benefit of reduced CO₂ emissions by energetically efficient CO₂ capture. EX1003, ¶168; *see also, KSR Int’l v. Teleflex Inc.*, 550 U.S. 398, 421 (2007) (“When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp.”).

Recognition in the art of performance benefits achieved by implementing hydrogen separation and carbon capture in gas reforming provided additional motivation to combine. Benefits achieved from combining a dual reforming configuration (e.g., GHR and ATR combination) with hydrogen separation and cryogenic CO₂ separation were well-documented in the art as of the critical date, including energy efficiency, high CO₂ capture efficiency, decreased flue gas emissions and lower overall CO₂ emissions to the atmosphere. EX1003, ¶¶169, 228, 321. In addition, benefits of selection of PSA for hydrogen separation in gas

reforming were also recognized in the art as of the critical date including: (i) the capability for generating high purity H₂ at a useful pressure, and (ii) the practical robustness and ease of implementation of PSA with gas reforming and cryogenic CO₂ separation. EX1003, ¶¶169–170. Recognition of these technical benefits would have motivated a POSA at the critical date to combine the teachings of Reinertsen and Darde to arrive at the invention of the '805 patent. *Motorola, Inc. v. Interdigital Tech. Corp.*, 121 F.3d 1461, 1472 (Fed. Cir.1997) ("there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention. Rather, the suggestion to combine may come from the prior art, as filtered through the knowledge of one skilled in the art.").

Moreover, a POSA combining the teachings of Reinertsen and Darde would have reasonably expected to successfully practice the method of claims 1–6, 11, and 12. Reinertsen discloses the process steps, in the same sequence, as the process of claim 1 of the '805 patent. To the extent that a POSA would require some additional degree of teaching, Darde addresses the goal identified in Reinertsen of generating hydrogen by gas reforming with reduced CO₂ emissions using the same downstream processes of WGS conversion with hydrogen separation and cryogenic CO₂ separation. Given that each of Reinertsen and Darde use well-known processes to achieve the same solution of CO₂ capture to reduce CO₂

emissions in gas reforming, a POSA would have been readily able to adapt the teachings of these references to arrive at the claimed invention with a reasonable likelihood of success. EX1003, ¶¶224–228; *see Wyers v. Master Lock Co.*, 616 F.3d 1231, 1240 (Fed. Cir. 2010) (“where all of the limitations of the patent were present in the prior art references, and the invention was addressed to a known problem, KSR...compels the grant of summary judgment of obviousness.”).

A POSA would have reasonably concluded that the overlapping reforming and separation processes of Reinertsen with Darde would be compatible with similar process conditions (e.g., pressures, flow rates, temperatures), similar process inputs (e.g., feed stream), intermediates (synthesis gas streams, shifted syngas stream and residual gas stream) and similar process outputs (e.g., hydrogen-rich stream and CO₂ rich stream). EX1003, ¶¶172, 227. Therefore, a POSA would have readily combined teachings of Reinertsen and Darde with a reasonable expectation of success because the combination requires only ordinary skill, and results in no more than a practical selection of known processes used in their ordinary manner to achieve the commonly recognized goal of hydrogen production with reduced CO₂ emissions. EX1003, ¶¶224–228.

2. Reinertsen and Darde Combine to Disclose the Limitations of the Claims

Reinertsen teaches each element of claims 1, 6, 11, and 12. *See*, Section VIII.A.1–18, *supra*. Darde supplements the disclosure in Reinertsen.

(a) Element 1.pre: Preamble

See, Section VIII.A.1, *supra*.

(b) Element 1.1: providing a feed gas stream

See, Section VIII.A.2, *supra*.

(c) Element 1.1.1: hydrocarbon component and steam

See, Section VIII.A.3, *supra*.

Darde similarly discloses that a natural gas stream **1** is mixed with two streams of steam **22** and **27** to generate a feedstock stream **3**, as shown in the Figure.

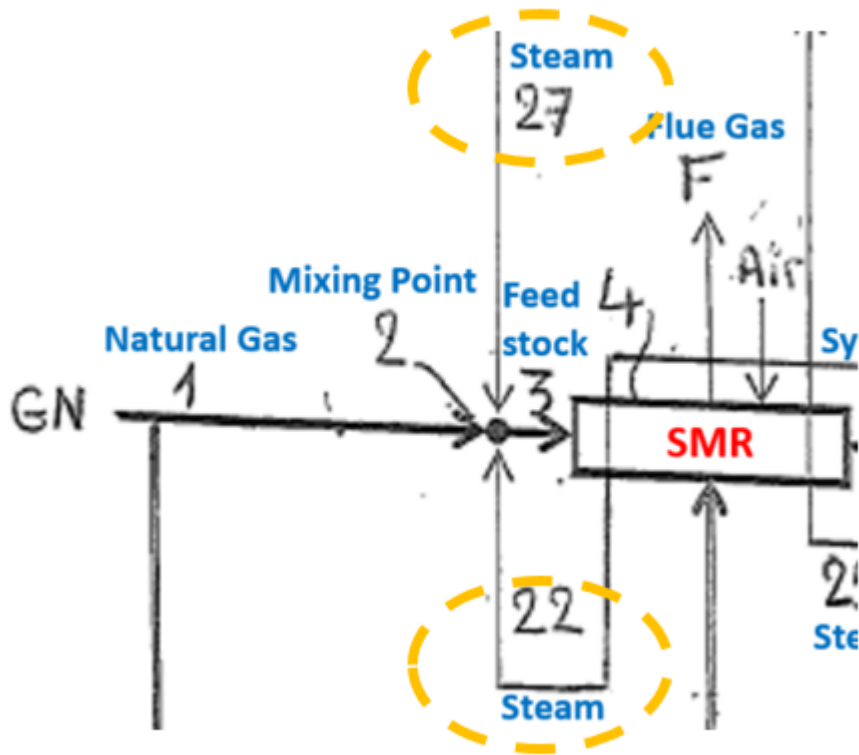


Figure 1, excerpt, annotated

Darde explains, “[t]he stream 3 resulting from the mixing constitutes the feedstock feeding a steam methane reforming (SMR) module 4”. EX1008, p.15, ln.28–29.

(d) Element 1.1.2: methane

See, Section VIII.A.4, *supra*.

Darde similarly discloses this element. (“the hydrocarbon feedstock is a gaseous feedstock, generally natural gas or a mixture of light hydrocarbons, the main constituent of which is methane”). EX1008, p.7, ln.14–16.

(e) Element 1.2: endothermic reforming step

See, Section VIII.A.5, *supra*.

Darde similarly discloses this element. EX1008, p.7, ln.19–20 (“The strongly endothermic reforming reaction takes place at high temperature and at high pressure.”), p.5, ln.13–15 (“processes for steam methane reforming (SMR) by means of a reforming catalyst”).

(f) Element 1.2.1: first synthesis gas

See, Section VIII.A.6, *supra*.

While Reinertsen discloses this feature, the combination with Darde makes this property explicit. Darde discloses reforming processes for producing synthesis gases comprising hydrogen, CO, CO₂, and unreacted methane. Darde explains, “the synthesis gases can have different compositions, but are always in the form of a mixture containing mainly hydrogen (H₂) and carbon monoxide (CO) and in smaller proportions carbon dioxide (CO₂), but also unreacted methane (CH₄), excess steam and traces of various compounds”). EX1008, p.5, ln.29–34; EX1003, ¶182.

(g) Element 1.3: reforming in an ATR step

See, Section VIII.A.7, *supra*.

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

See, Section VIII.A.8, *supra*.

Darde supplements the disclosure in Reinertsen by providing “hydrocarbons are mixed with steam, and then they are partially oxidized in a burner, thus producing the heat required for the reforming reaction at the same time as a hydrogen-depleted gas; this first gas produced is then steam-reformed...[which] is carried out by means of a reforming catalyst”. EX1008, p.5, ln.13–20.

(i) Element 1.3.2: second and third synthesis gas

See, Section VIII.A.9, *supra*.

(j) Element 1.3.3: heat from ATR step

See, Section VIII.A.10, *supra*.

(k) Element 1.4: converting the CO

See, Section VIII.A.11, *supra*.

Darde similarly discloses this element. EX1008, p.5, ln.35–p.6, ln.2 (“synthesis gas produced is then treated in at least one reactor where the CO conversion reaction takes place...in which the carbon monoxide produced during the reforming is, under the action of steam present in the synthesis gas...converted into additional hydrogen and carbon dioxide”).

(l) Element 1.4.1: fourth synthesis gas

See, Section VIII.A.12, *supra*.

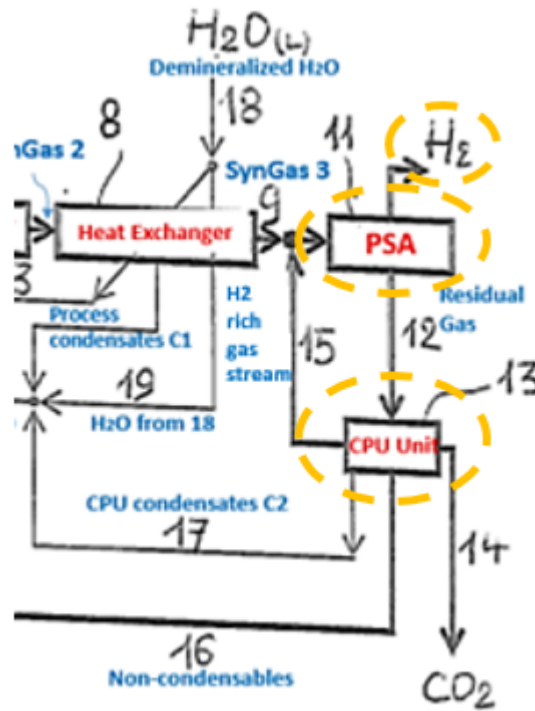
While Reinertsen discloses this feature, the combination with Darde makes this property explicit. Darde discloses reforming processes for producing synthesis

gases comprising hydrogen, CO, CO₂, and unreacted methane. *See*, Section VIII.B.2(f), *supra*. Darde explains, “the synthesis gases can have different compositions, but are always in the form of a mixture containing mainly hydrogen (H₂) and carbon monoxide (CO) and in smaller proportions carbon dioxide (CO₂), but also unreacted methane (CH₄), excess steam and traces of various compounds.” EX1003, ¶190; EX1008, p.5, ln.29–34.

(m) Element 1.5: separating hydrogen

See, Section VIII.A.13, *supra*.

Darde supplements the description in Reinertsen given its explicit disclosure of hydrogen separation by PSA followed by cryogenic CO₂ capture using a CO₂-purifying CPU unit, as shown in the Figure. EX1008, p.7, ln.26–27, p.8, ln.22, p.16, ln.6–10.



EX1008, Figure, excerpt, annotated

Darde explains, “[the PSA] produces at least one gaseous stream of highly pure (greater than 99%) hydrogen, and also a residual gas 12” which is provided to the CPU Unit. EX1008, p.16, ln.6–7.

A POSA would have been motivated to make the specific selection of PSA, as described in Darde, in the process of Reinertsen as one of a finite number of identified, predictable solutions for reducing CO₂ emissions and to achieve additional benefits recognized in the art at the critical date. *See*, Section VIII.B.1, *supra*; EX1003, ¶¶169–171, 192.

(n) Element 1.5.1: first residual gas

See, Section VIII.A.14, *supra*.

While Reinertsen discloses this feature, the combination with Darde makes this property explicit. Darde discloses, “[the PSA] produces...a residual gas **12** which for its part contains all the carbon dioxide, the vast majority of the unconverted methane and of the unconverted carbon monoxide, and a large part of the nitrogen and hydrogen.”). EX1003, ¶¶172, 194; EX1008, p.16, ln.6–9

(o) Element 1.6: separating CO₂

See, Section VIII.A.15, *supra*.

Darde similarly discloses this element. EX1003, ¶196; EX1008, p.8, ln.22–23 (“A process of CO₂ capture by CPU—applied to the PSA offgas—operates according to the following scheme...”).

(p) Element 1.6.1: second residual gas

See, Section VIII.A.16, *supra*.

While Reinertsen discloses this feature, the combination with Darde makes this property explicit. EX1003, ¶198. Darde discloses, “the gaseous stream of offgas...undergoes one or more successive condensation/separation steps in the CPU unit so as to produce a liquid stream enriched with CO₂ and a gaseous stream (capture offgas) enriched with hydrogen and with other constituents lighter than

CO₂ and therefore non-condensable under the operating conditions, in particular CH₄, H₂ and CO.” EX1008, p.8, ln. 24–29.

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

Reinertsen teaches each feature of claim 1 from which claim 2 depends. *See*, Sections VIII.A.1–16, *supra*.

As illustrated in Figure 4, Reinertsen describes a process for generation of a rest gas (**132**) enriched in hydrogen from a residual gas from cryogenic CO₂ separation, as shown in FIGURE 4. EX1003, ¶201; EX1005, ¶¶[0123]–[0125], [0131]–[0136], EX1022, p.23, ln.11–26, p. 25, ln.24–30, p.26. ln.1–4; EX1023, p.23, ln.20–30, p.24, ln.1–5, p.25, ln.29–30, p. 26, ln.1–8.

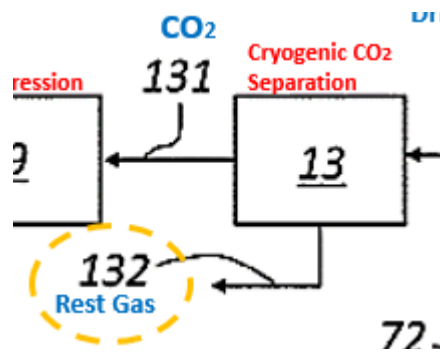
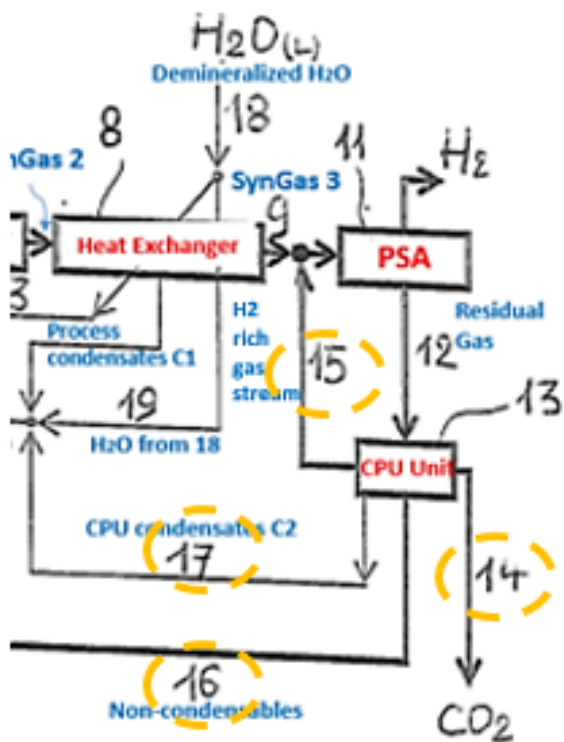


FIGURE 4, excerpt, annotated

Darde describes a cryogenic CO₂ separation process carried out in a CPU unit to produce “a gaseous stream (capture offgas) enriched with hydrogen and with other constituents lighter than CO₂ and therefore non-condensable under the operating conditions, in particular CH₄, H₂ and CO.” EX1008, p.8, ln.25–30;

EX1003, ¶202. The capture offgas in Darde is equivalent to the second residual gas in the '805 patent because both result from cryogenic CO₂ separation. EX1003, ¶202.

As illustrated in the Figure, the CPU Unit of Darde is depicted as generating a stream **14** of CO₂, an H₂-enriched gaseous stream **15**, a stream **16** of noncondensables, and a liquid stream **17** of CPU condensates. EX1008, p.16, ln.11–14.



EX1008, Figure, excerpt, annotated

Given that the gas streams are shown individually, a POSA would recognize that the CPU Unit of Darde additionally provides for separation of the offgas from

cryogenic CO₂ separation into two separate product streams: an H₂-rich gaseous stream **15** and a noncondensables stream **16**. EX1003, ¶202; EX1008, p.9, ln.22–30 (“[PSA offgas] is compressed and dried...then it undergoes one or more successive condensation/separation steps in the CPU unit so as to produce a liquid stream enriched with CO₂ and a gaseous stream (capture offgas) enriched with hydrogen and with other constituents”). Therefore, the H₂-rich gaseous stream **15** is equivalent to the second hydrogen-rich stream of the ’805 patent, and the noncondensables stream **16** is equivalent to the third residual gas stream of the ’805 patent. EX1003, ¶¶199–203.

(r) Element 3: membrane separation

See, Section VIII.B.2.(q), *supra*.

Reinertsen discloses using a Pd-membrane for separation of hydrogen-containing streams to generate an H₂-enriched stream. EX1005, ¶¶[0129], [0138], EX1022, p.25, ln.4–17, p.25, ln.24–30, p.26, ln.1–4; EX1023, p.25, ln.9–22, p.24, ln.1–5, p.25, ln.29–30, p. 26, ln.1–8.

Darde discloses for the CPU unit **13** “[t]he condensation/separation steps can be supplemented by membrane separation steps.” EX1008, p.8, ln.22–30. A POSA would recognize the membrane separation steps described in Darde as applicable to the residual gas from cryogenic separation to generate a hydrogen-rich stream because membrane separation is specifically contemplated for the separation steps

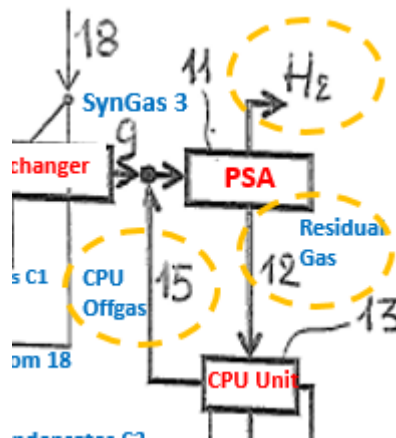
in the CPU Unit **13**, which is shown as generating hydrogen-rich gas stream **15**.

EX1008, p.8, ln.22–30, Figure. Therefore, the “membrane separation steps” in Darde are equivalent to the hydrogen separation of the second residual gas stream of the ’805 patent. EX1003, ¶¶204–208.

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

See, Section VIII.B.2.(q), supra.

As illustrated in the Figure, Darde discloses that gas from the CPU unit **13** is recycled to feed the PSA unit. EX1008, p.16, ln.11–14.



EX1008, Figure, excerpt

Darde explains, “[t]he residual gas **12** is sent at **13** to a CPU unit for separation of the CO₂, the CPU unit producing at least one stream **14** of CO₂, a gaseous stream **15** rich in hydrogen H₂ which is recycled so as to feed the H₂ PSA in order to recover the hydrogen contained and to thus improve the overall hydrogen yield of the facility”. EX1008, p.16, ln.11–14. Therefore, recycling stream **15** to the PSA in

Darde is equivalent to supplying the second hydrogen-rich stream to the fourth synthesis gas stream for separation of hydrogen by PSA of the '805 patent.

EX1003, ¶¶209–212.

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

See, Section VIII.B.2.(q), *supra*.

Darde discloses a cryogenic separation step resulting in a gaseous stream (capture offgas) enriched with hydrogen. *See*, Section VIII.B.2.(o), *supra*.

Reinertsen teaches use of a residual gas from cryogenic separation as a fuel for providing energy in fired heater(s), which would be understood by a POSA as referring to a component of an ATR. EX1005, ¶¶[0053], [0103], [0110] (“The rest gas **102** contains remnants of CO and CH₄ together with unseparated CO₂ and hydrogen. The energy in the rest gas is utilized for fuel in fired heater(s)”).

EX1003, ¶215, EX1022, p.19, ln.18–20; EX1023, p. 19, ln.28–30. Table 4 (below) of Figure 13 in EX1005 similarly references “Heat available in Fired Heater” with respect to the rest gas. A POSA would recognize that rest gas **102** is enriched with hydrogen given that it is a residual gas after separation of the CO₂. EX1003, ¶215.

Therefore, use of the residual gas as fuel in Reinertsen is equivalent to use of the hydrogen-rich stream as fuel gases for heating in the ATR step of the '805 patent.

EX1003, ¶¶213–215.

Table 4. Effect of recycling rest-gas to ATR.

	Embodiment Example 2	Embodiment Example 5	Embodiment Example 6	Embodiment Example 7
Recycle option	No recycle	50%	80%	90%
O ₂ to ATR (kg/h)	4179	4316	4426	4482
H ₂ production (kmol/h)	752	777	794	799*
Carbon capture (%)	89.7	94.4	97.7	98.8
Heat available in Fired heater (MW)	4.6	2.5	1.0	0.5

EX1005, FIGURE 13, excerpt, annotated

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

See, Sections VIII.A.1–16, supra.

Darde discloses the liquid CO₂ generated by cryogenic CO₂ separation may be distilled to achieve CO₂ purities greater than 99%. EX1008, p.8, ln.18–21 (“Under these temperature and pressure conditions, it will partially condense, the liquid phase being particularly enriched with CO₂ and the gas phase with non-condensable gases. The liquid obtained can then be distilled so as to achieve CO₂ purities greater than 99%.”). A POSA would have understood that methane is a major impurity in the separated CO₂, and thus understood Darde to teach that methane from the CO₂-rich stream from cryogenic CO₂ separation may be removed by distillation as provided in the ’805 patent. EX1003, ¶¶216–218.

(v) Element 11: compression step and cooling step

See, Section VIII.A.17, supra.

While Reinertsen discloses this feature, the combination with Darde makes this property explicit, as Darde discloses compression and cooling in cryogenic CO₂ separation. EX1008, p.8, ln.12–18 (“(CPU) calls for the partial condensation and/or the distillation of the CO₂ contained in the CO₂-rich gaseous stream in a cryogenic purification unit (CPU)...The gas, after drying and compression to a pressure between 20 and 100 bar(a), is cooled to a temperature close to that of the triple point of CO₂ (approximately -56°C).”). EX1003, ¶¶219–220.

(w) Element 12: plant configured to perform process

See, Section VIII.A.18, *supra*.

Darde further discloses, “[a]ccording to another aspect of this invention, the latter relates to a facility for producing hydrogen by reforming hydrocarbons using steam, combined with carbon dioxide capture and steam production.” EX1003, ¶223, EX1008, p.13, ln.33–35.

C. Ground 3: Claims 1, 6, 11, and 12 are Obvious Over Rytter and Darde

Claims 1, 6, 11, and 12 would have been obvious to a POSA based on the combination of Rytter and Darde. EX1003, Section XI.C.

1. Motivation to Combine, Reasonable Expectation of Success

A POSA would have been motivated to combine the teachings of Rytter and Darde in the manner claimed.

Rytter and Darde implement a similar combination of known gas reforming and separation processes to achieve a common purpose, namely production of a hydrogen product by reforming with reduced CO₂ emissions. EX1003, ¶¶231–241; EX1009, p.3, ln.17–18; EX1008, p.7, ln.2–12. Rytter describes the same goal recited in Reinertsen of reducing CO₂ emissions from gas reforming. Section VIII.B.1, *supra*; EX1009, p.3, ln.18–22. Darde explicitly acknowledges, as essential, that to achieve this goal of reduced emissions, the CO₂ generated in gas reforming may be captured to prevent emissions to the atmosphere. Section, VIII.B.1, *supra*; EX1008, p.6, ln.28–30. Therefore, a POSA would have been motivated to incorporate aspects from Darde into the reforming process in Rytter to reduce CO₂ emissions by cryogenic capture of CO₂. EX1003, ¶¶231–233.

Rytter provides the process steps for the series configuration of claims 1, 6, 11, and 12 and includes H₂ separation by PSA and cryogenic CO₂ separation. EX1009, p.6, ln.18–23. While Rytter discloses CO₂ separation (**13**) occurs upstream of H₂ separation (**15**) in the embodiment shown in FIGURE 3, it also discloses that CO₂ separation may occur downstream of H₂ separation as an alternative hydrogen separation sequence. EX1009, p.12, ln.19–20, p.20, ln.6–10. A POSA would have been motivated to substitute the sequence of hydrogen separation provided upstream of cryogenic CO₂ separation, as disclosed in Darde, into the process of Rytter to achieve energetically efficient CO₂ capture for

reducing emissions of CO₂. *See*, Sections VIII.B.1.(m)–(p), *supra*; EX1003, ¶¶234–237; *In re Ethicon, Inc.*, 844 F.3d 1344, 1351 (Fed. Cir. 2017) (“The normal desire of artisans to improve upon what is already generally known can provide the motivation to optimize variables.”).

A POSA would have readily been aware that the processes and order of H₂/CO₂ separation steps are selectable, as recognized in Rytter, depending on the goals and requirements of the overall process. EX1003, ¶¶235–237. The separation processes and their order in Rytter represent a finite set of only six practical permutations for H₂/CO₂ separation from a shifted gas, summarized below: EX1003, ¶¶234–237.

<i>Separation Processes</i>	
H₂ Separation	CO₂ Separation
Membrane (e.g., Pd-membrane)	Amine Separation/Solvent Separation
PSA	Cryogenic Separation
<i>Practical Sequences of Separation Steps</i>	
H₂ Separation Upstream	CO₂ Separation Upstream³

³ A POSA would not reasonably place a cryogenic CO₂ separation step upstream of a H₂ separation step due to practical considerations. EX1003, ¶234.

<ol style="list-style-type: none"> 1. Membrane → Amine Separation 2. Membrane → Cryogenic Separation 3. PSA → Amine Separation 4. PSA → Cryogenic Separation 	<ol style="list-style-type: none"> 1. Amine Separation → Membrane 2. Amine Separation → PSA
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Therefore, a POSA would view the sequence of H₂ and CO₂ separation processes as selectable and would have been motivated to substitute hydrogen separation using PSA provided upstream of CO₂ separation, as described in Darde, into the process of Rytter as one of a finite number of identified, predictable solutions to achieve a residual gas with desirable CO₂ content and pressure for cryogenic CO₂ capture. EX1003, ¶¶234–237. This substitution corresponds to a routine optimization based on a finite number of well-known design choices to achieve H₂ production with reduced CO₂ emissions. *See KSR*, 550 U.S. at 421. As additional motivation for selecting this sequence for the hydrogen separation process of Rytter, Darde explains, that it is preferable to place a CO₂ separation step downstream of H₂ separation to allow for effective cryogenic CO₂ capture:

The PSA offgas is the gaseous stream *richest in CO₂* of the process ...

By virtue of this relatively high CO₂ content, the cryogenic CO₂ capture may be applied to the PSA offgas.

EX1008, p.8, ln.8–11.

The recognized performance benefits achieved by implementing hydrogen separation and carbon separation/capture in gas reforming provides additional motivation to combine the teachings of Rytter and Darde, including the effectiveness of PSA for hydrogen separation in gas reforming and benefits from combining a dual reforming configuration (e.g., GHR and ATR combination) with hydrogen separation and cryogenic CO₂ separation. *See*, Section VIII.B.1, *supra*. Rytter itself provides results demonstrating the increased energy efficiency achieved by combining dual reforming with CO₂ separation, thereby reinforcing this motivation to combine:

The GHR 1 and ATR 2 combination according to an embodiment gives significantly lower consumption of natural gas, less CO₂ needs to be captured (capture efficiencies being approximately equal), and the energy efficiency is significantly improved. Compared to using only an ATR reformer, the GHR 1 and ATR 2 combination requires significantly less imported oxygen.

EX1009, p.16, ln.10–16.

A POSA combining the teachings of Rytter and Darde would have reasonably expected to successfully practice the method of claims 1, 6, 11, and 12. Darde addresses the technical goal identified in Rytter of generating hydrogen by gas reforming with reduced CO₂ emissions using the same downstream processes

of WGS conversion, hydrogen separation and cryogenic CO₂ separation. Given that well-known, overlapping processes are used, in the same manner, to achieve the same technical solution in Rytter and Darde, a POSA would have been readily able to adapt the teachings of these references to arrive at the claimed invention with a reasonable likelihood of success. EX1003, ¶¶282–285; *see, Wyers*, 616 F.3d at 1231.

A POSA would have also reasonably concluded that the overlapping processes of Rytter with Darde would be compatible with similar process conditions (e.g., pressures, flow rates, temperatures), similar process inputs (e.g., feed stream), intermediates (synthesis gas streams, shifted syngas stream and residual gas streams), and similar process outputs (e.g., hydrogen-rich stream and CO₂ rich stream). EX1003, ¶¶282–285. Therefore, a POSA would have readily combined these teachings with a reasonable expectation of success because the combination of Rytter and Darde requires no more than common sense or ordinary skill, and results in little more than a practical selection of known processes used in their ordinary manner to achieve the commonly recognized goal of hydrogen production with low CO₂ emissions. *Id.*; *Wyers*, 616 F.3d at 1242–43.

2. Rytter and Darde Combine to Disclose the Limitations of the Claims

(a) Element 1.pre: Preamble

Rytter discloses a process for preparing hydrogen by reforming hydrocarbons with steam, and for separation of CO₂. EX1003, ¶¶244–246.

With reference to Figure 3, Rytter explains, “Figure 3 shows production of hydrogen and CO₂ by combination of ATR 2 and GHR 1” which includes “[s]eparation process 13 separates CO₂ 131 from the shifted gas, and the CO₂ is compressed 14 and optionally liquified.” EX1009, p.14, ln.32–33, p.15, ln.13–14.

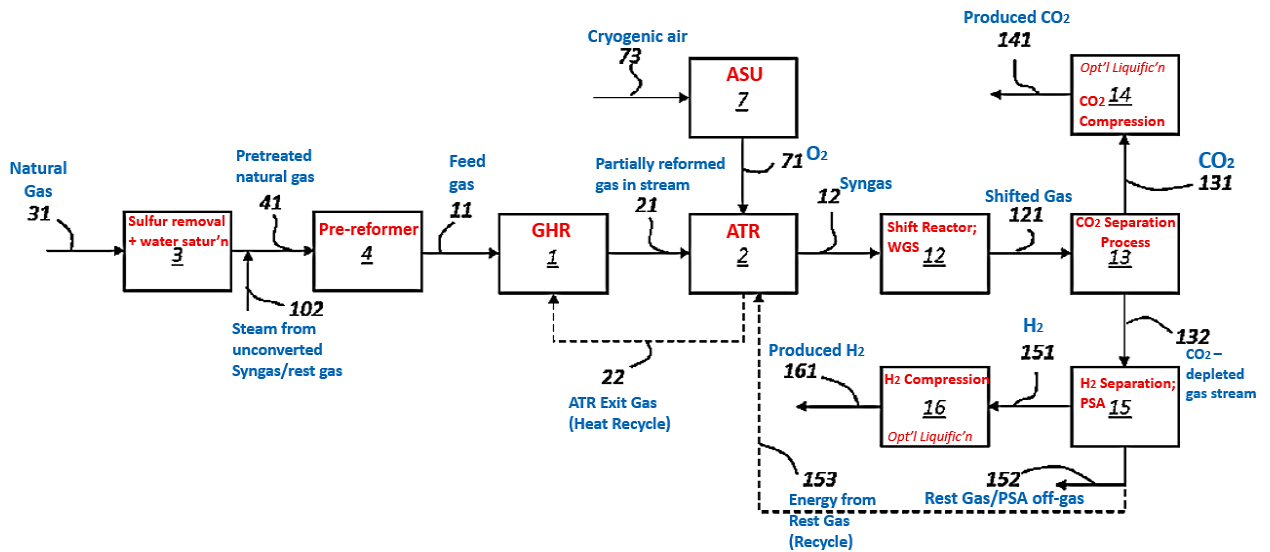


Figure 3, annotated

(b) Element 1.1: providing a feed gas stream

Rytter discloses providing a feed gas stream. EX1009, p.4, ln.18–19;
EX1003, ¶247.

As illustrated in Figure 3, Rytter describes a process wherein feed gas **11** is provided.

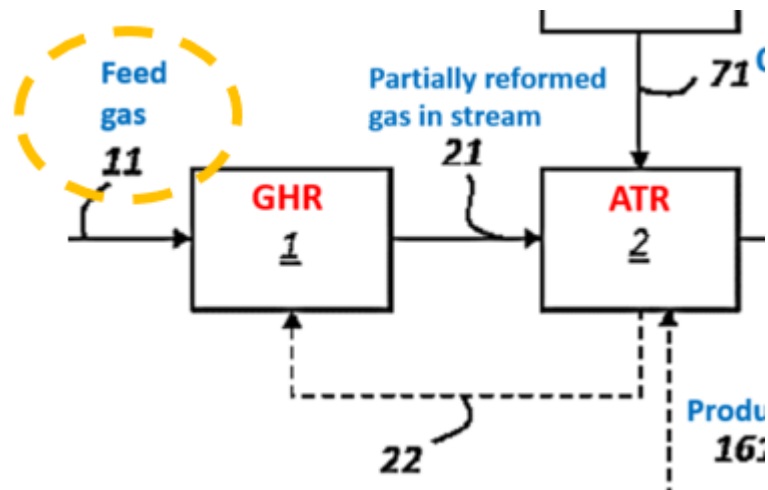


Figure 3, excerpt annotated

Rytter provides, “the method comprising: receiving a feed gas comprising hydrocarbons; and performing reforming processes so as to generate hydrogen.”
EX1009, p.4, ln.18–19.

(c) Element 1.1.1: hydrocarbon component and steam

Rytter discloses the feed gas stream comprises a hydrocarbon component and steam. EX1009, p.4, ln 26–27, p.9, ln.6–9 & 15, p.17, ln.17–18, p.20, ln.30;
EX1003, ¶¶248–249.

Rytter discloses a process including “receiving a feed gas comprising hydrocarbons”. EX1009, p.4, ln.18–19. Rytter explains, “Preferably, the feed gas is a hydrocarbon rich gaseous stream”. EX1009, p.5, ln.13–14.

Rytter discloses that steam is introduced to the feed gas stream for pre-treatment. EX1009, p.9, ln.8–9 (“Pre-treatment may comprise pre-reforming whereby higher hydrocarbons, such as ethane, are converted by steam to methane and CO₂.”). Additionally, Rytter discloses a feed gas comprising steam by describing “saturating the feed gas with at least water.” EX1009, p.4, ln.26–27, p.20, ln.30. When the water-saturated feed gas is heated, as described in Rytter, a POSA would understand that steam is produced and is necessarily present within the feed gas stream. EX1003, ¶249. Rytter makes this understanding explicit by referring to the chemical reaction “CH₄ + H₂O ⇌ CO + 3H₂” of the reforming process as “Steam reforming.” EX1009, p.9, ln.15. Therefore, the composition of the feed gas in Rytter is equivalent to that of the feed gas stream in the ’805 patent and necessarily includes a hydrocarbon component and steam. EX1003, ¶¶248–249.

Darde similarly discloses a feed gas stream comprises a hydrocarbon component and steam. *See*, Section VIII.B.2.(c), *supra*.

(d) Element 1.1.2: methane

Rytter discloses a feed gas stream with a hydrocarbon component containing methane. EX1009, p.9, ln.6–7, p.15, ln.24–26; EX1003, ¶250.

Rytter discloses, “[i]n a preferred embodiment, cleaning and pre-treatment of natural gas is performed so that the gas feed mainly comprises methane.” EX1009, p.9, ln.6–7. Rytter explains, “[p]rocess simulations of the flow-sheet in Figure 3...is based on natural gas with molar composition 88.8% methane” *Id.*, p.15, ln.24–26.

Darde similarly discloses a feed gas stream with a hydrocarbon component containing methane. *See*, Section VIII.B.2.(d), *supra*.

(e) Element 1.2: endothermic reforming step

Rytter 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. EX1009, p.9, ln.15–19, p.10, ln. 4–5, ln.30–33; EX1003, ¶¶251–252.

As illustrated in Figure 3, Rytter discloses a process wherein feed gas **11** is provided to GHR (**1**) for endothermic reforming.

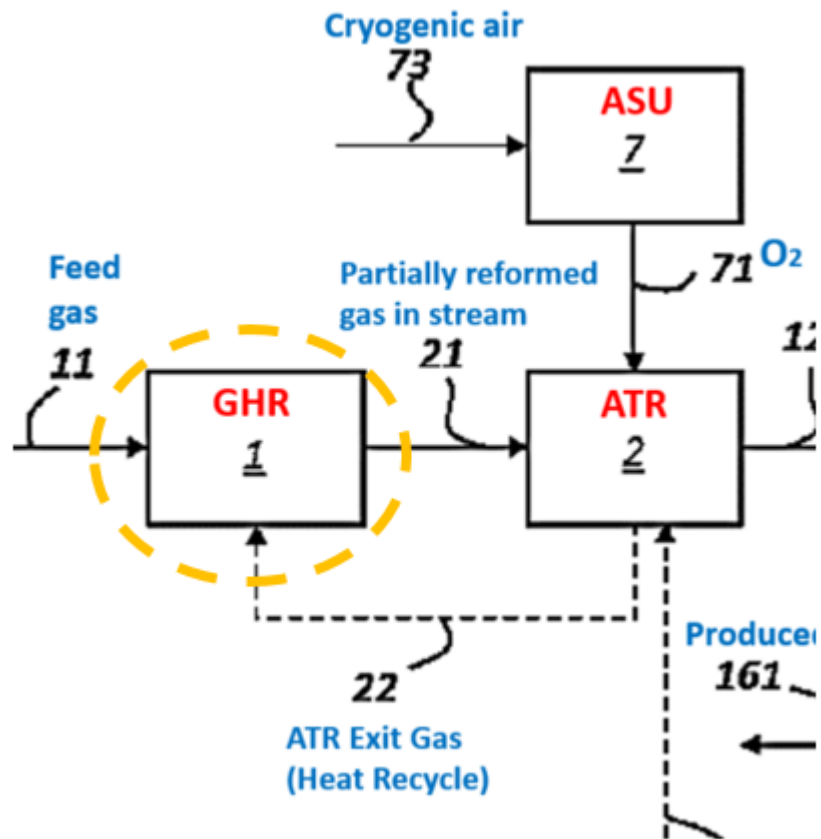


Figure 3, excerpt, annotated

Rytter explains, “[t]he feed gas **11** first passes through the catalyst in the GHR 1”.

EX1009, p.10, ln.30–33. Rytter describes the “steam reforming” chemical reaction

“ $\text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + 3\text{H}_2$ ” of the feed gas stream reforming process as being

“strongly endothermic.” EX1009, p.9, ln.15–19. Therefore, endothermic reforming

of the GHR in Rytter is equivalent to the endothermic reforming step in the ’805

patent. EX1003, ¶¶251–252.

Darde similarly discloses an endothermic reforming step over a reforming catalyst. Section VIII.B.2.(e), *supra*.

(f) Element 1.2.1: first synthesis gas

Rytter discloses a first synthesis gas stream comprising hydrogen, CO, CO₂, and unreacted methane. EX1009, p.9, ln.15–19, p.11, ln.2–3; EX1003, ¶¶253–256.

As illustrated in Figure 3, Rytter discloses producing partially reformed gas stream **21** from endothermic reforming by GHR (**1**).

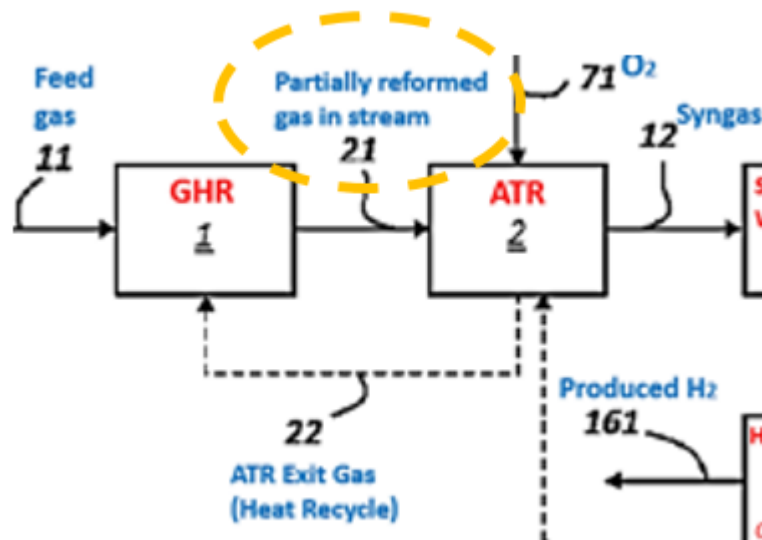


FIGURE 3, excerpt, annotated

Rytter describes reversible chemical reactions that occur during the production of synthesis gas including:



EX1009, p.9, ln.15–19. The “Steam reforming reaction” is designated an equilibrium reaction (as shown by \rightleftharpoons symbol, above). Therefore, both CH₄ and steam (H₂O) are present in the output of the GHR process, as well as unreacted methane and the H₂, CO and CO₂ product gases. Rytter explains, “[t]he gas mixture from the reformer reactor contains mainly the gas components CO, H₂, H₂O, CO₂ and some CH₄.” EX1009, p.11, ln.2–3. Therefore, the components of partially reformed gas in stream **21** are equivalent to that of first synthesis gas stream of the ’805 patent and necessarily includes hydrogen, CO, CO₂, and unreacted methane as a natural result of the GHR process of Rytter. EX1003, ¶¶253–256; *Arbutus*, 65 F.4th at 662.

Additionally, the combination with Darde makes this feature explicit, as Darde discloses reforming processes for producing synthesis gases comprising hydrogen, CO, CO₂, and unreacted methane. Section VIII.B.2.(f), *supra*.

(g) Element 1.3: reforming in an ATR step

Rytter discloses reforming the first synthesis gas stream in an ATR step thereby producing a third synthesis gas stream. EX1009, p.10, ln.30–33, p.14, ln.6–8, p.15, ln.1–2; EX1003, ¶257.

As illustrated in Figure 3, Rytter discloses providing partially reformed gas in stream (21) to ATR (2) for autothermal reforming.

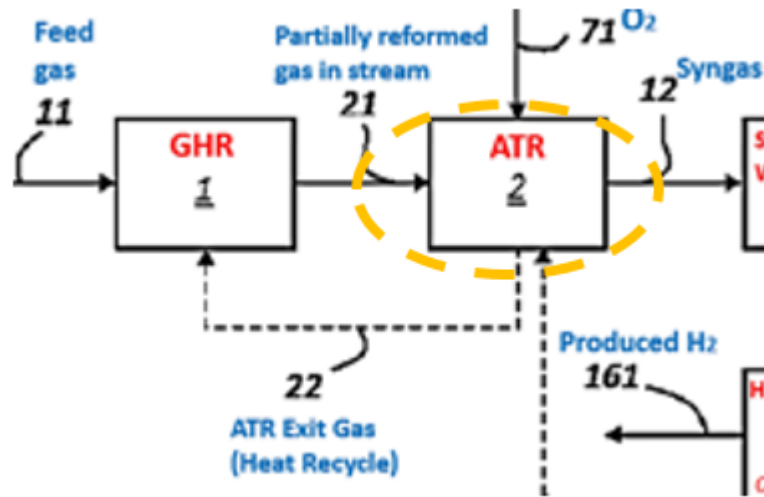


FIGURE 3, excerpt, annotated

Rytter discloses, “[t]he feed gas 11 first passes through the catalyst in the GHR 1, then the ATR 2 by stream 21.” EX1009, p.10, ln.30–33.

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

Rytter discloses the ATR step comprises exothermic partial oxidation and endothermic reforming with steam over a reforming catalyst. EX1009, p.10, ln.1–5; EX1003, ¶258.

Rytter explains, “[i]n an ATR...[t]he energy which is required to operate the endothermic steam reforming reactions is provided by the exothermic reactions between hydrocarbons and/or hydrogen and oxygen...After the combustion

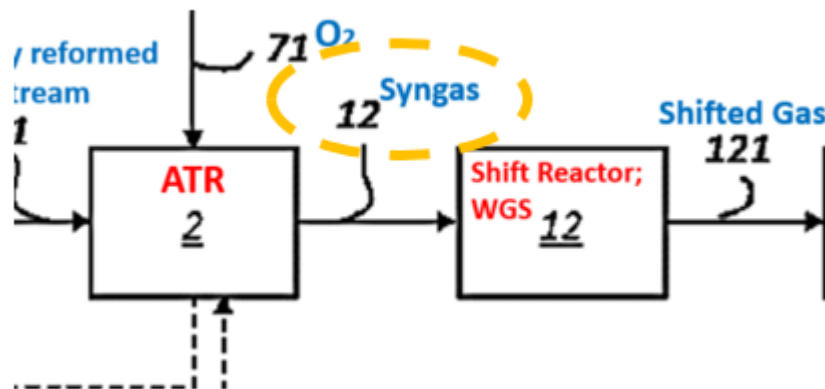
chamber the reactions may be driven to equilibrium over a catalyst bed". EX1009, p.10, ln.1–5. Thus, exothermic partial oxidation and endothermic reforming of the ATR in Rytter is equivalent to the autothermal reforming step in the '805 patent. EX1003, ¶258.

Darde similarly discloses an ATR step including partial oxidation and endothermic reforming over a reforming catalyst. Section VIII.B.2.(h), *supra*.

(i) Element 1.3.2: second and third synthesis gas

Rytter discloses the third⁴ synthesis gas stream comprises hydrogen, CO, CO₂, and unreacted methane. EX1009, p.11, ln.1–3, p.14, ln.22–25; EX1003, ¶¶259–261.

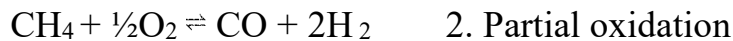
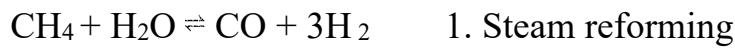
As illustrated in Figure 3, Rytter discloses producing syngas (12) from autothermal reforming by ATR (2).



⁴ As Rytter discloses the serial arrangement of reformers, only the third synthesis gas is referenced.

FIGURE 3, excerpt, annotated

Rytter describes reversible chemical reactions that occur during the production of synthesis gas including:



EX1009, p.9, ln.15–19. The “Steam reforming” and “Partial oxidation” reactions are designated equilibrium reactions (as shown by \rightleftharpoons symbol, above). Therefore, CH₄ and steam (H₂O) are present in the output of the ATR process, as well as unreacted methane and the H₂, CO and CO₂ product gases. EX1003, ¶¶259–261.

Rytter explains, “[t]he gas mixture from the reformer reactor contains mainly the gas components CO, H₂, H₂O, CO₂ and some CH₄.” EX1009, p.11, ln.1–3.

Therefore, the components of syngas stream **12** are equivalent to third synthesis gas stream of the ’805 patent and necessarily includes hydrogen, CO, CO₂, and unreacted methane as a natural result from the ATR process of Rytter. EX1003, ¶¶259–261; *Arbutus*, 65 F.4th at 662.

(j) Element 1.3.3: heat from ATR step

Rytter discloses the heat generated by the ATR step is utilized for heating in the endothermic reforming step of step (b). EX1009, p.10, ln.30–33, p.15, ln.2–3; EX1003, ¶262.

As illustrated in Figure 3, Rytter discloses heat recycle (22) wherein heat generated from the ATR (2) is utilized for heating endothermic reforming in the GHR (1).

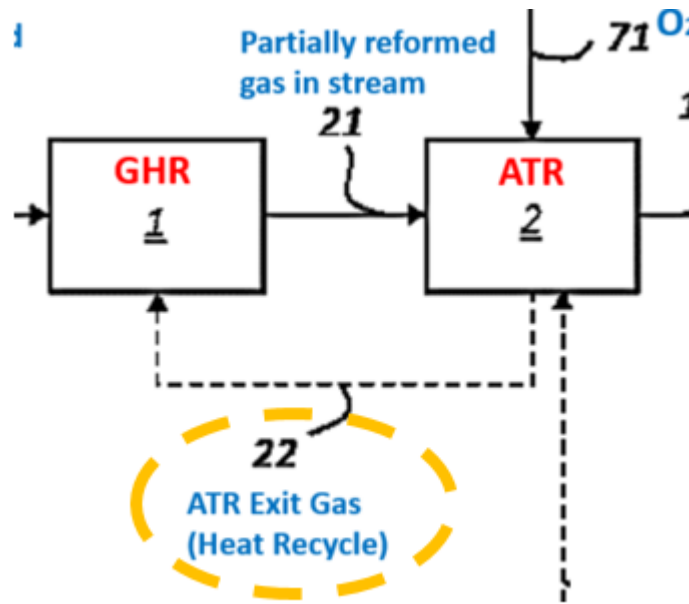


Figure 3, excerpt, annotated

Rytter discloses generating “hydrogen by performing a gas-heated reforming process and an autothermal reforming process, with heat generated by the autothermal reforming process supplied to the gas-heated reforming process.” EX1009, p.3, ln.6–8. Rytter explains, “the hot, autothermally reformed gas 22 is used to heat the catalyst tubes in a GHR 1” and “[t]he feed gas 11 first passes through the catalyst in the GHR 1, then the ATR 2 by stream 21 and finally the heating side of the GHR to provide the heat for the initial reaction.” EX1009, p.10, ln.30–33; *see also*, p.15, ln.2–3.

(k) Element 1.4: converting the CO

Rytter discloses converting the CO present in the third synthesis gas stream with steam producing hydrogen and CO₂ thereby producing a fourth synthesis gas stream. EX1009, p.9, ln.15–16, p.15, ln.9–12; EX1003, ¶263.

As shown in Figure 3, Rytter describes conversion of the syngas (12) by water gas shift (WGS) in shift reactor (12).

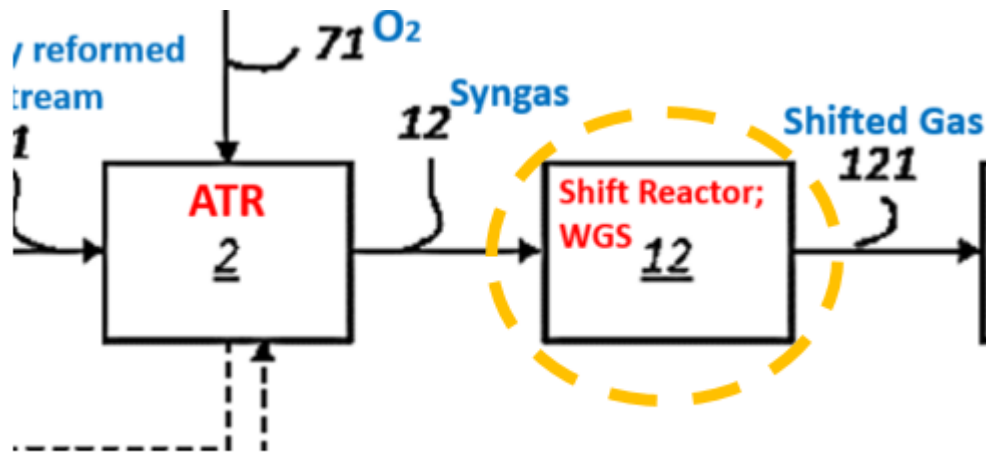


Figure 3, excerpt, annotated

Rytter discloses, “[t]he produced syngas 12 is shifted to increase the content of hydrogen and CO₂ in one or more shift reactors 12...to produce the shifted gas 121. Steam may be added to the gas mixture before the gas mixture is input into the shift reactor(s) 12. EX1009, p.15, ln.9–12. Rytter explains that the shift process produces hydrogen and CO₂, which is made explicit by reference to “CO+H₂O ⇌ CO₂+H₂” as the “Shift Reaction”. EX1009, p.9, ln.15–16.

Darde similarly discloses a CO conversion step with steam where CO produced during the reforming step is converted to produce hydrogen and CO₂. Section VIII.B.2.(k), *supra*.

(I) Element 1.4.1: fourth synthesis gas

Rytter discloses the fourth synthesis gas stream comprises hydrogen, CO₂, unreacted methane, and CO unconverted in step (d). EX1009, p.15, ln.9–14; EX1003, ¶¶264–265.

As illustrated in FIGURE 3, Rytter discloses producing shifted gas (121) by conversion by WGS in shift reactor (12).

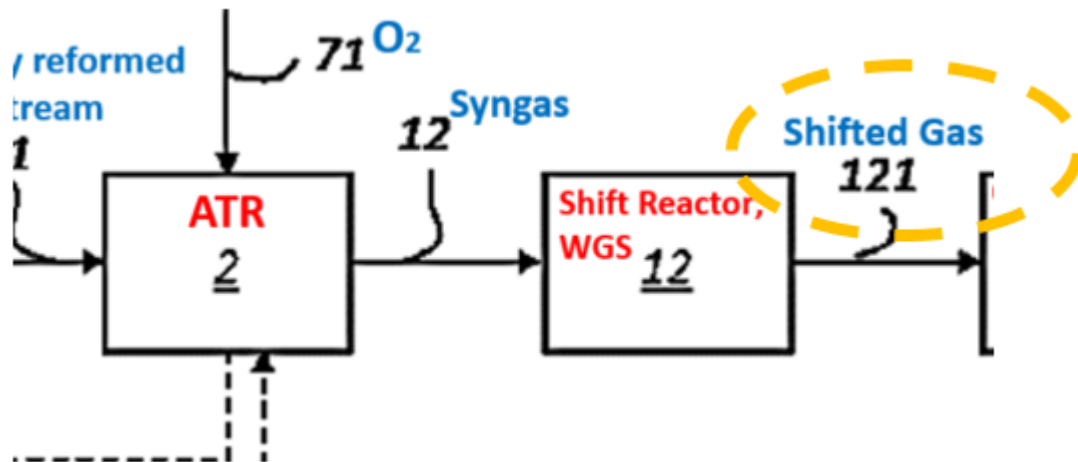


Figure 3, excerpt, annotated

Rytter designates shift reaction, “CO + H₂O ⇌ CO₂ + H₂” as an equilibrium reaction (shown by ⇌ symbol). EX1009, p.9, ln.15–19. Therefore, both CO and H₂O are present in shifted gas (61), as well as unreacted methane and the H₂ and

CO₂ product gases. Rytter explains, “by operating a shift reactor at certain conditions the equilibrium can be forced to the right and a gas mixture is obtained which is rich in hydrogen and carbon dioxide, and where the concentration of carbon monoxide is low”, and “the method further comprises separating carbon dioxide from the shifted gas”. EX1009, p.11, ln.8–10, p.5, ln.1. Thus, the components of shifted gas (**121**) are equivalent to the fourth synthesis gas stream as recited in claim 1 of the ’805 and necessarily includes hydrogen, CO₂, unreacted methane and CO as a natural result of the WGS process of Rytter. EX1003, ¶¶264–265; *Arbutus*, 65 F.4th at 662.

Additionally, the combination with Darde makes this feature explicit, as Darde discloses reforming processes for producing synthesis gases comprising hydrogen, CO, CO₂, and unreacted methane. Section VIII.B.2(1), *supra*.

(m) Element 1.5: separating hydrogen

The combination of Rytter and Darde provides separating hydrogen from the fourth synthesis gas stream by PSA, thereby producing a first hydrogen-rich stream and a first residual gas stream. EX1009, p.20, ln.7–11, p.15, ln.16–17; EX1003, ¶¶266–269.

As illustrated in Figure 3, Rytter discloses producing a hydrogen stream **151** by hydrogen separation using a PSA **15**.

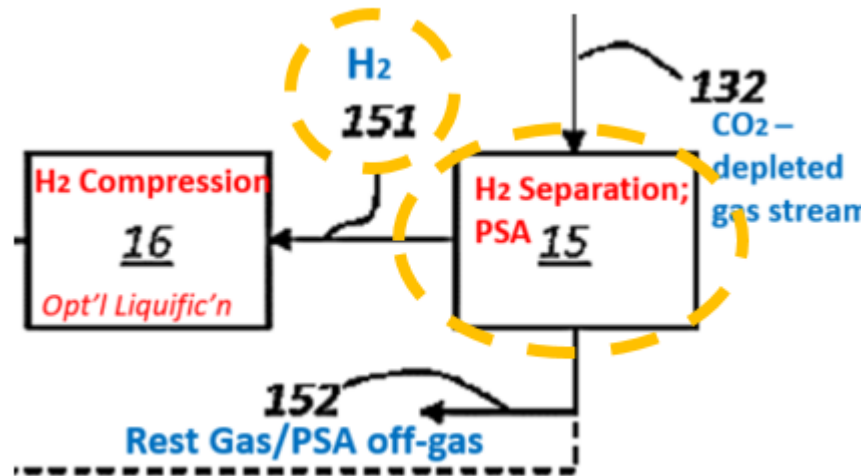
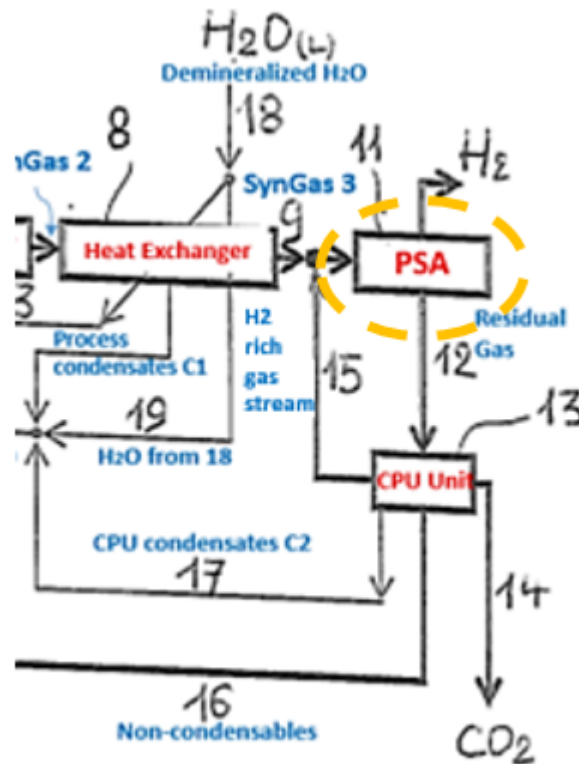


Figure 3, excerpt, annotated

While the PSA is provided after CO₂ separation in Figure 3, Rytter also discloses a process sequence with hydrogen separation before CO₂ separation by stating: “[e]mbodiments also include the hydrogen being separated from the gas mixture before the carbon dioxide is separated from the gas mixture.” EX1009, p.20, ln.7–11.

Darde supplements the disclosure in Rytter in connection with the sequence of hydrogen and CO₂ separation steps by explicitly disclosing separating hydrogen by PSA **11** provided upstream of cryogenic CO₂ separation by CPU unit **13** as depicted in the Figure. Section VIII.B.2.(m), *supra*.



EX1008, Figure, excerpt, annotated

A POSA would view the sequence of H₂ and CO₂ separation processes as selectable and would have been motivated to substitute hydrogen separation using PSA provided upstream of CO₂ separation, as described in Darde, into the process of Rytter as one of a finite number of identified, predictable solutions to achieve a residual gas with desirable CO₂ content and pressure for cryogenic CO₂ capture and to achieve additional benefits recognized in the art at the critical date. Section VIII.B.1, *supra*; EX1003, ¶¶234–238, 266–269.

(n) Element 1.5.1: first residual gas

The combination of Rytter and Darde provides a PSA hydrogen separation process for generating the first residual gas stream comprises CO₂, CO unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane, particularly when provided downstream of cryogenic CO₂ separation. EX1003, ¶¶239–241, 270–271.

H₂ depleted gas stream would necessarily include CO₂, unconverted CO, hydrogen not separated and unreacted methane because it naturally results from PSA hydrogen separation in the reforming process of Rytter. EX1003, ¶¶240–241, 270–271; *Arbutus*, 65 F.4th at 662.

Additionally, the combination with Darde makes this feature explicit, as Darde discloses a PSA process for producing a first residual gas with a composition comprising CO₂, CO unconverted in step (d), hydrogen not separated off in step (e), and unreacted methane. Section VIII.B.2.(n), *supra*.

(o) Element 1.6: separating CO₂

The combination of Rytter and Darde provides separating CO₂ by cryogenic CO₂ separation, thereby producing a first CO₂-rich stream and a second residual gas stream. EX1009, p.15, ln.13–15, p.23, ln.5–6; EX1003, ¶¶239–241, 272–273, Section VIII.B.2.(o), *supra*.

As illustrated in Figure 3, Rytter discloses CO₂ separation process **13** for generating CO₂ stream **131**.

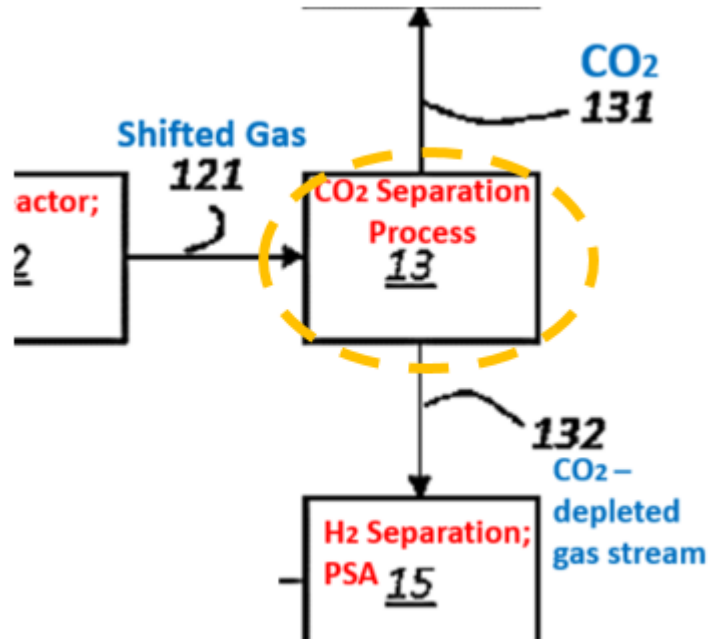
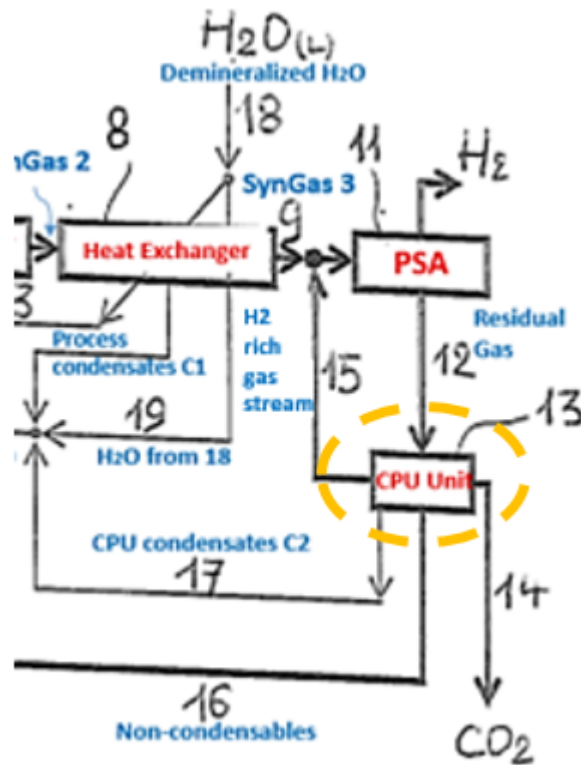


Figure 3, excerpt, annotated

Rytter discloses, “[s]eparation process **13** separates CO₂ **131** from the shifted gas, and the CO₂ is compressed **14** and optionally liquified.” EX1009, p.15, ln.13–15. Additionally, Rytter describes, “[C]arbon dioxide is separated by cryogenic processes.” EX1009, p.23, ln.5–6.

Darde supplements the disclosure in Rytter in connection with the sequence of hydrogen and CO₂ separation steps by explicitly disclosing a cryogenic CO₂ separation by CPU unit **13** downstream from a PSA **11** for separating CO₂ from PSA offgas. Section, VIII.B.2.(o), *supra*; EX1008, Figure.



EX1008, Figure, excerpt, annotated

A POSA would have been motivated to make the selection of the process sequence of cryogenic CO₂ separation provided downstream of hydrogen separation, as described in Darde, in the process of Rytter as one of a finite number of identified, predictable solutions to achieve an energetically efficient CO₂ capture solution. Section VIII.B.2(o), *supra*; EX1003, ¶¶234–238, 268–269, 272–273.

(p) Element 1.6.1: second residual gas

The combination of Rytter and Darde provide 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. EX1003, ¶¶274–275; EX1009, p.15, ln.18–20; Section VIII.B.2.(p), *supra*.

As illustrated in Figure 3, Rytter discloses formation of rest gas **152** resulting from CO₂ separation **13** and hydrogen separation **15**.

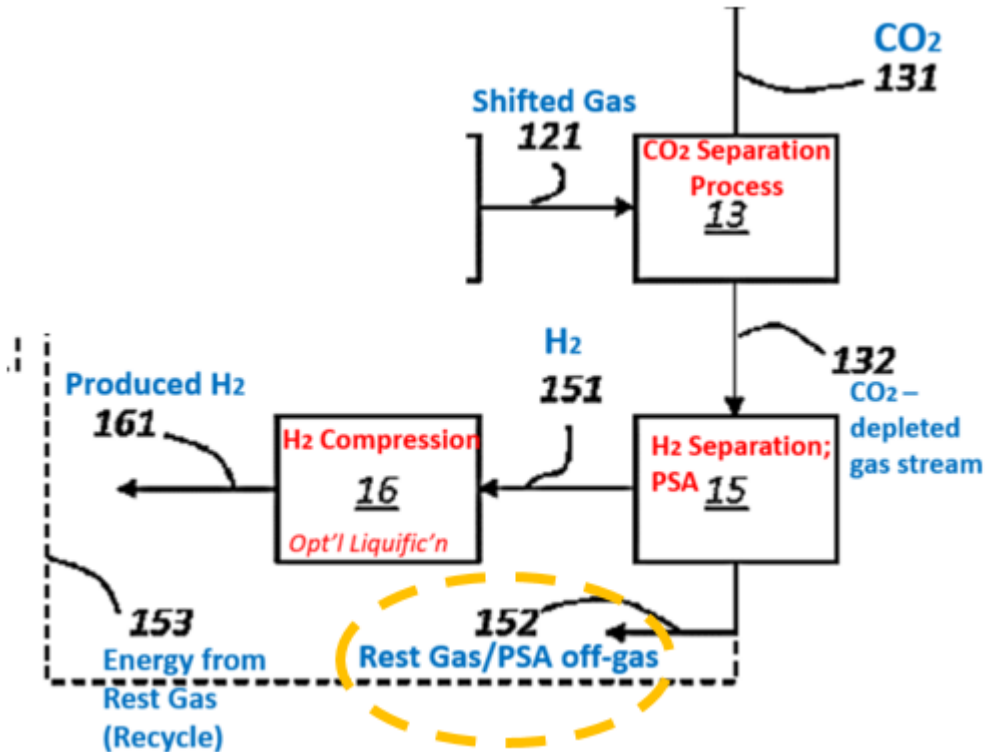


Figure 3, excerpt, annotated

Rytter explains, “[t]he rest gas **152** contains remnants of CO and CH₄ together with unseparated CO₂ and hydrogen.” EX1003, ¶¶274–275; EX1009, p.15, ln.18–20. Thus, the components of the rest gas **152** are equivalent to the fourth synthesis gas stream as recited in claim 1 of the ’805 patent and necessarily includes unconverted CO, hydrogen not separated, CO₂ not separated and unreacted

methane as a natural result of the cryogenic CO₂ separation process of Rytter.

EX1003, ¶¶240–241; *Arbutus*, 65 F.4th at 662.

Additionally, the combination with Darde makes this feature explicit, as Darde discloses 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. Section VIII.B.2.(p), *supra*.

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

The combination of Rytter and Darde teaches each element of claim 1 from which claim 6 depends. Sections VIII.C.2.(a)–(p), *supra*.

The additional features of element 6 are disclosed by Darde. Section VIII.B.2.(u), *supra*; EX1003, ¶¶276–277.

(r) Element 11: compression step and cooling step

The combination of Rytter and Darde teaches each element of claim 1 from which claim 11 depends. *See*, Sections VIII.C.2.(a)–(p), *supra*.

The cryogenic CO₂ process of Rytter necessarily includes at least one compression step and at least one cooling step. EX1003, ¶¶278–279.

Additionally, the combination with Darde makes this feature explicit, as Darde discloses, “(CPU) calls for the partial condensation and/or the distillation of the CO₂ contained in the CO₂-rich gaseous stream in a cryogenic purification unit (CPU) ... The gas, after drying and compression to a pressure between 20 and 100

bar(a), is cooled to a temperature close to that of the triple point of CO₂ (approximately -56 °C).”). EX1008, p.8, ln.12–18; Section VIII.B.2.(v), *supra*.

Therefore, Rytter, alone or in combination with Darde, includes at least one compression step and at least one cooling step as provided in the ’805 patent.

Section VIII.B.2.(v), *supra*; EX1003, ¶¶278–279.

(s) Element 12: plant configured to perform process

See, Section VIII.B.2.(w), *supra*.

Rytter further discloses, “Figure 3 shows a configuration of a hydrogen production plant according to an embodiment.” EX1009, p.8, ln.14., Figure 3; EX1003, ¶¶280–281.

D. Ground 4: Claims 2-5 are Obvious over Reinertsen in Combination with Darde and in Further View of Terrien

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

1. Motivation to Combine, Reasonable Expectation of Success

Motivation to combine the teachings of Reinertsen and Darde is demonstrated above. Section VIII.B.1, *supra*.

Terrien relates to a process for efficient recovery of hydrogen and CO₂ which, similar to Reinertsen and Darde, is applied to gas reforming. Terrien

teaches generating and using hydrogen-rich gas streams as feed into a PSA unit or as fuel for heating in a reformer.

A POSA would have been motivated to implement the recycle and purification steps of Terrien to the hydrogen production process of Reinertsen/Darde to achieve commonly recognized goals of increasing yield of hydrogen and CO₂ products, thereby increasing overall energy efficiency of the combined process. EX1003, ¶¶289–290, 293–296.

Modification of the Reinertsen/Darde process to include aspects of Terrien would not change the principles of operation of the combined process, because the recycle and purification steps of Terrien 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, ¶¶291–292.

A POSA would have reasonably expected success in integrating the process steps/process units of Terrien with those of Reinertsen/Darde, as the combination merely represents the combination of known overlapping methods to achieve their well-understood functions. EX1003, ¶¶292–296; *Wyers*, 616 F.3d at 1242–43.

2. Reinertsen and Darde in view of Terrien Disclose the Limitations of Claims 2-5.

(a) Element 1

See, Sections VIII.A.1–16 and VIII.B.2.(a)–(u), *supra*.

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

Reinertsen and Darde disclose generating a hydrogen-rich stream and residual gas stream. Section VIII.B.2.(q), *supra*.

Terrien FIG. 5 illustrates CO₂ lean non-condensable stream **10** from a CO₂ separation unit **8** which, in view of the compression/liquefaction and distillation steps described, includes a cryogenic CO₂ separation unit. EX1024, ¶¶[0037]–[0038]; EX1003, ¶301. 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, ¶¶300–302. Therefore, stream **12** is equivalent to the second hydrogen-rich stream of the '805 patent and hydrogen lean residual stream **13** is equivalent to the third residual gas stream of the '805 patent. EX1003, ¶¶300–302. Accordingly, these teachings from Terrien combined with those of Reinertsen, alone or in combination with Darde, include separating hydrogen from the second residual gas stream to produce the second hydrogen-rich stream and third residual gas stream as provided in the '805 patent. EX1003, ¶¶300–302.

(c) Element 3: membrane separation.

The combination of Reinertsen and Darde in view of Terrien teach each element of claim 2 from which claim 3 depends. Sections VIII.B.2.(q),(r), *supra*.

The CO₂ lean non-condensable stream **10** of Terrien is equivalent to RG**2** of the '805 patent, hydrogen rich permeate **12** of Terrien is equivalent to HG**2** of the '805 patent and second hydrogen-lean residual stream **13** of Terrien is equivalent to RG**3** of the '805 patent. Section VIII.B.2.(q), *supra*; EX1003, ¶¶305–306. In Terrien FIG. 5, stream **10** is passed to H₂ selective membrane **11** to generate hydrogen-rich permeate **12**. EX1003, ¶¶305–306. 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. Accordingly, the teachings from Terrien combined with those of Reinertsen, alone or in combination with Darde, provide hydrogen separation from second residual gas stream by membrane separation as provided in the '805 patent. EX1003, ¶¶305–306.

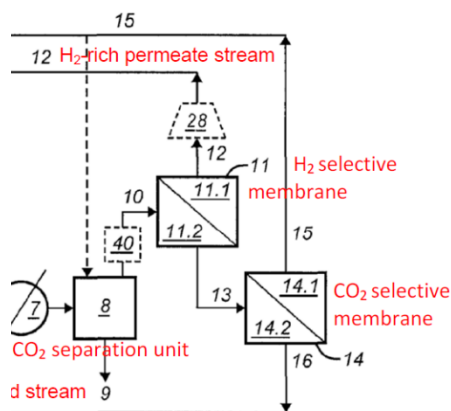


FIG. 5, excerpt, annotated

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

The combination of Reinertsen and Darde in view of Terrien teach each element of claim 2 from which claim 4 depends. Sections VIII.B.2.(q),(s), *supra*.

Terrien in FIG. 5 shows that stream **10** from a cryogenic CO₂ separation unit **8** is introduced to H₂ selective membrane **11** to generate hydrogen-rich permeate **12**. The hydrogen-rich permeate **12** is recycled to feed gas stream **19** which can be synthesis gas. Feed gas **19** enters process unit **0** which contains a hydrogen separation unit, specifically a PSA unit. 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, ¶¶307–309. A POSA would be motivated to apply the hydrogen recycling to a PSA as taught by Terrien to increase hydrogen yield and overall efficiency of the process of Reinertsen and/or Darde. EX1003, ¶¶307–309. Therefore, Terrien combined Reinertsen, alone or in combination with Darde, provide supplying the second hydrogen-rich stream to the fourth synthesis gas stream for separation of hydrogen by PSA as provided in the '805 patent. EX1003, ¶¶307–309.

(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 Reinertsen and Darde teach each element of claim 2 from which claim 5 depends. Sections VIII.B.2.(q),(t), *supra*.

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, ¶¶311–314.

A POSA would have been motivated to employ a hydrogen-rich gas stream generated by removing hydrogen from a residual gas stream from a cryogenic CO₂ separation step, as taught in Terrien, as fuel to heat the ATR in the Reinertsen/Darde process to increased efficiency of hydrogen production and

improved capture of CO₂. EX1003, ¶¶311–314. Therefore, Terrien combined with Reinertsen, alone or in combination with Darde, provide utilizing gases in the second hydrogen-rich stream as fuel gases for heating in the ATR step, as provided in the '805 patent. EX1003, ¶¶311–314.

E. 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*, 550 U.S. at 417); *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 patent 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, 11 and 12 of the '805 patent be canceled as unpatentable under 35 U.S.C. §102 for anticipation and/or §103 for obviousness.

Respectfully submitted,

The logo for Leydig, featuring the word "Leydig" in a bold, sans-serif font. The letter "i" in "Leydig" has a small blue star above it.

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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 13,762 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:

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