

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Topsoe, Inc.

Petitioner,

v.

Casale SA

Patent Owner.

Case No. IPR2025-01455

Patent 11,286,168

**Petition for *Inter Partes Review*
of U.S. Patent No. 11,286,168**

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EXHIBIT LIST

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EX1001	U.S. Patent No. 11,286,168 with reexamination certificate (“the ’168 Patent”)
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EX1004	CV of Petitioners’ Expert, Dr. James A. Ritter
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EX1006	S.E. Nielsen “Future Energy Efficiency and CO ₂ Reduction Potential” International Fertilizer Association (IFA) Technical Committee Meeting, March 13, 2007 (<i>2007 IFA</i>).
EX1007	US 2012/0292574 (<i>Terrien</i>)
EX1008	US 6,809,121 (<i>Rytter</i>)
EX1009	US 8,137,422 (<i>Licht</i>)
EX1010	US 6,505,467 (<i>Fjellhaug</i>)
EX1011	U.S. Pub. No. 2002/0143219 (<i>Price</i>)
EX1012	U.S. Patent No. US 8,309,617 (<i>Ji</i>)
EX1013	US 4,681,745 (<i>Pinto</i>)
EX1014	M. Appl, Ammonia Principles and Industrial Practice, Wiley-Vch (1999)
EX1015	Carbon Dioxide Capture and Storage, B. Metz, et al. (eds), IPCC (2005)
EX1016	R. P. Sharma, “Purge gas as feed in ammonia plant” Chemical Engineering World Vol 24, Issue 8, August 1989 (<i>Sharma</i>)

Exhibit	Description
EX1017	IFA Technical Committee Meeting on “Energy Efficiency and CO2 Reduction, Prospects in Ammonia Production” Proceedings, Ho Chi Minh City, Viet Nam, March 2007” (2007_tech_hcmc_all_slides.pdf)
EX1018	Intentionally Omitted
EX1019	2025/06/25 Mina Ching Declaration Regarding 2007 IFA Technical Meeting
EX1020	2025/04/05 Mina Ching Declaration Regarding <i>Lako</i>
EX1021	Intentionally Omitted
EX1022	Intentionally Omitted
EX1023	National Academy of Engineering. The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs, Washington, DC: National Academies Press (2004)
EX1024	T. Rostrup-Nielsen, “Manufacture of Hydrogen” Catalysis Today 106 (2005)
EX1025	U.S. Pat. No. 7,682,597 (<i>Blumenfeld</i>)
EX1026	Intentionally Omitted
EX1027	G. R. Maxwell, Synthetic Nitrogen Products, Kluwear (2004)
EX1028	U.S. Pat. No. 9,353,022 (<i>Lindell</i>)
EX1029	Intentionally Omitted
EX1030	U.S. Pat. No. 9,683,176 (<i>Christensen</i>)
EX1031	US2009/0184294 (<i>Han</i>)
EX1032	U.S. Pat. No. 8,580,153 (<i>Vauk</i>)

Exhibit	Description
EX1033	A.D. Ebner and J. A. Ritter, “State-of-the art adsorption and membrane separation processes for carbon dioxide production from carbon dioxide emitting industries” Separation Science and Technology, 44:1273-1421 (2009)
EX1034	U.S. Pat. No. 9,028,794 (<i>Darde</i>)
EX1035	L. Eide and D. Bailey, “Precombustion decarbonization Process” Oil & Gas Sci. and Tech – Rev. IFP, vol. 60, No. 3 (2005)
EX1036	H. Hiller et al., “Gas Production,” Ullmann’s Encyclopedia of Industrial Chemistry (2012)
EX1037	A. Nielsen (ed.), Ammonia Catalysis and Manufacture, Springer-Verlag (1995)
EX1038	K. Aasbert-Petersen et al. “Synthesis gas production for FT synthesis” in Studies in Surface Science and Catalysis 152, Elsevier B.V. (2004)
EX1039	Intentionally Omitted
EX1040	US 10,941,038 (<i>Jensen</i>)
EX1041	T.S. Christensen and I.I. Primdahl, “Improve syngas production using autothermal reforming” Hydrocarbon Processing, March 1994
EX1042	J. A. Ritter and A.D. Ebner, “State-of-the art adsorption and membrane separation processes for hydrogen production in chemical and petrochemical industries” Separation Science and Technology, 42:1123-1193 (2007)
EX1043	B.M. Tindall and M.A. Crews, “Alternative technologies to steam-methane reforming” Hydrocarbon Processing, November 1995

LIST OF CHALLENGED CLAIM ELEMENTS

Claim Element	Claim Language
1[pre]	A process for synthesis of ammonia from natural gas, the process comprising:
1[a]	conversion of a charge of desulphurized natural gas and steam, with oxygen-enriched air or with oxygen, into a synthesis gas containing hydrogen, CO and CO ₂ , in a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween;
1[b]	treatment of said synthesis gas including at least a shift reaction of the carbon monoxide into CO ₂ , and subsequent separation of CO ₂ from the gas, thus obtaining a CO ₂ -depleted synthesis gas and a CO ₂ -rich gaseous flow containing the CO ₂ separated from the gas;
1[c]	separation of a part of said CO ₂ -depleted synthesis gas as fuel fraction, wherein said fuel fraction is fed as fuel to at least one furnace and wherein said separation of the fuel fraction includes the split of said CO ₂ -depleted synthesis gas into at least a first stream and a second stream, said first and second streams having the same composition, wherein the first stream forms the fuel fraction and ...
1[d]	... the second stream is process gas intended for the synthesis of ammonia.
2	The process of claim 1, wherein the first stream forms the fuel fraction and the second stream is the process gas intended for the synthesis of ammonia after further purification.
3	The process of claim 1, wherein said fuel fraction is between 1% and 40% of the total amount of said CO ₂ -depleted syngas
4	The process of claim 1, wherein said fuel fraction is between 10% and 30% of the total amount of said CO ₂ -depleted syngas.
5	The process of claim 1, further comprising a step for methanation of the synthesis gas and/or addition of nitrogen to the synthesis gas.
6	The process of claim 5, wherein said fuel fraction is separated upstream of the methanation step or upstream of the nitrogen addition step.

Claim Element	Claim Language
7	The process of claim 1, wherein said CO ₂ -depleted syngas contains no more than 1000 ppm by volume of CO ₂ .
8	The process of claim 1, wherein said enriched air contains at least 50% oxygen.
9	The process of claim 1, wherein said enriched air contains at least 90% oxygen.
10	The process of claim 1, wherein said fuel fraction of the synthesis gas feeds one or more of the following apparatuses: a steam production and/or superheating furnace; or one or more furnaces for pre-heating the charge of the autothermal reformer or natural-gas desulphurization section.
11	The process of claim 1, wherein: a purge gas of the ammonia synthesis process, containing hydrogen and methane, is treated so as to recover the hydrogen contained in the purge gas, obtaining a hydrogen-rich gas and a tail gas containing methane; at least part of said tail gas is recycled as process gas and subjected to said step of conversion of the natural gas into synthesis gas.
17	The process of claim 1, wherein said synthesis gas fuel fraction forms all of the fuel of the furnaces used in the conversion section, or an amount of natural gas is provided as trim fuel, said trim fuel accounting for not more than 15% of the total combustion heat.
18	The process of claim 1, wherein: the fuel fraction is produced in excess with respect to the fuel necessary for the conversion section, the quantity of said fuel fraction exceeding that required being exported from the process; and regulation of the conversion section is performed by modulating the quantity of said fuel fraction directed towards the conversion section and the quantity exported from the process.
19	The process of claim 1, wherein: conversion of the charge of desulphurized natural gas and steam into the synthesis gas in the autothermal reformer is performed with a steam/carbon ratio not greater than 2.

I. INTRODUCTION

Topsoe, Inc. petitions for IPR of claims 1-11 and 17-19 of U.S. Patent No. 11,286,168. Casale SA (“P.O.”) purports to own all substantial rights, title, and interest in the ’168 Patent.

II. REQUIREMENTS FOR IPR

A. Standing

The ’168 Patent is eligible for IPR. Petitioner is not barred or estopped from requesting IPR of the Challenged Claims.

B. Relief Requested

Petitioner requests an IPR on Grounds 4-5B below.¹

Ground	References	Challenged Claims
4	35 U.S.C. § 102: <i>Terrien</i> (EX1007)	1, 7, 10
4A	35 U.S.C. § 103: <i>Terrien</i> and Ordinary Knowledge	1, 3-6, 8-19, 18-19
4B	35 U.S.C. §§ 102/103: <i>Terrien</i> and <i>Price</i> (EX1011)	1, 2, 5-7, 19
4C	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Ji</i> (EX1012)	11
4D	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Licht</i> (EX1009)	17
4E	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Rytter</i> (EX1008)	3-4, 8-9
5	35 U.S.C. § 103: <i>Licht</i> (EX1009) and <i>Price</i> (EX1011)	1-10, 17-19

¹ These grounds are a continuation of those asserted in Petitioner’s co-filed petition.

Ground	References	Challenged Claims
5A	35 U.S.C. § 103: <i>Licht, Price, and Ji</i> (EX1012)	11
5B	35 U.S.C. § 103: <i>Licht, Price and Rytter</i> (EX1008)	3-4, 8-9

The application that issued as the '168 Patent was filed as a PCT application on January 31, 2018, and claims priority to EP17156256, which was filed on February 15, 2017 and EP17195305 which was filed on October 6, 2017.

EX1001. Petitioner does not concede that any of the Challenged Claims are entitled to the benefit of the filing date of any of the alleged priority applications but for purposes of this Petition treats February 15, 2017 as the Critical Date.

Each reference that forms the basis of Grounds 4-5B qualifies as prior art with respect to the Critical Date.

C. Claim Construction

Petitioner submits that no formal claim constructions are necessary. Petitioner reserves the right to respond to any constructions offered by P.O, or adopted by the Board. Petitioner is not conceding that each Challenged Claim satisfies all statutory requirements, nor is Petitioner waiving any arguments concerning claim scope or grounds that can only be raised in district court.

D. Level of Ordinary Skill in the Art

As of the '168 Patent's Critical Date, a person of ordinary skill in the art ("POSA") would have a graduate degree in chemical engineering (M. Sc. or

higher), with at least 3-5 years' experience working in an industry or field that involves syngas production, which may include operations in the syngas and/or ammonia production industry and experience with reforming methane, water-gas shift processes, and syngas purification processes. This definition is approximate, and more education may substitute for industry experience or vice versa. EX1005 ¶¶ 32-36.

III. SUMMARY OF THE '168 PATENT

A. Description

The '168 Patent relates to converting natural gas into a synthesis gas intended for subsequent synthesis of ammonia. Ammonia can be synthesized from natural gas through a series of well-known steps. *Id.* ¶¶ 37, 43-44. Natural gas (methane, CH₄) is combined with a source of oxygen (O₂) and steam, resulting in a synthesis gas (syngas). *Id.* ¶ 46. Carbon monoxide (CO) is removed using any suitable method including treating the syngas in a shift reaction. *Id.* ¶ 50. Subsequently, carbon dioxide (CO₂) is removed from the syngas using well-known methods. *Id.* ¶ 51. The result is a CO₂-rich stream and a CO₂-depleted syngas stream. *Id.* ¶ 56. Conversion of methane to syngas in conversion sections was well-known in the art and may include reformers, pre-reformers, primary reformers, secondary reformers, and autothermal reformers ("ATRs"). *Id.* ¶¶ 45-49. The

particular configuration varies, but a pre-reformer followed by an ATR without an intermediate primary reformer was well-known. *Id.*

CO₂-depleted syngas has a variety of uses: hydrogen synthesis, ammonia synthesis, methanol synthesis, synfuels, energy production (fuel), and coproduction of multiple products. *Id.* ¶¶ 42, 56. Naturally, CO₂-depleted syngas can be used in part for ammonia synthesis and in part as fuel. *Id.* ¶¶ 40, 56. Such dual use of the CO₂-depleted syngas—fuel and ammonia synthesis—requires splitting the syngas stream into at least two separate streams. *Id.* ¶ 52. The fuel stream is used in any suitable combustion-based device or process, such as a furnace for heating or turbine for generating power. *Id.* ¶ 56. The other syngas stream—the process or feed stream—is used for ammonia synthesis. *Id.* Because both streams originate from the source, both streams have the same composition. *Id.*

Syngas and ammonia synthesis, related methods, and related devices were well-known in the art. Methods intended to reduce carbon emissions from natural gas, including pre-combustion carbon capture, were well-known in the art. *Id.* ¶ 52. Further, there was significant motivation to apply well-known methods of reducing carbon emissions to processes to treat natural gas, as industries move further towards environmentally friendly processes. *Id.* ¶¶ 37, 40-41. Because ammonia synthesis from natural gas was known to generate carbon emissions, processes for ammonia synthesis with carbon emission reduction steps also were well-known. *Id.*

Applying well-known methods of reducing carbon emissions to well-known processes to produce syngas and synthesize ammonia, which were already known to be well-suited to carbon emission reduction steps, was altogether well-known in the art. *Id.* ¶ 41.

B. Relevant Prosecution History

Only one office action was issued during the initial prosecution of the '168 Patent. EX1002 at 290. In response, P.O. argued that the cited prior art did not teach that “said first and second streams [have] the same composition.” *Id.* at 314-15. The Examiner allowed the claims because he thought the prior art did not disclose “said first and second streams having the same composition.” *Id.* at 329.

After issuance, P.O. filed a request for supplemental examination. EX1003 at 524. The Examiner determined that there was a new question of patentability raised by the request, reexamination was instituted, and an office action rejecting the claims issued. *Id.* at 585. The Examiner found that the prior art disclosed each feature claimed. *Id.* at 587-88.

P.O. then amended independent claim 1 to recite “a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween” arguing that this configuration was not taught by the prior art *Id.* at 631, 638-42, 908, 914-15. The Examiner allowed the amended claims based on his understanding that the prior art did not disclose “a conversion

section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween.” *Id.* at 1184.

There are many references which were not before the Examiner during initial or supplemental examination that disclose the claimed method including the “conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween.” *See* EX1005 ¶¶ 45-49, 123-30. This petition is based on these references along with other references that disclose the additional elements of the challenged claims.

IV. SUMMARY OF PRIOR ART

The subject matter of the Challenged Claims was well-known before the Critical Date. EX1005, Section VII. In addition to a POSA’s knowledge, the following prior art demonstrates that the Challenged Claims were anticipated and/or obvious.

A. *Terrien* (EX1007)

U.S. Pat. Pub. No. 2012/0292574 (*Terrien*), published on November 22, 2012. *Terrien* is prior art at least under 35 U.S.C. § 102(a)(1) (post-AIA) (“§ 102(a)(1)”) because *Terrien* predates the Critical Date.

Terrien relates to a process for hydrogen synthesis that increases recovery of hydrogen and CO₂ from syngas, thus decreasing environmental impacts. EX1007, Abstract. *Terrien* teaches a feed of natural gas treated with a variety of steps,

including use of an ATR. *Id.* ¶¶ 73-75. *Terrien* also discloses splitting the H₂-rich (CO₂-depleted) stream for various uses including as fuel. *Id.* ¶¶ 78, 86, 93; *see* EX1005 ¶¶ 99-106.

B. *Licht* (EX1009)

U.S. Pat. No. 8,137,422 (*Licht*), issued March 20, 2012. *Licht* is prior art at least under § 102(a)(1) because *Licht* predates the Critical Date.

Licht relates to a process for hydrogen synthesis with reduced CO₂ emissions including use of a portion of the hydrogen as fuel in a reformer. EX1009, Abstract. *Licht* discloses splitting a syngas stream so a portion can be used as fuel. *Id.* 5:7-14; 5:27-42; *see* EX1005 ¶ 108.

C. *Rytter* (EX1008)

U.S. Pat. No. 6,809,121 (*Rytter*), issued on October 26, 2004. *Rytter* is prior art at least under § 102(a)(1) because *Rytter* predates the Critical Date.

Rytter discloses a process for syngas production to make methanol, dimethyl ether (DME), and/or other oxygenates. EX1008, 1:1-9. *Rytter* discloses a syngas stream being used for both ammonia synthesis and as fuel. *Id.* 4:41-57; 7:26; *see* EX1005 ¶¶ 95-97.

D. *Price* (EX1011)

U.S. Pub. No. 2002/0143219 (*Price*), published on October 3, 2002. *Price* is prior art at least under § 102(a)(1) because *Price* predates the Critical Date.

Price relates to a process for production of hydrogen-rich syngas including splitting the syngas into multiple streams, in which a portion of the syngas is used for ammonia synthesis. *Id.* ¶¶ 59, 63, 26. *Price* discloses, among other things, a conversion section comprising an ATR. *Id.* ¶ 53; EX1005 ¶¶ 113-16.

E. *Ji* (EX1012)

U.S. Pat. No. 8,309,617 (*Ji*), issued on November 13, 2012. *Ji* is prior art at least under § 102(a)(1) because *Ji* predates the Critical Date.

Ji also relates to a process for the synthesis of ammonia from natural gas. *Id.* 1:17-24; EX1005 ¶¶ 120-21.

F. Motivation to Combine

As set forth below, a POSA would have found it obvious to modify and combine teachings of *Rytter*, *Terrien*, *Licht*, *Price*, and/or *Ji*. All are in the same technical field of syngas production and use and are analogous to one another and to the '168 Patent. A POSA would have found modifying and combining these references to be one of a finite number of identified means for generating syngas for downstream applications, such as ammonia synthesis, and further, would have had a reasonable expectation of success in modifying and combining their teachings. *See* EX1005 ¶¶ 291-336.

A POSA seeking to reduce carbon emissions in a syngas process would have been motivated to apply ordinary skill and knowledge to *Terrien* to reach the

requirements of the challenged claims. *Terrien* provides a strong starting point: it discloses conversion of a charge of natural gas and steam with oxygen or oxygen-enriched air, wherein the conversion section comprises a broad variety of devices and configurations thereof into a syngas (*infra* Section V(A)(1)(b)), subsequent treatment of the syngas with a CO shift reaction followed by CO₂ removal (*infra* Section V(A)(1)(c)), and splitting the syngas into a first stream (fuel fraction) and a second stream (process gas) having the same composition (*infra* Section V(A)(1)(d)).

Likewise, a POSA seeking to reduce carbon emissions in a syngas process would have been motivated to apply ordinary skill and knowledge to *Licht* to reach the requirements of the challenged claims. *Licht* provides a strong starting point: it discloses conversion of a charge of natural gas and steam with oxygen or oxygen-enriched air in a conversion section into a syngas (*infra* Section V(G)(1)(b)), subsequent treatment of the syngas with a CO shift reaction followed by CO₂ removal (*infra* Section V(G)(1)(c)), splitting the syngas into a first stream (fuel fraction) and a second stream (process gas) having the same composition (*infra* Section V(G)(1)(d)), and wherein the process gas is intended for ammonia synthesis (*infra* Sections V(G)(1)(e)).

A POSA's motivations to make necessary modifications or confirmations arise from, for example, routine optimization, mere design choice, addressing

known problems in the art, responding to market pressures, and applying known principles and techniques.

V. THE CHALLENGED CLAIMS ARE UNPATENTABLE

Claims 1-11 and 17-19 of the '168 Patent are unpatentable under 35 U.S.C. §§ 102 and 103 as anticipated by and/or obvious over the cited references. This Petition is accompanied by the Declaration of Dr. James Ritter (EX1005), an expert in processes and systems for syngas production, with over 42 years of experience in the industry. EX1005, Section II(A).

A. GROUND 4: Claims 1, 7, and 10 are Anticipated by *Terrien*

1. Claim 1

a) 1[pre]: A process for synthesis of ammonia from natural gas, the process comprising

Preambles are typically not limiting.² Although this phrase has no patentable weight, H₂ is a necessary intermediate product for ammonia synthesis, and a POSA would have understood that *Terrien's* front-end hydrogen synthesis process could

² See e.g., *Catalina Mktg. Int'l v. Coolsavings.com, Inc.*, 289 F.3d 801, 808 (Fed. Cir. 2002). Here, the preamble is merely stating a “purpose or an intended use of the invention,” therefore does not have patentable weight. See also EX1003 at 596 (P.O. did not dispute that the preamble recited an intended result and thus had not patentable weight).

be used as the front-end of an ammonia synthesis plant. *See* EX1005 ¶¶ 155; EX1007 ¶ 3 (“Hydrogen is an important feedstock for many chemical and petrochemical processes.”). Therefore, this element is anticipated by *Terrien* alone.

- b) **1[a] conversion of a charge of desulphurized natural gas and steam, with oxygen-enriched air or with oxygen, into a synthesis gas containing hydrogen, CO and CO₂, in a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween**

Terrien discloses conversion of a charge of desulphurized natural gas.

EX1007 ¶ 74 (explaining the prereformer heats desulfurized natural gas). *Terrien*’s conversion section disclosed various components including a prereformer, a steam CH₄ reformer, and an ATR. *Id.* ¶¶ 73-75. *Terrien* describes a feed gas stream produced by a producing unit including an ATR. *Id.* ¶¶ 18, 95. *Terrien* defines “feed gas producing unit” as “any unit which produces a feed gas that can be subjected to treatment for the removal of hydrogen” referring interchangeably to reformer units generically and ATR specifically. *Id.* ¶ 73.

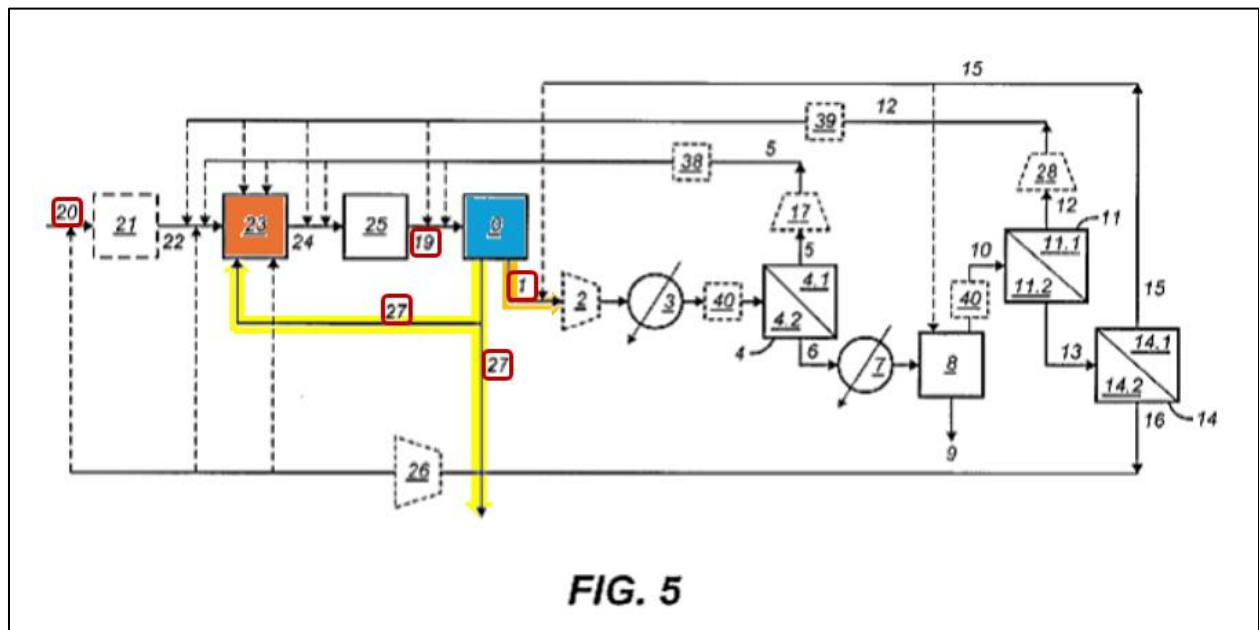
- c) **1[b] treatment of said synthesis gas including at least a shift reaction of the carbon monoxide into CO₂, and subsequent separation of CO₂ from the gas, thus obtaining a CO₂-depleted synthesis gas and a CO₂-rich gaseous flow containing the CO₂ separated from the gas**

After the conversion section, *Terrien* discloses treating the syngas using a shift reaction to convert CO into CO₂. EX1007 ¶ 80. *Terrien* discloses subsequent

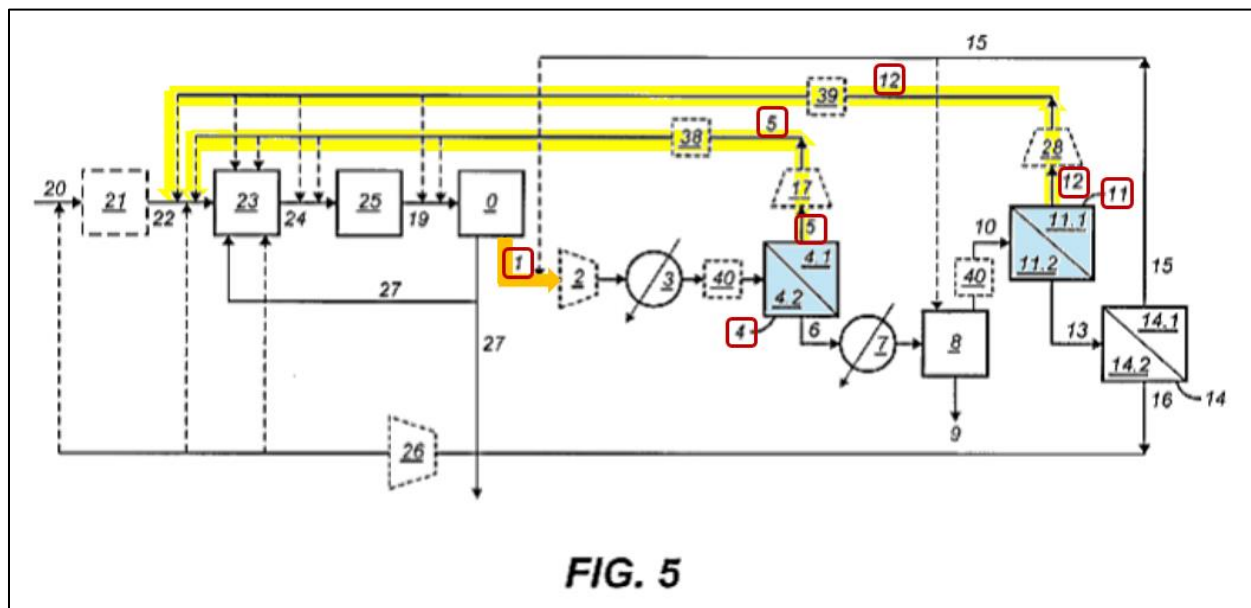
removal of CO₂ from the syngas forming H₂-rich (CO₂-depleted) stream for various uses, including use as fuel. *Id.* ¶¶ 73, 78, 86, 93; EX1005 ¶ 133.

- d) 1[c] separation of a part of said CO₂-depleted synthesis gas as a fuel fraction, wherein said fuel fraction is fed as fuel to at least one furnace and wherein said separation of the fuel fraction includes a split of said CO₂-depleted synthesis gas into at least a first stream and as second stream, said first and second streams having the same composition, wherein the first stream forms the fuel fraction and...

Terrien discloses splitting the CO₂-depleted syngas. With reference to Figure 5 (annotated below), *Terrien* shows and describes separation of the H₂ product stream (27) with “a portion”—also labelled (27)—used for fuel. EX1007 ¶¶ 35, 78:



Terrien also discloses splitting two other H₂-rich streams with a portion used for fuel, *e.g.*, the first H₂-rich permeate stream (5), the second H₂-rich permeate stream (12). *Id.* ¶¶ 79, 89; *see* EX1005 ¶¶ 144-48.



A “portion” of a stream has the same composition as the original stream and as the other portion(s) of the stream. *Id.* ¶ 145. Accordingly, each of streams 5 and 12 necessarily have the same composition when split unless and until subject to a treatment step that alters the composition. *Id.* ¶ 56. *Terrien* explains that the streams resulting from gas separation processes, like streams (5) and (12), are “hydrogen rich” containing 40-90% H₂. EX1007 ¶ 29. As such, the “hydrogen rich permeate stream (5)” and “hydrogen rich permeate stream (12)” are split and, once split, have the same composition. *Id.* ¶¶ 25, 41.

Terrien discloses the hydrogen-rich stream(s) used as fuel for the conversion section. *See e.g., id.* ¶ 69. A POSA would have understood that a H₂-rich stream used as fuel to a conversion section can be directed to a furnace or any other suitable device. EX1005 ¶ 148.

e) 1[d] the second stream is process gas intended for the synthesis of ammonia.

Although this phrase may have no patentable weight, H₂ is a necessary intermediate product for ammonia synthesis, and a POSA would have understood that *Terrien*'s front-end hydrogen synthesis process could be used as the front-end of an ammonia synthesis plant. *See* EX1005 ¶ 155. Therefore, this element is anticipated by *Terrien*.

2. Claim 7: The process of claim 1, wherein said CO₂-depleted syngas contains no more than 1000 ppm by volume of CO₂

Terrien does not explicitly disclose the amount of CO₂ to remove from the syngas. However, this is merely a design choice as to the amount of CO₂ to remove from the syngas. The general conditions of the claim are disclosed in the prior art, so it is not inventive to select a range that merely addresses design preferences.³

³ *See e.g., Titanium Metals Corp. of America v. Banner*, 778 F.2d 775, 783 (Fed. Cir. 1985) (“A *prima facie* case of obviousness exists where the claimed ranges or amounts do not overlap with the prior art but are merely close.”); *see also* In re

The claim requires that the CO₂-depleted syngas contain no more than 1000 ppm CO₂. The '168 Patent describes this as a low CO₂ content and makes no distinction that any particular amount solves any stated problem or has any particular purpose than the well-known strategy of precombustion carbon capture to reduce carbon emissions. EX1001, 3:16-21; EX1005 ¶ 193. The amount of CO₂ content is immaterial to the operation of the claimed process and would be an obvious matter of design choice with respect to how much one desires to reduce carbon emissions, which was well within the knowledge and skill of a POSA. EX1005 ¶¶ 37-41. A POSA would readily have appreciated that in a precombustion carbon capture process where CO₂ is removed from syngas the target CO₂ content is merely a design choice depending on the particular goals for the process. *Id.* ¶¶ 52, 190-96.

Nevertheless, *Terrien* describes using the CO₂-depleted stream as a fuel to boost CO₂ capture such that “it is possible to eliminate or reduce the carbon dioxide emissions.” EX1007 ¶ 94 (describing CO₂ capture rates from 80-100%). Where CO₂ emissions are eliminated, as in *Terrien*, the CO₂-depleted syngas necessarily contains no more than 1000 ppm by volume of CO₂. For example, *Terrien* describes eliminating 100% of CO₂ emissions, which requires that the

Kuhle, 526 F.2d 553 (CCPA 1975) (the particular placement of a contact in a conductivity measuring device was held to be an obvious matter of design choice).

CO₂-depleted syngas to be combusted as a fuel contain potentially less than 1000 ppm by volume of CO₂. *Id.* ¶ 73. Therefore, this claim is anticipated by *Terrien*.

3. **Claim 10: The process of claim 1, wherein said fuel fraction of the synthesis gas feeds one or more of the following apparatuses: a steam production and/or superheating furnace; or one or more furnaces for pre-heating the charge of the autothermal reformer or natural-gas desulphurization section.**

Terrien discloses the fuel fraction of the syngas being recycled upstream for various uses, including to fuel the conversion section and the feed gas producing unit. EX1007 ¶¶ 35, 78; EX1005 ¶ 207. *Terrien* describes a feed gas stream produced by a producing unit including an ATR (EX1007 ¶¶ 18, 95) and defines “feed gas producing unit” as “any unit which produces a feed gas that can be subjected to treatment for the removal of hydrogen” referring to reformer unit generically and ATR specifically. *Id.* ¶¶ 73, 95 (describing that the process may be used any feed gas producing unit). *Terrien* also explains that a portion of the hydrogen product stream that has been split off can be used “for hydrogen fueling of the feed gas producing unit.” *Id.* ¶¶ 35, 46, 93. Accordingly, this claim is anticipated by *Terrien*.

B. GROUND 4A: Claims 1, 3-6, 8-9, and 18-19 are Obvious Over *Terrien* and Ordinary Knowledge

1. Claim 1

a) 1[pre]

As discussed above, the preamble, which is not limited, is anticipated by *Terrien*. See *supra* Section V(A)(1)(a). Moreover, to the extent that this element has patentable weight and to the extent that this element is not anticipated by *Terrien*, a POSA would understand that it would be obvious to modify *Terrien* in light of ordinary knowledge to apply *Terrien* to ammonia synthesis. EX1005 ¶¶ 155, 293.

b) 1[a]

As discussed above, this element is anticipated by *Terrien*. See *supra* Section V(A)(1)(b). To the extent that this claim element is not anticipated by *Terrien*, a POSA would have understood that an ATR requires steam, therefore, *Terrien*'s disclosure of an ATR would necessitate use of a steam source. EX1005 ¶¶ 125-26. Therefore, this element is obvious over *Terrien* and ordinary knowledge. *Id.* ¶¶ 125-26, 291-93.

c) 1[b]

As discussed above, this element is anticipated by *Terrien*. See *supra* Section V(A)(1)(c).

d) 1[c]

As discussed above, this element is anticipated by *Terrien*. See *supra* Section V(A)(1)(d).

e) 1[d]

As discussed above, this element is anticipated by *Terrien*. See *supra* Section V(A)(1)(e). To the extent that this element has patentable weight and is not anticipated by *Terrien*, a POSA would understand that *Terrien* can be modified to have a syngas stream intended for ammonia synthesis in light of ordinary knowledge. EX1005 ¶¶ 155, 291-93.

2. Claims 3 – 4: The process of claim 1, wherein said fuel fraction is between 1% and 40% (claim 3) and between 10% and 30% (claim 4) of the total amount of said CO₂-depleted syngas

Terrien does not explicitly disclose the relative amount of the CO₂-depleted syngas used as the fuel fraction. However, this is merely a design choice as to the amount of CO₂-depleted syngas used as fuel. See *supra* note 3. Here, the claim requires use of a specific percentage of the total syngas. The '168 Patent offers several different ranges and makes no distinction that any range solves any stated problem or has any particular purpose. EX1001, 2:55-63. The relative amount of syngas used as fuel is immaterial to the operation of the claimed process and would be an obvious matter of design choice well within the skill of the art. A POSA would readily have appreciated that in a process where syngas is split into a fuel

fraction and process fraction, e.g., those disclosed in *Terrien*, the relative amount used as the fuel fraction is merely a design choice depending on the particular goals for the process. *See* EX1005 ¶¶ 169-70.

3. Claim 5: The process of claim 1, further comprising a step for methanation of the synthesis gas and/or addition of nitrogen to the synthesis gas.

Both methanation and addition of nitrogen prior to ammonia synthesis were well-known in the art and a POSA would have been motivated to modify *Terrien* to include these steps. First, nitrogen is an essential element for ammonia production, so the addition of nitrogen is a requirement of basic chemistry. *See id.* ¶¶ 38, 46, 57. Second, methanation prior to ammonia synthesis also was well-known in the art. *Id.* ¶¶ 53-55, 178-82. Methanation converts residual CO and CO₂, which poison the ammonia synthesis catalysts, into CH₄, which is not a catalyst poison. Indeed, the '168 Patent acknowledges that methanation in this context was already disclosed in the prior art. EX1001, 1:24-29. A POSA thus would have been motivated to modify *Terrien* to include nitrogen addition and/or methanation prior to ammonia synthesis. EX1005 ¶¶ 53-55, 178-82, 291, 294.

4. Claim 6: The process of claim 5, wherein said fuel fraction is separated upstream of the methanation step or upstream of the nitrogen addition step

As discussed above, it would have been obvious to a POSA to include a step for methanation and/or nitrogen addition to the syngas. *See supra* Section V(B)(3).

Terrien discloses separation of a fuel fraction of the syngas. *See e.g.*, EX1007 ¶ 78. Moreover, as applied to ammonia synthesis, *Terrien* would necessarily separate the fuel fraction prior to nitrogen addition because nitrogen is added as a necessary reactant for ammonia synthesis, whereas nitrogen is not useful as a fuel. EX1005 ¶¶ 183-89. Therefore, a POSA would have understood that it is more efficient to use a portion of the syngas for fuel prior to additional treatment steps and nitrogen addition and thus separate the fuel fraction prior to this step. *Id.* ¶¶ 183-89, 291-943, 295. Therefore, it would have been obvious to a POSA to modify *Terrien* to separate the fuel fraction upstream of a step for methanation and/or nitrogen addition. *Id.* ¶ 295.

5. Claims 8 – 9: The process of claim 1, wherein said enriched air contains at least 50% (claim 8) and at least 90% (claim 9) oxygen

As noted for claim 1, use of ATR with oxygen and oxygen-enriched air was well-known in the art as ATR uses oxygen to partially oxidize methane. *See supra* Section V(A)(1)(b); *see also* EX1005 ¶ 45. Atmospheric air contains 21% oxygen, so a POSA would have understood that adding additional oxygen, e.g., by providing oxygen-enriched air comprising at least 50% or 90% oxygen, or using 100% oxygen can be helpful to optimize the ATR process. *Id.* ¶¶ 46, 198, 200-01, 304; *see also* EX1041 at 1 (explaining oxygen feedstocks for ATRs vary from air to pure oxygen). A POSA thus would have been motivated to modify *Terrien* to

oxygen-enriched air that contains at least 50% and at least 90% oxygen. EX1005 ¶¶ 197-98, 200-01, 291, 296. Further, a POSA would have understood that modifying the amount of oxygen, including the percentage of oxygen in the oxygen-enriched air is merely a matter of ordinary experimentation and design of systems. *Id.* ¶¶ 197-98, 200-01.

Terrien does not explicitly disclose the amount of oxygen contained in the oxygen-enriched air. However, this claim is merely directed towards the optimum or workable ranges of the concentration of oxygen in enriched air. *Id.* ¶¶ 197-98, 200-01. A POSA implementing the systems described by *Terrien* would have achieved, through routine experimentation, the enriched air containing at least 50% oxygen and at least 90% oxygen. *Id.* ¶¶ 197-98, 200-01, 291, 296.⁴

⁴ See e.g., *Genentech, Inc. v. Hospira, Inc.*, 946 F.3d 1333, 1341 (Fed. Cir. 2020); *In re Applied Materials, Inc.*, 692 F.3d 1289, 1295 (Fed. Cir. 2012); MPEP § 2144.05 (“[W]here the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges by routine experimentation.”) (quoting *In re Aller*, 220 F.2d 454, 456 (CCPA 1955)).

6. **Claim 18: The process of claim 1, wherein: the fuel fraction is produced in excess with respect to the fuel necessary for the conversion section, the quantity of said fuel fraction exceeding that required being exported from the process; and regulation of the conversion section is performed by modulating the quantity of said fuel fraction directed towards the conversion section and the quantity exported from the process**

This claim is directed towards a design choice as to the amount of fuel fraction produced with respect to the fuel demand of the conversion section.

EX1005 ¶ 226. Where, as here, the general conditions of a claim are disclosed in the prior art, it is not inventive to select a range that merely addresses design preferences. *Id.* Here, the claim requires modulation of the fuel fraction to regulate the conversion section output. *Id.* A POSA readily would have appreciated that the output of a step can be controlled by modulation of the input to that step. *Id.* In fact, it was well-known in the art to produce excess syngas to regulate upstream steps and that the excess syngas could be used as fuel and/or exported. *See e.g.*, EX1037 at 307 (“Case c shows a solution where the extra carbon dioxide is obtained by production of excess synthesis gas. ***The excess synthesis gas can be extracted as a side stream before the synthesis gas compressor and used as fuel in the reformer or exported*** as such or as hydrogen after purification.”); EX1043 at 3 (describing achieving desired H₂/CO ratio by producing excess H₂ and using that excess as fuel for reformers, heaters, and steam generation); EX1013, 6:48-54 (“The H₂:N₂ molar ratio is preferably in the range 1.5 to 2.3 in the gas entering the

synthesis catalyst in step (e). Whatever its ratio within the defined broad or preferred range, it is maintained preferably within 20% of the ratio in the fresh synthesis gas produced in step (d). By this means the rate of flow of the hydrogen recovery stream and thus the power consumption are limited.”).

Regardless, a POSA would have known that excess fuel can be exported, as exporting fuel to use and/or storage offsite is well known in the art. EX1005 ¶ 56. Further, a POSA would have known that a method step is inherently regulated by the quantity of the input to the step. *Id.* ¶ 226. This claim element is merely directed towards the fundamental concepts of conservation of mass and energy, whereby mass and energy are neither created nor destroyed in chemical reactions, it just changes form with energy consumed or generated. *Id.* A POSA would have understood that modulating the quantity of an input (the fuel fraction) would necessarily result in regulating the output (the quantity [of syngas]) of a process. *Id.* Therefore, this claim is obvious over *Terrien* and a POSA’s knowledge and skill. *Id.* ¶¶ 225-26, 228, 291, 297.

7. Claim 19: The process of claim 1, wherein conversion of the charge of desulphurized natural gas and steam into the synthesis gas in the autothermal reformer is performed with a steam/carbon ratio not greater than 2

Terrien alone does not directly disclose the optimum S/C ratio in the ATR. However, this is merely a design choice as to the S/C ratio in the ATR. *See supra* note 3; EX1005 ¶¶ 229-30. Here, the claim requires use of a specific range of S/C

ratios. The '168 Patent offers several different ranges and states only that the S/C ratio “helps reduce the heat required by the furnace.” EX1001, 6:36-43. A POSA would have understood that a variety of ranges of S/C ratios could be used in the ATR to achieve the desired results. EX1005 ¶¶ 47-48, 230. In particular, a POSA would have understood that a well-known advantage of ATR is that it can operate at relatively low S/C ratios. *Id.* As stated in the '168 Patent, it is a desired feature to reduce the heat required by the furnace and, as demonstrated in the prior art, it was well-known that reducing the S/C achieves this result. EX1001 6:25-36; EX1005 ¶¶ 47-48, 230; *see also* EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 41-43 (describing reforming with ATR and S/C ratios of 0.2-2 and as low as 0.1); EX1038 at 64 (“[T]he advantages of ATR are such that it has, especially after development of processes operating at steam to carbon ratios [S/C] below 1.0, become the preferred route to synthesis gas for these syntheses”); EX1043 at 4 (“ATR plants can operate at a lower [S/C] ratio, often about 1.35”); EX1011 (S/C ratio of 0.6 and 0.9). Therefore, it would have been obvious to a POSA to operate the ATR with a S/C ratio not greater than 2 in light of ordinary knowledge. EX1005 ¶¶ 229-30, 291, 298.

C. GROUND 4B: Claims are Obvious Over *Terrien* and *Price*

1. Claim 1

a) 1[pre]

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Sections V(A)(1)(a); V(B)(1)(a). Moreover, to the extent that this element has patentable weight and to the extent that this element is not anticipated and/or obvious over *Terrien*, of *Price* discloses the second stream being intended for ammonia synthesis. See EX1011, Abstract; EX1005 ¶¶ 155, 158, 29-300, 302, 309.

b) 1[a]

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Sections V(A)(1)(b); V(B)(1)(b). Furthermore, to the extent that *Terrien* does not disclose an ATR downstream from a prereformer without a primary reformer therebetween, *Price* does. EX1011 ¶ 56 (“The reforming section consists of a steam reformer followed by an autothermal reformer.”); *id.*, Example 2 Figure, Example 3 Figure. A POSA would have understood that the step of reforming the syngas prior to the ATR step can be accomplished by a prereformer, a steam reformer, or any other reformer, reformers, or combinations thereof. EX1005 ¶¶ 125-26, 130, 299-301, 309.

c) 1[b]

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Sections V(A)(1)(c); V(B)(1)(c).

d) 1[c]

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Sections V(A)(1)(d); V(B)(1)(d).

e) 1[d]

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Sections V(A)(1)(e); V(B)(1)(e). To the extent that this element has patentable weight and is not anticipated and/or obvious over *Terrien* alone, *Price* discloses the second stream being intended for ammonia synthesis. *Price* discloses processing a methane into a syngas intended for use in ammonia synthesis. EX1011, Abstract. In *Price*, natural gas is reformed, CO₂ is removed from the syngas, H₂ is separated from other gases, and H₂ further purified before use in ammonia synthesis. See e.g., EX1011 ¶¶ 55-58. *Price* describes a front-end process similar to *Terrien*, that then uses the syngas for ammonia synthesis. EX1005 ¶¶ 155, 157-58, 299-301, 309; EX1011, Abstract.

2. Claim 2: ...the process gas intended for the synthesis of ammonia after further purification

Purification of syngas prior to ammonia synthesis was well-known in the art as small amounts of impurities remaining the syngas can poison the catalysts used for ammonia synthesis. EX1005 ¶¶ 51, 53-55; see also EX1001, 1:63-65. Nevertheless, *Terrien* describes purification to provide hydrogen-rich streams that can be used in downstream processes. EX1007 ¶¶ 16, 17 (“‘process unit’ refers to

any unit which includes a purification step that results in the production of a hydrogen rich fraction that can be used downstream.”). Therefore, to the extent that *Terrien* fails to disclose further purification of the second stream prior to ammonia synthesis, A POSA would have been motivated to modify *Terrien* to include further purification prior to ammonia synthesis. EX1005 ¶¶ 159-60, 164, 166, 168, 299-300, 302, 309.

Additionally, *Price* discloses purification of syngas streams with pressure swing adsorption (PSA), membrane units, or any other known method (EX1011 ¶ 39), as well as the syngas stream being subject to “further purification” prior to ammonia synthesis (*Id.* ¶¶ 40, 55). *Price* also discloses an additional purification/treatment step of methanation. *Id.* ¶ 5 (“Methanation is used as the final treatment step.”). While *Price* does not disclose a CO₂-depleted synthesis gas stream being split into a first and second stream, *Terrien* does. Both *Terrien* and *Price* disclose methods to increase the concentrations of H₂ and/or nitrogen in the syngas stream prior to ammonia synthesis, as this was a well-known goal of ammonia synthesis methods. EX1005 ¶ 299-300; EX1007 ¶¶ 16; EX1011 ¶ 40. Synthesis of ammonia, which results from combining H₂ and nitrogen, requires these elements to be provided to the synthesis step. Accordingly, processes that are intended to synthesize ammonia necessarily require higher concentrations of H₂ and nitrogen to increase output, as well as purification to remove ammonia catalyst

poisons. Therefore, it would have been obvious to combine *Price* with *Terrien*, to result in a process with only a portion (the second stream) of a CO₂-depleted synthesis gas stream being treated with further purification before being used to synthesize ammonia. EX1005 ¶¶ 299-300, 302, 309.

3. Claim 5

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Section V(B)(3).

Regardless, *Price* discloses a methanation step. EX1011 ¶¶ 5, 44. *Price* also discloses adding nitrogen to the syngas. *Id.* It would have been obvious to a POSA to modify *Terrien* to include *Price*'s steps of methanation and adding nitrogen to the syngas to achieve beneficial and expected results. EX1005 ¶¶ 178, 181-82, 299-300, 304, 309.

4. Claim 6

As discussed above, this claim element is anticipated and/or obvious over *Terrien*. See *supra* Section V(B)(4).

Price discloses splitting the syngas stream upstream of both the methanation and nitrogen addition steps. *Price* discloses the syngas stream being split into at least two streams. EX1011 ¶ 26. *Price* discloses methanation and N₂ addition steps occurring after the split, as methanation is “the final treatment step” and the H₂-rich gas, which is a product of the split, is “combined with N₂.” *Id.* ¶¶ 5, 44.

To the extent that *Price* does not disclose the fuel fraction being separated upstream of the methanation step or upstream of nitrogen addition, *Terrien* does. *See e.g.*, EX1007 ¶ 78. Moreover, as applied to ammonia synthesis, *Terrien* would necessarily separate the fuel fraction prior to nitrogen addition because nitrogen is added as a necessary reactant for ammonia synthesis, whereas nitrogen is not useful as a fuel. EX1005 ¶¶ 183, 185-86, 188. Therefore, a POSA would have understood that it is more efficient to use a portion of the syngas for fuel prior to additional treatment steps and nitrogen addition and thus separate the fuel fraction prior to this step. *Id.* ¶¶ 183, 185-86, 188, 299-300, 304, 309.

5. Claim 7

As discussed above, this claim element is anticipated over *Terrien*. *See supra* Section V(A)(2).

Furthermore, *Price* discloses the CO₂-depleted syngas containing no more than 1000 ppm by volume of CO₂. EX1011 ¶ 45 (after PSA “[t]he resulting H₂ stream is greater than 99% pure.”). In disclosing a H₂ stream that is “greater than 99% pure,” *Price* discloses a H₂ stream with a maximum partial volume of non-H₂ gas of 10000 vppm. *Id.* EX1005 ¶ 194. Therefore, the CO₂ range disclosed in *Price* is between 0 and 10000 vppm, which includes a volume of “not more than 1000 ppm by volume of CO₂.” EX1005 ¶¶ 190-94, 196. It would have been obvious to a

POSA to modify *Terrien* to include *Price*'s partial volume of CO₂ in the syngas.

EX1005 ¶¶ 190-94, 196, 299-300, 305, 309.

6. Claim 19

As discussed above, this claim element is obvious over *Terrien*. *See supra* Section V(B)(7).

Furthermore, *Price* discloses conversion of a charge of desulphurized natural gas and steam in an ATR with a steam/carbon ratio not greater than 2. EX1011 ¶¶ 43, 45, 59 (describing S/C ratios of 0.6 and 0.9); EX1005 ¶¶ 232. It would have been obvious to a POSA to modify *Terrien* to include *Price*'s S/C ratio to achieve beneficial and expected results. EX1005 ¶¶ 229-32, 299-300, 308-09.

7. Rationale for Combining *Terrien* with *Price*

A POSA would have considered *Terrien* and *Price*. Both are in the same field of endeavor, as they relate to reducing carbon emissions. EX1007 ¶ 3; EX1011 ¶¶ 56-58. Both are directed to syngas production. EX1007 ¶¶ 3, 35; *see generally* EX1011. The disclosure of *Price* relied upon to supplement *Terrien* were each well-known in the art, therefore, a POSA would readily have relied upon *Price* to modify the disclosure of *Terrien*. EX1005 ¶¶ 299-309.

A POSA would have been aware that various conversion sections in a process could be substituted with one another to achieve desired results, therefore, would have modified *Terrien* with *Price* to have a prereformer followed by an

ATR without a primary reformer therebetween. *Id.* ¶¶ 299-301. Additionally, a POSA would have relied on *Price* to modify *Terrien* with further purification, as purification of a syngas stream was well-known in the art. *Id.* ¶ 302. A POSA would have known to modify *Terrien* with *Price* to include a step of methanation and/or nitrogen addition of the process gas after the fuel fraction is split, as both methanation and nitrogen addition were well-known in the art. *Id.* ¶ 304. A POSA would have known that the content of CO₂ in the CO₂-depleted syngas could be modified by *Price* because it was well-known in the art that the goal of CO₂-removal is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *Id.* ¶ 305. A POSA would have known to modify *Terrien* with *Price* to supply the conversion section with oxygen or oxygen-enriched air because supplying a conversion section, particularly an ATR, with high concentrations of oxygen was well-known in the art. *Id.* ¶ 306. A POSA would have known to modify *Terrien* with *Price* to select the types of furnaces disclosed in *Price*, as various types of furnaces were well-known in the art. *Id.* ¶ 307. A POSA would have known to modify *Terrien* with *Price* to operate the ATR at a S/C ratio less than 2. *Id.* ¶ 308.

A POSA would have had a reasonable expectation of success when combining *Terrien* and *Price* because they are directed towards syngas production with a common goal of reduced emissions and disclose processes with substantial

overlap. Therefore, a POSA would have known that one process that discloses, e.g., conversion of natural gas in a conversion section, a CO-shift reaction, and CO₂ removal, could be modified by applying process steps used in another process that discloses the same overlapping steps. *Id.* ¶¶ 299-309.

D. GROUND 4C: Claim 11 is Obvious Over *Terrien*, *Price*, and *Ji*

1. Claim 11: ...a purge gas...is treated... at least part of said tail gas is recycled as process gas and subjected to said step of conversion...

Terrien discloses separating a H₂-rich stream (27) from a process stream (1). EX1007 ¶ 21. The process stream contains “at least carbon dioxide, hydrogen and methane.” *Id.* The process stream is separated from the H₂-rich stream during a purge step. *Id.* ¶ 20. *Terrien* also discloses the process stream splitting into a first H₂-rich permeate stream (5) and a first H₂-lean permeate stream (6) (*Id.* ¶ 78); a second H₂-rich permeate stream (12) and a second H₂-lean permeate stream (13) (*Id.*); and a CO₂-enriched permeate stream (15) and a CO₂-depleted residue stream (16) (*Id.* ¶ 93). Because the process stream (1) contains at least CO₂, H₂ and CH₄, removal of the first and second H₂-rich permeate streams (5, 12) results in the first and second H₂-lean permeate streams (6, 13) containing at least CO₂ and CH₄. By separating out the CO₂-enriched permeate stream (15) in the CO₂ selective membrane separation unit (14), the CO₂-depleted residue stream (16) contains at least CH₄. *Terrien* discloses recycling the CO₂-depleted residue stream (16) as feed

for the conversion step. *Id.* (“The carbon dioxide depleted residue stream (16) that is recovered...can be used as a supplemental feed for the prereformer (21).”).

Accordingly, *Terrien* discloses a purge gas containing H₂ and CH₄ treated to separate a H₂-rich gas (5, 12) and a tail gas containing CH₄ (16), wherein the tail gas is recycled as process gas and is subjected to the conversion step. *Id.*, FIG. 5.

Further, to the extent that this element is not disclosed by *Terrien*, *Ji* discloses treating a H₂- and CH₄-containing purge gas of the ammonia synthesis process to recover the H₂, thus obtaining a H₂-rich stream and a purge gas containing CH₄, wherein at least a part of the purge gas is recycled as process gas, subject to the step of conversion of the natural gas into synthesis gas. EX1012 5:56-6:8; FIG. 2; EX1005 ¶¶ 216. A POSA would have known that a purge gas can be separated into a H₂-rich gas and a tail gas, wherein at least a portion of the tail gas could be recycled as feed to the conversion section. EX1005 ¶ 217. It would have been obvious to a POSA to modify *Terrien* alone or with *Price* to include *Ji*’s purge gas recycle to achieve beneficial and expected results. EX1005 ¶¶ 215-17, 219, 310-12.

2. Rationale for Combining *Terrien*, *Price*, and *Ji*

A POSA would have considered *Terrien*, *Price*, and *Ji* for the reasons above with respect to *Terrien* and *Price*. Additionally, each is in the same field of endeavor, relating to syngas production for use as a feedstock for producing

products such as ammonia. EX1007 ¶ 3; EX1011 ¶ 20; EX1012, 1:17-24.

Additionally, each is intended to reduce carbon emissions and/or reuse products of processes as inputs. *See generally* EX1007 ¶¶ 3, 8; EX1011 ¶¶ 21, 55-57, 60; EX1012, 1:6-13. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would be reasonably likely to succeed. EX1005 ¶¶ 310-12. The disclosure that *Ji* is relied upon was well-known in the art, and therefore, a POSA would readily have relied upon *Ji* to modify the disclosure of *Terrien* and *Price*. *Id.* In fact, the '168 Patent acknowledges that such recycling of purge and tail gases was known in the prior art. EX1001, 1:63-66.

A POSA would have had a reasonable expectation of success in combining *2007 IFA* and *Ji*. Because both are directed towards processes for reducing carbon emissions in ammonia synthesis processes, a POSA would have expected success in combining the disclosures of the two references to obtain the desired result, namely, to reduce carbon emissions associated with ammonia synthesis. *Id.* ¶¶ 215-17, 310-12.

E. GROUND 4D: Claim 17 is Obvious Over *Terrien*, *Price*, and *Licht*

- 1. Claim 17: ...fuel fraction forms all of the fuel of the furnaces used in the conversion section, or an amount of natural gas is provided as trim fuel...accounting for not more than 15% of the total combustion heat**

This claim is directed towards a design choice as to the amount of the fuel fraction and/or the amount of a trim fuel used as the fuel of the furnaces used in the conversion section. *See supra* note 3; EX1005 ¶ 221. Here, the claim requires use of a specific range of percentages of the fuel fraction and/or a trim fuel used as fuel to the furnaces. The '168 Patent discloses several potential ranges of the amount of fuel being from a trim fuel in order to “quickly raise or lower the load if needed.” EX1001, 3:50-52. Despite this contemplated benefit of the trim fuel, the '168 Patent still contemplates the fuel fraction forming “all—or substantially all—the fuel of the furnaces.” *Id.* 3:44-45. A POSA readily would have appreciated that, in a process where fuel is required to be fed to a furnace and there is a generated fuel source (i.e., the fuel fraction), the generated fuel source could have been used as the entire fuel source or a supplemental fuel source (e.g., the trim fuel) could have been provided in any suitable quantity. EX1005 ¶¶ 220-21, 223-24.

To the extent that this claim is patentably distinct from independent claim 1 and not rendered obvious by *Terrien* and *Price*, *Licht* discloses the synthesis gas fuel fraction forming all of the fuel of the furnaces used in the conversion section or an amount of natural gas being provided as trim fuel accounting for not more

than 15% of the total combustion heat. *See infra* Section V(G)(9). It would have been obvious to a POSA to modify *Terrien* and/or *Price* to include *Licht*'s amount of heat from trim fuel to achieve beneficial and expected results. EX1005 ¶¶ 220-21, 223-24, 313-15.

2. Rationale for Combining *Terrien*, *Price*, and *Licht*

A POSA would have considered *Terrien*, *Price* and *Licht* for the reasons above with respect to *Terrien* and *Price*. Additionally, each is in the same field of endeavor, relating to syngas production for use as a feedstock for producing products such as ammonia. EX1007 ¶ 3; EX1011 ¶ 20; EX1009, Abstract. Both *Terrien* and *Licht* relate to processes by which natural gas is treated to reduce carbon emissions. EX1007 ¶ 3; EX1009, Abstract. The disclosure that *Licht* is relied upon to supplement *Terrien* and *Price* was well-known in the art, therefore, a POSA would have relied upon *Licht* to modify *Terrien* and *Price*. EX1005 ¶¶ 56, 313-15. Moreover, the use of trim fuel was a well-known design strategy used to optimize the efficiency of the process. *Id.* ¶ 314. Trim fuel allows one to adjust the temperature and composition of the syngas. *Id.* For example, it was well-known to use trim fuel to increase hydrogen content by adding more fuel, to adjust the H₂/CO ratio, and increase temperature. *Id.*

A POSA would have had a reasonable expectation of success when combining *Terrien*, *Price* and *Licht*. Each reference is directed towards

hydrocarbon synthesis processes. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would be reasonably likely to succeed. *Id.* ¶ 315.

F. GROUND 4E: Claims 3, 4, 8, and 9 are Obvious Over *Terrien*, *Price*, and *Rytter*

1. Claims 3 – 4

This claim is obvious over *Terrien* and *Price* because it is directed towards a design choice as to the amount of the CO₂-depleted syngas that is used as fuel. *See supra* Section V(B)(2).

To the extent that this claim is patentably distinct from independent claim 1 and not rendered obvious by *Terrien* and *Price*, *Rytter* discloses the fuel fraction being between 1% and 40% and between 10% and 30% of the total amount of the CO₂-depleted syngas. EX1008, 4:10-14 (discussing “at least 5%” of the H₂-containing stream being fed to the synthesis (i.e., second stream) step). Between 1% and 40% and between 10% and 30% are within the range of 0% to 95%. The heat-generating station is described as being, for example, “gas turbines,” which are used to “considerably reduce the emission of CO₂ in the production of electrical power.” *Id.* 1:33-35. The motivation for directing a portion of the H₂-containing stream is to reduce carbon emissions, which is the same motivation for using the first stream as a fuel fraction. EX1005 ¶¶ 169-70, 172-73. Further, *Rytter* discloses the remaining part of the H₂-containing stream being fed “to other H₂-

requiring processes,” which includes use as fuel in a furnace. EX1008 4:10-14.

Accordingly, it would have been obvious to a POSA to apply *Rytter*’s fuel fraction percentage to *Terrien* and/or *Price*. EX1005 ¶¶ 169-70, 172-73, 316-17, 319.

2. Claims 8 – 9

This claim is obvious over *Terrien* and *Price* because it is directed towards a design choice as to the amount of oxygen in oxygen-enriched air. *See supra* Section V(B)(5).

To the extent that this claim is patentably distinct from independent claim 1 and not rendered obvious by *Terrien* and *Price*, *Rytter* discloses the natural gas being combined with “an oxygen containing gas stream, and particularly using substantially pure O₂ as an oxygen containing gas.” EX1008, 4:26-29.

“Substantially pure O₂” which is an oxygen containing gas stream, includes oxygen-enriched air. EX1005 ¶¶ 198-203. “Substantially pure O₂,” being composed substantially of oxygen, contains significantly more than 50% and more than 90% oxygen. *Id.* Accordingly, it would have been obvious to a POSA to apply *Rytter*’s oxygen concentration in the oxygen-enriched air to *Terrien* and/or *Price*. EX1005 ¶¶ 198-203, 316, 318-19.

3. Claim 10

This claim is obvious over *Terrien* alone or in view of *Price* for the reasons noted above. *See supra* Section V(A)(3).

To the extent, however, that *Terrien* and/or *Price* do not disclose the furnace being a steam production and/or superheating furnace, a POSA would have understood that the disclosures of *Terrien* could have been modified to use a steam production and/or superheating furnace, which was well-known in the art. EX1005 ¶¶ 52, 56, 206. Further, *Rytter* discloses using a steam production and/or superheating furnace. *Rytter* discloses feeding the fuel fraction to use as fuel in a furnace, including to “steam producing electrical power.” EX1008, 6:8-13. Accordingly, *Rytter* teaches feeding one or more of (1) a steam production and/or superheating furnace and (2) one or more furnaces for pre-heating the charge of the ATR or natural gas desulphurization section. EX1005 ¶¶ 206.

4. Rationale for Combining *Terrien*, *Price*, and *Rytter*

A POSA would have considered *Terrien*, *Price*, *Rytter* for the reasons above with respect to *Terrien* and *Price*. Additionally, each is in the same field of endeavor, relating to syngas production for use as a feedstock for producing products such as ammonia. EX1007 ¶ 3; EX1011 ¶ 20; EX1008, 3:10-16. Additionally, each is intended to reduce carbon dioxide emissions. *See generally* EX1008; EX1007 ¶ 3; EX1011 ¶ 21. The disclosure that *Rytter* is relied upon was well-known in the art, therefore, a POSA would readily have relied upon *Rytter* to modify *Terrien* and *Price* to have optimum or workable ranges. *See supra* Sections V(F)(1)-(3).

A POSA would have been motivated to modify the process disclosed in *Terrien* and *Price* to optimize certain working ranges considering *Rytter*. *See supra* Sections V(F)(1)-(3). Accordingly, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is a mere design choice, the amount of oxygen contained in the oxygen-enriched air (claims 8-9), which is a mere design choice, and the type of furnace to which the fuel fraction is fed (claim 10), which is also a design choice. EX1005 ¶¶ 316-19. Further, use of CO₂-depleted syngas as a fuel fraction, among other uses, is well-known in the art. *Id.* ¶¶ 52, 136-52.

A POSA would have had a reasonable expectation of success when combining *Terrien*, *Price*, and *Rytter*. Each is directed towards hydrocarbon synthesis processes. *Id.* ¶ 316. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would have been reasonably likely to succeed. *Id.* ¶¶ 316-19.

G. GROUND 5: Claims 1- 10, 17, and 19 are Obvious Over *Licht* and *Price*

1. Claim 1

a) 1[pre]

Preambles are typically not limiting. *See supra* note 2. Although this phrase has no patentable weight, *Licht* in view of *Price* discloses a process for ammonia synthesis. *See e.g.*, EX1009, 7:17-19 (“Secondary reforming reactors are well-

known in the art and used widely for the production of ammonia and methanol.”); EX1011, Abstract; EX1005 ¶¶ 157-58.

b) 1[a]

Licht discloses conversion of a charge of natural gas and steam into a synthesis gas containing H₂, CO, and CO₂, the conversion taking place in a conversion section comprising a prereformer followed by reformers. EX1009, 3:25-36; 5:56-58. *Licht* discloses combining the steam and natural gas further with an oxygen-rich stream. *Id.* 7:5-16. While *Licht* does not directly disclose the natural gas being desulphurized, a POSA would have understood that this is necessary, as sulfur compounds are known to damage conversion sections and synthesis process efficiency. EX1005 ¶¶ 44, 128-29.

Licht does not explicitly disclose a prereformer followed by an ATR without a primary reformer therebetween, but a POSA would have understood an oxygen secondary reformer following the prereformer to be equivalent to an ATR. *Id.* ¶¶ 128-29. An ATR uses the combination of a steam reformer reaction and partial oxidation, which is similarly utilized by an oxygen secondary reformer. *Id.* ¶¶ 45-49, 129.

To the extent that *Licht* does not disclose an ATR downstream from a prereformer without a primary reformer therebetween, *Price* does. EX1011 ¶ 56. A POSA would have understood that prereforming the syngas prior to the ATR step

can be accomplished by a steam reformer. EX1005 ¶¶ 46, 49, 60, 65, 130, 320-21.

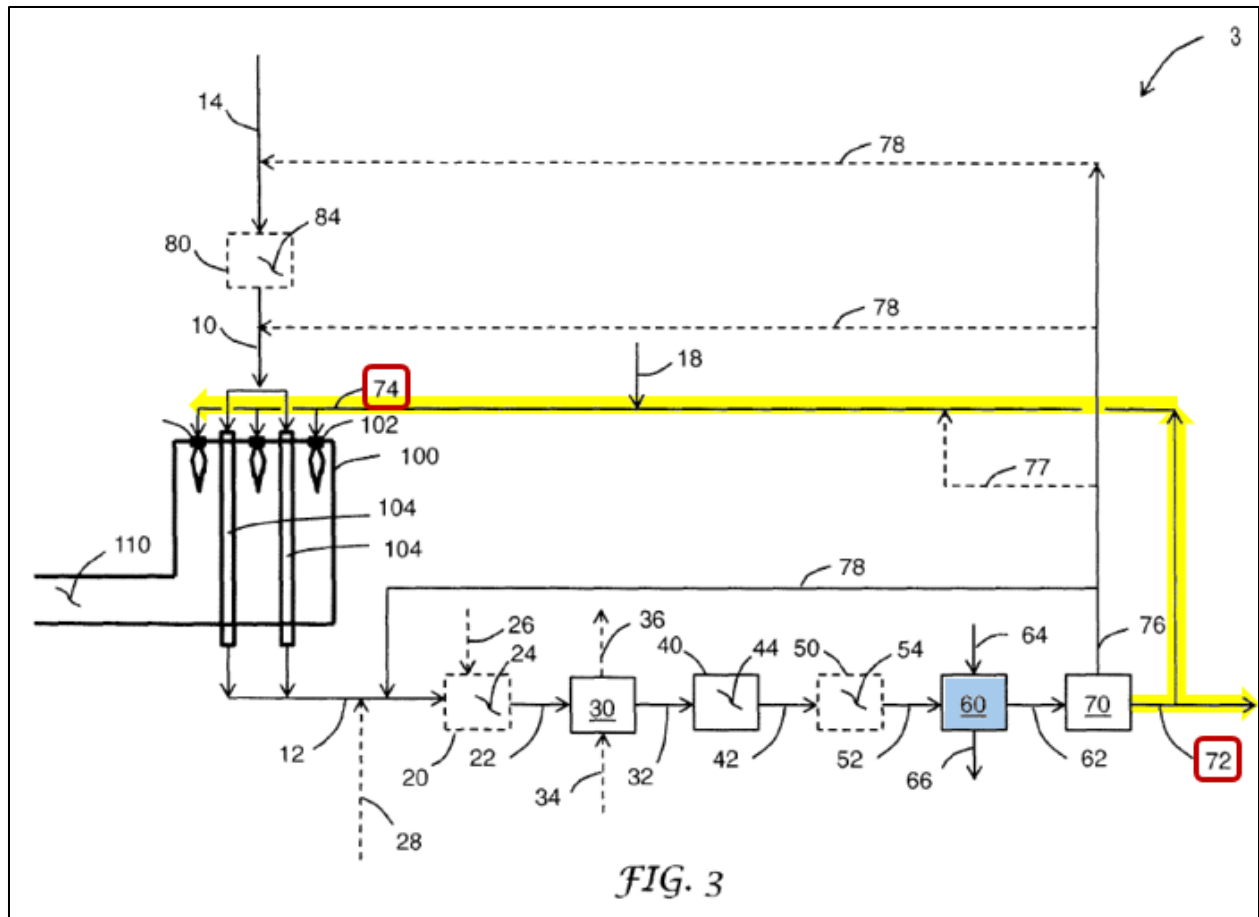
Accordingly, it would have been obvious to a POSA to apply *Price*'s conversion section configuration to the *Licht* system. *Id.* ¶¶ 320-21, 329.

c) 1[b]

After passing through this conversion section, *Licht* discloses treatment of the synthesis gas including at least a shift reaction of the CO into CO₂. EX1005 ¶ 135. In the shift reaction, the CO in the synthesis gas is converted into CO₂ so that the CO₂ can be removed from the synthesis gas. The result is a CO₂-depleted synthesis gas and a CO₂-rich gaseous flow containing the CO₂ separated from the gas. EX1009, 3:61-67. *Licht* further discloses treatment of the syngas to remove CO₂ after the shift reaction. *Id.* 4:13-16; FIG 3.

d) 1[c]

Licht discloses splitting the CO₂-depleted syngas stream into a first stream—the fuel fraction—and a second stream. Specifically, *Licht* discloses splitting the H₂-containing product gas 72 into fuel gas 74. EX1005 ¶¶ 151-52; EX1009, 5:27-33; FIG. 3:



Licht discloses the first and second streams having the same composition. *Id.* 5:7-14 (“The portion 78 of the by-product gas 76 may be a divided portion of the by-product stream 76 formed from the separation of the carbon dioxide-depleted stream 62 and thereby have the same composition as the by-product stream 76 formed from the separation of the carbon dioxide-depleted stream 62.”); EX1005 ¶ 152.

e) 1[d]

Although this phrase may have no patentable weight, *Licht* discloses the process being used for ammonia synthesis. *Id.* 7:17-19. *Licht* relates primarily to

H₂ synthesis processes, which precede further synthesis processes, e.g., ammonia synthesis. *Id.* Abstract. Accordingly, a POSA would have understood *Licht*'s front-end H₂-synthesis process to be applicable to a process including ammonia synthesis. EX1005 ¶ 157. Further, to the extent that this phrase has patentable weight and *Licht* does not disclose it, *Price* does. EX1011, Abstract; EX1005 ¶ 158.

2. Claim 2

Purification of syngas prior to ammonia synthesis was well-known in the art as small amounts of impurities remaining the syngas can poison the catalysts used for ammonia synthesis. *Id.* ¶ 46; *see also*, EX1001, 1:63-65. A POSA thus would have been motivated to modify *Licht* to include further purification prior to ammonia synthesis. Indeed, *Licht* describes purification to provide hydrogen rich streams that can be used in downstream processes. EX1007 ¶¶ 16, 17; EX1005 ¶¶ 159-60, 165-66, 168.

Additionally, *Price* discloses purification of syngas streams with pressure swing adsorption (PSA), membrane units, or any other known method (EX1011 ¶ 39), as well as the syngas stream being subject to further purification prior to ammonia synthesis (*Id.* ¶¶ 40, 55); EX1005 ¶ 165. *Price* also discloses an additional purification step of methanation. EX1011 ¶ 5. While *Price* does not disclose a CO₂-depleted synthesis gas stream being split into a first stream and a

second stream, *Licht* does. EX1009, 5:27-33. *Price* discloses methods to increase the concentrations of H₂ and/or nitrogen in the syngas stream prior to ammonia synthesis, as this was a well-known goal of ammonia synthesis methods. EX1005 ¶ 166. Synthesis of ammonia, which results from combining H₂ and nitrogen, necessarily requires these elements to be provided to the synthesis step. *Id.* Accordingly, processes that are intended to synthesize ammonia necessarily would require higher concentrations of H₂ and nitrogen to increase output. *Id.* Accordingly, it would have been obvious to a POSA to apply *Price*'s further purification to the *Licht* system. *Id.* ¶¶ 159-60, 165-66, 168, 320, 322, 329.

3. Claims 3 – 4

Licht alone and in view of *Price* does not directly disclose the optimum amount of the CO₂-depleted syngas that is used as the fuel fraction. However, this is merely a design choice as to the amount of CO₂-depleted syngas used as fuel. *See supra* Section V(B)(2).

4. Claim 5

Both methanation and addition of nitrogen prior to ammonia synthesis were well-known in the art and a POSA would have been motivated to modify *Licht* to include these steps. *See supra* Section V(B)(3).

Further, *Price* discloses a methanation step and a step of adding nitrogen to the syngas. *Id.* Therefore, a POSA would have been motivated to apply the

methanation and/or nitrogen addition step(s) of *Price* to *Licht*. EX1005 ¶¶ 178, 181-82, 320, 324, 329.

5. Claim 6

A POSA applying *Licht* to ammonia synthesis would have split the syngas stream upstream of methanation and nitrogen addition. *See supra* Section V(B)(4); EX1005 ¶¶ 181-82, 188-89. While residual CO and CO₂ are problematic for ammonia catalysts, they pose no problems when syngas is used as a fuel. *Id.* ¶¶ 51, 53-55. Accordingly, a POSA would have used the fuel fraction prior to methanation or nitrogen addition. EX1005 ¶¶ 188-89.

Additionally, *Licht* in view of *Price* discloses splitting the syngas stream upstream of both the methanation and nitrogen addition steps. *Id.* ¶¶ 183, 188-89, 320, 324, 329. *Price* discloses the syngas stream being split into at least two streams. EX1011 ¶ 26 (“The synthesis gas exiting the reforming section may be split into at least two streams ...”). *Price* discloses methanation and N₂ addition steps occurring after the split, as methanation is “the final treatment step” and the H₂-rich gas, which is a product of the split, is “combined with N₂.” *Id.* ¶¶ 5, 44. To the extent that *Price* does not disclose the fuel fraction being separated upstream of the methanation step or upstream of nitrogen addition, *Licht* does. *See e.g.*, EX1009, FIG. 3. Moreover, as applied to ammonia synthesis, *Licht* would necessarily separate the fuel fraction prior to nitrogen addition because nitrogen is

added to reduce residual CO and CO₂, which are not a concern for syngas used as fuel, whereas nitrogen is necessary for ammonia synthesis. EX1005 ¶¶ 38, 46, 57, 165, 181-82, 188-89. Therefore, it is more efficient to use a portion of the syngas for fuel without the additional treatment step, thus necessitating removal of the fuel fraction prior to this step. *Id.* Accordingly, it would have been obvious to a POSA to apply *Price*'s methanation and/or nitrogen addition steps downstream of a split in a syngas stream to the *Licht* system. *Id.* ¶¶ 181-82, 188-89, 320, 324, 329.

6. Claim 7

This claim is merely directed towards the design choice as to the amount of CO₂ to remove from the syngas. *See supra* Section V(A)(2). To the extent, however, that these claims are patentably distinct from claim 1, a POSA would have been motivated to modify *Licht* to use a CO₂-depleted syngas that contains no more than 1000 ppm by volume of CO₂ given the point of *Licht* is to reduce carbon emissions. *See* EX1005 ¶ 320.

Additionally, *Price* discloses the CO₂-depleted syngas containing no more than 1000 ppm by volume of CO₂. *See supra* Section V(A)(2). Accordingly, it would have been obvious to a POSA to apply *Price*'s partial volume of CO₂ in the CO₂-depleted syngas to the *Licht* system. EX1005 ¶¶ 194, 196, 320, 325, 329.

7. Claims 8 – 9

As noted for claim 1, use of ATR with oxygen and oxygen-enriched air was well-known in the art as ATR uses oxygen to partially oxidize methane. *See supra* Sections V(A)(1)(b); V(G)(1)(b); EX1005 ¶¶ 197-203. A POSA thus would have been motivated to modify *Licht* and *Price* to use oxygen-enriched air that contains at least 50% and at least 90% oxygen. *Id.* ¶¶ 197-203, 320, 326, 329.

To the extent that *Licht* does not directly disclose this feature, this claim is merely directed towards the optimum or workable ranges of the concentration of oxygen in enriched air. *See supra* note 5. A POSA implementing the system described by *Licht* and of *Price* would have achieved, through routine experimentation, the enriched air containing at least 50% oxygen and at least 90% oxygen. *See supra* Section V(B)(5).

8. Claim 10

Licht discloses the fuel fraction of the syngas being recycled upstream for various uses, including to fuel the conversion section furnaces. EX1009, 5:27-42; 7:17-22. To the extent that *Licht* and/or *Price* do not disclose the furnace being a steam production and/or superheating furnace, a POSA would have understood that the disclosures of *Licht* and/or *Price* could be modified to use a steam production and/or superheating furnace, which was well known in the art. EX1005 ¶¶ 204, 209, 320, 327, 329.

9. Claim 17

This claim is merely directed towards a design choice as to the amount of the fuel fraction and/or the amount of a trim fuel used as the fuel of the furnaces used in the conversion section. *See supra* Section V(E)(1).

To the extent that this claim is patentably distinct from independent claim 1, *Licht* discloses the synthesis gas fuel fraction forming all of the fuel of the furnaces used in the conversion section or an amount of natural gas being provided as trim fuel accounting for not more than 15% of the total combustion heat. EX1009, 5:37-42 (“The supplementary fuel 18 is often called a trim fuel and may be, for example, natural gas. The portion of the hydrogen-containing product gas 72 and the portion of the by-product gas 76 may be divided portions of the respective gases.”); 10:4-9 (“Fuel to fire the reformer 100 is provided by by-product gas 76 and hydrogen-containing product gas 72... . No natural gas trim fuel is used.”); EX1005 ¶ 223.

10. Claim 18

This claim is directed towards a design choice as to the amount of fuel fraction produced with respect to the fuel demand of the conversion section. *See supra* Section V(B)(6). A POSA would have understood that modulating the quantity of an input (the fuel fraction) would necessarily result in regulating the output (the quantity [of syngas]) of a process. EX1005 ¶ 226. Therefore, this claim

is obvious over *Licht* and/or *Price* and a POSA's knowledge and skill. *Id.* ¶¶ 225-26, 320, 329.

11. Claim 19

This claim is merely directed towards the optimum or workable ranges of the steam/carbon (S/C) ratio in the ATR. *See supra* Section V(B)(7); note 5.

To the extent that this claim is patentably distinct from independent claim 1, *Price* discloses conversion of a charge of desulphurized natural gas and steam in an ATR with a steam/carbon ratio not greater than 2. *See supra* Section V(B)(7); EX1005 ¶¶ 229-30, 232, 320, 328-29.

12. Rationale for Combining *Licht* and *Price*

A POSA would have considered *Licht* with *Price*. Each is in the same field of endeavor, relating to syngas production for use as a feedstock for producing products such as ammonia and reducing carbon emissions. EX1011 ¶ 21; EX1009, Abstract. Additionally, each relates to methods to convert natural gas to ammonia. EX1005 ¶ 320. The disclosure that *Price* is relied upon to supplement *Licht* were well-known in the art, therefore, a POSA would readily have relied upon *Price* to modify the disclosure of *Licht*. *Id.* ¶¶ 320-29. Various types of reformers, prereformers, and combinations thereof can form a conversion section. *Id.* ¶ 321. A POSA would have known to combine the disclosure of the first stream forming the fuel fraction and the second stream being process gas intended for the synthesis of

ammonia after further purification because steps of further purification were well-known in the art. *Id.* ¶ 322. It was well-known in the art to use a step of methanation and/or addition of nitrogen to the syngas, including wherein the fuel fraction is separated upstream of the methanation and/or addition of nitrogen. *Id.* ¶ 324. A POSA would have known that the content of CO₂ in the CO₂-depleted syngas could be modified by *Price* because it was well-known in the art that the goal of CO₂-removal of the syngas is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *Id.* ¶ 325. A POSA would have known that the steam/carbon ratio in the ATR could be modified to any known value to obtain the desired result, as ranges of steam/carbon ratios were well known in the art. *Id.* ¶ 328.

A POSA would have had a reasonable expectation of success when combining *Licht* and *Price*. Each is directed towards hydrocarbon synthesis processes. *Id.* ¶ 329. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would have been reasonably likely to succeed. Further, *Licht* and *Price* both disclose processes with substantial overlap. Therefore, a POSA would have known that one process that discloses, e.g., conversion of natural gas in a conversion section, a CO-shift reaction, CO₂ removal, and using at least a portion of the CO₂-

depleted stream for ammonia synthesis, could be modified by applying process steps used in another process that discloses the same overlapping steps. *Id.*

H. GROUND 5A: Claim 11 is Obvious Over *Licht*, *Price*, and *Ji*

1. Claim 11

Ji discloses treating a H₂- and CH₄-containing purge gas of the ammonia synthesis process to recover the H₂, thus obtaining a H₂-rich stream and a purge gas containing CH₄, wherein at least a part of the purge gas is recycled as process gas, subject to the step of conversion of the natural gas into synthesis gas. *See supra* Section V(D)(1). Accordingly, it would have been obvious to a POSA to apply *Ji*'s recycle of a CH₄-rich tail gas from a purge gas as process gas subject to the conversion section to the *Licht* and/or *Price* system. *Id.* ¶¶ 216-17, 330-32.

2. Rationale for Combining *Licht*, *Price*, and *Ji*

A POSA would have considered *Licht*, *Price*, and *Ji*. Each is in the same field of endeavor, as they relate to syngas production for use as a feedstock for producing products such as ammonia and reducing carbon emissions. EX1011 ¶ 21; EX1012, 1:17-24; EX1009, Abstract. Additionally, each relates to methods to convert natural gas to ammonia. EX1005 ¶ 330. A POSA would have known to combine the disclosure of a purge gas of the ammonia synthesis process being treated to recover a hydrogen-rich gas stream and a tail gas containing methane, wherein at least part of the tail gas is recycled as process gas and subject to the step of conversion of the natural gas into syngas. *Id.* ¶ 331. The '168 Patent

acknowledges that such recycling of purge and tail gases was known in the prior art. *Id.* Therefore, a POSA would have readily relied on *Ji* to modify the disclosure of *Licht* and *Price*. *Id.* ¶¶ 330-32.

A POSA would have had a reasonable expectation of success when combining *Licht*, *Price*, and *Ji*. Each is directed towards hydrocarbon synthesis processes. *Id.* ¶ 332. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would have been reasonably likely to succeed. *Id.*

I. Ground 5B: Claims 3, 4, 8, and 9 are Obvious Over *Licht*, *Price*, and *Rytter*

1. Claims 3 – 4

To the extent, however, that these claims are patentably distinct from claim 1 and not disclosed by *Licht* and *Price*, *Rytter* discloses the fuel fraction being between 1% and 40% and between 10% and 30% of the total amount of the CO₂-depleted syngas. *See supra* Section V(F)(1). Accordingly, it would have been obvious to a POSA to apply *Rytter*'s fuel fraction percentage to *Licht* and/or *Price*. EX1005 ¶¶ 169-77, 333-34, 336.

2. Claim 8 – 9

To the extent that these claims are patentably distinct from claim 1 and not disclosed by *Licht* and *Price*, *Rytter* discloses the natural gas being combined with “an oxygen containing gas stream, and particularly using substantially pure O₂ as

an oxygen containing gas.” *See supra* Section V(F)(2). Accordingly, it would have been obvious to a POSA to apply *Rytter*’s concentration of O₂ in the oxygen-enriched air to *Licht* and/or *Price*. EX1005 ¶¶ 197-203, 333, 335-36.

3. Claim 10

This claim is obvious over *Licht* alone or in view of *Price* for the reasons noted above. *See supra* Section V(G)(8).

To the extent, however, that *Licht* and/or *Price* do not disclose the furnace being a steam production and/or superheating furnace, a POSA would have understood that the disclosures of *Licht* could have been modified to use a steam production and/or superheating furnace, which was well-known in the art. EX1005 ¶¶ 52, 56, 204-09. Further, *Rytter* discloses using a steam production and/or superheating furnace. *See supra* Section V(F)(3).

4. Rationale for Combining *Licht*, *Price*, and *Rytter*

A POSA would have considered *Licht*, *Price*, and *Rytter*. Each is in the same field of endeavor, as they relate to syngas production for use as a feedstock for producing products such as ammonia and reducing carbon emissions. *See generally* EX1008; EX1009, Abstract; EX1011 ¶ 21. Additionally, each relates to methods to convert natural gas to ammonia. EX1009, 7:17-18; EX1008, 3:10-16; *See generally* EX1011.

A POSA would have been motivated to modify the process disclosed in *Licht* and *Price* to optimize certain working ranges considering *Rytter*. *See supra* Sections V(I)(1)-(3). Accordingly, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is a mere design choice, the amount of oxygen contained in the oxygen-enriched air (claims 8-9), which is a mere design choice, and the type of furnace to which the fuel fraction is fed (claim 10), which is also a design choice. EX1005 ¶¶ 333-36. Further, use of CO₂-depleted syngas as a fuel fraction, among other uses, is well-known in the art. *Id.* ¶¶ 52, 336.

A POSA would have had a reasonable expectation of success when combining *Licht*, *Price*, and *Rytter*. Each is directed towards hydrocarbon synthesis processes. *Id.* ¶ 336. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in another would have been reasonably likely to succeed. *Id.*

VI. NO SECONDARY CONSIDERATIONS

Petitioner is not aware of any of any secondary considerations or nexus to the Challenged Claims. Evidence of secondary considerations, if any, should be addressed in a trial where the parties may develop, and the Board may consider, a full record.

VII. CONCLUSION

The Challenged Claims are unpatentable. Petitioner respectfully requests institution of IPR and cancellation of all Challenged Claims.

VIII. MANDATORY NOTICES UNDER 37 C.F.R. §42.8(A)(1)

A. Real Party-in-Interest under 37 C.F.R. §42.8(b)(1)

The real party-in-interest in this *inter partes* review (“IPR”) is Topsoe, Inc. and further may include Topsoe A/S.

B. Related Matters under 37 C.F.R. §42.8(b)(2)

The ’168 Patent was subject to Supplemental Examination and *Ex Parte* Reexamination and a *Ex Parte* Reexamination Certificate issued under 35 U.S.C. § 257. EX1003.

The ’168 Patent is subject to a co-pending civil action: *Topsoe, Inc. v Casale US, Inc. and Casale SA*, No. 3:24-cv-00033 (S.D. Tex. Jan. 31, 2024). Petitioner has not asserted that the ’168 Patent is invalid in the co-pending civil action. In any event, the Court has not yet entered a scheduling order, and a trial date has not been set.

C. Lead and Back-Up Counsel Under 37 C.F.R. §42.8(b)(3)

Petitioners provide the following designation of counsel.

Lead Counsel	Back-Up Counsel
Robert Riddle Reed Smith LLP 1221 McKinney Street, Suite 2100 Houston, TX 77010 Phone: (713) 469-3881 Email: IPR_Topsoe@reedsmith.com USPTO Reg. No. 69,599	Jennifer Black Reed Smith LLP 1717 Arch Street, #3100 Philadelphia, PA 19103 Telephone: (215) 241-5460 Email: IPR_Topsoe@reedsmith.com USPTO Reg. No. 79,591 Jonathan Detrixhe Reed Smith LLP 101 Second Street, Suite 1800 San Francisco, CA 94105 Telephone: (415) 659-4856 Email: IPR_Topsoe@reedsmith.com USPTO Reg. No. 68,556

D. Service Information under 37 C.F.R. §42.8(b)(4)

Please address all correspondence and service to the addresses listed above.

Petitioner consents to electronic service by electronic mail of all documents and correspondence related to this proceeding at **IPR_Topsoe@reedsmith.com**.

A Power of Attorney is filed concurrently herewith under 37 C.F.R. § 42.10(b).

E. Payment of Fees – 37 C.F.R. § 42.103

The Office is authorized to charge fees that become due to Deposit Account No 180586.

Dated: August 22, 2025

Respectfully submitted,

/s/ Robert Riddle

Robert Riddle
Registration No. 69,599
Reed Smith LLP
1221 McKinney Street, Suite 2100
Houston, TX 77010

Counsel for Petitioner

CERTIFICATE OF COMPLIANCE

Pursuant to 37 C.F.R. § 42.24(d), the undersigned certifies that the foregoing Petition, exclusive of the exempted portions provided in 37 C.F.R. § 42.24(a), totals **12,131** words, which is less than the 14,000 allowed under 37 C.F.R. § 42.24(a). This Petition complies with the general format requirements of 37 C.F.R. § 42.6(a) and has been prepared using Microsoft® Word in 14-point Times New Roman.

Dated: August 22, 2025

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Counsel for Petitioner

Certificate of Service

Pursuant to 37 C.F.R. §§ 42.6(e) and 42.105(b), the undersigned certifies that on August 22, 2025, a complete and entire copy of this Petition for *Inter Partes* Review, Power of Attorney, and all supporting exhibits were provided via Express Mail, postage prepaid, to the Patent Owner by serving the correspondence address of record as follows:

Dorsey & Whitney / UT General
111 South Main Street, 21st Floor
Salt Lake City, UT 84111-2176

The undersigned further certifies that a courtesy copy of the complete and entire Petition, and all supporting exhibits, were provided by electronic service to counsel retained by Patent Owner in the Related Matters identified herein:

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Dated: August 22, 2025

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