

UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT TRIAL AND APPEAL BOARD

Topsoe, Inc.

Petitioner,

v.

Casale SA

Patent Owner.

Case No. IPR2025-01454 & IPR2025-01455

Patent No. 11,286,168

Declaration of Dr. James A. Ritter

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a.	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	79
b.	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	86
c.	1[c] separation of a part of said CO ₂ -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 CO ₂ -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	89
d.	1[d] ...the second stream is process gas intended for the synthesis of ammonia	97
2.	Claim 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.	99
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- a. [3] The process of claim 1, wherein said fuel fraction is between 1% and 40% of the total amount of said CO₂-depleted syngas.....102
- b. [4] The process of claim 1, wherein said fuel fraction is between 10% and 30% of the total amount of said CO₂-depleted syngas.....104
- 4. Claim 5: The process of claim 1, further comprising a step for methanation of the synthesis gas and/or addition of nitrogen in the synthesis gas 106
- 5. 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.....108
- 6. Claim 7: The process of claim 1, wherein said CO₂-depleted syngas contains no more than 1000 ppm by volume of CO₂ 110
- 7. Claims 8 – 9 113
 - a. [8] The process of claim 1, wherein said enriched air contains at least 50% oxygen. 113
 - b. [9] The process of claim 1, wherein said enriched air contains at least 90% oxygen. 115
- 8. 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 116
- 9. Claim 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.....120
- 10. Claim 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	127
11.	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.....	129
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I. Introduction

1. My name is James A. Ritter, Ph.D. I am over the age of 18 and competent to make this declaration. I have personal knowledge of the facts and opinions set forth in this declaration and, if called upon to do so, I would testify competently thereto.

2. I have been retained as an independent expert witness by Topsoe, Inc. (“Topsoe” or “Petitioner”) for the above-captioned *inter partes* review (IPR) against Casale’s U.S. Patent No. 11,286,168, as amended by the ex parte reexamination certificate issued on July 16, 2024 (the ’168 Patent), to provide independent evaluation and opinions regarding the patentability of the challenged claims. I have been asked to provide my opinion regarding whether a person of ordinary skill in the art (“POSA”) in the subject matter of the claims would have found them anticipated or obvious over certain published prior art references. I understand that this declaration accompanies Topsoe’s Petitions for the IPR.

3. This declaration sets forth my analyses and opinions based on my technical background, skills, knowledge, training, education and experience in the relevant art, and the materials I have considered. Attached hereto as Appendix A is a true and correct copy of my Curriculum Vitae describing my background and experience. As I explain below, it is my opinion that claims 1-11, and 17-19 of the

U.S. Patent 11,286,168 ('168 patent) are anticipated and/or rendered obvious by the combination of prior art references discussed herein.

II. Qualifications and Compensation

A. Background and Qualifications

4. I have over 42 years of experience in the areas of gas separation, purification, and product synthesis. As a Full Professor in the Department of Chemical Engineering at the University of South Carolina ("USC") for the last 32 years, I hold three named chairs— the Carolina Distinguished Professorship, the L.M. Weisiger Professor of Engineering, and the Gibbons Teaching Professorship of Chemical Engineering.

5. I received my Ph.D., M.S. and B.S. from the State University of New York at Buffalo in 1989, 1985, and 1983, respectively. Each of my degrees are in Chemical Engineering.

6. I have authored or coauthored over 170 peer-reviewed journal articles and I hold eight patents. My articles and patents are primarily in the area of cyclic adsorption processes for gas separation and purification.

7. I have also served or am serving as a consultant for more than 40 companies, government agencies and national laboratories, including the National Aeronautics and Space Administration ("NASA"), Department of Energy ("DOE"), ExxonMobil and Eastman Chemical.

8. I also served on the Editorial Boards of four journals: Separation Science and Technology; Adsorption, Journal of the International Adsorption Society; Recent Patents in Chemical Engineering; and Industrial and Engineering Chemistry Research. Most recently, I served as the Associate Editor for Adsorption, Journal of the International Adsorption Society from January 2021 to July 2024, and am now serving as the Editor-in-Chief for the same journal from August 2024 to present.

9. I have also been actively involved with the Separations Division of the American Institute of Chemical Engineers (“AIChE”) since 1991, serving most recently as a Director in the Division. I have also been involved with the Industrial and Engineering Chemistry (“I&EC”) Division of the American Chemical Society (“ACS”) since 1994, serving most recently as the I&EC Division Chair-Elect, Chair and Past-Chair in 2013, 2014 and 2015, respectively. I also served on the Board of Directors of the International Adsorption Society from May 2007 to April 2013. I was named a Fellow of the ACS in July 2012, a Fellow of the AIChE in June 2013, and a Fellow of the International Adsorption Society in July 2023.

10. At USC, I was the recipient of the 2012 USC Educational Foundation Research Award for Science, Mathematics, and Engineering, being only the third engineer to ever receive this award since its inception in 1984. I also served as the

Graduate Director in the Department of Chemical Engineering from August 2007 to December 2015.

11. Key references (among many proprietary reports, etc.) from my CV that highlight me as a POSA, including publications, presentations and funded research projects, are:

- J. A. Ritter, A. D. Ebner, J. Wang and R. Zidan, “Implementing a Hydrogen Economy,” *Materials Today*, September, 18-23 (2003).
- J. A. Ritter and A. D. Ebner, “State-of-the-Art Adsorption and Membrane Separation Processes for Hydrogen Production in the Chemical and Petrochemical Industries,” *Sep. Sci. Tech*, 42, 1123-1193 (2007).
- D. Ebner and J. A. Ritter, “State-of-the-Art Adsorption and Membrane Separation Processes for Carbon Dioxide Production from Carbon Dioxide Emitting Industries,” *Sep. Sci. Tech*, 44, 1273-1421 (2009).
- M. D. LeVan, G. Carta, J. A. Ritter and K. S. Walton, “Adsorption and Ion Exchange,” in *Perry’s Chemical Engineers’ Handbook*, 9th Ed., (D. W. Green and R. H. Perry, eds.), McGraw-Hill, NY (2018).
- J. A. Ritter, A. D. Ebner, S. Bhadra, M. A. Nicholson, and C. E. Holland, “High Temperature Pressure Swing Adsorption Process for the Production of Ammonia,” *AIChE Annual Meeting*, Salt Lake City, UT, November, 2010.
- J. A. Ritter, A. D. Ebner, S. Bhadra, C. E. Holland and F. Jegede, “Application of Pressure Swing Adsorption in the Production of Ammonia,” *AIChE Spring National Meeting*, Tampa, FL, April 2009.
- S. Bhadra, C. H. Holland, M. A. Nicholson, A. D. Ebner, F. Jegede and J. A. Ritter, “Production of Ammonia with Pressure Swing Adsorption Utilized in Key Separations Steps,” *AIChE Annual Meeting*, Philadelphia, PA, November, 2008.

- F. Jegede, J. A. Ritter and A. D. Ebner, “Ammonia by Pressure Swing Adsorption,” AIChE Spring National Meeting, New Orleans, LA, April 2008.
- D. Ebner and J. A. Ritter, “Adsorption and Membrane Processes in Hydrogen Production,” 2006 AIChE Spring National Meeting, Orlando, FL, April 2006.
- J. A. Ritter and A. D. Ebner, “State-of-the-Art Adsorption and Membrane Separation Processes for H₂ Production in the Chemical and Petrochemical Industries,” 2006 AIChE Spring National Meeting, Orlando, FL, April 2006.
- Office of Naval Research, “Development, Assessment and Simulation of Enabling Fuels for Naval Decarbonization,” \$3,000,000, September 1, 2022 to July 19, 2025, W. E. Mustain (PI), R. Dougal, S.-H. Won, N. Huynh, J. Lauterbach, K. Huang and J. A. Ritter (\$245,000 for JAR to develop a pressure swing adsorption reactor for ammonia production).
- SmartKoncept Technology Inc. and DOE, “Integrated Ammonia Reactor and Ammonia Pressure Swing Adsorption Recovery, \$79,690, October 1, 2010 to September 30, 2011, J. A. Ritter (PI) and A. D. Ebner.
- SmartKoncept Technology Inc. and DOE, “Ammonia Process by Pressure Swing Adsorption, \$341,570, October 1, 2007 to September 30, 2010, J. A. Ritter (PI) and A. D. Ebner.
- Intelligent Energy Inc. and DOE, “Development of a Process Simulator for Adsorption Enhanced Reforming/Pressure Swing Reformer,” \$75,000, October 15, 2007 to July 31, 2008, J. A. Ritter (PI) and A. D. Ebner.

12. Therefore, based on my education, professional experience of over 42 years, and scholarly books and publications, I am an expert in the relevant field of the '168 Patent at issue here and have been an expert in this field since before the '168 Patent was filed with the United States Patent and Trademark Office

(“USPTO”). I am familiar with how a POSA would have understood and used the terminology found in the ’168 Patent at the time of its filing.

B. Compensation

13. I am being compensated for my time in connection with this IPR. My compensation is not contingent on reaching any particular findings or conclusions, or the outcome of the case. The opinions contained in this report are mine and are based on my own personal knowledge, experience, training, and study of the materials discussed below in this report.

III. Summary of Opinions

14. As I explain in this declaration, it is my opinion that claims 1-11 and 17-19 of the ’168 Patent are unpatentable over the following references:

- 1: Claims 1, 5-6, 10 over *2007 IFA* (EX1006)
- 1A: Claims 2-4, 7-9, 11, 17-19 over *2007 IFA* (EX1006)
- 1B: Claims 3-4, 8-9 over *2007 IFA* (EX1006) and *Rytter* (EX1008)
- 1C: Claims 2, 7, 19 over *2007 IFA* (EX1006) and *Price* (EX1011)
- 1D: Claim 11 over *2007 IFA* (EX1006) and *Ji* (EX1012)
- 1E: Claim 17 over *2007 IFA* (EX1006) and *Licht* (EX1009)
- 2: Claims 1, 3-4, 8-10, 18 over *Rytter* (EX1008)
- 2A: Claims 2, 5-7, 19 over *Rytter* (EX1008) and *Price* (EX1011)
- 2B: Claim 11 over *Rytter* (EX1008) and *Ji* (EX1012)
- 2C: Claim 17 over *Rytter* (EX1008) and *Licht* (EX1009)

- 3: Claims 1, 2, 5-6, 10, 19 over *Fjellhaug* (EX1010)
- 3A: Claims 3-4, 7, 10 over *Fjellhaug* (EX1010)
- 3B: Claims [1,] 3-4, 8-10, 19 over *Fjellhaug* (EX1007) and *Rytter* (EX1008)
- 3C: Claim 11 over *Fjellhaug* (EX1010), *Rytter* (EX1008) and *Ji* (EX1012)
- 3B: Claim 17 over *Fjellhaug* (EX1010), *Rytter* (EX1008) and *Licht* (EX1009)
- 4: Claims 1, 7, 10 over *Terrien* (EX1007)
- 4A: Claims 1, 3-6, 8-9, 18-19 over *Terrien* (EX1007) and Ordinary Knowledge
- 4B: Claims 1, 2, 5-7, 19 over *Terrien* (EX1007) and *Price* (EX1011)
- 4C: Claim 11 over *Terrien* (EX1007), *Price* (EX1011), and *Ji* (EX1012)
- 4D: Claim 17 over *Terrien* (EX1007), *Price* (EX1011), and *Licht* (EX1009)
- 4E: Claim 18 over *Terrien* (EX1007), *Price* (EX1011), and *Pinto* (EX1013)
- 4D: Claims 3, 4, 8, 9 over *Terrien* (EX1007), *Price* (EX1011), and *Rytter* (EX1008)
- 5: Claims 1-10, 17-19 over *Licht* (EX1009) and *Price* (EX1011)
- 5A: Claim 11 over *Licht* (EX1009), *Price* (EX1011), and *Ji* (EX1012)
- 5B: Claims 3, 4, 8, 9 over *Licht* (EX1009), *Price* (EX1011), and *Rytter* (EX1008)

IV. List of Exhibits

15. In forming my opinions, I have reviewed the '168 Patent, its prosecution history and references cited by the Examiner, the materials cited in the List of Exhibits, and the materials cited throughout my declaration. I also relied on my extensive familiarity with technical literature in this field. Each of these materials is a type of document that experts in my field would reasonably rely upon when forming their opinions.

Exhibit	Description
EX1001	U.S. Patent No. 11,286,168 with reexamination certificate (“the '168 Patent”)
EX1002	Prosecution History of the '168 Patent
EX1003	Prosecution History of the '168 Patent Supplemental Examination No. 96/000,424
EX1004	CV of Petitioners' Expert, Dr. James A. Ritter
EX1005	Expert Declaration of Petitioners' Expert, Dr. James A. Ritter
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>)

Exhibit	Description
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>)
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>)

Exhibit	Description
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>)
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

Exhibit	Description
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

16. All citations to exhibits reference original page numbers found in the underlying document, and all emphases are added.

V. Legal Standards

17. I am a scientist, engineer, principal investigator, and instructor by trade, and the opinions I express in this declaration involve the application of my scientific knowledge and experience to the evaluation of the claims of the '168 Patent and the impact of certain prior art on the '168 Patent. I am not a lawyer, nor do I offer any legal opinion in this declaration. Counsel from Reed Smith LLP has advised me, however, as to various legal standards that apply to the technical issues I address in this declaration. I have applied those standards in arriving at my conclusions expressed in this declaration.

A. Claim Construction

18. My understanding is that a primary step in determining the validity of patent claims is to properly construe the claims to determine claim scope and meaning. I understand that when interpreting the claims of the '168 Patent, I must do so from the perspective of one of ordinary skill in the art at the relevant priority date. I have not independently determined the priority date to which the '168 Patent is entitled. For purposes of this proceeding, I have been asked to assume that the '168 Patent has a priority date of February 15, 2017, the filing date of EP Application No. 17156256, the earliest-filed application to which the '168 Patent claims the benefit of priority. My analysis does not change if the '168 Patent is entitled to a later priority date.

19. I understand that in determining whether a patent claim under IPR before the Patent Trial and Appeal Board (PTAB) is unpatentable in view of prior art, the words of the claims of a patent are generally given their ordinary and customary meaning from the perspective of and as interpreted by a POSA at the time of the claimed invention. I also understand that patent claims are construed in light of the claim language, the patent specification (including the drawings), and the prosecution history (including the references cited during the prosecution of the patent). Specifically, it is my understanding that in determining whether a patent claim under IPR before the PTAB is unpatentable in view of prior art, the PTAB

uses the standard for claim construction used in civil courts, which is to say that the claims must be given the meaning that the terms would have had to a person of ordinary skill in the art at the time of the priority date of the '168 Patent consistent with the specification and file history of the '168 Patent.

20. For this declaration, it is my opinion that each claim term can be easily understood by the skilled artisan without further construction, that is, my analysis is based on the plain and ordinary meaning of the claim terms, unless otherwise indicated. I reserve the right, however, to supplement my opinions if Patent Owner proposes any constructions or the Board adopts any claim constructions.

B. Prior Art

21. I understand that, due to procedural limitations for IPR proceedings, the reasons of invalidity discussed herein are based solely on prior art patents and other printed publications. The absence of discussion of other reasons should not be interpreted as indicating that there are no such additional reasons for invalidity of the '168 Patent. Similarly, absence of discussion of other printed prior art references here should not be interpreted as indicating that there are no other printed prior art references that either anticipate or render obvious the '168 Patent.

22. I understand that prior art includes various categories of information such as printed publications and published patents applications. I generally

understand that a reference qualifies as prior art to a challenged claim if it was issued or published more than a year before the priority date of the patent containing the challenged claim, and that, starting in 2013, the grace period of one year prior to the priority date does not necessarily apply. I also understand that a patent or published patent application can qualify as prior art if it was filed before the invention claimed in the '168 Patent.

23. Additionally, I understand that statements by an applicant/patent owner in the specification or made during prosecution identifying the work of another as “prior art” is an admission which can be relied upon in combination with other prior art references, as well as factual foundation as to what a skilled artisan would have known at the time of the invention.

C. Anticipation

24. It is my understanding that a claim is anticipated under 35 U.S.C. § 102 if each and every element and limitation of the claim is found either expressly or inherently in a single prior art reference. I understand that for an element to be inherently disclosed, a POSA must have understood that the missing element must necessarily be present in the prior art reference. I understand that anticipation is a question of fact. I further understand that the requirement of strict identity between the claim and the reference is not met if a single element or limitation required by the claim is missing from the applied reference.

D. Obviousness

25. I understand that a claim is unpatentable under 35 U.S.C. § 103 if the claimed subject matter as a whole would have been obvious to a POSA at the time of the alleged invention, which I have been instructed to treat at present as no earlier than February 15, 2017, the filing date of EP Application No. 17156256, the earliest-filed application to which the '168 Patent claims the benefit of priority.

26. I understand that a POSA provides a reference point from which the prior art and the alleged invention should be viewed. This reference point prevents a person of ordinary skill from using one's insight or hindsight in deciding whether a claim is obvious. I understand the use of such hindsight is impermissible. I also understand that a claim can be obvious in light of a single reference or a combination of multiple prior art references. I understand that such a combination must meet certain requirements, further described below.

27. I understand that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was known in the prior art. It has been explained to me that three requirements must be satisfied for a combination of prior art references to render obvious a claimed invention. First, the cited art must teach or suggest all the requirements of the invention as recited in the claims. However, I understand that a claim is obvious if a missing feature would be a natural result of the combination of prior art elements. Second,

the cited art, coupled with the knowledge generally available in the art at the time of the invention, must contain some suggestion or incentive that would have motivated the ordinary skilled artisan to modify a reference or to combine references. I understand that the reason to combine prior art references can come from a variety of sources, such as common sense, and not just from the prior art itself. Third, the proposed modification of the cited art must have had a reasonable expectation of success, determined from the vantage point of the ordinary skilled artisan at the time the invention was made. I also understand that a reasonable expectation of success does not require that success is certain.

28. I understand that only analogous art may be considered in an obviousness analysis. Art is considered analogous if it is in the same field of endeavor as the challenged patent or if it is reasonably pertinent to the particular problem with which the challenged patent is involved. A reference is reasonably pertinent if, though in a different field, it would have commended itself to an inventor's attention in considering the problem the inventor is addressing.

29. I understand that it is impermissible to use hindsight to arrive at the claimed invention. My understanding is that to preclude hindsight in the obviousness analysis there must be evidence at the time of the invention of some reason to make the variation or combination. Furthermore, I understand that, to render a claim obvious, the prior art cannot be vague, but rather, must collectively

guide a person of ordinary skill in the art towards the particular solution claimed. I understand that obviousness does not exist where the prior art discourages or teaches away from the claimed invention.

30. I understand that certain objective factors, sometimes known as objective indicia, must be taken into account in determining whether a claimed invention would have been obvious. I understand that the following is a nonexclusive list of secondary considerations to analyze for this inquiry: (i) a strong showing of commercial success of a product covered by the patent claims that can be attributed to the merits of the invention; (ii) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (iii) the willingness of industry members to license the patent at issue; (iv) evidence that those of skill in the art were skeptical as to the merits of the invention, or that prior art references taught away from the invention; (v) evidence that those of skill in the art were surprised by the capabilities of the claimed invention; (vi) praise of the invention by others skilled in the art; and (vii) deliberate copying of the invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination.

31. I understand that any assertion of the above indications must be accompanied by a nexus between the merits of the purported invention and the evidence offered. If there is no such connection between the claimed technology

and the secondary evidence, then that evidence does not actually establish the purported invention was nonobvious.

VI. Level of Ordinary Skill in the Art

32. I understand that whether a patent is invalid as anticipated or obvious in light of the prior art is considered from the perspective of a POSA at the time of the alleged invention. The “art” is the field of technology to which the patent is related. I am knowledgeable about what the level of ordinary skill in the art would have been at the time of the alleged invention based on my education and experience.

33. I understand that the POSA is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. In determining the definition of a POSA, I have considered the following factors: (1) the level of education and experience of those in the field; (2) the complexity of the technology at issue; (3) the rate of innovation; (4) the kinds of problems faced by those in the art; and (5) solutions to such problems known in the prior art. I understand that not all such factors may be present in every case, and one or more of them may predominate. I understand that a POSA would also have knowledge from the teachings of all relevant prior art, including the art cited below.

34. Due to the similar nature of the underlying technology, descriptions within the specifications, and claimed material, it is my opinion that the same level of experience and skill is applicable to a POSA for the '168 Patent as a POSA for the prior art references cited herein.

35. In my opinion, on or before February 15, 2017, a POSA relating to the technology of the '168 Patent would have had at least a graduate degree (M. Sc. or higher) in chemical engineering, or a similar discipline, and at least 3-5 years of 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.

36. Well before February 15, 2017, my level of skill in the art was at least that of a POSA. I am qualified to provide opinions concerning what a POSA would have known and understood at that time, based on my teaching and interactions with individuals with that level of experience at the time, and my analysis and conclusions herein are from the perspective of a POSA as of February 15, 2017.

VII. Technical Background and State of the Art

37. Ammonia is one of the largest volume products in the chemical sector. Demand for ammonia production is driven by agriculture—more than 80% of

ammonia produced worldwide is used for fertilizer. In recent years, ammonia also has found application as fuel in internal combustion engines. Ammonia production, however, is emission-intensive and responsible for hundreds of millions of tons of carbon dioxide (CO₂) emissions annually. Ammonia production thus has long been a target for mitigating carbon emissions. *See e.g.*, EX1015 at 37 (“Applications separating CO₂ in large industrial plants, including natural gas treatment plants and ammonia production facilities, are already in operation today”). Ammonia synthesis and its various process steps were well-known in the art and have been commonly used for the better part of a century. *See e.g.*, EX1025 3:64-67 (“The method steps described [for ammonia synthesis], which are used within the scope of the teaching according to the invention, are all ***technically mature technologies that have proven themselves both in the production of hydrogen and in the production of ammonia.***”).

38. Ammonia is synthesized by catalytically reacting hydrogen (H₂) with nitrogen (N₂) at a molar ratio of 3 to 1. Nitrogen is easily sourced by extracting it from atmospheric air, which is 78% nitrogen. The hydrogen is sourced from synthesis gas (“syngas”)—a blend of gases obtained by processing hydrocarbons into a mixture consisting principally of hydrogen and carbon monoxide (CO).

39. Coal, crude oil, and natural gas are all starting materials for syngas. While syngas can be produced from coal by gasification and from crude oil by

cracking of heavy hydrocarbons, these processes are inefficient and generate significant pollutants. In the 1950s improved plant designs and growing availability of light hydrocarbon feedstocks resulted in a shift away from coal and heavy hydrocarbon feedstocks. *See* EX1014 at 15. Natural gas (predominantly methane, CH₄) became the preferred feedstock for syngas. *See* EX1023 at 50 (“Natural gas is the primary feedstock for existing hydrogen production.”). Compared with other fossil fuels, natural gas is cost effective because it is widely available, easy to handle, and has a high hydrogen-to-carbon ratio, which minimizes formation of by-product carbon dioxide.

40. Syngas is a source of hydrogen for ammonia synthesis but also is a building block for synthesizing a diverse array of other valuable chemicals and fuels. Syngas and its associated hydrogen are used to synthesize chemicals such as hydrogen for usage in petrochemical refineries (e.g., hydrodesulfurization), methanol, urea, hydrochloric acid, and synthetic hydrocarbons from gas-to-liquid processes (e.g., Fischer-Tropsch process). *See e.g.*, EX1024 at 1-4; EX1042 at 2. Syngas, and hydrogen from syngas, also are used as fuel in various applications including heat and power generation. Production of syngas and hydrogen, regardless of the application, releases a significant amount of CO₂ emissions. *See e.g.*, EX1025, 1:16-44 (explaining hydrogen production results in significant CO₂ emissions); EX1009, 1:6-27 (same); EX1007 ¶ 3 (“Hydrogen is an important

feedstock for many chemical and petrochemical processes. However, hydrogen production is associated with large amounts of carbon dioxide emissions.”).

41. With respect to ammonia synthesis, the series of processes that convert a natural gas feedstock into a syngas and useable source of hydrogen for generating the syngas occurs in the “front-end” of a plant, while the ammonia synthesis occurs in the “back-end” of the plant. As such, the front-end includes processes used in production of a diverse array of products. Generating the syngas in the front-end is responsible for the emissions, and as such has long been a target for mitigation. *See* EX1023 at 30 (“Two public goals—environmental quality, especially the reduction of greenhouse gas emissions, and energy security—provide the policy foundation for the hydrogen programs of the DOE.”); *Id.* at 17 (“About 60 percent of this becomes feedstock for ammonia production and subsequent use in fertilizer.”).

42. Notably, syngas (and ammonia) production is often integrated with other processes to make a variety of products. Such integration takes advantage of the various process streams, similar equipment needs, and/or use of the same raw materials. For example, methanol may be co-produced with ammonia. Methanol does not require ammonia as raw material but may be made from the same raw materials as ammonia. Another example is urea, which leverages CO₂ that is removed from syngas as part of the front-end. *See, e.g.*, EX1001, 2:53-54 (“In

combined ammonia/urea plants said furnace may form part of the urea section).

Syngas and ammonia production also are integrated with Fischer-Tropsch processes for the production of liquid hydrocarbons. In such systems, the syngas is split, with a portion going to the Fischer-Tropsch process and the other going to ammonia synthesis.

43. At least six well-known process steps are required to produce ammonia from natural gas: (1) natural gas desulfurization to remove sulfur impurities, (2) reforming (syngas generation) to generate hydrogen, (3) carbon monoxide (CO) shift to generate more hydrogen and remove CO, (4) carbon dioxide (CO₂) removal, (5) purification to remove water (H₂O) and other impurities to downstream ammonia synthesis, and (6) ammonia synthesis. These process steps have been commonly used for the better part of a century. *See e.g.*, EX1025, 3:64-67; EX1037 at 212 (Fig. 6.1); EX1042 (Fig 1(b) and 1(c)). While all ammonia plants use this basic process, details such as operating pressures, temperatures, and quantities of feedstock vary from plant to plant based on the characteristics of the feedstock, process goals, design considerations, costs, and other factors.

44. Ammonia can be synthesized from natural gas through a series of well-known treatment steps. Natural gas often contains sulfur compounds that poison catalysts used in downstream processes. Accordingly, one of the first steps

is to remove these sulfur compounds by hydrodesulfurization. *See* EX1014 at 186; EX1027 at 79-80 (“This step will prevent damage to (i.e., deactivation of) the nickel or platinum catalysts in downstream processes.”); *see also* EX1001, 1:24-29 (discussing prior art including desulfurization of natural gas); EX1042 at 3; EX1013, 7:46-47. The next step is reforming. Reforming is a general term referring to the reaction of hydrocarbons like methane with water to produce a mixture of carbon monoxide and hydrogen. EX1027 at 74. For natural gas or methane reforming, a catalyst promotes a reaction between methane and oxygen and/or steam to produce a mixture of carbon monoxide and hydrogen, i.e., syngas, and takes place inside a reaction vessel referred to as a reformer. Reforming may occur stepwise in different stages. For example, depending on the front-end configuration, there may be an initial reforming stage called prereforming, which does some reforming upstream of the main reforming reaction. *See* EX1042 at 9; EX1014 at 98; EX1027 at 83; EX1038 at 17 (“prereforming is well established in the ammonia and methanol industries, for hydrogen production in refineries, and for the production of synthesis gas for a variety of other chemicals”).

45. The primary ways in which methane is converted into hydrogen involve reaction with either steam (steam reforming), oxygen (partial oxidation) or both in sequence (autothermal reforming or ATR). EX1001, 1:30-38 (discussing prior art including ATR); EX1023 at 216 (SMR, POX, and ATR “are mature

technologies today for the conversion of natural gas to hydrogen”); EX1028, 3:42-44 (“It is well-known to produce a synthesis gas by either ATR or SMR (steam methane reforming) followed by subsequent removal of part of the CO₂”); EX1011 ¶ 7 (same); *see generally* EX1043. In steam methane reforming (SMR) a catalyst bed is heated by an external burner to elevate the temperature and “crack” the methane to produce a syngas: $CH_4 + H_2O \leftrightarrow 3 H_2 + CO$. Partial oxidation (POX) typically is used for heavier hydrocarbons and is a chemical reaction where partial combustion of a feedstock generates syngas. *See* EX1014 at 107-08. Both SMR and POX require a furnace to generate heat resulting in flue gases that are a significant source of CO₂ emissions.

46. ATR combines partial oxidation with steam reforming and was initially developed in the late 1950s for ammonia and methanol synthesis, and then further developed in the 1990s by Haldor Topsoe.¹ EX1027 at 91; EX1028, 4:14-42 (“Autothermal reforming (ATR) is a technology commonly used for the production of syngas”); EX1030, 1:29-30 (“It is well-known to use autothermal reforming (ATR) for producing synthesis gas from e.g., natural gas....”). ATR involves a simultaneous combination of partial oxidation and steam reforming reactions enabled by adding oxygen, or oxygen-enriched air. Atmospheric air

¹ In 2022, Haldor Topsoe A/S changed its name to Topsoe A/S.

contains about 21% oxygen, so ATRs are commonly fed oxygen or air enriched with oxygen to increase the oxygen concentration. *See* EX1041 at 1 (explaining oxygen feedstocks for ATRs vary from air to pure oxygen); EX1037 at 214 (describing ATR as using “oxygen or oxygen-enriched air”); EX1042 at 10. In the context of ammonia synthesis, which requires nitrogen, oxygen is often obtained synergistically when nitrogen is separated from atmospheric air, which also results in concentrating oxygen.

47. Inside the ATR reactor, the oxygen partially oxidizes the methane, producing heat and syngas. *See, e.g., id.* (“the oxygen from the cryogenic ASU optionally including VPSA, is mixed with steam prior to entering the ATR or CPO. The steam serves to dilute the oxygen to the required levels in the ATR”); EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen); EX1038 at 64 (“[ATR] has in the past been used with air or enriched air for production of NH₃ synthesis gas”); *id.* (“[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, especially for very large capacities.”); EX1043 at 4 (“ATR plants can operate at a lower [S/C] ratio, often about 1.35”). Subsequently, steam reforming in the presence of a catalyst occurs,

with steam reacting with the remaining methane to yield additional hydrogen and carbon monoxide: $2 CH_4 + H_2O + \frac{1}{2} O_2 \leftrightarrow 5 H_2 + 2 CO$. This dual reaction mechanism is notable for efficient hydrogen production while simultaneously generating the heat necessary for the endothermic steam reforming reaction. As the ATR process does not require external heat input, there is no CO₂ generated from combustion. *See e.g.*, EX1015 at 143.

48. ATR processes have been used for the production of syngas for ammonia synthesis. *See, e.g.*, EX1042 at 10; EX1038 at 64. ATRs are particularly suited for large-scale processes and benefit from being able to operate at low S/C. *See* EX1043 at 4. And it was well-known in the art that prereforming allows the downstream reformer to operate at a lower S/C. EX1027 at 83; EX1028, 3:3-12. Low S/C operation saves energy and has lower operating costs due to savings in process steam consumption, as well as higher syngas throughput. *See e.g.*, EX1040, 3:1-2, 3:41-43 (describing ammonia synthesis process using ATR with S/C as low as 0.1).

49. Prereformers are commonly used with ATRs. *See, e.g.*, EX1028, 5:20-21 (“it is preferred that the syngas section comprises a prereformer combined with an autothermal reformer (ATR)”). A prereformer does a small amount of reforming and is situated upstream of the main reformer. EX1027 at 83. ATRs are commonly used alone with prereformers, and with primary reformers in various

configurations, including configurations with a prereformer followed by an ATR without a primary reformer therebetween. *See e.g.*, EX1032, 2:53-54 (“Prereforming of hydrocarbons upstream of the SMR or ATR is a well known process.”); EX1014 at 102 (“reforming reaction could be performed without a tubular reformer by autothermal catalytic reforming...using oxygen or oxygen enriched air”); EX1014 at 98, 212 (discussing prereforming); EX1042 at 3-6.

50. After methane reforming, the resulting syngas is a mixture of hydrogen and carbon monoxide, as well as carbon dioxide, unconverted methane, and unconverted steam. To increase the hydrogen concentration, the syngas is subjected to a water-gas shift reaction (shift). *See* EX1027 at 152 (“Carbon Monoxide Shift reaction is one of the traditional purification steps that will still be found in many ammonia plants.”); EX1042 at 10. Reaction of carbon monoxide with steam over a catalyst produces additional hydrogen and carbon dioxide: $CO + H_2O \leftrightarrow CO_2 + H_2$. The shift reaction is typically performed in steps—a high temperature shift followed by a low temperature shift.

51. After the shift reaction, the syngas contains more hydrogen but also contains CO_2 and excess steam as well as impurities such as residual CO and CH_4 . These impurities are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst. CO_2 is removed in well-established chemical or physical absorption process. *See generally* EX1033; EX1042 at 11.

The '168 Patent acknowledges that CO₂ removal steps were already known in the prior art. EX1001, 1:24-29.

52. While CO₂ can be vented into the atmosphere, it can instead be captured and used to synthesize other chemicals (e.g., urea) or sequestered. *See* EX1023 at 106 (“The majority of the early carbon capture and storage projects...could involve the capture of the CO₂ impurities in natural gas, the capture of CO₂ produced at electric plants, or the capture of CO₂ at ammonia and synfuels plants.”). Thus, removing carbon dioxide from syngas before it is combusted or used as a fuel is one well-known approach to reducing carbon emissions. *See, e.g.*, EX1025, 2:18-34 (explaining use of hydrogen depleted of CO₂ as a fuel reduces CO₂ emissions by 75%); EX1009, 5:42-51 (explaining that use of hydrogen depleted of CO₂ as a fuel substantially reduced emissions); EX1032, 6:3-7 (describing use of a portion of a syngas stream as fuel to reduce emissions); EX1034, 2:6-41, 3:22-33 (describing removal of CO₂ from syngas prior to combustion in order to reduce emissions). This approach is sometimes referred to as pre-combustion carbon capture. *See* EX1015 at 17 (“The technology required for pre-combustion capture is widely applied in fertilizer manufacturing and in hydrogen production. Although the initial fuel conversion steps of pre-combustion are more elaborate and costly, the higher concentrations of CO₂ in the gas stream and the higher pressure make the separation easier.”); EX1024 at 4 (describing

syngas process using ATR and pre-combustion carbon capture); EX1033 at 109.

The processing of natural gas into a synthesis gas using reforming, shift reactions, and CO₂ removal as a strategy to capture CO₂ pre-combustion to create a low-emission fuel has been explored in the literature for decades. *See e.g.*, EX1015 at 37, 121, 142; EX1035 at 2-10 (“The basic steps in [precombustion decarbonization] have been used for more than 50 years and are considered to be mature.”). Notably, precombustion strategies have been in use commercially for many years, including with respect to syngas production, as well as for production of methanol, synfuels, ammonia, and hydrogen. EX1035 at 5. It also was well-known in the art that one advantage of pre-combustion carbon capture was the generation of a hydrogen-rich fuel that could be used synergistically in other processes. *Id.*

53. After the bulk removal of the CO and CO₂ through shift reaction and CO₂ removal units, the small amounts of these compounds, and other impurities, remaining in the syngas are removed as they can poison the ammonia synthesis catalyst. Commercial technologies for final gas purification include methanation, liquid nitrogen wash, pressure swing adsorption, membrane separation, etc. Choices of different technologies depend on many factors, including the type of technology employed for syngas production, the energy consumption and

availability of the purification technologies. *See generally* EX1036; EX1014, Section 4.3.2; EX1027 at 172; EX1042 at 11.

54. Methanation converts residual CO and CO₂, which poison the ammonia synthesis catalysts, into CH₄, which is not a poison. *See e.g.*, EX1038 at 67. Methanation as a step in producing syngas intended for ammonia synthesis was well-known in the art. *See, e.g.*, EX1013, 5:48-55; EX1040, 1:38-41; EX1036 at 18; EX1027 at 173-76. Indeed, the '168 Patent acknowledges that methanation in this context was already disclosed in the prior art. EX1001, 1:24-29.

55. Purification steps, like pressure swing adsorption, are used to remove impurities from the syngas. *See* EX1038 at 67. Purification as a step in producing syngas intended for ammonia synthesis was well-known in the art. *See, e.g.* EX1036 at 16; EX1027 at 177-79. The result is a high purity hydrogen stream that can be used, with the addition of nitrogen, to synthesize ammonia. *Id.* As with methanation, these were well-known processes so the '168 Patent acknowledges that purifications steps were already disclosed in the prior art. EX1001, 1:63-65; EX1013, 9:10-17; EX1040, 5:19-22.

56. The CO₂-depleted synthesis gas is hydrogen-rich and can be used for a variety of purposes. The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production. It was well-known in the art that the hydrogen from syngas after CO₂ removal is a

desirable fuel source, as its combustion results in decreased carbon emissions. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). The art also appreciated that syngas could be produced in excess and that upstream steps could be modulated by using excess syngas as fuel. *See e.g.*, EX1037 at 307 (“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 use of excess H₂ as fuel for reformers, heaters, and steam generation). Splitting of the syngas stream and directing as fuel towards various devices (e.g., furnaces, including turbines and boilers) that operate via combustion to generate thermal energy are well known in the art. *See* EX1015 at 121. Syngas streams also are split for the coproduction of ammonia and methanol. For ammonia and methanol coproduction, the syngas is split into two streams, one processed for ammonia production and the other for methanol production. A POSA would have understood that, when an original stream is “split” the resulting two or more streams would necessarily have the same composition as one another and as the original stream, unless the streams are split by virtue of a treatment step. Further, the two or more streams continue to have the

same composition as one another unless and until one or more is subject to a treatment step that alters the composition.

57. In the case of ammonia, the resulting purified hydrogen is then ready for use in the ammonia synthesis loop. The synthesis of ammonia requires nitrogen (N_2) along with H_2 in a proportion of 1 to 3. Typically, N_2 is separated from atmospheric air in an air separation unit (ASU) given air is almost 80% N_2 . Additionally, purge and tail gases formed as part of syngas production and ammonia synthesis are a well-known feed to conversion sections. EX1016 at 3-4 (“To maintain the synthesis reaction in forward direction same [sic] amount of inert gases are required to be purged from the synthesis loop at a constant rate because the inert gases disturb[] the reaction equilibrium.... Formerly this Purge Gas was partially used in Reformer as fuel in conjunction with associated gas and the remaining gas was vented to atmosphere causing problem of pollution. Since the purge gas is rich in hydrogen and methane content[,] it was conceived that this gas may be used in reformer as feed on 3rd January 1986, purge gas was fed to reformer alongwith [sic] feed gas.... No significant change was observed in any process parameters.”).

VIII. Overview of the '168 Patent

58. The '168 Patent is titled “process for the synthesis of ammonia with low emissions of CO_2 in atmosphere.” It is assigned to Casale, was filed as a PCT

application on January 31, 2018, and claims priority to EP17156256 filed on February 15, 2017, and EP17195305 filed October 6, 2017. EX1001 at 1.

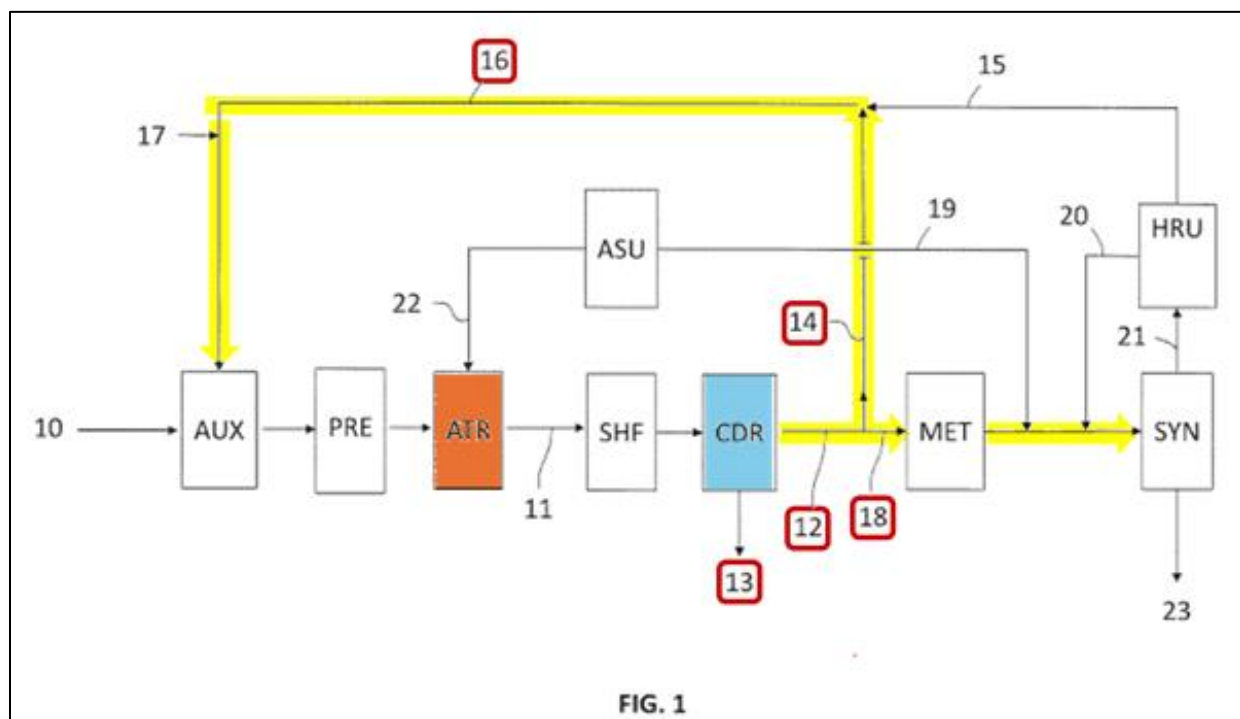
59. The '168 Patent purports to describe “[p]rocess for the synthesis of ammonia from natural gas.” EX1001, Abstract. The stated “object of the invention” is an ammonia synthesis process with reduced CO₂ emissions. *Id.* 2:6-12. The '168 Patent explains that reduced CO₂ emissions are obtained by removing CO₂ from syngas and then splitting that CO₂-depleted syngas stream so it can be used as fuel. *Id.* 3:5-35. Combustion of H₂ from such a CO₂-depleted syngas has reduced amounts of CO₂ and thus reduces emissions. *Id.* As explained by the '168 Patent, this is purportedly different than the prior art, which uses natural gas as a fuel (3:26-29) or “only allocating as fuel any purge streams derived from purification processes and containing methane.” *Id.* 3:13-15.

60. Specifically, '168 Patent relates to a method of ammonia synthesis including the steps of combining a charge of desulfurized natural gas with oxygen or oxygen-enriched air and steam to make a syngas using an autothermal reformer downstream from a prereformer, treating the resulting syngas with a shift reaction to convert CO to CO₂, and subsequent separation of CO₂ from the syngas. The resultant CO₂-depleted syngas stream is then split into a first and a second stream having the same composition. The first stream is used as fuel fraction and is fed as fuel to at least one furnace. The '168 Patent explains that a furnace is “an apparatus

chosen from among a steam reformer or a charge preheater or a steam generator or a steam superheater.... which operate by means of combustion, [and] are identified by the term ‘fired heater’.” *Id.* 4:47-51. These furnaces also include those “for the production and/or superheating of steam” (*id.* 7:41-43), which also include steam generators and gas turbines for generating electricity (*id.* 7:44-53).

61. The second stream is intended for the synthesis of ammonia.² An annotated version of Figure 1 from the ’168 Patent is provided below. The ATR (orange) refers to autothermal reforming. The CDR (blue) refers to the CO₂ removal section (decarbonation), which produces CO₂-depleted syngas (12) (highlighted in yellow) and CO₂ (13). EX1001, 13:9-11. A portion of the syngas stream (12) is split to provide a fuel fraction (14) (highlighted in yellow) that is used as fuel in a furnace (AUX) in the front end via a fuel line (16) while the rest of the syngas stream (18) is treated in a methanator (MET). *Id.* 13:14-17.

² Counsel has informed me that the second stream being “intended for” the synthesis of ammonia does not have “patentable weight,” meaning that prior art references need not teach the second stream actually being used to synthesize ammonia to anticipate and/or render obvious the ’168 Patent. For thoroughness and clarity, however, I have included the step of ammonia synthesis in my analysis. Regardless and as shown herein, use of syngas to synthesize ammonia is well known in the art.



A. Specification

62. The specification describes that the features claimed by the '168 Patent were already well-known in the prior art. *Id.* 1:10 (PRIOR ART). According to the '168 Patent at least the following was well-known in the art prior to the '168 Patent:

- Converting natural gas into a synthesis gas and using that synthesis gas to synthesize ammonia. *Id.* 1:12-23.
- Process steps such as desulfurization of natural gas, reforming, shift reaction, removal of CO₂ from syngas, and methanation. *Id.* 1:24-29.
- Reforming processes such as steam reforming and autothermal reforming (ATR), including ATR preceded by a furnace. *Id.* 1:30-39.
- CO₂ emissions from plants was a problem. *Id.* 1:40-53.

- Using CO₂-depleted streams as fuel reduces CO₂ emissions, such as purge flows from PSA units that have reduced CO₂ content. *Id.* 1:63-67; 3:13-16.

63. The basic process claimed in the '168 Patent includes the following steps:

- **Conversion of Natural Gas into Syngas:** Converting a charge of desulfurized natural gas and steam with oxygen or oxygen-enriched air into a synthesis gas containing H₂, CO, and CO₂ in a conversion section;
- **Conversion Section:** The conversion section including a prereformer followed by an ATR without a primary reformer therebetween;
- **Shift Reaction:** Treating the syngas using a shift reaction to convert CO to CO₂;
- **CO₂ Removal:** Subsequently removing CO₂ to obtain a CO₂-depleted syngas and a CO₂-rich gaseous flow;
- **Splitting CO₂-Depleted Syngas:** Separating a part of the CO₂-depleted syngas as a fuel fraction by splitting the CO₂-depleted syngas into at least a first stream (e.g., the fuel fraction) and a second stream;
- **Fuel Fraction:** Feeding the fuel fraction to at least one furnace;
- **Same Composition:** Wherein the first stream and the second stream have the same composition; and
- **Ammonia Synthesis:** Wherein the second stream is process gas intended for the synthesis of ammonia.

64. **Conversion of Natural Gas into Syngas:** The specification describes conversion of desulfurized natural gas to generate a stream comprising “essentially hydrogen, carbon monoxide CO and carbon dioxide CO₂” as being known in the prior art. *Id.* 1:24-26 (discussing prior art). While it is not specified explicitly that

the desulfurized natural gas is combined with steam and oxygen or oxygen-enriched air, this was well known in the art. *See supra* ¶¶ 43-44. The specification does not describe this step as being different in any manner from what is described with respect to the prior art. *See e.g.*, EX1001, 12:66-13:2.

65. **Conversion Section:** The specification describes various conversion sections for the reforming process, including steam reformers, primary reformers, secondary reformers, and ATRs as being known in the art. *Id.* 1:36-39 (discussing prior art). The specification describes different configurations for the conversion section as alternatives, such as “primary reforming followed by secondary reforming”; “ATR, optionally preceded by a preliminary reforming (pre-reforming)”; “ATR without preliminary reforming” (*id.* 6:15-24); catalytic and non-catalytic partial oxidation (*id.* 5:48-54).

66. **Shift Reaction:** The specification describes a shift reaction to convert CO to CO₂ as being known in the art. *Id.* 1:26-28 (discussing prior art). The description of the invention does not differ from the summary of the prior art. *See e.g., id.* 13:3-8.

67. **CO₂ Removal:** The specification describes removal of CO₂ as being known in the art. *Id.* 1:28 (discussing prior art). The description of the invention does not differ from the summary of the prior art. *See e.g., id.* 13:3-8.

68. **Splitting CO₂-Depleted Syngas:** The specification describes removal of a portion of the CO₂-depleted syngas for use as fuel as being known in the art. *Id.* 1:63-2:2 (discussing prior art). The specification, however, characterizes the prior art as only disclosing such a fuel stream as being a purge stream. *Id.* 3:13-16 (“The prior art, on the other hand, teaches only allocating as fuel any purge streams derived from purification processes and containing methane.”).

69. **Fuel Fraction:** The specification describes removal of a CO₂-depleted stream for use as a fuel (*Id.* 1:63-2:2 (discussing prior art)) and preheating a stream for use in an ATR with a furnace (*Id.* 1:37-39), including a gas turbine (*Id.* 7:43-55). Accordingly, aside from the nature of the fuel fraction, the description of the invention does not differ from the description of the prior art.

70. **Same Composition:** The specification describes “deliberately allocating a part of the process flow to the fuel fraction, the fuel fraction being directly separated from the process flow and having the same composition. *Id.* 3:10-13. This reflects the unremarkable concept that splitting a stream results in streams with the same composition.

71. **Ammonia Synthesis:** The specification describes use of a CO₂-depleted syngas stream for synthesis of ammonia as being known in the prior art. *Id.* 1:12-17. Accordingly, the specification only differs with respect to this element insofar as the stream intended for synthesis of ammonia is only a “second stream”

of the CO₂-depleted syngas stream, meaning that not all of the CO₂-depleted syngas stream is used for ammonia synthesis. *See e.g., id.* 2:55-63.

B. Original Prosecution

72. The application that would issue as the '168 Patent, Patent Application No. 16/485,695 (the '695 application), was filed on August 13, 2019. EX1001, at cover. Prosecution of the '695 application was short. *See generally* EX1002. In the only office action issued during prosecution that rejected claims over the prior art, the Examiner rejected all pending claims as being unpatentable over *Reddy* and *Ostuni*. *Id.* at 48-50. In response, Patent Owner argued that the key feature distinguishing the claims from the prior art was splitting a CO₂-depleted syngas stream for use as fuel in a furnace. *Id.* at 39-41. Based on those arguments, the Examiner issued a notice of allowance that reiterated Patent Owner's arguments as the reasons for allowance.

C. Supplemental Examination and Reexamination

73. Patent Owner filed a request for supplemental examination on February 16, 2023, with a corrected request received on April 26, 2023. EX1003 at 524. The supplemental examination request identified prior art including *Licht* and *Blumenfeld* (EP 1,648,817). *Id.* at 869. The USPTO issued a supplemental examination certificate on May 11, 2023, finding that some of the prior art raised a

substantial new question of patentability, and the Patent Office ordered reexamination. *Id.* at 354.

74. The substantial new question of patentability was found, in part because of the teachings of *Licht* and *Blumenfeld*. *Licht* was cited as teaching “steam-hydrocarbon reforming with reduced carbon dioxide emissions wherein a portion of the hydrogen-containing product gas is fed to the reformer furnace (col. 5, lines 27-56). *Id.* at 359. *Blumenfeld* was cited as teaching “a process of producing hydrogen from a methane-containing gas wherein CO₂ depleted synthesis gas is separated by pressure swing adsorption into a product gas stream and a waste stream and the waste stream is fed to the combustion chamber of the reformer (Claim 1, Figure 1).” *Id.* at 359-60.

75. In response to the Office Action that issued because of the substantial new question of patentability, Patent Owner amended independent claim 1 to require that the conversion section “includ[e] an autothermal reformer downstream from a prereformer and without a primary reformer therebetween.” *Id.* at 295. Patent Owner argued that this amendment distinguished the prior art raised during reexamination and conceded that this was a “narrowing amendment” made to address the newly cited prior art. *Id.* at 302. Patent Owner argued that *Licht* does not disclose an ATR and, even if *Licht* disclosed an ATR, it did not disclose one preceded by a prereformer without a primary reformer therebetween. *Id.* at 303-05.

Further, Patent Owner argued that *Licht* did not disclose “said fuel fraction [being] fed as fuel to at least one furnace.” *Id.* at 305. These amendments and arguments obtained allowance. *Id.* at 249 (“The following is a statement of reasons for the indication of patentable subject matter: The claims, as amended, require an autothermal reformer downstream from a prereformer and without a primary reformer therebetween which arrangement is not taught by the cited prior art.”). Accordingly, the claim element added by amendment (namely, the prereformer followed by an ATR without a primary reformer therebetween) was cited as distinguishing the prior art and not the argued element (namely, the fuel fraction fed as fuel to at least one furnace).

76. The Examiner issued a reexamination certificate on July 16, 2024. *Id.* at 1.

77. While both *Licht* and *Blumenfeld* disclose splitting a CO₂-depleted syngas stream for use as fuel in a furnace, neither explicitly discloses a prereformer followed by an ATR without a primary reformer therebetween as claimed in the amendment made during reexamination. However, conversion sections with prereformers followed by ATRs without primary reformers therebetween were well known in the art when the ’168 Patent was filed. *See supra* Section VII. The Examiner did not conduct a search for prior art concerning this sort of ATR

configuration or have the benefit of evaluating any such prior art during reexamination.

78. The Examiner did not consider that *Licht* could be modified to remove the primary reformer. In fact, Patent Owner argued that modifying *Licht* to remove the reformer furnace would result in the disclosed process not operating as intended. EX1003 at 641. However, it is well known in the art to preheat feed for an ATR, including by a furnace, without a primary reformer. *See supra* Section VII.

D. Comparison of references to prior art discussed during prosecution

79. I have been asked to review the examination history of the '168 Patent, and to compare the prior art grounds presented herein to those considered in rejections by the Examiner during the examination of the '168 Patent. As I describe below, my opinion is that the references considered herein are not cumulative of the prior art considered by the Examiner during examination.

80. I have relied on *Licht* (EX1009) as a base (or primary) reference. *Licht* was considered by the Examiner during the reexamination of the '168 Patent. However, *Licht* was not considered in view of the state of the art and other references known in the art. For example, *Licht* was not considered in the context

of whether a POSA would have combined it with references disclosing use of ATRs without primary reformers.

81. *Licht*, alone, discloses substantially all of claim 1 of the '168 Patent. Further, *Licht*, in combination with prior art references not considered during prosecution or supplemental examination of the '168 Patent, discloses all of the elements of the challenged claims. A POSA would have considered *Licht* in combination with other prior art references. *Licht* would have been understood by a POSA to be modifiable, in contrast with Patent Owner's characterization during prosecution and supplemental examination.

E. Challenged Claims

82. I understand that the '168 Patent was subject to supplemental examination and *ex parte* reexamination, and that the claims were amended in that process. EX1003 at 1. Claims 1-11 and 17-19 are challenged in the Petition and claim 1 is the only independent claim. The challenged claims set forth below. Some of the claim elements have been further sub-divided for ease of reference.

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

Claim Element	Claim Language
	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.
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.

Claim Element	Claim Language
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.

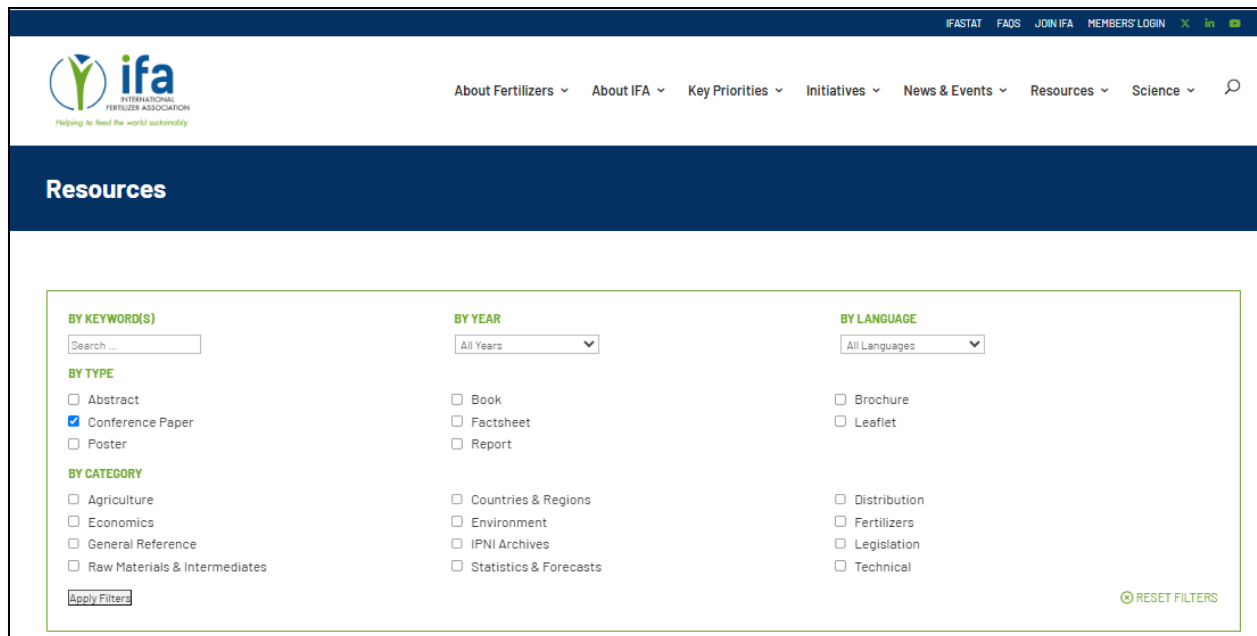
IX. Overview of the Prior Art

A. 2007 IFA (EX1006)

83. 2007 IFA are the published slides presentation by Svend Erik Nielsen entitled “Future Energy Efficiency and CO₂ Reduction Potential” that was

presented to attendees of the International Fertilizer Association's 2007 conference on March 13, 2007.

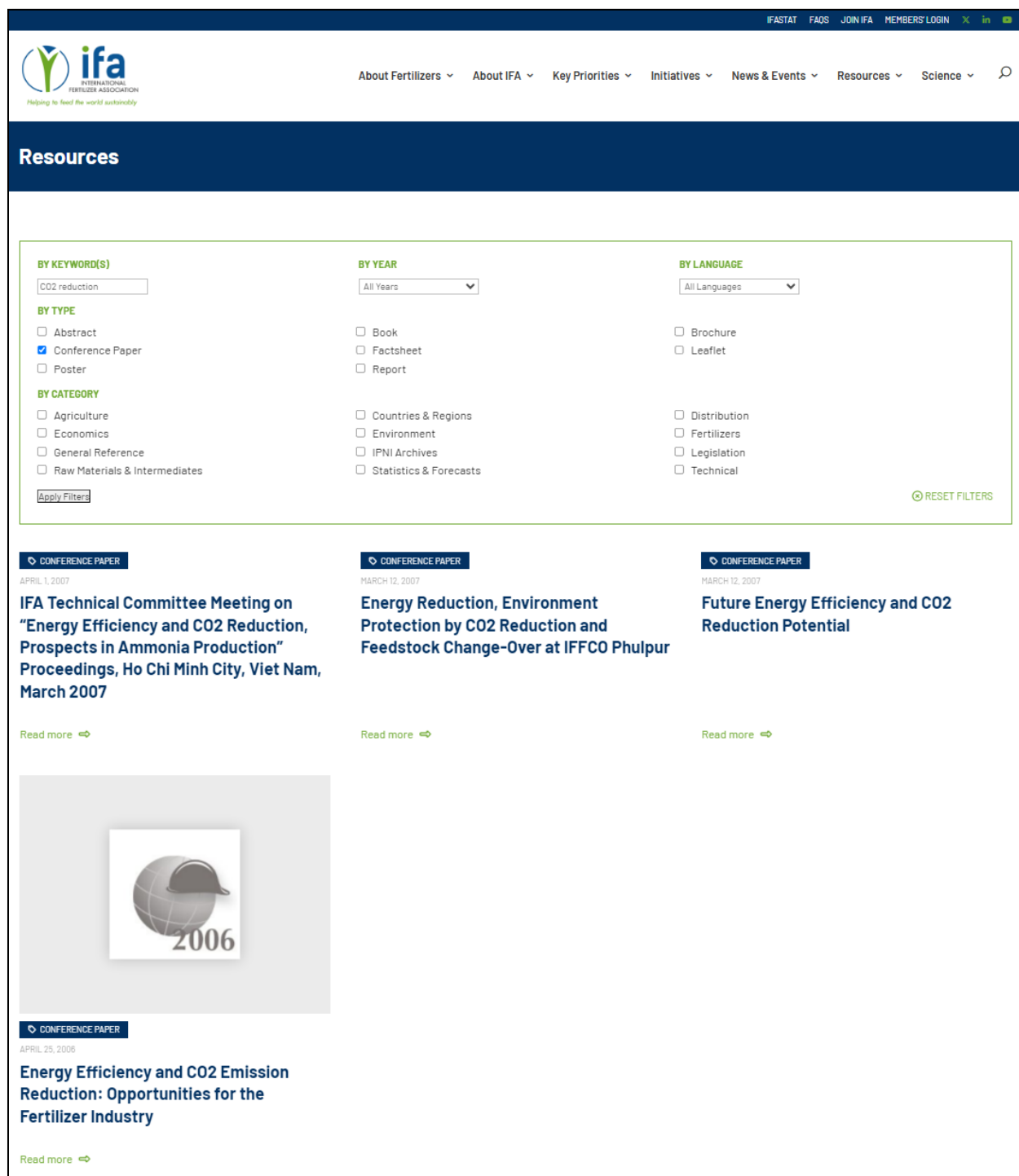
84. The slides were published and made available to the interested public through the IFA's website, which includes searchable page for IFA resources: <https://www.fertilizer.org/resources/>. A screen shot showing this search functionality is below.



85. I searched the IFA resources webpage for “ammonia” or “CO₂ reduction” under “Conference Paper.” The first page of the results returned for this search included both *2007 IFA*, as well as the proceedings that include all slides from the meeting, “IFA Technical Committee Meeting on ‘Energy Efficiency and CO₂ Reduction, Prospects in Ammonia Production’ Proceedings, Ho Chi Minh City, Viet Nam, March 2007” (*see* EX1017 in which *2007 IFA* beginning on page

83 of the pdf). Shown below is a screen shot of these search results (see

https://www.fertilizer.org/resources?_sf_s=CO2%20reduction&_sft_resource_type=conference-paper):



86. Shown below is a screen shot of the IFA website where the conference proceedings are downloadable (PDF file named

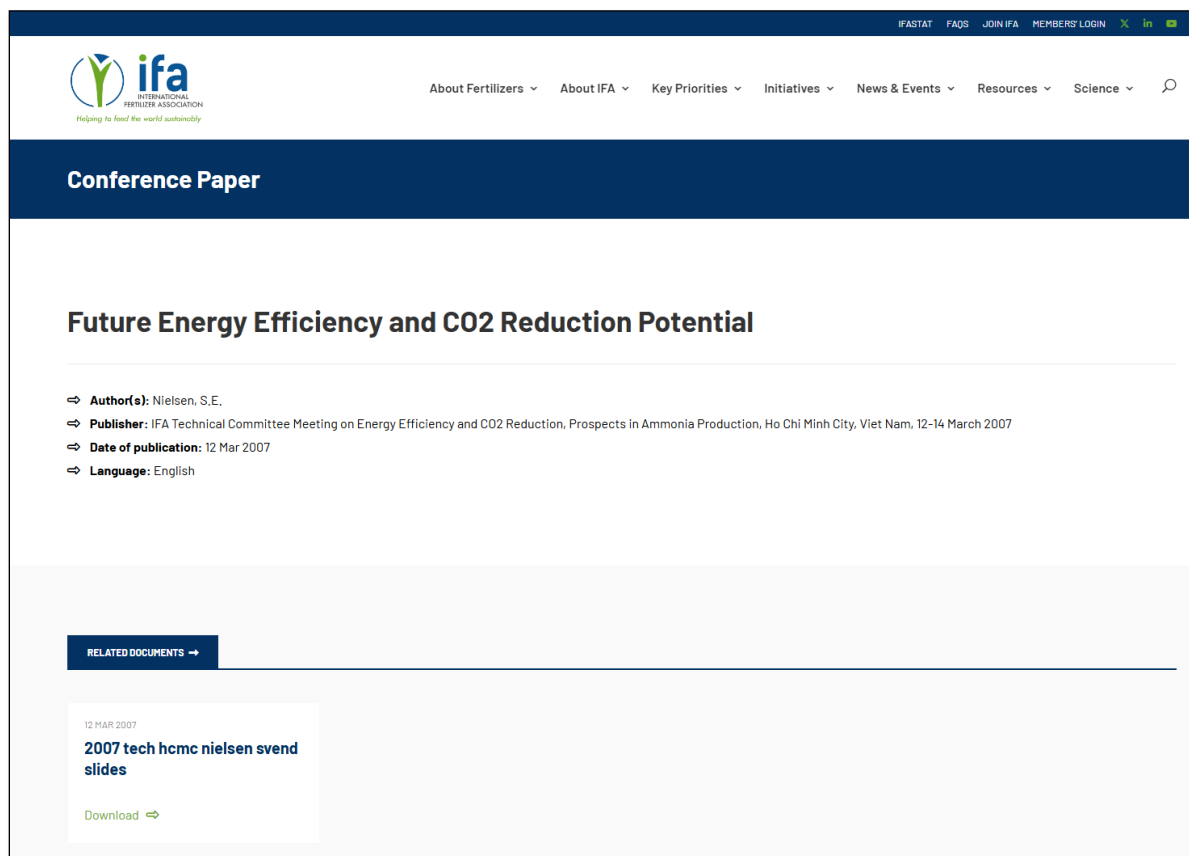
“2007_tech_hcmc_all_slides.pdf” (EX2017)) at

<https://www.fertilizer.org/resource/ifa-technical-committee-meeting-on-energy-efficiency-and-co2-reduction-prospects-in-ammonia-production-proceedings-ho-chi-minh-city-viet-nam-march-2007/>.



87. Each presenter’s slides from this meeting, including 2007 IFA, were also made available separately. As shown below, 2007 IFA was made publicly accessible via download as a PDF file named “2007_tech_hcmc_nielsen_svend_slides.pdf” though the IFA resources website at

<https://www.fertilizer.org/resource/future-energy-efficiency-and-co2-reduction-potential/>.



88. To confirm the public availability of *2007 IFA*, I checked the Internet Archive’s Wayback Machine to understand whether *2007 IFA* was available on the IFA’s website before the earliest priority date of the ’168 Patent. The Wayback Machine captured the URL of the IFA webpage for the “2007 IFA Technical Meeting” on March 10, 2010 that included a link to download *2007 IFA*. EX1019. The Wayback Machine, however, did not archive the linked PDF of *2007 IFA*.

89. Thus, to confirm that *2007 IFA* was publicly accessible before the earliest priority date of the '168 Patent, I investigated whether *2007 IFA* had been cited in publicly available prior art publications. I found that *2007 IFA* was cited in P. Lako, "Energy conservation potential of the nitrogen fertilizer industry" dated March 2009 and published by the Energy Research Center of the Netherlands (ECN). EX1020. The Lako paper is currently downloadable from the TNO³ Repository at <https://repository.tno.nl/SingleDoc?find=UID%20bcba288b-2253-4bbc-b390-43c01faa5d42>. Using the Wayback Machine, I confirmed that the Lako paper was publicly available prior to the effective filing date of the '168 patent. *See* EX1020 (Internet Archive Declaration and the Lako paper).

90. The Lako paper cites *2007 IFA* as "Nielsen 2007a" and provides the following citation:

Nielsen, S.E. (2007a): *Future Energy Efficiency and CO₂ Reduction Potential*. IFA 2007 Technical Committee Meeting - Workshop on Energy Efficiency and CO₂ Reduction Prospects in Ammonia Production, 12-14 March 2007, Ho Chi Minh City, Viet Nam.

EX1020 at 44.

³ The TNO is a research organization of the Netherlands. *See* <https://www.tno.nl/en/about-tno/>. In 2018, the Energy Research Center of the Netherlands (ECN) merged with TNO. *See* <https://www.tno.nl/en/about-tno/organisation/units/energy-transition/ecn-tno/>.

91. The Lako paper also refers specifically to data from 2007 IFA. As shown below (EX1020 at 26) Lako reports values reproduced from 2007 IFA (EX1006 at 2):

Yara's D and E plants (Sluiskil) with a capacity of 1,750 t NH₃/d, and approx. 2,000 t NH₃/d, respectively, are in the first quartile of the corresponding class of the benchmark (green 'triangles' in Figure 3.6). This ranking appears to be confirmed by the fact that Ammonia plants that have been revamped exhibit a net energy efficiency of at best 7.1 Gcal/t NH₃ ≈ 29.7 GJ/t NH₃, according to (Nielsen, 2007a).

The net energy efficiency in BAT - Best Available Technique - reforming processes ranges from 28 to 31 GJ/t NH₃ (Balken, 2007). When using process waste heat in a gas heated reformer, the process itself will not produce enough steam to drive all the compressors. Part of the power demand may be imported, whereby the energy use may be reduced to the practical minimum of 27 GJ/t NH₃ (EFMA, 2000a). Around 1998, the reference was 28.3 GJ/t NH₃ (Kongshaug, 1998). Advanced processes - KBR's KAAPplus™, Uhde's Dual Pressure³, and Haldor Topsoe's Leading Concept - show efficiencies of 27.5 to 29 GJ per tonne of NH₃ (Table 3.5).

Table 3.5 Energy use of state-of-the-art Ammonia plants with credit for steam or utilities

Company Process	BAT 1998 Autothermal reforming?	Lurgi MEGAMMONIA ^x	Haldor Topsoe Low Energy Ammonia	ICI Leading Concept	KBR KAAPplus™	ICI Dual Pressure	KBR Dual Pressure
Size of plant [mtpd]		Up to 4,000	650-2,050	450	Up to 1,850	230-1,350	500-3,300
Plants worldwide		-	60	N/A	>200	3	14
Feed [GJ/t NH ₃]	25.0						
Fuel [GJ/t NH ₃]	5.6						
Steam [GJ/t NH ₃]	-2.5						
Electricity [GJ/t NH ₃]	0.2						
Energy use [GJ/t NH ₃]	28.3	29.5	27.6-28.8	31.1	27.9 ^a	29.3	27.6-30.1 ^b
[Gcal/t NH ₃]	6.76		6.6-6.89	7.2	6.673 ^a	7.0	6.6-7.2 ^b

a Based on an Ammonia/Urea plant in China with a capacity of 450,000 t/a of ammonia (Yexin, 2004).
b A net efficiency of 7.1-7.2 Gcal/t NH₃ ≈ 29.7-30.1 GJ/t NH₃, in the Middle East corresponds to 6.95-7.05 Gcal/t NH₃ ≈ 29.1-29.5 GJ/t NH₃ in Western Europe with approx. 10°C lower cooling water temperatures (Humphrys, 2005; Nielsen, 2007a).
Sources: Nielsen, 2007a; Balken, 2007; Lippmann and Frisse, 2004; Yexin, 2004; Okuzumi et al., 2001; Christensen, 2001; Humphrys, 2005; Uhde, 2006; Kongshaug, 1998; DoE, 2005; Internet Sources 8-9.

Historical development - ammonia plants

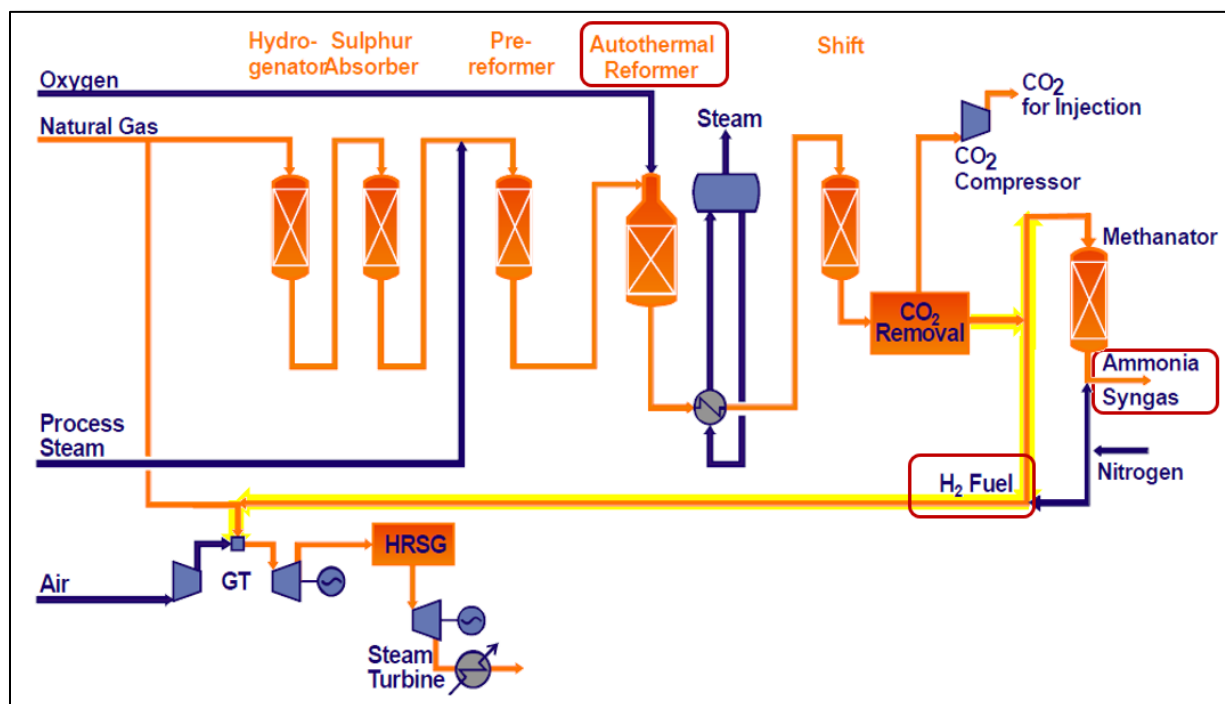
- Plant energy consumption in the early 1980'ies was around 10.5 Gcal/MT NH₃
- In the late 1980'ies, this figure was around 7.75 Gcal/MT NH₃
- Many plants have been revamped, and best current plant is today around 7.1 Gcal/MT NH₃ after revamp
- For new plants, the current state-of-the-art consumption is around 6.6 Gcal/MT NH₃



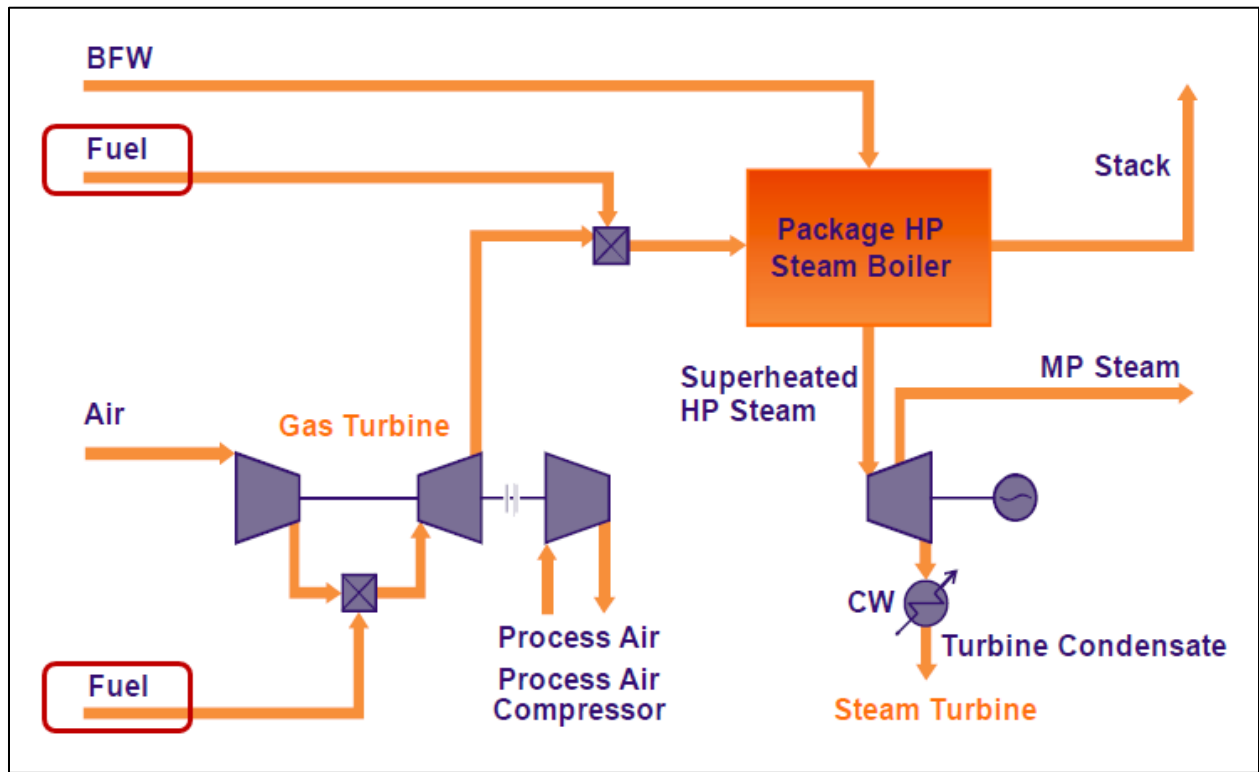
It is clear to me from the Lako paper that the author had access to *2007 IFA*. The Lako paper cites specific values taken directly from *2007 IFA*. Additionally, the Lako paper cites two other presentations and data from the same IFA conference (e.g., Balken, Nielsen, J., Prince, and Williams). Taken together, this confirms that *2007 IFA* was publicly accessible at least as of the publication of the Lako paper in 2007.

92. *2007 IFA* generally relates to reducing CO₂ emissions from the front-end of ammonia synthesis plants. EX1006 at 1. The process strategy disclosed is shown in the annotated figure below and uses desulfurized natural gas combined

with steam in a prereformer followed by an oxygen fed ATR without a primary reformer therebetween, to generate a synthesis gas, followed first by a shift reaction and subsequent CO₂ removal. Directly after CO₂ removal, the syngas is split into two streams. One stream of syngas is used for ammonia synthesis and undergoes methanation in a methanator followed by nitrogen addition. The other stream of syngas is used as fuel (“H₂ fuel”) in an auxiliary furnace of a gas turbine (GT) and heat recovery steam generator (HRSG). *Id.* at 9.



93. More details about the use of this fuel stream is provided as shown below. *Id.* at 8. The fuel is combusted to drive a turbine, heat is recovered for steam generation, and fuel also is combusted to generate steam from boiler feedwater (BFW).



B. *Rytter* (EX1008)

94. *Rytter* is U.S. Pat. No. 6,809,121 and is titled “Cogeneration of methanol and electrical power”. *Rytter* was filed on September 23, 2002, and issued on October 26, 2004. EX1008, at 1. *Rytter* was originally filed as an international (PCT) application on November 20, 2000, which was published on May 25, 2001. The filing of *Rytter*, as well as the filing and publication of its PCT application, thus predate the claimed priority date of the ’168 Patent.

95. *Rytter* discloses a process for the production of methanol, dimethyl ether (DME), and/or other oxygenates thereof, along with an H₂-rich stream and

CO₂ rich stream. EX1008, 1:1-9. A POSA would have understood that an H₂-rich stream (syngas), as produced in *Rytter*, is an intermediate product for production of ammonia, methanol, dimethyl ether, and/or other oxygenates thereof. Methods of producing syngas for ammonia, methanol, and DME synthesis utilize identical, similar, and overlapping methods, devices, and concepts. Further, *Rytter* discloses an H₂-containing stream being used for both ammonia synthesis and as a fuel. *Id.* 4:41-57; 7:26. *Rytter* discloses providing natural gas, steam, and oxygen to a reforming plant that includes an autothermal reformer. *Id.* 4:14-29; 6:40-56. *Rytter* discloses the gas stream being treated by a prereformer then by an ATR without a primary reformer therebetween. *Id.* 4:30-33 (“Particularly the autothermic reformer will be fed natural gas as natural gas as a lower hydrocarbon gas, and it may beneficially be a prereformed natural gas”). The synthesis gas of *Rytter* is then treated with a shift reaction to remove carbon monoxide. *Id.* 5:48-55 (“The first stream consisting of hydrogen (H₂), carbon monoxide (CO) and carbon dioxide (CO₂) is fed to a shift reactor, which may also be fed further steam. In the shift reactor a shift reaction is carried out under shift reaction conditions, and as a product stream from the shift reactor a stream mainly consisting of carbon dioxide and hydrogen gas is withdrawn, which is passed to a separation plant 6.”). The CO-depleted synthesis gas stream is then treated to remove CO₂. *Id.* 4:6-9 (“passing the shifted gas stream substantially comprising H₂ and CO₂ to a separation plant and

subjecting it to a separation therein into two streams substantially comprising H₂ and CO₂ respectively”). *Rytter* also suggests that “[t]he surplus of the hydrogen stream which is separated in the separator 6, may be passed to hydrogen power station 7 which is supplied with air for the combustion of the hydrogen gas to steam producing power plant.” *Id.* 6:8-12.

96. An annotated version of the Figure from *Rytter* is provided below. As shown below natural gas is prereformed in pretreatment plant 1. *Id.* 5:37-42. Then methane is reformed in reformer 2 (orange), preferably an ATR, and the resulting syngas is fed to a shift reactor 5. *Id.* 5:37-55. Next the syngas is fed to a separation plant 6 (blue) where CO₂ and hydrogen are separated. *Id.* 5:55-56. The hydrogen from the separation plant 6 is split for different uses, including as feed for methanol synthesis plant 4 (*id.* 5:60-63), as a fuel in a hydrogen power station 7 (*id.* 6:8-12), as fuel for the reforming plant (*id.* at claim 11), and feed for “other uses” such as ammonia synthesis (*id.* 4:47-50).

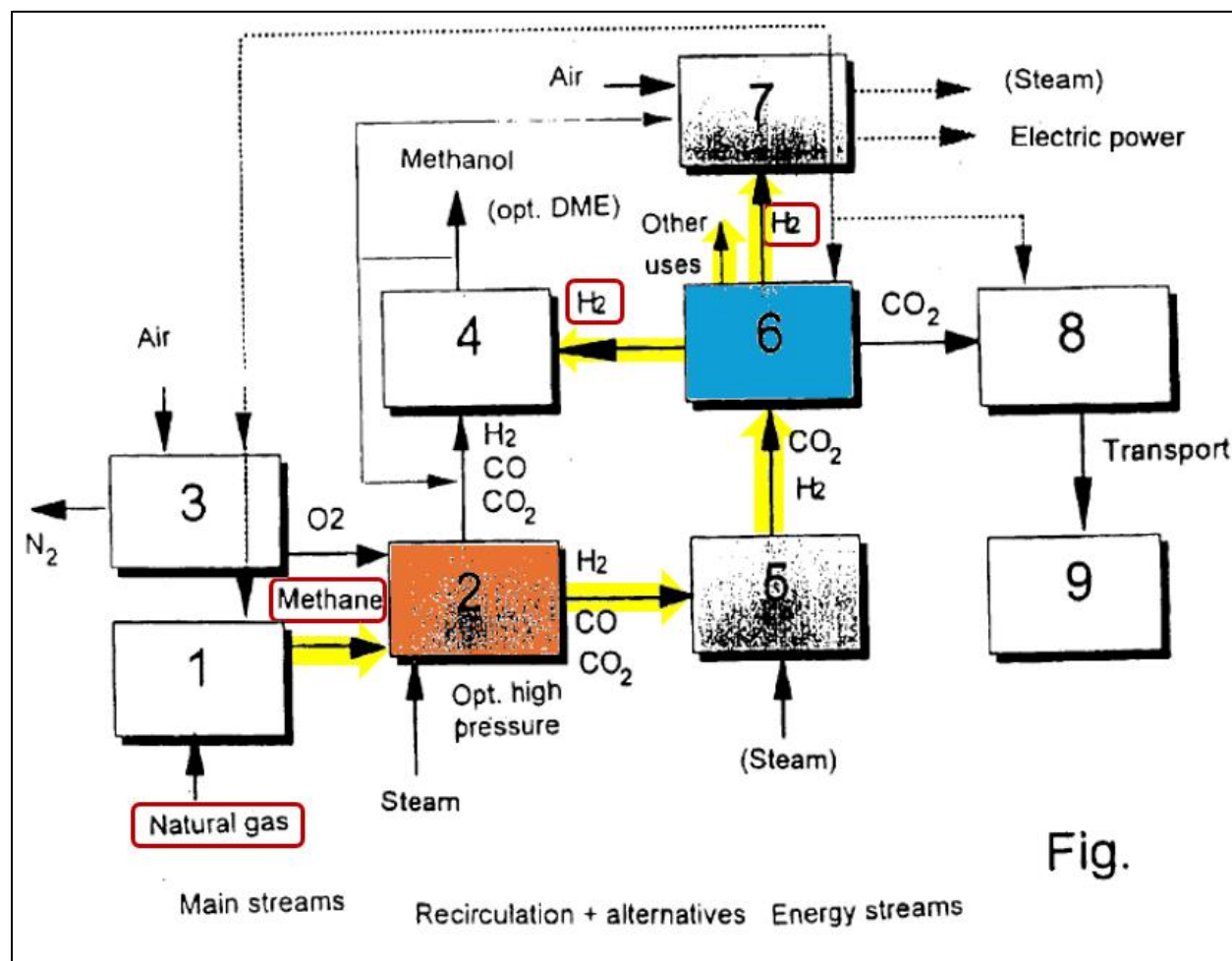


Fig.

97. *Rytter* further discloses the fuel fraction being between 1% and 40% and between 10% and 30% of the total amount of the carbon dioxide-depleted synthesis gas. *Id.* 4:10-14 (“[A]t least 5% of substantially H₂-containing stream being fed—optionally as partial streams—to the methanol synthesis reactor(s), and the remaining part of the H₂-containing stream to one or more heat-generating station(s) or to other H₂-requiring processes.”). Because *Rytter* discloses “at least” 5% of the syngas stream being used for synthesis, the amount of the syngas used for synthesis can be anywhere from 5% to 100%. The “remaining” part of the

syngas, which is disclosed as being used for fuel, is therefore anywhere from 0% to 95% of the syngas. Therefore, *Rytter* discloses the fuel fraction being between 1% and 40% and between 10% and 30%.

C. *Terrien* (EX1007)

98. *Terrien* is U.S. Pat. Pub. No. 2012/0292574 and is titled “Process for the production of hydrogen and carbon dioxide.” EX1007 at 1. *Terrien* was filed on June 27, 2011, and published on November 22, 2012. *Terrien* was originally filed as provisional application on May 18, 2011. The filing of *Terrien*, as well as its publication, predates the claimed priority date of the ’168 Patent.

99. Generally, *Terrien* relates to a process for hydrogen synthesis that increases recovery of hydrogen and capture of the carbon dioxide in the syngas, thus decreasing environmental impacts. EX1007, Abstract. *Terrien* describes a hydrogen plant, as such a POSA would have understood that *Terrien* could be used as the front-end process for making other products such as ammonia.

100. *Terrien* teaches a feed of natural gas treated with a variety of steps, including a conversion step (*Id.* ¶¶ 73-75), a subsequent shift reaction to convert carbon monoxide to carbon dioxide (*Id.* ¶ 76), and subsequent removal of carbon dioxide (*Id.* ¶¶ 77-78). *Terrien* explains that the hydrogen generation may be carried out utilizing any feed gas producing unit, such as an ATR, that produces a gas mixture that contains at least hydrogen, CO, and CO₂. *Id.* ¶¶ 19, 95. In

connection, *Terrien* describes a feed gas stream produced by a producing unit including an ATR. *Id.* ¶¶18, 95. And *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 unit generically and ATR specifically. *Id.* ¶ 73.

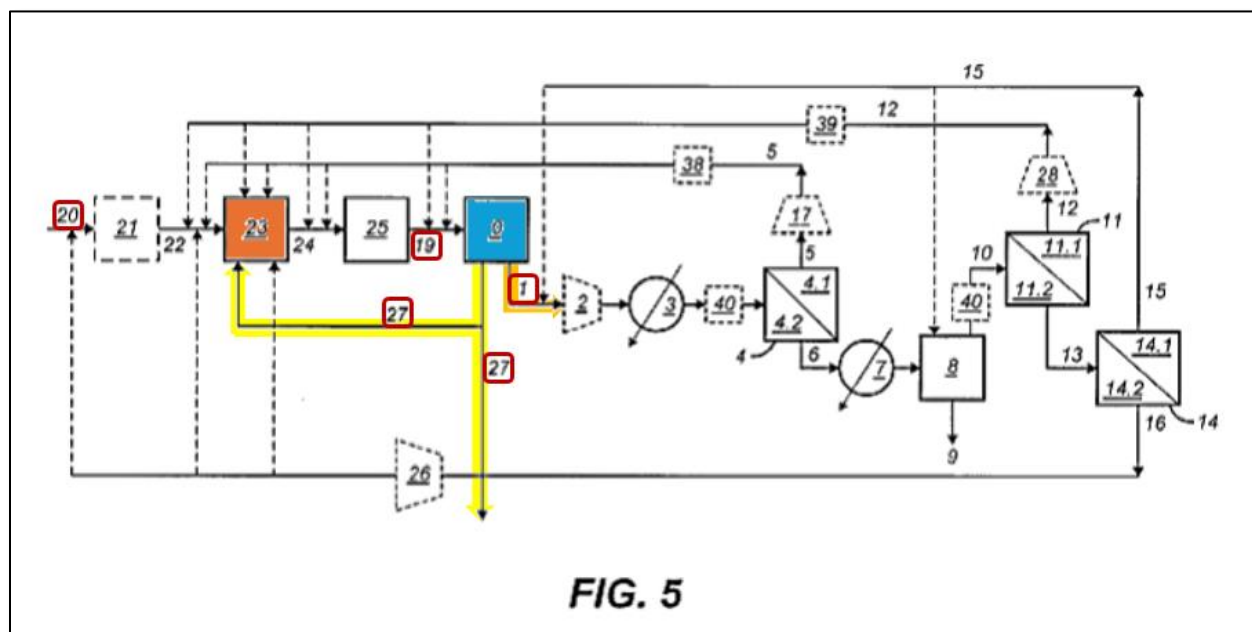
101. As *Terrien*’s stated goal is reduced CO₂ emissions, it describes a number of approaches for removing CO₂, including use of carbon dioxide separation units and hydrogen selective membranes. In connection, *Terrien* describes using the CO₂ depleted stream as a fuel to boost CO₂ capture such that “it is possible to eliminate or reduce the carbon dioxide emissions.” EX1007 ¶¶ 86, 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 CO₂-depleted syngas contain potentially less than 1000 ppm by volume of CO₂.

102. *Terrien* describes purification to provide hydrogen rich streams that can be used in downstream processes. *Id.* ¶¶ 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.”). For example, pressure swing adsorption is “used to recover and purify hydrogen.” *Id.* ¶ 20. The result are two

different gas streams—one is tail gas process stream that is further purified in successive steps and the other is an H₂-rich (CO₂-depleted) stream. *Id.*

103. *Terrien* discloses splitting the H₂-rich (CO₂-depleted) stream for various uses, including for use as fuel. *Id.* ¶¶ 78, 86, 93. With reference to Figure 5 (annotated below), *Terrien* shows and describes the H₂ product stream (27) as having “a portion” used for H₂ fuel. *Id.* ¶¶ 35, 78. The portion of the stream (27) used for fuel firing is shown to be split from the original stream without treatment steps. These streams, being split from one another without an intervening treatment, necessarily have the same composition.

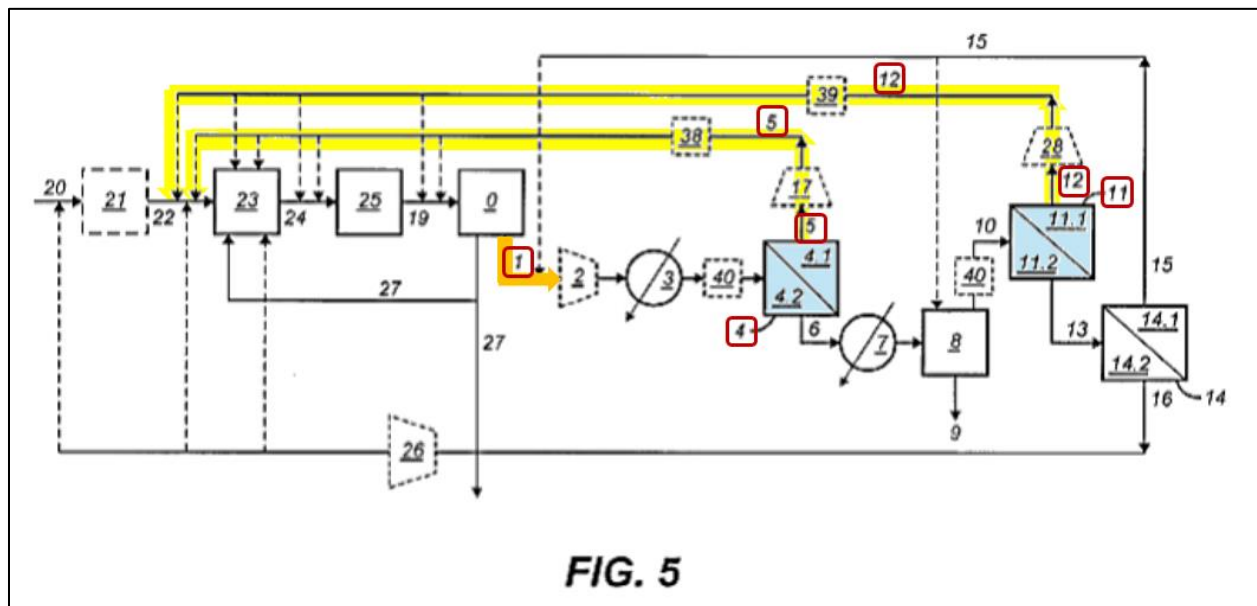
104. Referring to Figure 5, *Terrien* discloses:



- 20: hydrocarbon feed stream. *Id.* ¶ 74.
- 21: prereformer. *Id.* ¶ 74.

- 23: steam methane reformer (orange). *Id.* ¶ 75 (“the present invention is not meant to be limited by the steam methane reformer (23) or the process for carrying out the reaction in the steam methane reformer unit (23)”).
- 25: water gas shift reactor. *Id.* ¶ 76.
- 19: feed gas from a reformer unit/water gas shift unit...an ATR unit. *Id.* ¶ 73.
- 0: “‘process unit’ (blue) refers to any unit which includes a purification step that results in the production of a hydrogen rich fraction that can be used downstream.” *Id.* ¶ 18. Pressure swing adsorption (PSA) unit. *Id.* ¶ 78. The PSA “results in a hydrogen product (27) and process stream (1) purged from the process unit (0) that contains “at least methane, carbon monoxide, **carbon dioxide**, water, and any unrecovered hydrogen.” *Id.* ¶ 21.
- 27: hydrogen product stream or syngas (yellow) from which a portion is split and recycled for use as fuel in the reformer. *Id.* ¶ 78.

105. *Terrien* discloses other hydrogen-rich streams that are split for use as fuel. For example, with reference to Figure 5:



- 1: process stream from the process unit (0) that contains “at least methane, carbon monoxide, carbon dioxide, water, and any unrecovered *hydrogen*.” *Id.* ¶¶ 21, 78.
- 4: hydrogen selective membrane separation unit. *Id.* ¶ 78.
- 5: hydrogen rich permeate stream, which can be recycled as fuel. ¶ *Id.* ¶¶ 78, 79. “A ‘hydrogen rich’ permeate stream will generally contain greater than or equal to 40% hydrogen, preferably up to or greater than 90% hydrogen.” *Id.* ¶ 29.
- 11: second hydrogen selective membrane separation unit. *Id.* ¶ 78.
- 12: second hydrogen rich permeate stream, which can be used as a fuel. *Id.* ¶¶ 78, 79, 86.

Terrien explains that streams resulting from gas separation processes, like streams (5) and (12), are “hydrogen rich” containing 40-90% H₂. *Id.* ¶ 29. As such, the “hydrogen rich permeate stream (5)” and “hydrogen rich permeate stream (12) can have the same composition too. *See id.* ¶¶ 25, 41; FIG. 5.

106. While *Terrien* does not explicitly disclose the second stream of H₂-rich syngas being used to synthesize ammonia, this is not a limiting element of the claims. *See supra* note 2. Regardless, 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 supra* ¶¶ 37-41.

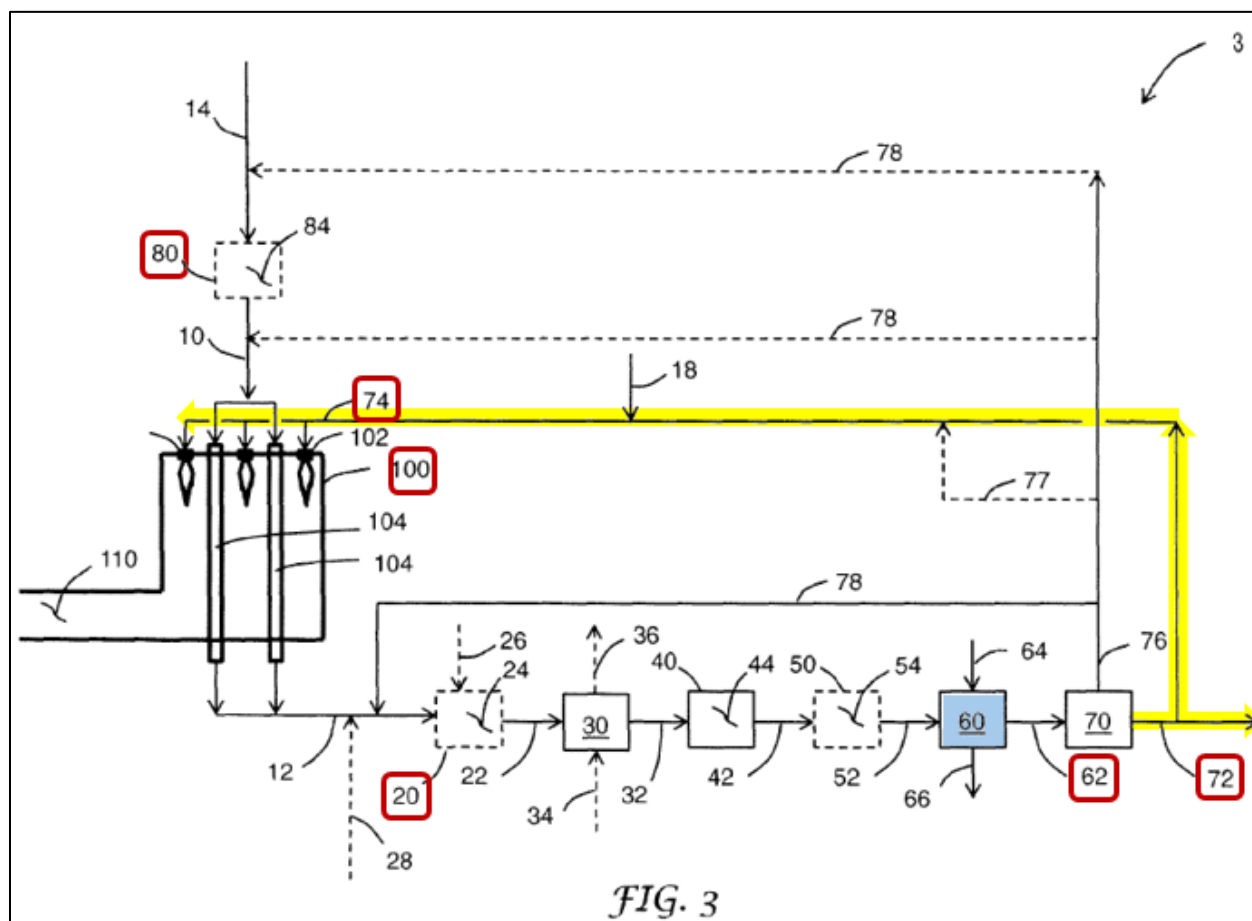
D. *Licht* (EX1009)

107. *Licht* is U.S. Pat. No. 8,137,422 and is titled “Steam-hydrocarbon reforming with reduced carbon dioxide emissions.” EX1009 at 1. *Licht* was filed June 3, 2009, and issued March 20, 2012. The filing and issuance of *Licht* predates the claimed priority date of the ’168 Patent.

108. *Licht* relates to a process for hydrogen with reduced carbon emissions including use of a portion of the hydrogen as fuel in a reformer. *Id.* at Abstract. *Licht* explains that “[t]here is growing pressure to reduce carbon dioxide emissions from industrial processes” and that hydrogen production plants are a significant source of carbon dioxide. *Id.* 1:6-10. *Licht* discloses a process by which natural gas is treated to reduce carbon dioxide emissions. *Id.* 3:20-24. *Licht* further discloses mixing a hydrocarbon stream with steam. *Id.* 1:33-35. The resulting stream is directed towards a conversion section including a prereformer and at least one reformer, including an oxygen secondary reformer. *Id.* 4:56-5:58 (“FIG. 2 and FIG. 3 show additional optional features, for example a so-called prereformer 80, an oxygen secondary reformer 20”). Oxygen secondary reformers are functionally equivalent to ATRs as both are fed oxygen and partial oxidation reactions occur in a combustion zone before passing through a catalyst bed where reforming reactions occur, except insofar as ATRs function without primary reforming, whereas oxygen secondary reformers are typically preceded by a primary reformer. *See*

EX1009, 7:17-37; EX1043 at 1-2. The syngas is treated in a shift reaction to convert CO to CO₂. *Id.* 3:61-67 (“The reformat stream is passed to shift reactor 40. The process further comprises reacting carbon monoxide and steam in the reformat stream 32 in the presence of a shift catalyst 44 at a temperature ranging from 190° C. to 500° C. and a pressure ranging from 2 to 50 atmospheres to form a second process stream 42 comprising carbon dioxide, hydrogen, carbon monoxide and methane.”). *Licht* discloses subsequently removing CO₂ from the syngas. *Id.* 4:13-16 (“The process further comprises scrubbing the second process stream 42 with a wash stream 64 to form a carbon dioxide-depleted stream 62 and a carbon dioxide-loaded wash stream 66.”). *Licht* discloses, as seen in the annotated Figure 3 from *Licht* below, splitting the CO₂-depleted syngas stream into a first stream—the fuel fraction—and a second stream. *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. As used herein a “divided portion” of a stream is a portion having the same chemical composition as the stream from which it was taken.”). *Licht* further discloses a synthesis gas fuel fraction forming all of the fuel of the furnaces of the conversion section or an amount of natural gas being provided as trim fuel not more than 15% of the total combustion heat. *Id.* 5:27-42

(“The process further comprises combusting a fuel gas 74 comprising a portion of the hydrogen-containing product gas 72, optionally a portion 77 of the by-product gas 76, and optionally a supplementary fuel 18 in the reformer furnace 100 external to the plurality of catalyst-containing reformer tubes 104 to supply energy for reacting methane and steam inside the plurality of catalyst-containing reformer tubes 104. Flue gas 110 is withdrawn from the reformer furnace 100, and because the fuel gas 74 comprises hydrogen in an amount greater than conventional reformer furnaces, the flue gas will contain a reduced amount of carbon dioxide compared to conventional reformer furnaces. 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.”). As *Licht* explains, combusting the fuel fraction supplies energy for the catalytic reaction of the process stream (*id.* 1:60-67) and that this combustion takes place in a furnace external to the reformer (*id.* 5:27-33).



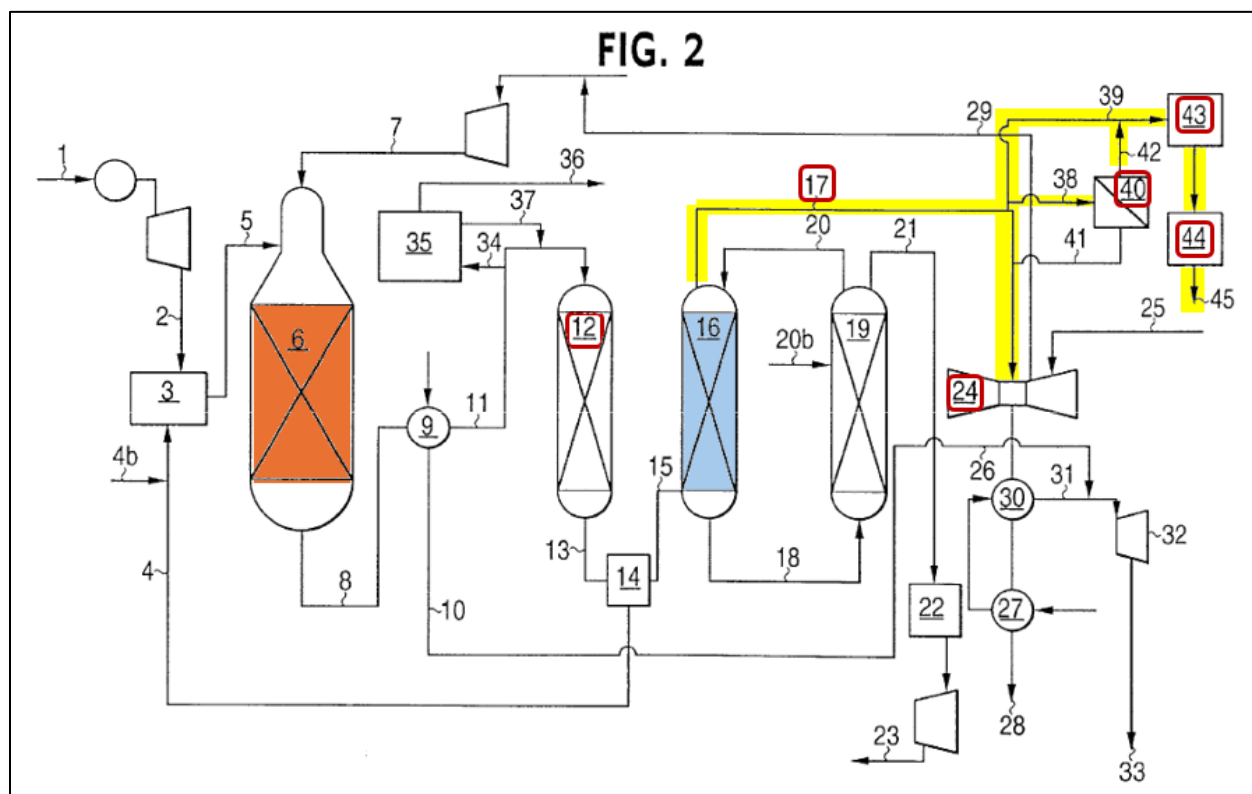
- 80: prereformer. *Id.* 5:56-58.
- 100: reformer furnace. *Id.* 5:27-42.
- 20: oxygen secondary reformer. *Id.* 5:56-58.
- 60: gas scrubber (blue). *Id.* 4:13-21.
- 62: carbon dioxide-depleted syngas stream. *Id.* 4:13-15.
- 70: separator. *Id.* 4:36-45 (e.g., PSA).
- 76: by-product gas comprising methane and carbon monoxide. *Id.*
- 72: hydrogen-containing product syngas (yellow). *Id.*
- 74: fuel syngas with a reduced amount of carbon dioxide. *Id.* 5:34-38.

E. *Fjellhaug* (EX1010)

109. *Fjellhaug* is U.S. Pat. No. 6,505,467 and is titled “Process for generating electric energy, steam and carbon dioxide from hydrocarbon feedstock.” EX1010 at 1. *Fjellhaug* was filed on March 12, 2001, and issued on January 14, 2003. *Fjellhaug* was originally filed as an international (PCT) application on July 13, 1998, which was published on January 20, 2000. The filing of *Fjellhaug*, as well as the filing and publication of its PCT application, predate the claimed priority date of the ’168 Patent.

110. Generally, *Fjellhaug* relates to a process for hydrogen synthesis in which the hydrogen is used to generate CO₂-free electric energy and also production of synthesis gas products such as methanol and ammonia. EX1010, Abstract. As shown in the annotated figure below, *Fjellhaug* discloses providing natural gas to a conversion section. *Id.* 3:60-67 (“Gaseous hydrocarbon feedstock, for instance natural gas, is supplied as stream 1.... The hydrocarbon feed which is at least partly saturated with water is then fed to an ATR unit 6 as stream 5.”). *Fjellhaug* discloses a prereformer followed by a reformer (orange). *Id.* 4:1-2 (“Optionally a pre-reformer 6b may be arranged upstream the ATR unit 6.”). *Fjellhaug* teaches treating the synthesis gas in a shift reaction to remove carbon monoxide. *Id.* 4:14-19. *Fjellhaug* discloses subsequent separation of carbon dioxide from the synthesis gas (blue). *Id.* 4:19-23. The ATR is air driven (*id.* 3:6-7)

but also supplemented with exhaust from the gas turbine to increase O₂ provided to the ATR. *Id.* 3:28-29 (“At least part of the exhaust from the gas turbine can be recycled to the ATR as an oxygen source”. A POSA would have understood that *Fjellhaug* discloses the ATR being supplied with oxygen or oxygen-enriched air, as the ATR is supplied with air and with a supplemental O₂ source, meaning that the air is “oxygen-enriched.” *See supra* ¶ 46. *Fjellhaug* discloses a portion of the CO₂-depleted stream being used as fuel and a portion of the CO₂-depleted stream being directed towards ammonia synthesis. *Id.* 4:34-5:4 (“The gas stream 17 will then be used as fuel for a combined cycle gas turbine 24 As feed for an ammonia synthesis may be drawn from the line 17. One side stream 38 is first fed to a membrane gas separation unit 40 for supplying hydrogen 42 to a line 39 to adjust the H₂:N₂ ratio to 3:1 before this gas mixture is treated in a methanation unit 43 prior to a ammonia synthesis 44 producing ammonia 45.”); 6:4-9.



111. *Fjellhaug* discloses the second stream being process gas for ammonia synthesis after further purification. *Id.* 4:65-5:2 (“One side stream 38 is first fed to a membrane gas separation unit 40 for supplying hydrogen 42 to a line 39 to adjust the $H_2:N_2$ ratio to 3:1 before this gas mixture is treated in a methanation unit 43 prior to a ammonia synthesis 44 producing ammonia 45.”). This further purification step may include a step for methanation of the syngas. *Id.* *Fjellhaug* discloses the separation of the fuel fraction occurring upstream of the methanation step. *Id.* 4:65-5:4; FIG. 2.

F. Price (EX1011)

112. *Price* is U.S. Pat. Pub. No. 2002/0143219 and is titled “Natural gas conversion to hydrocarbons and ammonia”. EX1011 at 1. *Price* was filed on January 25, 2002, and published on October 3, 2002. *Price* is a continuation of an International Application that was originally filed on July 25, 2000. The filing of *Price* thus predates the claimed priority date of the '168 Patent.

113. *Price* discloses a process for production of hydrocarbons and ammonia using a combined Fischer-Tropsch process plant and ammonia synthesis plant. *Id.* ¶ 1. One goal of *Price* is to reduce emissions of CO₂. *Id.* ¶ 21. In *Price*, natural gas is reformed with an ATR, CO₂ is removed from the syngas, H₂ is separated from other gases, and H₂ further purified before use in ammonia synthesis. *See e.g., id.* ¶¶ 55-58.

114. *Price* discloses steam methane reforming and ATR. *See e.g., id.* ¶¶ 53, 56. *Price* discloses conversion of a charge of desulfurized natural gas and describes steam-to-carbon (S/C) ratios of 0.6, 4.0, and 0.9. *Id.* ¶¶ 43, 44, 45, 59. *Price* further discloses producing excess syngas (*id.* ¶¶ 55, 63), splitting a gas stream (*e.g., id.* ¶¶ 57, 59, 64) and using a portion of a hydrogen rich stream for ammonia synthesis (*e.g., id.* ¶¶ 26, 63).

115. *Price* discloses the CO₂-depleted syngas “is cooled and a portion split off and transferred to a pressure swing adsorption (PSA) unit. The resulting H₂

stream is greater than 99% pure.” *Id.* ¶ 45 By disclosing a H₂ stream that is “greater than 99% pure,” *Price* discloses a H₂ stream with a maximum volume of non-H₂ gas of 10000 vppm.

116. *Price* describes a split in the “offgas” from the H₂ recovery unit, which is a H₂ poor stream, rather than a split in the syngas stream that is subsequently used as fuel and/or synthesis. *Id.* ¶ 59. At least a portion of the syngas stream is then used for ammonia synthesis. *See e.g., id.* ¶ 26. Accordingly, *Price* does not explicitly describe a first stream and a second stream having the same composition. Nevertheless, *Price* discloses purification of syngas streams with pressure swing adsorption (PSA), membrane units, or any other known method (*id.* ¶ 39), as well as the syngas stream being subject to further purification prior to ammonia synthesis (*id.* ¶ 55). *Price* also discloses an additional treatment step of methanation. *Id.* ¶ 5 (“Methanation is used as the *final* treatment step.”).

G. *Pinto* (EX1013)

117. *Pinto* is U.S. Pat. No. 4,681,745 and is titled “Ammonia production process”. EX1013 at 1. *Pinto* was filed on May 9, 1985, and issued on July 21, 1987. Thus, *Pinto* predates the claimed priority date of the ’168 Patent.

118. *Pinto* discloses a process by which natural gas is used to produce ammonia. *Id.* 1:5-14. *Pinto* describes desulfurizing natural gas (*id.* 7:50-52), prereforming (*e.g., id.* 1:11-14, 3:4-6; 7:57-59, Fig. 1 “22”), “secondary

catalytically reforming” (*id.* 1:15, 4:53-60; 7:64-8:8, Fig. 1 “30”) with “air enriched with oxygen” up to 50% v/v/ (*id.* 1:53-55). This is further described as occurring in an adiabatic reactor with oxygen enriched air (*id.* 1:51-55, 4:53-60, 7:7-8), which also can be used to describe an ATR. *See, e.g.*, EX1043. As such, *Pinto* describes prereforming (Fig 1 “22”) followed by an ATR (Fig. 1 “30”) with no primary reformer in between. *Pinto* discloses water-gas shift (*id.* 7:29-35), methanation (*id.* 7:35), and purification (*id.* 9:10-17). *Pinto* discloses a CO₂-depleted syngas stream with 1,000 ppmv CO₂ or lower. *Id.* 9:18-22, Table 1. *Pinto* also discloses purge gas recycle. *Id.* 7:2-4, 12:3-8. *Pinto* further discloses a method wherein the quantity of a stream input impacts the output of a step. *Id.* 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.”); *Id.* 6:48-54 (“The conventional sequence of high temperature and low temperature shift can be used, or a single shift stage gas described above. In the single stage the inlet steam to-gas volume ratio can be at least 0.8 which, with suit able temperature control, enables the outlet CO content to be low enough (up to 0.5% w/v on a dry basis) for final removal by methanation.”); *Id.* 10:26-36 (“The temperature and rate of feed of air

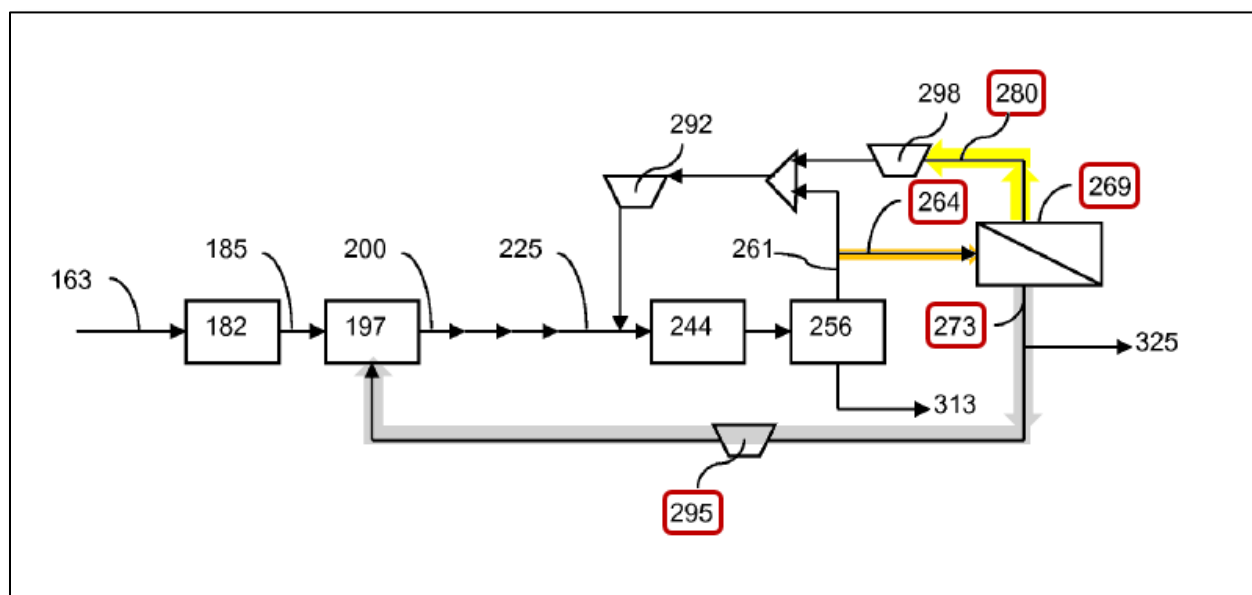
are chosen so that the gas leaving 130 contains nitrogen in excess of what can react later with hydrogen to produce ammonia. It also contains methane to an extent that would normally be regarded as excessive in ammonia synthesis gas: this is preferred because the feedstock economy due to more complete methane reaction would entail extra energy consumption in compressing air and in removing nitrogen later or, alternatively or additionally, would require higher fuel consumption in furnace 118.”).

H. *Ji* (EX1012)

119. *Ji* is U.S. Pat. No. 8,309,617 and is titled “Recycling methane-rich purge gas to gasifier.” EX1012 at 1. *Ji* was filed on May 21, 2010, and issued on November 13, 2012. *Ji* was originally filed as provisional application on December 31, 2009. The filing of *Ji* thus predates the claimed priority date of the ’168 Patent.

120. *Ji* discloses a process by which natural gas is converted to a syngas that can be utilized as a fuel and as a feedstock for producing ammonia and other products. *Id.* 1:17-24 (“Gasification processes are widely used to convert solid or liquid feedstocks such as coal, petroleum coke and petroleum residue into synthesis gas. Synthesis gas is predominantly composed of hydrogen gas (H₂) and carbon monoxide (CO), and is utilized both as fuel for the production of electricity, as well as a feedstock for producing chemicals such as hydrogen, methanol, ***ammonia***, synthetic natural gas or synthetic transportation oil.”); 2:32-38. *Ji*

explains the process described by Figure 2 (annotated below) “is applicable to a variety of different chemical production processes (as described) that utilize the components of synthesis gas as a feedstock.” *Id.* 5:26-29.



121. *Ji* describes off-gas (261) split to form stream 264 that feeds a membrane separation unit 269. *Id.* 5:50-54. The membrane separation unit (269) separates the stream (264) into a methane-rich purge gas (273) and a hydrogen-rich gas (280). *Id.* 5:56-58. The hydrogen-rich gas (280) is recovered and recycled. *Id.* 5:62-66. The methane-rich purge gas (273) is recycled as process gas, subject to the conversion step in a gasification reactor (197). *Id.* 6:2-8. *Ji* explains that the term “gas” is “synonymous with methane, natural gas, as well as gasoline or any other liquid hydrocarbon fuel.” *Id.* 7:19-22.

X. Basis for Unpatentability

Ground	References	Challenged Claims
1	35 U.S.C. § 102 based on <i>2007 IFA</i> (EX1006)	1, 5, 6, 10
1A	35 U.S.C. § 103 based on <i>2007 IFA</i>	2, 3, 4, 7, 8, 9, 11, 17-19
1B	35 U.S.C. § 103 based on <i>2007 IFA</i> and <i>Rytter</i> (EX1008)	3-4, 8-9
1C	35 U.S.C. § 103 based on <i>2007 IFA</i> and <i>Price</i> (EX1011)	2, 7, 19
1D	35 U.S.C. § 103 based on <i>2007 IFA</i> and <i>Ji</i> (EX1012)	11
1E	35 U.S.C. § 103 based on <i>2007 IFA</i> and <i>Licht</i> (EX1009)	17
2	35 U.S.C. §§ 102/103 based on <i>Rytter</i> (EX1008)	1, 3, 4, 8, 9, 10, 18
2A	35 U.S.C. § 103 based on <i>Rytter</i> and <i>Price</i>	2, 5, 6, 7, 19
2B	35 U.S.C. § 103 based on <i>Rytter</i> and <i>Ji</i>	11
2C	35 U.S.C. § 103 based on <i>Rytter</i> and <i>Licht</i>	17
3	35 U.S.C. § 102: <i>Fjellhaug</i> (EX1010)	1, 2, 5-6, 10, 19
3A	35 U.S.C. § 103: <i>Fjellhaug</i>	3-4, 7, 10
3B	35 U.S.C. § 103: <i>Fjellhaug</i> and <i>Rytter</i>	1, 3-4, 8-10, 18
3C	35 U.S.C. § 103: <i>Fjellhaug</i> , <i>Rytter</i> , and <i>Ji</i>	11
3D	35 U.S.C. § 103: <i>Fjellhaug</i> , <i>Rytter</i> , and <i>Licht</i>	17
4	35 U.S.C. § 102: <i>Terrien</i> (EX1007)	1, 7, 10

Ground	References	Challenged Claims
4A	35 U.S.C. § 103: <i>Terrien</i> and Ordinary Knowledge	1, 3-6, 8-9, 18-19
4B	35 U.S.C. § 103: <i>Terrien</i> and <i>Price</i>	1, 2, 5-7, 19
4C	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Ji</i>	11
4D	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Licht</i>	17
4E	35 U.S.C. § 103: <i>Terrien</i> , <i>Price</i> , and <i>Rytter</i>	3-4, 8-9
5	35 U.S.C. § 103 based on <i>Licht</i> in view of <i>Price</i>	1-10, 17-19
5A	35 U.S.C. § 103 based on <i>Licht</i> in view of <i>Price</i> and <i>Ji</i>	11
5B	35 U.S.C. § 103 based on <i>Licht</i> in view of <i>Price</i> and <i>Rytter</i>	3-4, 8-10

A. Challenged Claims 1-11 and 17-19

1. Claim 1⁴

122. The grounds of invalidity related to claim 1 include: Ground 1, Ground 2, Ground 3, Ground 3B, Ground 4, Ground 4A, and Ground 5. Anticipation and/or obviousness of claim 1 over the cited prior art references and a

⁴ It is my opinion that the preamble, “A process for synthesis of ammonia from natural gas, the process comprising;” is not limiting. To the extent it is limiting, the prior art references discussed disclose synthesis of ammonia.

POSA's knowledge and skill are discussed herein. The elements of claim 1 are separated for ease of understanding.

- a. **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**

123. **2007 IFA EX1006.** *2007 IFA* discloses conversion of a charge of desulfurized natural gas and steam with oxygen into a synthesis gas containing hydrogen, carbon monoxide, and carbon dioxide, the conversion taking place in a conversion section. EX1006 at 9. The natural gas is desulfurized by catalytic hydroprocessing ("hydrogenator" and "sulphur absorber") and the desulfurized natural gas, steam, and oxygen are converted into a syngas in the prereformer and then an ATR and without an intervening primary reformer (i.e., the conversion section). After passing through this conversion section, the synthesis gas stream contains H₂, CO, and CO₂. *Id.*

124. **Rytter EX1008.** *Rytter* discloses conversion of a charge of desulfurized natural gas and steam with oxygen into a synthesis gas containing hydrogen, carbon monoxide, and carbon dioxide, the conversion taking place in a conversion section. EX1008, 1:30-33 ("It is certain that there will exist a significantly increasing hydrogen demand in the refinery industry to remove

sulphur and reduce the contents of aromatics and olefins in the fuels produced.”); *id.* 3:64-67 (“The preparation of a synthesis gas comprising substantially H₂, CO, CO₂ and small amounts of methane in a reformation plant by feeding **lower hydrocarbons and steam** to the reforming plant.”); *id.* 4:14-29 (“Preferabl[y] the reforming plant includes at least one autothermic reformer.... Further, the autothermic reformer may suitably be supplied with **an oxygen containing gas stream, and particularly using substantially pure O₂** as an oxygen containing gas.”); *id.* 5:26-28 (“Further, the integrated plant comprises preferably an air separation plant for the feed of O₂ enriched gas to the reformer.”). *Rytter* discloses the conversion section including a prereformer followed by an ATR without a primary reformer therebetween. *Id.* 4:30-33 (“Particularly the autothermic reformer will be fed natural gas as natural gas as a lower hydrocarbon gas, and it may beneficially be a **prereformed natural gas**.”).

125. **Terrien EX1007.** *Terrien* discloses conversion of a charge of desulfurized natural gas. EX1007 ¶ 74 (explaining the prereformer heats desulfurized natural gas). *Terrien*’s conversion section is disclosed as including various conversion devices including, but not limited to, a prereformer, a steam methane reformer, and an autothermal reformer (ATR). *Id.* ¶¶ 19, 73. While *Terrien* describes the conversion section with reference to a steam methane reformer (23) preceded by a prereformer (21), *Terrien* still contemplates the

conversion section having other known configurations (*id.* ¶¶ 73-74) and specifically notes that “the present invention is not meant to be limited by the steam methane reformer unit (23)” (*id.* ¶ 75). *Terrien* describes a feed gas stream produced by a producing unit including an ATR. *Id.* ¶ 18. *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 unit generically and ATR specifically. *Id.* ¶ 73. Accordingly, a POSA would have understood that *Terrien* describes a conversion section that includes an ATR downstream from a prereformer without a primary reformer in between.

126. To the extent that *Terrien* does not explicitly describe conversion of a charge of desulfurized natural gas with steam and oxygen or oxygen-enriched air, *Terrien* does so inherently by disclosing the use of ATR, which was well-known to be used with steam and oxygen or oxygen-enriched air. *See supra* ¶¶ 46-47. And the '168 Patent acknowledges that the prior art includes use of desulfurized natural gas for reforming. Ex. 1001, 1:24-45.

127. ***Fjellhaug EX1010.*** *Fjellhaug* discloses conversion of a charge of natural gas in a conversion section. EX1010, 3:59-67 (“FIG. 1 shows an example for performing the invention. Gaseous hydrocarbon feedstock, for instance natural gas, is supplied as stream 1. The feedstock is heated and compressed before it passes through a conduit 2 to be supplied to a saturator 3 where the feedstock is

mixed with process water 4 and demineralized make up water supplied through a line 4b. The hydrocarbon feed which is at least partly saturated with water is then fed to an ATR unit 6 as stream 5.”). The conversion section is described as comprising a prereformer followed by an ATR and is shown to not have a primary reformer therebetween. *Id.* 3:67-4:5 (“Optionally a pre-reformer 6 b may be arranged upstream the ATR unit 6 (see FIG. 3). This will give increased flexibility with regard to the hydrocarbon feedstock and an increased content of heavier hydrocarbons can then be accepted.”). The ATR is air driven (*id.* 3:6-7) but also supplemented with additional oxygen from the gas turbine exhaust (*id.* 3:28-29). Exhaust from hydrogen-fired gas turbines consists of nitrogen, water vapor, and oxygen. Accordingly, such exhaust provides additional oxygen. *See Id.* 3:28-29 (“At least part of the exhaust from the gas turbine can be recycled to the ATR as an oxygen source”). To the extent that *Fjellhaug* does not explicitly describe conversion of a charge of desulfurized natural gas with steam and oxygen or oxygen-enriched air, *Fjellhaug* does so inherently by disclosing the use of an ATR, which was well-known to be used with steam and oxygen or oxygen-enriched air. *See supra* ¶¶ 46-47. Likewise, to the extent *Fjellhaug* does not state explicitly that the natural gas is desulfurized, a POSA would have understood that this is inherent, as sulfur compounds are known to damage conversion sections and decrease efficiency of synthesis processes. *See supra* ¶ 44. Moreover, the ’168 Patent

acknowledges that the prior art includes use of desulfurized natural gas for reforming. EX 1001, 1:24-45.

128. ***Licht* EX1009.** *Licht* discloses conversion of a charge of natural gas and steam into a synthesis gas containing hydrogen, CO, and CO₂, the conversion taking place in a conversion section. EX1009, 3:25-36 (“With reference to FIGS. 1-3, the process comprises introducing a process stream 10 comprising steam and at least one hydrocarbon selected from the group consisting of methane, ethane, propane, butane, pentane, and hexane into a plurality of catalyst-containing reformer tubes 104 in a reformer furnace 100 and reacting the at least one hydrocarbon and steam inside the plurality of catalyst-containing reformer tubes 104 at a temperature ranging from 700° C. to 1000° C. and a pressure ranging from 2 to 50 atmospheres to form hydrogen and carbon monoxide in the process stream 10 and withdrawing a reformat stream 12 from the plurality of catalyst-containing reformer tubes 104.”). *Licht* discloses combining the steam and natural gas further with an oxygen-rich stream. *Id.* 7:5-16 (“The process may further comprise introducing an oxygen-rich gas 26 into the reformat stream 12 after withdrawing the reformat stream 12 from the plurality of catalyst-containing reformer tubes 104 to partially oxidize the reformat stream, and reacting the partially oxidized reformat stream 12 in the presence of a reforming catalyst 24 in the secondary reforming reactor 20 under reaction conditions sufficient to form reaction products

comprising carbon monoxide and hydrogen in the reformat stream 22. The oxygen-rich gas 26 may be introduced into the reformat stream 12 before reactor 20 or may be introduced into the reformat stream 12 in reactor 20, for example through a burner.”). While *Licht* does not state explicitly that the natural gas is desulfurized, a POSA would have understood that this is inherent, as sulfur compounds are known to damage conversion sections and decrease efficiency of synthesis processes. *See supra* ¶ 44. Moreover, the ’168 Patent acknowledges that the prior art includes use of desulfurized natural gas for reforming. EX1001, 1:24-45.

129. *Licht* discloses a conversion section comprising a prereformer followed by a primary reformer followed by an oxygen secondary reformer, which is functionally equivalent to an ATR. EX1009, 5:56-58 (“FIG. 2 and FIG. 3 show additional optional features, for example a so-called prereformer 80, an oxygen-fed secondary reformer 20”); *see supra* ¶ 108. While *Licht* does not explicitly disclose omitting the primary reformer, a POSA would have understood that a prereformer and ATR without a primary reformer between them was a well-known configuration for the conversion section. *See supra* ¶¶ 49, 108. A POSA would have understood an oxygen-fed secondary reformer is functionally equivalent to an ATR. *Licht* discloses a primary reformer but contemplates the benefits of sizing the primary reformer smaller. *See id.* 8:35-42 (“The benefit of providing a feed gas

comprising at least one hydrocarbon and reacting the feed gas in the secondary reforming reactor 20 is that the size of the reformer furnace 100 and correspondingly, the plurality of catalyst-containing reformer tubes, will be smaller. One skilled in the art can suitably optimize the size of and amount of feedstock processed in the reformer furnace 100 and the secondary reforming reactor 20. Another benefit is that fuel requirements in the primary reformer are reduced.”). A POSA would have understood that *Licht*’s disclosure of a minimized primary reformer could support removal of the primary reformer altogether. An ATR uses the combination of an SMR and POX, which is similarly utilized by an oxygen-fed secondary reformer. *See supra* ¶ 45.

130. To the extent that *Licht* does not disclose an ATR downstream from a prereformer without a primary reformer therebetween, *Price* remedies this deficiency. EX1011 ¶ 56 (“The reforming section consists of a steam reformer followed by an autothermal reformer.”); *Id.*, Example 2 Figure and 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. *See* EX1001, 6:20 (describing ATR “optionally preceded by a preliminary reforming (pre-reforming).”).

- b. **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**

131. **2007 IFA EX1006.** After passing through the conversion section, *2007 IFA* discloses treatment of the synthesis gas including at least a shift reaction of the CO into CO₂. 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 (i.e., the stream directed to the “ammonia synthesis”) and a CO₂-rich gaseous flow containing the CO₂ separated from the gas (i.e., the stream directed to the “CO₂ compressor”). EX1006 at 9.

132. **Rytter EX1008.** *Rytter* discloses treatment of the synthesis gas in a shift reaction to convert CO to CO₂ and subsequent removal of the CO₂. EX1008, 5:48-55 (“The first stream consisting of hydrogen (H₂), carbon monoxide (CO) and carbon dioxide (CO₂) is fed to a shift reactor, which may also be fed further steam. In the shift reactor a shift reaction is carried out under shift reaction conditions, and as a product stream from the shift reactor a stream mainly consisting of carbon dioxide and hydrogen gas is withdrawn, which is passed to a separation plant 6.”); *Id.* 4:6-9 (“passing the shifted gas stream substantially comprising H₂ and CO₂ to a

separation plant and subjecting it to a separation therein into two streams substantially comprising H₂ and CO₂ respectively.”).

133. ***Terrien* EX1007**. After passing through the conversion section, *Terrien* discloses treating the syngas using a shift reaction to convert carbon monoxide into carbon dioxide. EX1007 ¶ 80 (“With regard to this particular embodiment, the objective is to optimize the use of the recycle stream (5) in order to maximize the conversion of carbon monoxide to carbon dioxide and hydrogen while at the same time maximizing the production of hydrogen product.”). *Terrien* discloses subsequent removal of CO₂. *Id.* ¶ 73 (“The present process is preferably executed in a variety of manners including: A) using one or more prereformers (21), a steam methane reformer (23), a water gas shift reactor (25), a pressure swing adsorption unit (0), a first hydrocarbon selective membrane separation unit (4), a carbon dioxide separation unit (8), a second hydrogen selective membrane separation unit (11) and a carbon dioxide selective membrane separation unit (14) or B) a steam methane reformer (23), a water gas shift reactor (25), a first hydrogen selective membrane separation unit (4), a pressure swing adsorption unit (0), a carbon dioxide separation unit (8), a second hydrogen selective membrane separation unit (11) and a carbon dioxide selective membrane separation unit (14).”). *See also* FIG. 5.

134. ***Fjellhaug EX1010.*** *Fjellhaug* discloses treatment of the synthesis gas in a shift reaction to convert CO to CO₂ and subsequent removal of the CO₂. EX1010, 4:14-23 (“A synthesis gas 8 from the ATR unit 6 is cooled in a boiler (steam generator) 9 before being supplied to a shift converter unit 12 as stream 11. The shift converter unit 12 may comprise two conventional CO-shift reactors, a low temperature (LT) reactor and a high temperature (HT) reactor, or just one single CO-shift reactor. A resulting gas mixture 13 is cooled, condensed water is removed in a unit 14 and a resulting gas mixture is then supplied as stream 15 to a CO₂ absorber 12 from which CO₂ and absorbent is supplied through a conduit 18 to a desorber 19.”).

135. ***Licht EX1009.*** After passing through this conversion section, *Licht* discloses treatment of the synthesis gas including at least a shift reaction of the CO into CO₂. 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 (“The reformat stream is passed to shift reactor 40. The process further comprises reacting carbon monoxide and steam in the reformat stream 32 in the presence of a shift catalyst 44 at a temperature ranging from 190° C. to 500° C. and a pressure ranging from 2 to 50 atmospheres to form a second process stream 42 comprising carbon dioxide, hydrogen, carbon monoxide and

methane.”). *Licht* further discloses treatment of the syngas to remove carbon dioxide after the shift reaction. *Id.* 4:13-16 (“The process further comprises scrubbing the second process stream 42 with a wash stream 64 to form a carbon dioxide-depleted stream 62 and a carbon dioxide-loaded wash stream 66.”). *See* FIG. 3.

- c. **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 ...**

136. **2007 IFA EX1006.** *2007 IFA* discloses separation of a part of the CO₂-depleted synthesis gas as a fuel fraction that is fed as fuel to at least one furnace and a split of the CO₂-depleted synthesis gas into at least a first stream (“H₂ Fuel”) (and a second stream (fed to “methanator”). In *2007 IFA* the arrow leading from the “CO₂ removal step” is directed towards a split, which shows the CO₂-depleted synthesis gas being split into two portions: a first stream (“H₂ Fuel”) and a second stream (fed to “methanator”). EX1006 at 9.

137. According to the ’168 Patent, the fuel is used in a furnace, which is “understood as meaning an apparatus chosen from among...a steam generator...” (EX1001, 2:47-49) and also steam generators and gas turbines for generating

electricity (*id.* 7:44-53). 2007 IFA shows integration of a gas turbine into the process and specifically shows using CO₂-depleted syngas as fuel for both a gas turbine and steam generator. EX1006 at 8. As discussed above, a POSA would have understood that, by definition, a gas turbine operates by means of combustion and therefore includes a “furnace.” *See supra* ¶ 56.

138. 2007 IFA discloses the first stream and the second stream having the same composition. EX1006 at 9. A POSA would have understood from the figure that a split in the stream represents a physical separation of one stream into two stream portions without a chemical change between the two resulting stream portions such that the “H₂ Fuel” stream and the stream directed towards the “methanator” have the same composition. *Id.*

139. First, the two streams are shown to split from the same original stream without any intervening treatment step (e.g., CO₂ removal, a shift reaction). Likewise, the process diagrams in FIGS. 1-4 in the '168 Patent, shows a gas flow, denoted by an arrowed line, splitting into two separate gas flows, denoted by arrowed lines from the original arrowed line, without any intervening treatment step. A POSA would have interpreted these diagrams as showing the two separate gas flows having the same composition as the original gas flow and one another.

140. Second, after treatment of the synthesis gas in a shift reaction and for CO₂ removal, the synthesis gas would be substantially formed of H₂. The syngas

stream, which was formed by combining desulfurized natural gas, steam, and an oxygen source, would, prior to treatment, consist primarily of hydrogen, CO, CO₂, and other trace gases. The shift step would substantially remove the CO. The CO₂ separation would substantially remove the CO₂. A POSA would have understood that, following these steps, the resulting syngas stream would be composed primarily of hydrogen. Therefore, the “H₂ Fuel” stream, which is specified as including H₂, would be the natural result of these steps. Accordingly, the second stream, split from the synthesis gas stream, would also necessarily be composed primarily of H₂.

141. Third, the second stream is directed towards an ammonia synthesis step, along with a nitrogen addition step. The reaction to form ammonia is $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$. Therefore, a POSA would have understood that, for the second stream to react with added nitrogen to form ammonia, it inherently must be formed substantially of H₂.

142. **Rytter EX1008.** *Rytter* discloses separation of a part of the CO₂-depleted synthesis gas by splitting the synthesis gas into a first stream and a second stream, wherein the first stream is fed as a fuel fraction fed to at least one furnace. EX1008, 4:55-57 (“According to a possible embodiment of the invention part of the H₂-containing stream from the separator for the H₂ and CO₂ reformer is supplied as fuel.”); *Id.* 4:10-14 (“[A]t least 5% of substantially H₂-containing

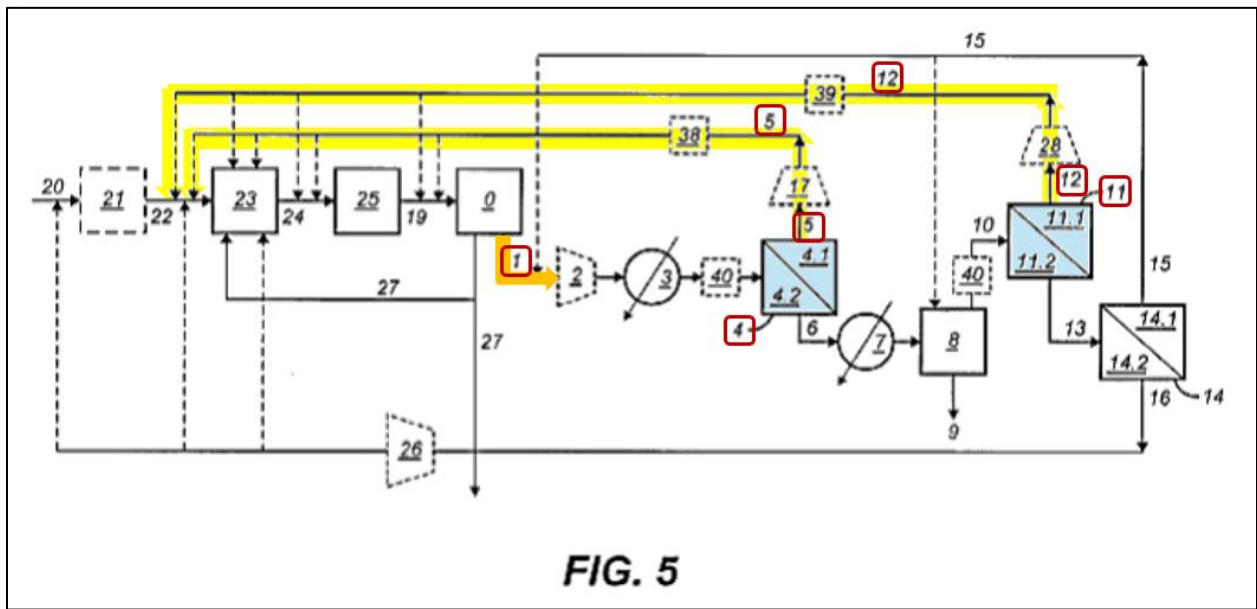
stream being fed—optionally as partial streams—to the methanol synthesis reactor(s), and the remaining part of the H₂-containing stream to one or more heat-generating station(s) or to other H₂-requiring processes.”); *Id.* 6:8-13 (“The surplus of the hydrogen, which is separated in the separator 6, may be passed to a hydrogen power station 7, which is also supplied with air for the combustion of the hydrogen gas to steam producing electrical power.”); *Id.* cl. 11 (“part of the H₂-containing stream from the separator for H₂ and CO₂ is fed to the reforming plant as a fuel”).

143. *Rytter* discloses the first and second streams having the same composition. *Id.* 4:55-57 (“According to a possible embodiment of the invention part of the H₂-containing stream from the separator for the H₂ and CO₂ reformer is supplied as fuel.”); *Id.* 4:10-14 (“[A]t least 5% of substantially H₂-containing stream being fed—optionally as partial streams—to the methanol synthesis reactor(s), and the remaining part of the H₂-containing stream to one or more heat-generating station(s) or to other H₂-requiring processes.”); *Id.* 6:8-13 (“The surplus of the hydrogen, which is separated in the separator 6, may be passed to a hydrogen power station 7, which is also supplied with air for the combustion of the hydrogen gas to steam producing electrical power.”). By referring to “part of the H₂-containing stream” being fed as fuel and “partial streams” being fed to a

synthesis step, *Rytter* discloses a CO₂-depleted synthesis gas stream being split into at least two streams having the same composition.

144. ***Terrien EX1007.*** *Terrien* discloses the separation of a part of the CO₂-depleted syngas stream for use as fuel. EX1007 ¶ 78 (“In this particular embodiment as depicted in FIG. 5, the feed gas (19) is introduced into the process unit (0) (in this particular case a pressure Swing adsorption unit) where it undergoes pressure Swing adsorption to produce a hydrogen product stream (27) and a process st[r]eam (1). While the hydrogen product stream (27) is recovered as product, a portion of this stream (27) can be recycled for use for hydrogen fueling of the steam methane reformer (23).”); *id.* ¶ 35 (“With regard to the additional streams, while the hydrogen product stream (27) is recovered as product, as in the previous embodiments, a portion of this stream (27) can be used for hydrogen fueling of the feed gas producing unit (34).”).

145. Further, *Terrien* discloses splitting numerous H₂-rich streams for use as fuel. The first hydrogen rich permeate stream (5) and the second hydrogen rich permeate stream (12) can be split and recycled as fuel. *Id.* ¶¶ 78, 79, 89. Likewise, the hydrogen product stream (27) is shown and described as having “a portion” used for hydrogen fuel. *Id.* ¶ 35. A “portion” of a stream has the same composition as the original stream and as the other portion(s) of the stream. The portion of the stream (27) used for fuel firing is shown to be split from the original stream



147. *Terrien* discloses numerous steps involving splitting of a H₂ rich stream. Streams having a split include the hydrogen product stream (27), the first hydrogen rich permeate stream (5), and the second hydrogen rich permeate stream (12). The hydrogen product stream (27) is shown and described as having “a portion” used for hydrogen fuel. *Id.* ¶ 35. A “portion” of a stream has the same composition as the original stream and as the other portion(s) of the stream. The portion of the stream (27) used for fuel firing is shown to be split from the original stream without any treatment steps, accordingly, the two streams split from the original stream have the same composition. The first hydrogen rich permeate stream (5) and the second hydrogen rich permeate stream (12) also are split for use in other processes. *Id.* ¶¶ 78, 79, 89. *Terrien* explains that the streams resulting from gas separation processes, like streams (5) and (12), are “hydrogen rich”

containing 40-90% hydrogen. *Id.* ¶ 29. As such, the “hydrogen rich permeate stream (5)” and “hydrogen rich permeate stream (12) can have the same composition. *See id.* ¶¶ 25, 41.

148. *Terrien* discloses the hydrogen-rich stream(s) used as fuel for the conversion section. *See e.g., id.* ¶ 69 (“The first hydrogen rich permeate stream (5) can be recycled after optionally compressing the stream as a supplemental feed for the steam methane reformer (23), the water gas shift reactor (25) or the process unit (0) or it can be recycled as fuel for the steam methane reformer (23).”). 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. *See supra* ¶ 56.

149. ***Fjellhaug EX1010.*** *Fjellhaug* discloses splitting the CO₂-depleted syngas stream into a first stream (the fuel fraction) and a second stream. EX1010, 4:34-5:4 (“The gas stream 17 will then be used as fuel for a combined cycle gas turbine 24 to which air 25 is supplied.... As feed for an ammonia synthesis may be drawn from the line 17.”); *see* FIG. 2.

150. *Fjellhaug* discloses the first stream and the second stream having the same composition. *Id.* 4:64-65 (“As feed for an ammonia synthesis may be drawn from the line 17.”). By referring to a feed being “drawn from” the line, which is “[t]he gas stream 17 ...used as fuel,” *Fjellhaug* teaches the second stream, used for ammonia synthesis, having the same composition as the line that feeds the first

stream for use as fuel. As such, the feed for ammonia synthesis and the gas stream used as fuel have the same composition.

151. ***Licht* EX1009.** *Licht* discloses splitting the CO₂-depleted syngas stream into a first stream (the fuel fraction) and a second stream. Specifically, *Licht* discloses splitting the hydrogen-containing product gas 72 into a fuel gas 74. EX1009, 5:27-33 (“combusting fuel gas 74 comprising a portion of the hydrogen-containing product gas 72”). *See* FIG. 3.

152. *Licht* discloses the first stream and the second stream 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 CO₂-depleted stream 62. As used herein a “divided portion” of a stream is a portion having the same chemical composition as the stream from which it was taken.”).

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

153. **2007 IFA EX1006.** Although this phrase may have no patentable weight, 2007 IFA nevertheless discloses the second stream being intended for the synthesis of ammonia, as the second stream labelled “ammonia syngas” In the flow diagram indicating that it is further sent to ammonia synthesis. EX1006 at 9.

Further, 2007 IFA is directed generally towards ammonia synthesis. *See, e.g., id.* at 1 (“Energy efficiency in ammonia plants... CO₂ reduction potential”).

154. **Rytter EX1008.** Although this phrase may have no patentable weight, *Rytter* discloses a process for ammonia synthesis. While much of *Rytter* is directed to methanol synthesis, *Rytter* still states that the process is applicable to ammonia synthesis. EX1008, 4:41-50. Accordingly, *Rytter* discloses processes by which a stream separated from a CO₂-depleted syngas can be used for synthesis of a desired compound and, more specifically, discloses processes resulting in the synthesis of ammonia. For example, *Rytter* discloses an H₂-containing stream being used for ammonia synthesis. *Id.* 4:41-57; 7:26.

155. **Terrien EX1007.** 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 supra* ¶¶ 37-41.

156. **Fjellhaug EX1010.** *Fjellhaug* discloses the second stream being process gas intended for ammonia synthesis. EX1010, 4:64-65 (“As feed for an ammonia synthesis may be drawn from the line 17.”). *Fjellhaug* discloses splitting the CO₂-depleted syngas stream into a first stream (the fuel fraction) identified as “17” and a second stream “38” and “39” intended for ammonia synthesis. *Id.* 4:34-5:4; FIG. 2; *See supra* ¶¶ 110-11.

157. **Licht EX1009.** Although this phrase may have no patentable weight, *Licht* nevertheless discloses the process being used for the synthesis of ammonia. EX1009, 7:17-19 (“Secondary reforming reactors are well-known in the art and used widely for the production of ammonia and methanol.”). *Licht* relates primarily to hydrogen synthesis processes, which precede further synthesis processes, e.g., ammonia synthesis. *Id.* at Abstract. Accordingly, while *Licht* does not focus significantly on ammonia synthesis, a POSA would have understood the disclosed front-end hydrogen-synthesis process to be applicable to a process including back-end ammonia synthesis. *See also supra* ¶¶ 37-41.

158. **Price EX1011.** *Price* discloses a stream being process gas intended for ammonia synthesis. EX1011, Abstract.

2. Claim 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.

159. The grounds of invalidity related to claim 2 include: Ground 1A, 1C, Ground 2A, Ground 3, Ground 4B, and Ground 5. Obviousness of claim 2 over the cited prior art references and a POSA’s knowledge and skill is discussed herein.

160. 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. EX1001, 1:63-65; *see supra* ¶¶ 51, 53-55.

161. **2007 IFA EX1006.** *2007 IFA*, which discloses methanation and nitrogen addition steps, *see infra* Section X(A)(4), discloses the second stream as the process gas intended for the synthesis of ammonia after further purification.

162. **Rytter EX1008.** *Rytter* discloses a method of gas synthesis intended to reduce CO₂ emissions. *See* EX1008, 1:33-36 (“A possible new use is as fuel for gas turbines of heat generating Stations to thus considerably reduce the emission of CO in the production of electrical power.”).

163. **Fjellhaug EX1010.** *Fjellhaug* discloses that one of the second streams, “38”, is purified by a membrane gas separation unit “40”. EX1010, 4:64-67.

164. **Terrien EX1007.** *Terrien* discloses purification to provide hydrogen rich streams that can be used in downstream processes. EX 1007 ¶¶ 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.”).

165. **Licht EX1009.** *Licht* describes purification to provide hydrogen rich streams that can be used in downstream processes. EX1007 ¶¶ 16, 17.

166. **Price EX1011.** *Price* discloses “excess hydrogen that has been removed above is *further purified* if required, compressed and sent to an ammonia synthesis reactor.” EX1011 ¶ 40. While *Price* does not disclose a CO₂-depleted synthesis gas stream being split into a first stream and a second stream, the above

discussed references do. *Price* discloses methods to increase the concentrations of hydrogen and/or nitrogen in the syngas stream prior to ammonia synthesis, and illustrates that further purification of syngas was a well-known process step preceding ammonia synthesis methods. Synthesis of ammonia, which results from combining hydrogen and nitrogen, necessarily requires these elements to be provided to the synthesis step. Accordingly, processes that are intended to synthesize ammonia necessarily would require higher concentrations of hydrogen and nitrogen to increase output. Therefore, it would have been obvious to combine *Price* with 2007 IFA, to result in a process where only a portion (the second stream) of a CO₂-depleted synthesis gas stream being treated with further purification before being used to synthesize ammonia.

167. ***Pinto* EX1013.** *Pinto* discloses a “regenerable adsorption unit 60.” EX1013 8:49-51. *Pinto* further discloses taking part of the dried gas “to regenerate adsorber 60, the remainder of the gas [being] resolved cryogenically or by adsorption or selective diffusion into the hydrogen-rich stream 82 fed to point 74 and a waste stream 86, which may have fuel value. The aqueous ammonia is distilled under pressure and the resulting anhydrous ammonia is fed out at 84 to the main product offtake 72.” *Id.* 9:10-17. *Pinto* discloses syngas intended for ammonia synthesis. *Id.* at Abstract. Accordingly, *Pinto* discloses “further purification” of a stream intended for ammonia synthesis.

168. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, a POSA's ordinary knowledge, *Price* and/or *Pinto* do.

3. Claims 3 – 4

169. The grounds of invalidity related to claims 3 – 4 include: Ground 1A, Ground 1B, Ground 2, Ground 3A, Ground 3B, Ground 4A, Ground 4C, Ground 4E, Ground 5, and Ground 5B. Obviousness of claims 3 – 4 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

a. [3] The process of claim 1, wherein said fuel fraction is between 1% and 40% of the total amount of said CO₂-depleted syngas.

170. This claim is directed towards a design choice as to the amount of the CO₂-depleted syngas used as fuel. I understand that 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. 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. The percentage of syngas used as the fuel fraction solves no stated problem and would be an obvious matter of design choice well within the skill of the art. Similarly, to the extent that

this claim is directed towards a feature that improves the function of the claimed process, this claim is merely directed towards the optimum or workable ranges of the amount of the CO₂-depleted syngas used as fuel. A POSA would readily have appreciated that in a process where syngas is split into a fuel fraction and process fraction the relative amount used as the fuel fraction is merely a choice depending on the particular goals for the process. Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*.

171. ***Rytter* EX1008.** Nevertheless, to the extent that this claim is considered patentably distinct from independent claim 1, *Rytter* discloses the fuel fraction being between 1% and 40% of the total amount of the CO₂-depleted syngas. EX1008, 4:10-14 (“[A]t least 5% of substantially H₂-containing stream being fed—optionally as partial streams—to the methanol synthesis reactor(s), and the remaining part of the H₂-containing stream to one or more heat-generating station(s) or to other H₂-requiring processes.”). Because *Rytter* discloses “at least 5%” of the H₂-containing stream being fed to the synthesis (i.e., second stream) step, the remaining portion—up to 95% of the H₂-containing stream—is directed towards the heat-generating station. Between 1% and 40% is within the range of 0% to 95%. The heat-generating station is described as, for example, “gas turbines,” which are used to “considerably reduce the emission of CO₂ in the production of electrical power.” *Id.* 1:33-35.

172. Further, the motivation of directing a portion of the H₂-containing stream to a heat-generating station is to reduce carbon emissions, which is the same motivation as using the first stream as a fuel fraction. In both cases, a H₂-containing stream is used as a fuel source for combustion. The purpose of both steps is the same, namely, to use a process product as a fuel source to reduce carbon emissions from the process. Both steps address a known industry issue, namely, high carbon emissions resulting from syngas production.

173. 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. *See e.g., Id.* 4:55-57. “H₂-requiring processes” include any known processes that H₂ is a required or beneficial input including, but not limited to, synthesis of other compounds (e.g., methanol), use as fuel, recycling as process gas (including for the synthesis of ammonia). *See supra* ¶¶ 52, 56.

b. [4] The process of claim 1, wherein said fuel fraction is between 10% and 30% of the total amount of said CO₂-depleted syngas.

174. As with claim 3, this claim is directed towards a design choice as to and the optimum or workable range of the amount of the CO₂-depleted syngas used as fuel and is obvious for the same reasons as set forth above for claim 3.

Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*.

175. **Rytter EX1008.** Nevertheless, with respect to (1) *2007 IFA*, to the extent that this claim is patentably distinct from independent claim 1, *Rytter* discloses the fuel fraction being between 10% and 30% of the total amount of the CO₂-depleted syngas for the same reasons set forth above for claim 3. Because *Rytter* discloses “at least 5%” of the H₂-containing stream being fed to the synthesis (i.e., second stream) step (EX1008, 4:10-14), the remaining portion—up to 95% of the H₂-containing stream—is directed towards the heat-generating station. Between 10% and 30% is within the range of 0% to 95%. The heat-generating station is described as, for example, “gas turbines,” which are used to “considerably reduce the emission of CO₂ in the production of electrical power.” *Id.* 1:33-35.

176. Further, the purpose of directing a portion of the H₂-containing stream to a heat-generating station is to reduce carbon emissions, which is the same as using the first stream as a fuel fraction. In both cases, a H₂-containing stream is used as a fuel source for combustion. The purpose of both steps is the same, namely, to use a process product as a fuel source to reduce carbon emissions from the process. Both steps address a known industry issue, namely, high carbon emissions resulting from syngas production.

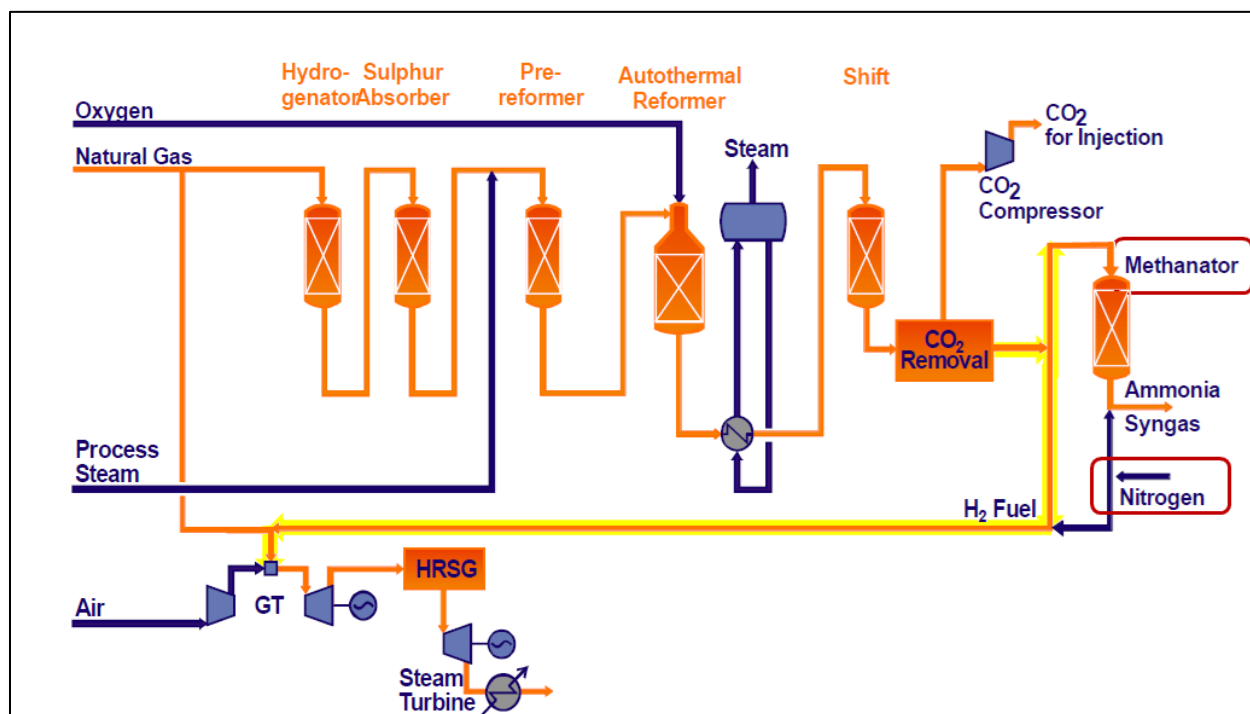
177. Further, *Rytter* discloses the remaining part of the H₂-containing stream being fed “to other H₂-requiring processes,” which includes use as fuel in a

furnace. *See e.g., Id.* 4:55-57. “H₂-requiring processes” include any known processes that H₂ is a required or beneficial input including, but not limited to, synthesis of other compounds (e.g., methanol), use as fuel, recycling as process gas (including for the synthesis of ammonia). *See supra* ¶ 52, 56.

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

178. The grounds of invalidity related to claim 5 include: Ground 1, Ground 2A, Ground 3, Ground 4A, Ground 4B, and Ground 5. Obviousness of claim 5 over the cited prior art references and a POSA’s knowledge and skill is discussed herein.

179. **2007 IFA EX1006.** 2007 IFA discloses a step for methanation (i.e., the “methanator”) and a step for addition of nitrogen to the synthesis gas (i.e., nitrogen → ammonia syngas). *See* FIG.:



EX1006 at 9. A POSA would have understood that a methanator is commonly used in ammonia plants to ensure that a small amount of CO and CO₂ left in the CO₂-depleted stream is removed, as CO and CO₂ are poisonous to ammonia synthesis catalysts. Remaining CO and CO₂ levels are typically less than 10 ppm.

180. **Fjellhaug EX1010.** *Fjellhaug* discloses a step for methanation of the syngas. EX1010, 4:65-5:4 (“One side stream 38 is first fed to a membrane gas separation unit 40 for supplying hydrogen 42 to a line 39 to adjust the H₂:N₂ ratio to 3:1 before this gas mixture is treated in a methanation unit 43 prior to a ammonia synthesis 44 producing ammonia 45.”).

181. **Price EX1011.** *Price* discloses a methanation step. EX1011 ¶ 5 (“Methanation is used as the final treatment step.”); *Id.* ¶ 44 (“The gas is then

passed to a methanation reactor which converts the remaining carbon oxides to CH₄.”). Further, *Price* discloses a step of adding nitrogen to the syngas. *Id.* (“Finally, the H₂ rich gas is compressed and combined with N₂ from a cryogenic air separation plant and fed to an ammonia synthesis reactor.”).

182. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, a POSA’s ordinary knowledge and/or *Price* does.

5. 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

183. The grounds of invalidity related to claim 6 include: Ground 1, Ground 2A, Ground 3, Ground 4A, Ground 4B, and Ground 5. Obviousness of claim 6 over the cited prior art references and a POSA’s knowledge and skill is discussed herein.

184. **2007 IFA EX1006.** *2007 IFA* discloses the fuel fraction (“H₂ fuel”) being separated upstream of both the methanation step (“methanator”) and the nitrogen addition step (nitrogen → syngas). EX1006 at 9.

185. A POSA would have understood that a methanator consumes H₂ to convert CO or CO₂ to CH₄. This is an exothermic reaction, causing part of the heat generated to be lost. Methanating the CO₂-depleted H₂ to be used as fuel is counterproductive, as energy would have been lost prior to use as fuel, decreasing

process efficiency. The methanation does not impact the CO₂ emission of the fuel. Therefore, drawing the fuel stream from the CO₂ depleted stream is preferably upstream of the methanator.

186. **Terrien EX1007.** Terrien would necessarily separate the fuel fraction prior to nitrogen addition because nitrogen is a necessary reactant for ammonia synthesis, whereas nitrogen is not useful as fuel. *See supra* ¶¶ 38, 46, 55-57.

187. **Fjellhaug EX1010.** Fjellhaug discloses separation of the fuel fraction upstream of the step for methanation of the synthesis gas. EX1010, 4:65-5:4 (“One side stream 38 is first fed to a membrane gas separation unit 40 for supplying hydrogen 42 to a line 39 to adjust the H₂:N₂ ratio to 3:1 before this gas mixture is treated in a methanation unit 43”). As shown in FIG. 2, the methanation step 43 is downstream of the splits in the syngas stream.

188. **Price EX1011.** Price discloses the stream being split upstream of both the methanation step and the nitrogen addition step. 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*, the first stream entering the Fischer-Tropsch reactor and the second stream being sent to a hydrogen extraction unit. The synthesis gas may be divided into a hydrogen-rich stream and a hydrogen-poor stream in the hydrogen extraction unit, and at least a portion of the high purity hydrogen-rich stream may be fed into the ammonia

synthesis process, thereby reducing or eliminating the danger of CO poisoning.”).

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 (“Methanation is used as the final treatment step.”); *Id.* ¶ 44 (“The gas is then passed to a methanation reactor which converts the remaining carbon oxides to CH₄.”). Further, *Price* discloses a step of adding nitrogen to the syngas. *Id.* (“Finally, the H₂ rich gas is compressed and combined with N₂ from a cryogenic air separation plant and fed to an ammonia synthesis reactor.”).

189. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, a POSA’s ordinary knowledge and/or *Price* does.

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

190. The grounds of invalidity related to claim 7 include: Ground 1A, Ground 1C, Ground 2A, Ground 3A, Ground 4, Ground 4A, and Ground 5. Obviousness of claim 7 over the cited prior art references and a POSA’s knowledge and skill is discussed herein.

191. Like claims 3-4, this claim is directed towards a design choice as to the volume of CO₂ contained in the CO₂-depleted syngas. Similarly, as with claims

3-4, this claim is directed towards the optimum or workable ranges of the amount of CO₂ in the CO₂-depleted syngas. A POSA would have understood that syngas intended for ammonia synthesis required removal of substantially all CO₂ from the stream, and achieving CO₂ removal to sub 1000 ppm was also well-known. *See, e.g.*, EX1014 at 127, 130 (Table 31). It was well-known in the art that it was a desired result to reduce the volume of CO₂ in syngas. *See* EX1040, Table 1-2, 2:57-59 (disclosing CO₂-depleted syngas stream with 20 ppm CO₂); EX1030, 8:49-51, Table 1 (showing complete CO₂ removal).

192. I understand that where, as here, the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges. Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*.

193. ***Terrien* EX1007**. Nevertheless, to the extent that this claim is patentably distinct from independent claim 1, *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.” EX1011 ¶¶ 86, 94 (describing CO₂ capture rates from 80-100%). Where CO₂ emissions are eliminated, as in *Terrien*, the CO₂-depleted syngas necessarily contain no more than 1000 ppm by volume of CO₂. For example, *Terrien* describes eliminating 100% of CO₂ emissions, which

requires that the CO₂-depleted syngas contain potentially less than 1000 ppm by volume of CO₂.

194. **Price EX1011.** Nevertheless, to the extent that this claim is patentably distinct from independent claim 1, *Price* discloses the CO₂-depleted syngas containing no more than 1000 ppm by volume of CO₂. EX1011 ¶ 45 (“The resultant synthesis gas is cooled and a portion split off and transferred to a Pressure Swing Adsorption (PSA) unit. The 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 volume of non-H₂ gas of 10000 vppm. This is because 1% is equal to 10,000 ppm and for gases (such as H₂, N₂, CO, and CO₂), when ppm or percentage concentration is provided, it is understood to be by volume (i.e., vppm). 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.”

195. **Pinto EX1013.** Further, to the extent that this claim is patentably distinct from independent claim 1, *Pinto* discloses the CO₂-depleted syngas containing no more than 1000 ppm by volume of CO₂. In *Pinto*, the CO₂-depleted syngas is dried in an adsorption unit. *Id.* 8:49-51. The resulting CO₂ concentration is zero, as shown in Table 1 at “60 outlet” and “62 outlet.” *Id.* at Table 1 (H₂ concentration percentage (72.29), CH₄ concentration percentage (1.18), Ar concentration percentage (0.31), and N₂ concentration percentage (26.59) add up to

100%). Therefore, the CO₂ range disclosed in *Pinto* is as low as 0 vppm, which is a volume of “not more than 1000 ppm by volume of CO₂.”

196. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, *Price* and/or *Pinto* do.

7. Claims 8 – 9

197. The grounds of invalidity related to claims 8 – 9 include: Ground 1A, Ground 1B, Ground 2, Ground 3B, Ground 4A, Ground 4E, Ground 5, and Ground 5B. Obviousness of claims 8 – 9 over the cited prior art references and a POSA’s knowledge and skill is discussed herein.

a. [8] The process of claim 1, wherein said enriched air contains at least 50% oxygen.

198. Like many of the proceeding claims, this claim is merely directed towards ordinary design choices and the optimum or workable ranges of the percentage of oxygen in the enriched air. I understand that where, as here, the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges. Therefore, this claim is obvious over (1) *2007 IFA*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht* and *Price*. In any event, to the extent that these references do not disclose this claim element, *Rytter* does.

199. ***Rytter* EX1008.** Nevertheless, to the extent that this claim is patentably distinct from independent claim 1, *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. “Substantially pure O₂,” being composed substantially of oxygen, contains significantly more than 50% oxygen. The purpose of providing oxygen or oxygen-enriched air to the process to be mixed with the natural gas and steam is to provide a source of oxygen to the gas stream. Accordingly, the benefit of providing oxygen-enriched air, which has a higher concentration of oxygen than unenriched air, is accomplished by providing “substantially pure O₂.” Further, “substantially pure O₂” includes oxygen-enriched air.

200. 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. *See e.g.*, EX1014 at 100 (“To close the heat balance between the exchanger reformer and secondary (autothermal) reformer, the latter has to take on a higher reforming duty, which may be achieved by using an over-stoichiometric amount of air or oxygen-enriched air.”); *id.* at p. 102 (“Other parameters of influence are oxygen purity, operating pressure, and amount of steam added for reaction moderation.”). Thus, it was well-known that a wide range of oxygen levels can be used with an ATR, including atmospheric air (21% oxygen) to 100% oxygen. *See, e.g.*, EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen,

up to 100% oxygen); *See* EX1041 at 1 (explaining oxygen feedstocks for ATRs vary from air to pure oxygen).

b. [9] The process of claim 1, wherein said enriched air contains at least 90% oxygen.

201. Like claim 8, this claim is merely directed towards ordinary design choices and the optimum or workable ranges of the percentage of oxygen in the enriched air. I understand that where, as here, the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges. Therefore, this claim is obvious over (1) *2007 IFA*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price* . In any event, to the extent that these references do not disclose this claim element, *Rytter* does.

202. ***Rytter* EX1008.** Nevertheless, to the extent that this claim is patentably distinct from independent claim 1, *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. “Substantially pure O₂,” being composed substantially of oxygen, contains at least 90% oxygen. The purpose of providing oxygen or oxygen-enriched air to the process to be mixed with the natural gas and steam is to provide a source of oxygen to the gas stream. Accordingly, the benefit of providing

oxygen-enriched air, which has a higher concentration of oxygen than unenriched air, is accomplished by providing “substantially pure O₂.” Further, “substantially pure O₂” includes oxygen-enriched air.

203. 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. *See e.g.*, EX1014 at 100 (“To close the heat balance between the exchanger reformer and secondary (autothermal) reformer, the latter has to take on a higher reforming duty, which may be achieved by using an over-stoichiometric amount of air or oxygen-enriched air.”); *id.* at 102 (“Other parameters of influence are oxygen purity, operating pressure, and amount of steam added for reaction moderation.”). Thus, it was well-known that a wide range of oxygen levels can be used with an ATR, including 100% oxygen. *See, e.g.*, EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen); EX1041 at 1 (explaining oxygen feedstocks for ATRs vary from air to pure oxygen).

- 8. 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**

204. The grounds of invalidity related to claim 10 include: Ground 1, Ground 2, Ground 3, Ground 3A, Ground 3B, Ground 4, Ground 5, and Ground 5B. Obviousness of claim 10 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

205. **2007 IFA EX1006.** *2007 IFA* discloses feeding the fuel fraction to “combustion air preheat to reduce fuel firing.” EX1006 at 8. Accordingly, *2007 IFA* teaches feeding the fuel fraction to 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 autothermal reformer or natural gas desulfurization section. *2007 IFA* also discloses feeding the fuel fraction to a steam production furnace. *Id.* at 8-9.

206. **Rytter EX1008.** *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 the fuel fraction to 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 autothermal reformer or natural gas desulfurization section.

207. **Terrien EX1007.** *Terrien* discloses the fuel fraction of the syngas being recycled upstream for various uses, including to fuel the conversion section and

fueling the feed gas producing unit. EX1007 ¶ 78 (“While the hydrogen product stream (27) is recovered as product, a portion of this stream (27) can be recycled for use for hydrogen fueling of the steam methane reformer (23).”); *id.* ¶ 35 (“With regard to the additional streams, while the hydrogen product stream (27) is recovered as product, as in the previous embodiments, a portion of this stream (27) can be used for hydrogen fueling of the feed gas producing unit (34). In a still further modification to this embodiment, it is advantageous to further heat the first hydrogen rich permeate fraction (5.1) prior to this stream being added as a supplemental feed to the feed gas producing unit.”). *Terrien* describes a feed gas stream produced by a producing unit including an ATR (*id.* ¶¶ 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, *Terrien* discloses the fuel fraction being recycled upstream for preheating the ATR or natural gas desulfurization section in any suitable furnace, alone or in combination with ordinary knowledge of the art.

208. ***Fjellhaug EX1010.*** *Fjellhaug* discloses the fuel fraction being suitable for combustion in gas turbines and the combustion exhaust heat is used to

produce steam. EX1010, 3:14-15; 4:34-37 (“The gas stream 17 will then be used as fuel for a combined cycle gas turbine 24”); 4:38-50 (“Exhaust 26 from the turbine 24 is heat exchanged with water in a steam generator 27 and the steam therefrom may be *superheated in a heat exchanger 30* before steam 31 is supplied to a power generator 32 to which the steam 10 may be supplied.”). In the ’168 Patent, the term “furnace” includes steam generators and gas turbines, which operate by means of a fired heater. EX1001, 7:44-53; *see supra* ¶ 60. To the extent that *Fjellhaug* does not disclose the furnace being a steam production and/or superheating furnace, a POSA would have understood that the disclosure of *Fjellhaug* could have been modified to use a steam production and/or superheating furnace, which were well known in the art.

209. ***Licht* EX1009.** *Licht* discloses the fuel fraction of the syngas being recycled upstream for various uses, including to fuel the conversion section which includes an ATR. EX1009, 5:27-42 (“The process further comprises combusting a fuel gas 74 comprising a portion of the hydrogen-containing product gas 72, optionally a portion 77 of the by-product gas 76, and optionally a supplementary fuel 18 in the reformer furnace 100 external to the plurality of catalyst-containing reformer tubes 104 to supply energy for reacting methane and steam inside the plurality of catalyst-containing reformer tubes 104. Flue gas 110 is withdrawn from the reformer furnace 100, and because the fuel gas 74 comprises hydrogen in

an amount greater than conventional reformer furnaces, the flue gas will contain a reduced amount of carbon dioxide compared to conventional reformer furnaces.

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.”); *Id.*

7:17-22 (“Secondary reforming reactors are well-known in the art and used widely for the production of ammonia and methanol. Secondary reforming reactors are refractory lined vessels with one or more burners and a reforming catalyst bed.

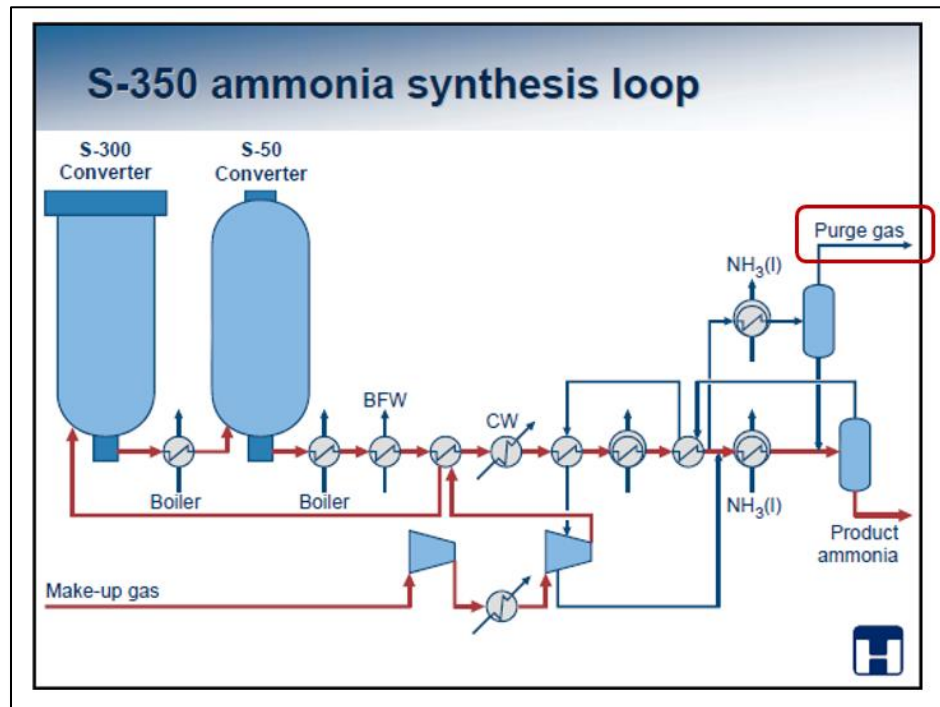
Heat required for the reforming reaction is provided by partial oxidation (combustion) of a portion of the feed.”). To the extent that *Licht* does not disclose the furnace being a steam production and/or superheating furnace, a POSA would have understood that the disclosure of *Licht* could be modified to use a steam production and/or superheating furnace, which was well known in the art.

9. **Claim 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**

210. The grounds of invalidity related to claim 11 include: Ground 1A, Ground 1D, Ground 2B, Ground 3C, Ground 4C, and Ground 5A. Obviousness of

claim 11 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

211. **2007 IFA EX1006.** 2007 IFA discloses a purge gas generated from the ammonia synthesis process.

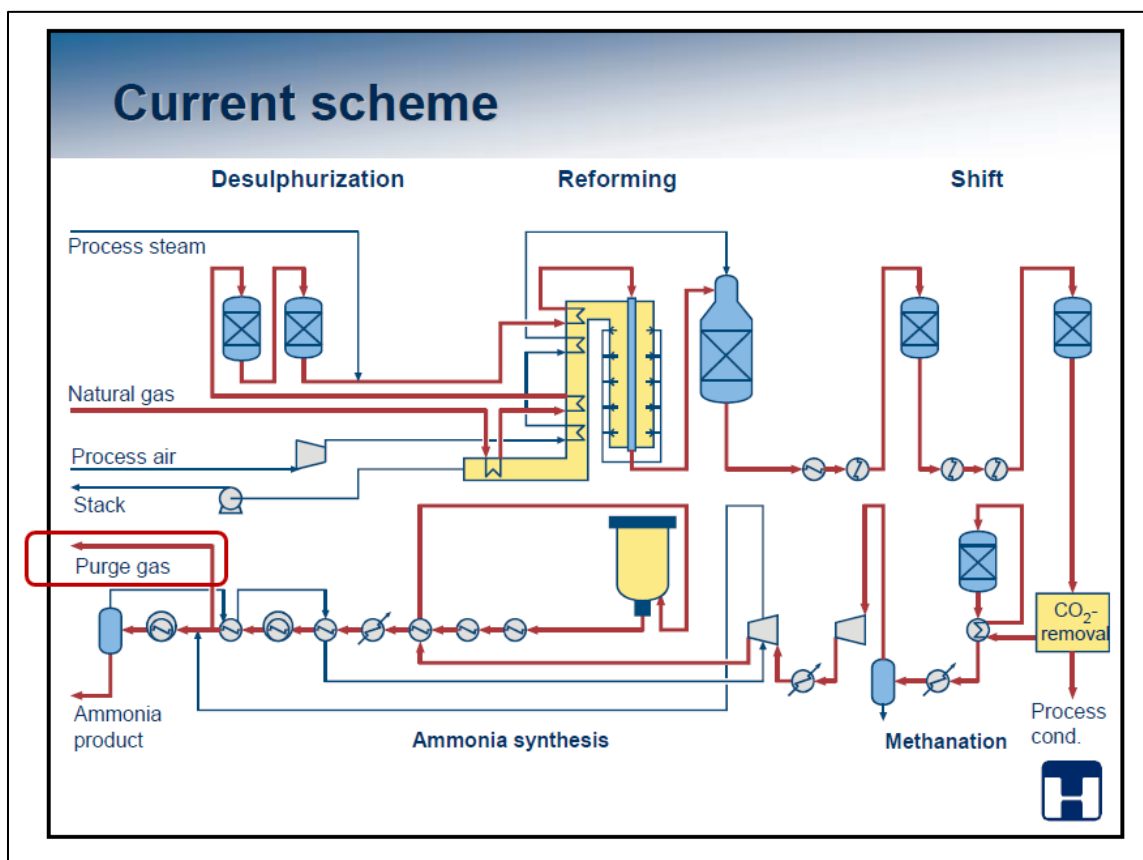


EX1006 at 6.

212. A POSA would have understood that the purge gas, which is removed from the synthesis loop after ammonia synthesis, would contain hydrogen. In fact, it is well known in the art that the ammonia purge gas stream not only contains hydrogen, but it also contains ammonia, methane, argon and nitrogen.

213. A POSA would also have known that the methane in the purge gas could be generated during methanation. Methanation steps are used to decrease the

concentrations of carbon monoxide and carbon dioxide in the syngas stream prior to the synthesis step. Methane, unlike carbon monoxide and carbon dioxide, is an inert gas with respect to the ammonia catalyst and therefore does not decrease the efficiency of ammonia synthesis. Even so, the methane and especially argon can build up in the ammonia loop, which requires purging to avoid dilution by these gases. Even assuming that the methane in the purge gas is not from a methanation step, because a methanation step is not always required, a POSA would have understood that the syngas stream could include amounts of methane stemming from unreacted methane from a reformer (referred to as methane slip). *Id.* at 2 (showing “Current Scheme” of ammonia synthesis that included a “purge gas”) (reproduced below).



214. 2007 IFA further discloses a “[c]ryogenic purge gas recovery unit, [which returns] the recovered hydrogen at high pressure compared to the membrane purge gas recovery unit.” *Id.* Therefore, 2007 IFA contemplates “recovery” of at least a portion of the purge gas as an “energy reducing feature[.]” *Id.* A POSA would have understood this to mean that at least part of the purge gas is separated and then used in any appropriate manner. The recovered (i.e., retained) purge gas can then be used in any suitable manner including, but not limited to, fuel, feedstock, etc. A POSA would have understood that the “recovery” of the purge gas could include a step of further separating the purge gas into a hydrogen-

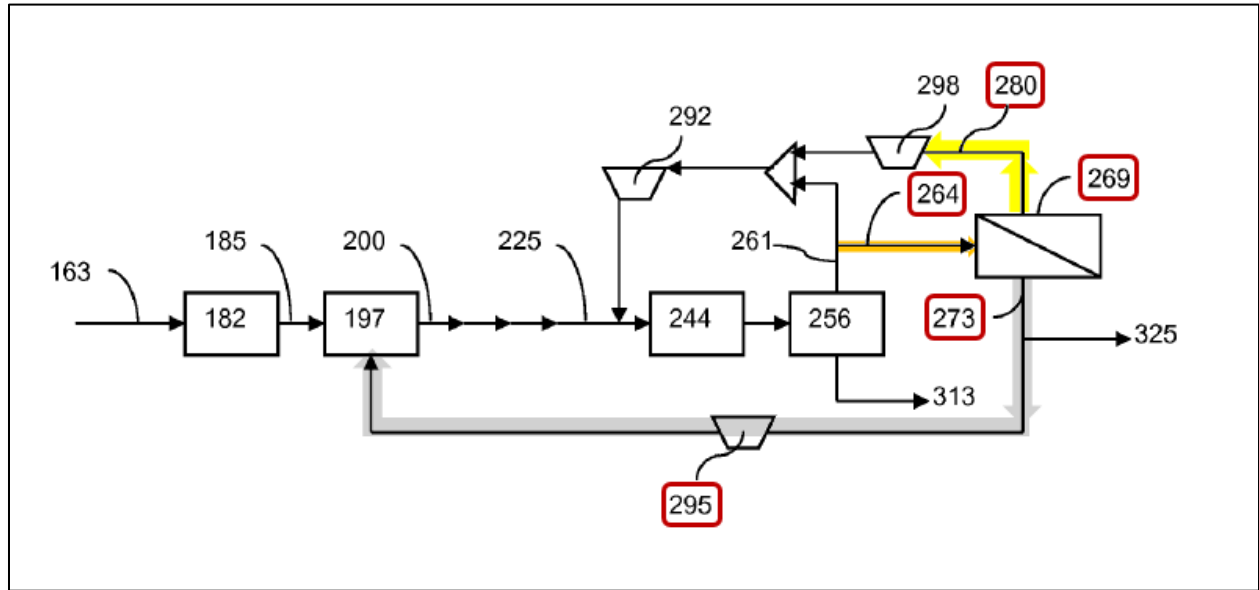
rich stream and a methane-rich stream, with the methane-rich stream (tail gas) being fed as feed to the conversion step.

215. **Terrien EX1007.** *Terrien* discloses separating a H₂-rich stream (27) from a process stream (1). EX1007 ¶ 21 (“The removal of hydrogen product (27) from the feed gas (19) in the process unit (0) results in a process stream (1) that is purged from the process unit (0).”). 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 (“**The process stream (1) is withdrawn from the adsorption beds** of the pressure swing adsorption unit **during** the depressurization and **purge steps.** As used herein, the phrase ‘medium to very high purity hydrogen stream’ refers to greater than 99% hydrogen.”). *Terrien* discloses the process stream being split numerous times. The process stream is disclosed as splitting into a first hydrogen-rich permeate stream (5) and a first hydrogen-lean permeate stream (6) (*Id.* ¶ 78); a second hydrogen-rich permeate stream (12) and a second hydrogen-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 carbon dioxide, hydrogen and methane, removal of the first and second hydrogen-rich permeate streams (5, 12) results in the first and second hydrogen-lean permeate streams (6, 13) containing at least carbon dioxide and methane. By separating out the CO₂-enriched permeate stream (15) in the

carbon dioxide selective membrane separation unit (14), the CO₂-depleted residue stream (16) contains at least methane. *Terrien* discloses recycling the CO₂-depleted residue stream (16) as feed for the conversion step. *Id.* ¶ 93 (“The carbon dioxide depleted residue stream (16) that is recovered, after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).”). Accordingly, *Terrien* discloses a purge gas containing hydrogen and methane treated to separate a hydrogen-rich gas (5, 12) and a tail gas containing methane (16), wherein the tail gas is recycled as process gas and is subjected to the conversion step. *See* FIG. 5.

216. ***Ji* EX1012.** *Ji* discloses treating a hydrogen- and methane-containing purge gas of the ammonia synthesis process to recover the hydrogen, thus obtaining a hydrogen-rich stream and a purge gas containing methane, 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 at 5:56-6:8 (“The membrane separation unit separates the gas into methane-rich purge gas 273 and hydrogen-rich gas 280 components.... The portion of the methane-rich purge gas 273 that is not purged is compressed in a compressor 295, and the compressed gas is routed to the gasification reactor 197 to be once again used as feedstock for syngas production. In certain embodiments that utilize a two stage gasification

reactor, the methane-rich purge gas is recycled to the first stage of the reactor 90 (shown in FIG. 1).”). *See also id.* at FIG. 2:



217. Moreover, treatment of a purge gas to recover a hydrogen-rich gas and a methane-containing tail gas, wherein at least a part of the tail gas is recycled as process gas subject to the conversion step, was well known in the art. *See e.g.*, EX1016 at 3-4 (“To maintain the synthesis reaction in forward direction same [sic] amount of inert gases are required to be purged from the synthesis loop at a constant rate because the inert gases disturb[] the reaction equilibrium.... Formerly this Purge Gas was partially used in Reformer as fuel in conjunction with associated gas and the remaining gas was vented to atmosphere causing problem of pollution. Since the purge gas is rich in hydrogen and methane content[,], it was conceived that this gas may be used in reformer as feed on 3rd January 1986, purge

gas was fed to reformer alongwith [sic] feed gas.... No significant change was observed in any process parameters.”); EX1014, Section 4.5.6 (discussing purge-gas management including recovery of hydrogen).

218. ***Pinto* EX1013.** *Pinto* discloses removing a purge gas containing methane, wherein at least a portion of the purge gas is recycled to the conversion section. EX1013 6: (“Such methane contents are substantially higher than have previously been considered suitable for ammonia production. They are specified, however, because it is now realized (1) that the plant for removing excess nitrogen from synthesis gas can also remove methane; (2) the methane finally purged is not wasted but is used as fuel in the reformer furnace.”). While *Pinto* discloses the methane being recycled as fuel, rather than feed, to the conversion section, a POSA would understand that any suitable use of methane would be appropriate to improve efficiency of the ammonia synthesis process disclosed in *Pinto*.

219. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, *Ji* and/or *Pinto* do.

10. Claim 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

220. The grounds of invalidity related to claim 17 include: Ground 1A, Ground 1E, Ground 2C, Ground 3D, Ground 4D, and Ground 5. Obviousness of

claim 17 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

221. 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. I understand that 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. 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 would readily 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 be used as the entire fuel source or a supplemental fuel source (e.g., the trim fuel) can be provided in any suitable quantity. Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*.

222. **2007 IFA EX1006.** *2007 IFA* does not directly disclose the optimum amount of the fuel of the furnaces that is from the fuel fraction. *2007 IFA* does,

however, disclose a process that does not include a fuel source other than the H₂ fuel.

EX1006 at 9. Accordingly, *2007 IFA* discloses said synthesis gas fuel fraction forms all of the fuel of the furnaces used in the conversion section.

223. ***Licht* EX1009.** 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.”); *Id.* 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.”).

224. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, *Licht* does.

11. **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

225. The grounds of invalidity related to claim 18 include: Ground 1A, Ground 2, Ground 3B, Ground 4A, and Ground 5. Obviousness of claim 18 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

226. 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. I understand that 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. Here, the claim requires modulation of the fuel fraction to regulate the conversion section output. A POSA would readily have appreciated that the output of a step can be controlled by modulation of the input to that step. 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) . This claim 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. For example *Pinto* describes controlling the input ($H_2:N_2$) to limit the output of both H_2 and power consumption, so modulating $H_2:N_2$ regulates the output from the reactor (H_2 and power). See EX1013, 6:48-54 (“The $H_2:N_2$ 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.”). 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. Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*, alone or in light of a POSA’s ordinary knowledge.

227. **2007 IFA EX1006.** *2007 IFA* does not directly disclose the excess fuel fraction being exported or the quantity of the fuel fraction regulating the conversion section. 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. Further, a POSA would have known that a method step is inherently regulated by the quantity of the input to the

step. 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. 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. Therefore, this claim is obvious in light of *2007 IFA*.

228. ***Fjellhaug* EX1010.** *Fjellhaug* explains that the prior art already included producing power in “a combined cycle power plant integrated with a reformer plant where a gas is fueled by hydrogen containing gas.” EX1010, 1:15-18. *Fjellhaug* is directed, in part, towards identifying “the best way of running the ATR.” *Id.* 2:16. In the context of discussing the “best way” of operating the ATR (e.g., the conversion section), *Fjellhaug* discloses “[t]he methane slip [being] varied in view of the operation of downstream units and finally, the synthesis gas produced in the ATR would be a relatively lean gas suitable for the gas driven turbine and comparable to fuel mixtures being used in proven, large scale combined cycle plants (IRCC).” *Id.* 2:23-27. As such, *Fjellhaug* discloses operating the upstream units (e.g., the conversion section) to modulate the downstream units (e.g., separation of fuel fraction). A POSA would understand that *Fjellhaug*’s disclosure of modulating an aspect of the conversion section, namely, the methane slip, merely states a basic chemical engineering process

principle: that an input can modulate an output. Accordingly, *Fjellhaug* discloses regulation of the conversion section being performed by modulating the quantity of fuel fraction directed towards the conversion section. *Rytter* discloses supplying syngas as fuel to generate power, as well as to the conversion section. *See supra* ¶ 143. Further, *Rytter* discloses “[h]ydrogen [being] withdrawn for other purposes such as upgrading product streams in a refinery and for the use as an energy carrier in transport means.” 3:4-45. And, *Fjellhaug* discloses making syngas so a portion can be used as a fuel to generate power, and portion can be used to generate products like ammonia. EX1010, 1:61-64. A POSA would thus be further motivated to modify *Fjellhaug* in view of *Rytter* to regulate the conversion section by modulating the quantity of fuel fraction directed towards the conversion section versus the amount exported/withdrawn. Accordingly, a POSA would be motivated to select the amount of fuel fraction produced with respect to the fuel demand of the conversion section. Therefore, this claim is obvious over *Fjellhaug* and *Rytter*.

12. 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

229. The grounds of invalidity related to claim 19 include: Ground 1A, Ground 1C, Ground 2A, Ground 3, Ground 4A, Ground 4B, and Ground 5.

Obviousness of claim 19 over the cited prior art references and a POSA's knowledge and skill is discussed herein.

230. As with numerous preceding claims, this claim is merely directed towards the optimum or workable ranges of the S/C ratio in the ATR. A POSA would have understood that the S/C ratio is merely a matter of ordinary experimentation and design of systems and use of S/C ratios of 2 and below were well-known in the art. *See, e.g.*, EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 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). I understand that where, as here, the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges. Therefore, this claim is obvious over (1) *2007 IFA*, (2) *Rytter*, (3) *Fjellhaug*, (4) *Terrien*, and (5) *Licht and Price*. To the extent that *2007 IFA*, *Rytter*, *Fjellhaug*, *Terrien*, and/or *Licht* do not disclose this claim element, *Price* does.

231. **Fjellhaug EX1010.** *Fjellhaug* discloses S/C not greater than 2. EX1010, 5:19-21 (referencing table). *Fjellhaug* discloses multiple ATR-based approaches that use S/C of 2. *Id.*

232. **Price EX1011.** To the extent that this claim is patentably distinct from independent claim 1, *Price* discloses conversion of a charge of desulfurized natural gas and steam in an autothermal reformer (*e.g.*, EX1011 ¶¶ 53, 56.) with a S/C ratio not greater than 2, and specifically with S/C ratios of 0.6 and 0.9 (*e.g.*, *id.* ¶¶ 43, 45, 59).

B. Bases for modifying or combining references

233. The '168 Patent is directed towards a process for treating natural gas to prepare syngas for use as a fuel and/or ammonia synthesis. At its core, the '168 Patent relies on nothing more than the concept of precombustion carbon capture—splitting a CO₂ depleted syngas so part of it can be used as fuel. This concept was well-known in the art prior to the '168 Patent.

234. Treatment of natural gas to produce ammonia is well known in the art. *See supra* ¶¶ 37-41. Numerous processes, including conversion steps, carbon monoxide shift reactions, and carbon dioxide removal, are well known in the art. *See supra* ¶¶ 43-53. Not only are these steps well known, specific variations of such steps, such as prereformers, autothermal reformers, and steam methane reformers, are also well known. *Id.* A POSA would have known that a process

disclosing each of the steps of the '168 Patent with, e.g., one step missing or one step replaced with another, can be modified by other well-known prior art to obtain the method claimed in the '168 Patent.

235. The stated objective of the '168 Patent is reducing carbon dioxide emissions. In recent decades, because of the growing concern regarding anthropogenic effects on the environment, market forces have been incentivizing processes that improve energy efficiency and reduce carbon emissions. *See supra* ¶ 41 (quoting EX1023 at 30). Accordingly, significant investment has been made in reducing emissions associated with syngas production, including in the ammonia synthesis industry, which is a significant contributor to carbon emissions. *See supra* ¶ 37 (citing EX1015, Carbon Dioxide Capture and Storage). The most common approach to resolving a known issue such a carbon emission is to apply known processes. Processes known in the art to reduce carbon emissions include, but are not limited to, pre-combustion carbon capture and use of CO₂-depleted syngas as a fuel source. *See supra* ¶ 56 (citing EX1027, Synthetic Nitrogen Products, at 108); *id.* ¶ 52 (citing EX1023, The Hydrogen Economy, at 106).

236. The method claimed in the '168 Patent utilizes known techniques, namely, known method steps to treat natural gas and known techniques to reduce carbon emissions, in the manner these techniques are known to be used, to address the known problem of excessive carbon emissions. Accordingly, references that

disclose methods, techniques, and devices intended to treat natural gas or other known syngas sources, generate syngas for production of various chemical products, and reduce carbon emissions are relevant to the '168 Patent. A POSA would have been aware of and motivated to combine such reference(s) to obtain a desired processes with reduced carbon emissions and have a reasonable expectation of success in doing so.

1. GROUND 1A: Rationale for Combining 2007 IFA with Ordinary Knowledge

237. A POSA would have considered *2007 IFA* alone or in combination with a POSA's ordinary degree of common knowledge in the art.

238. *2007 IFA* shows a process in which natural gas is desulfurized (hydrogenator sulfur absorber), processed in a prereformer and autothermal reformer, shifted, and then CO₂ is removed from the syngas. After CO₂ removal, the CO₂-depleted syngas is split so that some is used for ammonia synthesis, and some is used for fuel.

239. According to the '168 Patent, the fuel is used in a furnace, which is "understood as meaning an apparatus chosen from among:...a steam generator...." EX1001, 2:47-:49. *2007 IFA* uses CO₂-depleted syngas as fuel for a gas turbine, as well as fuel to generate steam from boiler feedwater. EX1006, at 186. A POSA would have understood a gas turbine and steam boiler to be within the scope of the

'168 Patent's definition of a furnace, particularly because the '168 Patent discloses a gas turbine as being within the scope of a "furnace." *See* EX1001, 7:43-:55.

Regardless, a POSA would have known that the process disclosed in *2007 IFA* using syngas to fuel a turbine could be successfully modified by using the syngas to fuel any suitable furnace, as furnaces are well known in the art and the goal is simply the well-known approach of combusting CO₂-depleted syngas to reduce emissions. *See e.g.*, EX1015 at 121 ("hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells."). Additionally, in the context of ammonia synthesis, the concept of producing excess syngas so that the excess could be split off and used as a fuel in a reformer or exported for other uses was recognized in the art. EX1037 at 307.

2. GROUND 1B: Rationale for Combining *2007 IFA* and *Rytter*

240. A POSA would have considered *2007 IFA* in conjunction with *Rytter* for several reasons. For example, *2007 IFA* and *Rytter* both relate to front-end processes in which natural gas is converted into a syngas and both also concern processing and using syngas in ways that reduce CO₂ emissions. *See e.g.*, EX1006, at 7 ("How much can the CO₂ emission be reduced in the (near) future in an ammonia plant?"); EX1008, 2:36-52. *2007 IFA* describes updates in the Topsoe ammonia synthesis process that was given at a conference for syngas professionals. Accordingly, a POSA would have, based on *2007 IFA*, known to search for

additional references to better understand and expand upon the ammonia synthesis process. One such reference is *Rytter*. Additionally, while *Rytter* describes, among other things, methanol synthesis, it also discusses the applicability of similar processes to ammonia synthesis, which is the focus of *2007 IFA*. See EX1008, 3:10-3:16. And because of their related process steps, ammonia synthesis was often integrated with methanol synthesis. See EX1037 at 308.

241. Moreover, *Rytter* specifically describes that part of the syngas stream may be used for ammonia synthesis. EX1008, 4:41-50. Both references also propose integrating power generation into the process to increase efficiency. See e.g., EX1006, at 8, 9 (“integrated reforming and power cycle”); EX1008, 6:6-15. Both describe processing natural gas with ATR, as well as pre-reforming. EX1006 at 9; EX1008, 4:15-20; 6:40-56; 6:66-7:8. These interrelated teachings provide further motivation to combine, as well as provide an expectation that the combination would be successful.

242. A POSA would have been motivated to modify the process disclosed in *2007 IFA* to optimize certain working ranges. Accordingly, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is also a mere design choice, and the amount of oxygen contained in the oxygen-enriched air (claims 8-9), also a design choice.

243. Regarding claims 3-4, use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”); EX1037 at 307 (excess syngas used as fuel for reformers). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

244. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Rytter*. *Rytter* discloses these elements and a POSA would have known to utilize knowledge in the art and/or additional references to select these ranges.

245. A POSA would have had a reasonable expectation of success when combining *2007 IFA* and *Rytter*. First, *2007 IFA* is directed to modifications to

Topsoe's existing ammonia synthesis plants, so a POSA would have reasonably expected success in modifying *2007 IFA* to have known ranges of CO₂-depleted syngas used as fuel and amount of oxygen contained in the oxygen-enriched air. Second, *2007 IFA* and *Rytter* 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 comprising a prereformer followed by an ATR, a CO-shift reaction, CO₂ removal, and separation of the CO₂-depleted syngas stream, could be modified by applying process steps used in another process that discloses the same overlapping steps.

3. GROUND 1C: Rationale for Combining *2007 IFA* and *Price*

246. A POSA would have considered *2007 IFA* in conjunction with *Price* for several For example, they are in the same field of endeavor, as both relate to syngas production for use as a feedstock for producing products such as ammonia. EX1006 at 9; EX1011 ¶ 40. Additionally, both are intended to reduce carbon dioxide emissions. *See generally* EX1006; EX1011 ¶ 21. *2007 IFA* describes updates in the Topsoe ammonia synthesis process that was given at a conference for syngas professionals. Accordingly, a POSA would have, based on *2007 IFA*, known to search for additional references to better understand and expand upon the ammonia synthesis process. One such reference is *Price*.

247. A POSA would have been motivated to combine the process disclosed in *2007 IFA* with the disclosure of *Price*. Indeed, the interrelated teachings of *2007 IFA* and *Price* provide further motivation to combine these references. *2007 IFA* is directed towards modifications to Topsoe's ammonia synthesis process. Accordingly, *Price*, which is also directed toward modifications to ammonia synthesis processes, would have been considered by a POSA.

248. Regarding claim 2, 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. *See supra* ¶ 53 (“Commercial technologies for final gas purification include methanation, liquid nitrogen wash, pressure swing adsorption, etc. Choices of different technologies depend on many factors, including the type of technology employed for syngas production, the energy consumption and availability of the purification technologies.”) (citing EX1036); *See* EX1014 at 127 et seq.. *Price* discloses “excess hydrogen that has been removed above is ***further purified*** if required, compressed and sent to an ammonia synthesis reactor.” EX1011 ¶ 40. And it was well-known in the art that syngas streams require purification prior to ammonia synthesis to avoid poisoning the ammonia synthesis catalysts.

249. Regarding claim 7, 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, as disclosed in *2007 IFA*, is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *See supra* ¶¶ 51, 53-55 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”).

250. Regarding claim 19, a POSA would have known that the S/C ratio in the ATR could be modified to any known value to obtain the desired result, as ranges of S/C ratios are well known in the art. *See e.g.*, EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 and as low as 0.1).

251. A POSA would have had a reasonable expectation of success in combining *2007 IFA* with *Price*. Because both are directed towards processes for reducing carbon emissions in ammonia synthesis processes, a POSA would have expected that combining the disclosures of the two references to obtain the desired result, namely, to reduce carbon emissions associated with ammonia synthesis. Further, *2007 IFA* 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.

4. GROUND 1D: Rationale for Combining 2007 IFA and Ji

252. A POSA would have considered *2007 IFA* in conjunction with *Ji* for several reasons. For example, they are in the same field of endeavor, as both relate to syngas production for use as a feedstock for producing products such as ammonia. *See generally* EX1006; EX1012, 1:17-1:24. Additionally, both are intended to reduce carbon emissions and/or reuse products of processes as inputs. *See generally* EX1006; EX1013, 1:6-13. *2007 IFA* discloses updates in the Topsoe ammonia synthesis process that was given at a conference for syngas professionals. Accordingly, a POSA would have, based on *2007 IFA*, known to search for additional references to better understand the details of the ammonia synthesis process. One such reference is *Ji*.

253. A POSA would have been motivated to combine the process disclosed in *2007 IFA* with the disclosure of *Ji*. *2007 IFA* is directed towards modifications to Topsoe's ammonia synthesis process. Accordingly, *Ji*, which is also directed toward modifications to ammonia synthesis processes, would have been considered by a POSA.

254. Regarding claim 11, 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. In fact, the '168 Patent acknowledges that such recycling of purge and tail gases was known in the prior art. EX1001, 1:63-66. In light of the '168 Patent's admission that such recycling was well-known in the art, as well as various other prior art disclosures and a POSA's knowledge and skill, a POSA would have known to recycle a portion of a tail gas of the syngas to the conversion section. *See e.g.*, EX1007 ¶ 93 ("The carbon dioxide depleted residue stream (16) that is recovered, after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).").

255. A POSA would have had a reasonable expectation of success in combining 2007 IFA with 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.

5. GROUND 1E: Rationale for Combining 2007 IFA and Licht

256. A POSA would have considered *2007 IFA* in conjunction with *Licht* for several reasons. For example, they are in the same field of endeavor, as both relate to syngas production for use as a feedstock for producing products such as ammonia and reduced carbon emissions. *See generally* EX1006; EX1009, Abstract, 7:17-18. *2007 IFA* discloses updates in the Topsoe ammonia synthesis process that was given at a conference for syngas professionals. Accordingly, a POSA would have, based on the *2007 IFA* presentation, known to search for additional references to better understand the details of the ammonia synthesis process. One such reference is *Licht*.

257. A POSA would have been motivated to combine the process disclosed in *2007 IFA* with the disclosure of *Licht*. *2007 IFA* is directed towards modifications to Topsoe's ammonia synthesis process. *Licht* is directed towards ammonia synthesis, relates to a process for ammonia synthesis, and would have been considered by a POSA.

258. Regarding claim 17, a POSA would have known to combine the disclosure of the syngas fuel fraction forming all of the fuel of the furnaces in the conversion section or using a trim fuel which accounts for not more than 15% of the total combustion heat, as maximizing the portion of purified H₂ was a well-known goal in order to reduce emissions. *See supra* ¶¶ 56-57 ("The purified

hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production. The hydrogen from syngas after CO₂ removal is a desirable fuel source, as it results in decreased carbon emissions.”). Moreover, the use of trim fuel was a well-known design strategy used to optimize the efficiency of the process. Trim fuel allows one to adjust the temperature and composition of the syngas. 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.

259. A POSA would have had a reasonable expectation of success in combining *2007 IFA* with *Licht*. Because each is towards processes for reducing carbon emissions in ammonia synthesis processes, a POSA would have expected that combining the disclosures of the two references to obtain the desired result, namely, to reduce carbon emissions associated with ammonia synthesis. Further, *2007 IFA* and *Licht* both disclose processes with substantial overlap. Therefore, a POSA would have known that one process that discloses, e.g., providing a natural gas stream, a CO-shift reaction, CO₂ removal, splitting the CO₂-depleted syngas stream, and using at least a portion of the CO₂-depletes syngas stream as fuel, could be modified by applying process steps used in another process that discloses the same overlapping steps.

6. GROUND 2: Rationale for Combining *Rytter* and Ordinary Knowledge

260. A POSA would have considered *Rytter* alone or in combination with a POSA's ordinary degree of common knowledge in the art.

261. *Rytter* shows a process in which natural gas is desulfurized, processed in a prereformer and autothermal reformer, shifted, and then CO₂ is removed from the syngas. After CO₂ removal, the CO₂-depleted syngas is split, with at least some of the syngas being capable of being used for ammonia synthesis and at least part being used for fuel. A POSA would have understood *Rytter* to disclose a process that could be applied to a process for ammonia synthesis given *Rytter* describes part of its syngas stream being "fed to ammonia synthesis." A POSA would have known that the process disclosed in *Rytter* could be applied to ammonia synthesis, as use of CO₂-depleted syngas for various secondary processes, e.g., ammonia synthesis, is well known in the art. *See supra* ¶ 56 ("The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production."); *see also Id.* ¶¶ 36, 38 (describing syngas as a well-known feedstock for a variety of products).

7. GROUND 2A: Rationale for Combining *Rytter* and *Price*

262. A POSA would have considered *Rytter* and *Price* for several reasons. Each is in the same field of endeavor, as both relate syngas production for use as a feedstock for producing products such as ammonia and reducing carbon emissions.

See generally EX1008; EX1011 ¶ 21. Additionally, while *Rytter* emphasizes methanol synthesis, it also discusses the co-production of ammonia, which is the focus of *Price*. EX1008 3:10-16; 4:45-50; EX1011 ¶ 40.

263. Regarding claim 2, 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. *See supra* ¶¶ 53 (“Commercial technologies for final gas purification include methanation, liquid nitrogen wash, pressure swing adsorption, etc. Choices of different technologies depend on many factors, including the type of technology employed for syngas production, the energy consumption and availability of the purification technologies.”) (citing EX1036); *See* EX1014 at 127 et seq.). *Price* discloses “excess hydrogen that has been removed above is further purified if required, compressed and sent to an ammonia synthesis reactor.” EX1011 ¶ 40. And it was well-known in the art that syngas streams require purification prior to ammonia synthesis to avoid poisoning the ammonia synthesis catalysts.

264. Regarding claims 5-6, 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. *See*

e.g., supra ¶¶ 53-55, 57. Accordingly, a POSA would have known to combine the disclosure of such final treatment step(s) in *Price* with the disclosure of *Rytter*.

265. Regarding claim 7, 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. *See supra* ¶¶ 51, 53-55 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”) (citations omitted).

266. Regarding claim 19, 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 are well known in the art. *See e.g.,* EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 and as low as 0.1). A POSA would have had a reasonable expectation of success when combining *Rytter* with *Price*. 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. Further, *Rytter* 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. A POSA would have had a reasonable expectation of success when combining *Rytter* with *Price* because they are directed towards hydrocarbon synthesis processes 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.

8. GROUND 2B: Rationale for Combining *Rytter* and *Ji*

267. A POSA would have considered *Rytter* and *Ji* for several reasons. Both are in the same field of endeavor, relating to syngas production for use as a feedstock for producing products such as ammonia. EX1008, 3:10-16; EX1012, 1:17-24. Additionally, each reference is intended to improve efficiency of gasification processes by, e.g., reducing carbon emissions and/or reusing products of processes as inputs. EX1008, 1:14-40; EX1012, 1:6-13.

268. Regarding claim 11, 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. In fact, the '168 Patent acknowledges that such recycling of purge and tail gases was known in the prior art. EX1001, 1:63-66. In light of the '168 Patent's admission that such recycling was well-known in the art, as well as various other prior art disclosures, a POSA would have known to recycle a portion of a tail gas of the syngas to the conversion section. *See e.g.*, EX1007 ¶ 93 ("The carbon dioxide depleted residue stream (16) that is recovered, after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).").

269. A POSA would have had a reasonable expectation of success when combining *Rytter* with *Ji*. 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.

9. GROUND 2C: Rationale for Combining Rytter and Licht

270. A POSA would have considered *Rytter* and *Licht* for several reasons. 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. EX1008, 1:14-40, 3:10-16; EX1009, Abstract.

271. Regarding claim 17, a POSA would have known to combine the disclosure of the syngas fuel fraction forming all of the fuel of the furnaces in the conversion section or using a trim fuel which accounts for not more than 15% of the total combustion heat, as maximizing the portion of purified H₂ was a well-known goal in order to reduce emissions. *See supra* ¶ 56 (“The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production. The hydrogen from syngas after CO₂ removal is a desirable fuel source, as it results in decreased carbon emissions.”) (citations omitted). Moreover, the use of trim fuel was a well-known design strategy used to optimize the efficiency of the process. Trim fuel allows one to adjust the temperature and composition of the syngas. 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.

272. A POSA would have had a reasonable expectation of success when combining *Rytter* with *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.

10. GROUND 3A: Rationale for Combining *Fjellhaug* with Ordinary Knowledge

273. A POSA would have considered *Fjellhaug* alone or in combination with a POSA's ordinary degree of common knowledge in the art.

274. *Fjellhaug* shows a process in which natural gas is processed in a prereformer and autothermal reformer, shifted, and then CO₂ is removed from the syngas. After CO₂ removal, the CO₂-depleted syngas is split so a portion can be used as fuel and a portion can be used for ammonia synthesis.

275. Regarding claims 3-4, a POSA would have been motivated to modify the process disclosed in *Fjellhaug* to optimize certain working ranges. 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. *See supra* ¶¶ 170, 174.

276. Regarding claim 7, a POSA would have known that the content of CO₂ in the CO₂-depleted syngas could be modified because it was well-known in the art that the goal of CO₂-removal of the syngas, as disclosed in *Fjellhaug*, is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *See supra* ¶¶ 51, 53-55 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”).

277. Regarding claim 10, various furnace types were well-known in the art. *See e.g.*, EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, specific types of furnaces, e.g., steam production furnaces, superheating furnaces, among other types of furnaces, were well-known in the art. Therefore, a POSA would have known to modify *Fjellhaug*’s disclosure to the extent that *Fjellhaug* does not disclose the claimed types of furnaces.

11. GROUND 3B: Rationale for Combining *Fjellhaug* and *Rytter*

278. A POSA would have considered *Fjellhaug* and *Rytter* for several reasons. For example, both *Fjellhaug* and *Rytter* relate to syngas production for use as a feedstock for producing products such as ammonia and reducing carbon emissions. EX1010, 4:64-65, 6:4-7; EX1008, 1:13-36; 3:13-19.

279. Regarding claim 1, a POSA would have been motivated to modify the conversion section disclosed in *Fjellhaug* to be supplied with oxygen or oxygen-enriched air, as disclosed in *Rytter*. It was well-known in the art to supply a conversion section, particularly an ATR, with oxygen or oxygen-enriched air, as ATRs are known to require a supply of oxygen. *See supra* ¶ 46. Accordingly, a POSA would have known that the conversion section of *Fjellhaug* could have been supplied with oxygen or oxygen-enriched air.

280. Regarding claims 3-4, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is also a mere design choice, and the amount of oxygen contained in the oxygen-enriched air (claims 8-9), also a design choice. Use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

281. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Rytter*.

282. Regarding claim 10, various furnace types were well-known in the art. *See e.g.*, EX1015 at 121 (“hydrogen-rich fuel which can be used in many

applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”).

Accordingly, specific types of furnaces, e.g., steam production furnaces, superheating furnaces, among other types of furnaces, were well-known in the art. Therefore, a POSA would have known to modify *Fjellhaug*’s disclosure to the extent that *Fjellhaug* does not disclose the claimed types of furnaces.

283. Regarding claim 18, it was well-known in the art to regulate a process step by modulating the quantity of an input supplied to the section. *See supra* ¶¶ 56, 226. In *Fjellhaug*, the syngas is supplied to drive a gas turbine, which is “comparable to fuel mixtures being used in proven, large scale combined cycle plants.” EX1010, 2:24-27. Because *Fjellhaug* teaches use of syngas as fuel as an alternative to use of syngas supplied to drive a gas turbine, a POSA would be motivated to apply *Rytter*’s disclosure of syngas supplied as fuel to a conversion section, along with a POSA’s ordinary knowledge and skill, to *Fjellhaug* to select the amount of fuel fraction produced with respect to the fuel demand of the conversion section. Accordingly, a POSA would have known that an excess amount of the fuel fraction could be produced, which would allow the conversion section to be regulated by modulating the quantity of the fuel fraction directed toward the conversion section.

284. A POSA would have had a reasonable expectation of success when combining *Fjellhaug* and *Rytter*. 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. Further, *Fjellhaug* and *Rytter* 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, with at least a portion of the CO₂-depleted syngas used for ammonia synthesis, could be modified by applying process steps used in another process that discloses the same overlapping steps.

12. GROUND 3C: Rationale for Combining *Fjellhaug*, *Rytter*, and *Ji*

285. A POSA would have considered *Fjellhaug* and *Rytter* in conjunction with *Ji* for several reasons. Each are 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. EX1010, 4:64-65, 6:4-7; EX1008, 1:13-36; 3:13-19; EX1012, 1:6-24.

286. Regarding claim 11, 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. In fact, the '168 Patent acknowledges that such recycling

of purge and tail gases was known in the prior art. EX1001, 1:63-66. In light of the '168 Patent's admission that such recycling was well-known in the art, as well as various other prior art disclosures, a POSA would have known to recycle a portion of a tail gas of the syngas to the conversion section. *See e.g.*, EX1007 ¶ 93 ("The carbon dioxide depleted residue stream (16) that is recovered, after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).").

287. A POSA would have had a reasonable expectation of success when combining *Fjellhaug*, *Rytter*, and *Ji*. 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.

13. GROUND 3D: Rationale for Combining *Fjellhaug*, *Rytter*, and *Licht*

288. A POSA would have considered *Fjellhaug* and *Rytter* in conjunction with *Licht* for several reasons. 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. EX1010, 4:64-65, 6:4-7; EX1008, 1:13-36; 3:13-19; EX1009, Abstract, 7:17-18.

289. Regarding claim 17, a POSA would have known to combine the disclosure of the syngas fuel fraction forming all of the fuel of the furnaces in the conversion section or using a trim fuel which accounts for not more than 15% of the total combustion heat, as maximizing the portion of purified H₂ was a well-known goal in order to reduce emissions. *See supra* ¶ 56 (“The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production. The hydrogen from syngas after CO₂ removal is a desirable fuel source, as it results in decreased carbon emissions.”). Moreover, the use of trim fuel was a well-known design strategy used to optimize the efficiency of the process. Trim fuel allows one to adjust the temperature and composition of the syngas. 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.

290. A POSA would have had a reasonable expectation of success when combining *Fjellhaug*, *Rytter*, 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.

14. GROUND 4A: Rationale for Combining *Terrien* with Ordinary Knowledge

291. A POSA would have considered *Terrien* alone or in combination with a POSA's ordinary degree of common knowledge in the art.

292. *Terrien* shows a process in which natural gas is processed in a prereformer and autothermal reformer, shifted, and then CO₂ is removed from the syngas. After CO₂ removal, the CO₂-depleted syngas is split so a portion can be used as fuel.

293. Regarding claim 1, *Terrien* shows a process for H₂ synthesis. A POSA would understand that a front-end H₂ synthesis process could be modified to include a step for ammonia synthesis, as H₂ is a necessary component for ammonia synthesis. *See supra* ¶¶ 38-41.

294. Regarding claims 3-4, a POSA would have been motivated to modify the process disclosed in *Terrien* to optimize certain working ranges. 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. *See supra* ¶¶ 170, 174.

295. Regarding claims 5-6, 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. *See*

e.g., supra ¶ 53-55, 57. Accordingly, a POSA would have known to combine the disclosure of such final treatment step(s) with the disclosure of *Terrien*.

296. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 (Han) ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen.

297. Regarding claim 18, it was well-known in the art to regulate a process step by modulating the quantity of an input supplied to the section. *See supra* ¶¶ 56, 226. Therefore, a POSA would be motivated to apply a POSA's ordinary knowledge and skill, to *Terrien* to select the amount of fuel fraction produced with respect to the fuel demand of the conversion section. Accordingly, a POSA would have known that an excess amount of the fuel fraction could be produced, which would allow the conversion section to be regulated by modulating the quantity of the fuel fraction directed toward the conversion section.

298. Regarding claim 19, a POSA would have known that the content of CO₂ in the CO₂-depleted syngas could be modified based on ordinary knowledge because it was well-known in the art that the goal of CO₂-removal of the syngas, as

disclosed in *Terrien*, is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *See supra* ¶¶ 48, 50-51 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”) (citations omitted). Finally, 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 are well known in the art. *See e.g.*, EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 and as low as 0.1).

15. GROUND 4B: Rationale for Combining *Terrien* and *Price*

299. A POSA would have considered *Terrien* in conjunction with *Price* for several reasons. For example, each is in the same field of endeavor, as both are directed to syngas production. EX1007 ¶ 35; *See generally* EX1011. Both *Terrien* and *Price* relate to reducing carbon dioxide emissions. EX1007 ¶ 3; EX1011 ¶¶ 56-58.

300. A POSA would have been motivated to modify the process disclosed in *Terrien* to include the conversion section disclosed in *Price*. A POSA would have been familiar with the interchangeability of conversion sections. Accordingly, a POSA would have been motivated to vary the configuration of the conversion section in *Terrien*.

301. Regarding claim 1, it was well-known in the art that various types of reformers, prereformers, and combinations thereof can form a conversion section to achieve desired results. *See, e.g.*, EX1032, 2:53-54 (“Prereforming of hydrocarbons upstream of the SMR or ATR is a well known process.”). Therefore, a POSA would have known to combine the disclosure of *Price* to supplement the disclosure of *Terrien* with respect to the configuration of the conversion section. Similarly, it was well-known in the art that CO₂-depleted syngas can be used in a variety of subsequent processes, e.g., ammonia synthesis. *See supra* ¶ 56 (“The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production.”).

302. Regarding claim 2, 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. *See supra* ¶ 53 (“Commercial technologies for final gas purification include methanation, liquid nitrogen wash, pressure swing adsorption, etc. Choices of different technologies depend on many factors, including the type of technology employed for syngas production, the energy consumption and availability of the purification technologies.”) (citing EX1036); *See* EX1014 at 127 et seq.). *Price* discloses “excess hydrogen that has been removed above is *further purified* if required,

compressed and sent to an ammonia synthesis reactor.” EX1011 ¶ 40. And it was well-known in the art that syngas streams require purification prior to ammonia synthesis to avoid poisoning the ammonia synthesis catalysts.

303. Regarding claims 3-4, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is also a mere design choice, and the amount of oxygen contained in the oxygen-enriched air (claims 8-9), also a design choice. Use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

304. Regarding claims 5-6, 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. *See e.g., supra* ¶¶ 53-55, 57. Accordingly, a POSA would have known to combine the disclosure of such final treatment step(s) in *Price* with the disclosure of *Terrien*.

305. Regarding claim 7, 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. *See supra* ¶¶ 51, 53-55 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”).

306. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 (Han) ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Price*.

307. Regarding claim 10, various furnace types were well-known in the art. *See e.g.*, EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, specific types of furnaces, e.g., steam production furnaces, superheating furnaces, among other types of furnaces, were well-known in the art. Therefore, a POSA would have known to apply *Price*’s disclosure of the specific types of furnaces to *Terrien*’s disclosure.

308. Regarding claim 19, 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, as disclosed in *Terrien*, is to reduce the concentration of CO₂ in the syngas as it is poisonous to ammonia synthesis catalysts. *See supra* ¶¶ 48, 50-51 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”) (citations omitted). Finally, 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 are well known in the art. *See e.g.*, EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip); EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 and as low as 0.1).

309. A POSA would have had a reasonable expectation of success when combining *Terrien* with *Price*. Both references are directed towards syngas production with a common goal of reduced emissions. Accordingly, a POSA would have expected that modifying one hydrocarbon synthesis process by implementing steps disclosed in the other would be reasonably likely to succeed. Further, *Terrien* 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, and CO₂

removal, could be modified by applying process steps used in another process that discloses the same overlapping steps.

16. GROUND 4C: Rationale for Combining *Terrien*, *Price*, and *Ji*

310. A POSA would have considered *Terrien* and *Price* in conjunction with *Ji* for the reasons above with respect to *Terrien* and *Price*. Additionally, *Terrien*, *Price*, and *Ji* are 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.

311. Regarding claim 11, 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. *See supra* ¶ 57. In fact, the '168 Patent acknowledges that such recycling of purge and tail gases was known in the prior art. Ex. 1001, 1:63-66. In light of the '168 Patent's admission that such recycling was well-known in the art, as well as various other prior art disclosures, a POSA would have known to recycle a portion of a tail gas of the syngas to the conversion section. *See e.g.*, EX1007 ¶ 93 ("The carbon dioxide depleted residue stream (16) that is recovered,

after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).”).

312. A POSA would have had a reasonable expectation of success when combining *Terrien* with *Price* and *Ji*. 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.

17. GROUND 4D: Rationale for Combining *Terrien*, *Price*, and *Licht*

313. A POSA would have considered *Terrien* and *Price* in conjunction with *Licht* for the reasons above with respect to *Terrien* and *Price*. Additionally, *Terrien*, *Price*, and *Licht* are 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.

314. Regarding claim 17, A POSA would have known to combine the disclosure of the syngas fuel fraction forming all of the fuel of the furnaces in the conversion section or using a trim fuel which accounts for not more than 15% of

the total combustion heat, as maximizing the portion of purified H₂ was a well-known goal in order to reduce emissions. *See supra* ¶ 56 (“The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production. The hydrogen from syngas after CO₂ removal is a desirable fuel source, as it results in decreased carbon emissions.”). Moreover, the use of trim fuel was a well-known design strategy used to optimize the efficiency of the process. Trim fuel allows one to adjust the temperature and composition of the syngas. 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.

315. A POSA would have had a reasonable expectation of success when combining *Terrien* with *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.

18. GROUND 4E: Rationale for Combining *Terrien*, *Price*, and *Rytter*

316. A POSA would have considered *Terrien* and *Price* in conjunction with *Rytter* for the reasons above with respect to *Terrien* and *Price*. Additionally, *Terrien*, *Price*, and *Rytter* are 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.

317. Regarding claims 3-4, use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”); EX1037 at 307 (excess syngas used as fuel for reformers). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

318. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 (Han) ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Rytter*. *Rytter* discloses these elements and a POSA would have known to utilize knowledge in the art and/or additional references to select these ranges.

319. A POSA would have had a reasonable expectation of success when combining *Terrien* with *Price* and *Rytter*. 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 the other would be reasonably likely to succeed. Further, each discloses 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

19. GROUND 5: Rationale for Combining *Licht* and *Price*

320. A POSA would have considered *Licht* with *Price* for several reasons. 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.

321. Regarding claim 1, it was well-known in the art that various types of reformers, prereformers, and combinations thereof can form a conversion section to achieve desired results. *See, e.g.*, EX1032, 2:53-54 (“Prereforming of hydrocarbons upstream of the SMR or ATR is a well-known process.”); *see supra* ¶ 49. Therefore, a POSA would have known to combine the disclosure of *Price* to

supplement the disclosure of *Licht* with respect to the configuration of the conversion section. Similarly, it was well-known in the art that CO₂-depleted syngas can be used in a variety of subsequent processes, e.g., ammonia synthesis. *See supra* ¶ 56 (“The purified hydrogen itself is a product, but it also is used for ammonia synthesis, methanol synthesis, and as a clean fuel for energy production.”).

322. Regarding claim 2, 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. *See supra* ¶ 53 (“Commercial technologies for final gas purification include methanation, liquid nitrogen wash, pressure swing adsorption, etc. Choices of different technologies depend on many factors, including the type of technology employed for syngas production, the energy consumption and availability of the purification technologies.”) (citing EX1036); *See* EX1014 at 127 et seq.). *Price* discloses “excess hydrogen that has been removed above is ***further purified*** if required, compressed and sent to an ammonia synthesis reactor.” EX1011 ¶ 40. And it was well-known in the art that syngas streams require purification prior to ammonia synthesis to avoid poisoning the ammonia synthesis catalysts.

323. Regarding claims 3-4, a POSA would have been motivated to adjust the amount of CO₂-depleted syngas used as fuel (claims 3-4), which is also a mere design choice, and the amount of oxygen contained in the oxygen-enriched air (claims 8-9), also a design choice. Use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

324. Regarding claims 5-6, 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. *See e.g., supra* ¶¶ 53-55, 57. Accordingly, a POSA would have known to combine the disclosure of such final treatment step(s) in *Price* with the disclosure of *Licht*.

325. Regarding claim 7, 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. *See supra* ¶¶ 51, 53-55 (“[CO₂ and CH₄] are removed as they add no value and are also poisonous for the subsequent ammonia synthesis catalyst.”).

326. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available EX1031 ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Price*.

327. Regarding claim 10, various furnace types were well-known in the art. *See e.g.*, EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”). Accordingly, specific types of furnaces, e.g., steam production furnaces, superheating furnaces, among other types of furnaces, were well-known in the art. Therefore, a POSA would have known to apply *Price*’s disclosure of the specific types of furnaces to *Licht*’s disclosure.

328. Regarding claim 19, 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 are well known in the art. *See e.g.*, EX1031 ¶¶ 20 (describing ATR with S/C ratio of 1.5-3 to prevent methane slip);

EX1040, 3:1-2, 3:41-43 (describing reforming with ATR and S/C ratios of 2-0.2 and as low as 0.1).

329. A POSA would have a reasonable expectation of success when combining *Licht* and *Price*. 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. 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.

20. GROUND 5A: Rationale for Combining *Licht*, *Price*, and *Ji*

330. A POSA would have considered *Licht* and *Price* in conjunction with *Ji* for several reasons. 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.

331. Regarding claim 11, 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. In fact, the '168 Patent acknowledges that such recycling of purge and tail gases was known in the prior art. EX1001, 1:63-66. In light of the '168 Patent's admission that such recycling was well-known in the art, as well as various other prior art disclosures, a POSA would have known to recycle a portion of a tail gas of the syngas to the conversion section. *See e.g.*, EX1007 ¶ 93 ("The carbon dioxide depleted residue stream (16) that is recovered, after optionally being turbo expanded in a turbo expander (26) (in order to recover compressed gas energy and use this energy to drive other components of the process) can be used as a supplemental feed for the prereformer (21).").

332. A POSA would have had a reasonable expectation of success when combining *Licht*, *Price*, and *Ji*. 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.

21. GROUND 5B: Rationale for Combining *Licht*, *Price*, and *Rytter*

333. A POSA would have considered *Licht* and *Price* in conjunction with *Rytter* for several reasons. 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.

334. Regarding claims 3-4, use of CO₂-depleted syngas as a fuel fraction, among other uses, was well-known in the art. *See* EX1027 at 113 (“Excess hydrogen, if present, must be removed from the product. This hydrogen may be valued as an additional product stream or as fuel.”); EX1015 at 121 (“hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.”); EX1037 at 307 (excess syngas used as fuel for reformers). Accordingly, a POSA would have known that any portion of the CO₂-depleted syngas could be used as fuel, with the remainder being used for any other suitable process(es).

335. Regarding claims 8-9, it was well-known in the art that conversion sections can be supplied with oxygen and/or oxygen-enriched air. *See* EX1027 at 91 (describing ATR as an effective option when oxygen or enriched air is available); EX1031 (Han) ¶¶ 16-17 (describing ATR with air or enriched air that is 30-70% oxygen, 40-50% oxygen, up to 100% oxygen). Accordingly, a POSA would have known that the oxygen-enriched air could include any suitable percentage of oxygen, including those disclosed in *Rytter*. *Rytter* discloses these

elements and a POSA would have known to utilize knowledge in the art and/or additional references to select these ranges.

336. A POSA would have had a reasonable expectation of success when combining *Terrien* with *Price* and *Rytter*. 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 the other would be reasonably likely to succeed. Further, each discloses 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

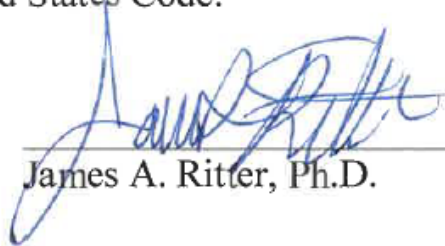
XI. Secondary Considerations of Non-Obviousness

337. I am not aware of, and the Patent Owner has not presented, any evidence of secondary considerations with respect to the '168 Patent. I also am not aware of any evidence of the existence of a nexus between the Challenged Claims of the '168 Patent and any evidence of secondary considerations. Should the Patent Owner attempt to show a nexus between the claims and any secondary considerations, I will respond accordingly.

XII. Declaration

338. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that those statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

8/20/2025
Date


James A. Ritter, Ph.D.