

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TOPSOE INC.,

Petitioner,

v.

CASALE SA,

Patent Owner.

Patent No. 11,286,168

Issued: March 29, 2022

Filed: January 31, 2018

Inventors: Francesco Baratto et al.

Title: PROCESS FOR THE SYNTHESIS OF AMMONIA WITH LOW
EMISSIONS OF CO₂ IN ATMOSPHERE

Inter Partes Review No. IPR2025-01454

**DECLARATION OF COLIN A. WOLDEN, PH.D. IN SUPPORT OF
PATENT OWNER'S RESPONSE**

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I, Colin A. Wolden, Ph.D., declare as follows:

I. INTRODUCTION

1. I have been retained on behalf of Casale S.A. (hereinafter, “Patent Owner”) for the above-captioned *Inter Partes* Review proceeding to provide my expert opinions and expert knowledge. I understand that this proceeding involves U.S. Patent No. 11,286,168 (“the ’168 Patent”) titled “Process for the synthesis of ammonia with low emissions of CO₂ in atmosphere” to Baratto *et al.*, and that the ’168 Patent is currently assigned to Patent Owner. I understand that the present proceedings involve a challenge to the validity of claims 1-11 and 17-19 of the ’168 Patent (the “Challenged Claims”).

2. In preparing this declaration, I have reviewed and am familiar with all the references cited herein. I have reviewed and am familiar with the ’168 Patent and its file history. I confirm that to the best of my knowledge the accompanying exhibits are true and accurate copies of what they purport to be, and that an expert in the field would reasonably rely on them to formulate opinions such as those set forth in this declaration.

3. The ’168 Patent describes a process for synthesizing ammonia from natural gas with greatly reduced CO₂ emissions by using oxygen-enriched air to generate a CO₂-depleted synthesis gas, diverting a portion of that gas as hydrogen-

rich fuel for the plant's furnaces instead of burning natural gas, and using the remaining portion to produce ammonia.

4. I am familiar with the technology described in the '168 Patent and state of the art as of the '168 Patent's earliest possible effective priority date of February 15, 2017, and its filing date of January 31, 2018.

5. I have been asked to provide my independent technical review, analysis, insights, and opinions regarding the '168 Patent and the references that form the basis for the grounds set forth in the Petitions for *Inter Partes* review of the '168 Patent.

II. QUALIFICATIONS

6. I received a B.S. in Chemical Engineering from the University of Minnesota in 1990, an M.S. in Chemical Engineering Practice from the Massachusetts Institute of Technology ("MIT") in 1992, and a Ph.D. in Chemical Engineering from MIT in 1995.

7. From 1995-1997, I was a National Research Council/Army Research Office Postdoctoral Fellow and conducted research at North Carolina State University, Department of Materials Science.

8. From 1997-2002, I was an assistant professor in the Department of Chemical Engineering at the Colorado School of Mines in Golden, Colorado. In

2002, I was promoted to Associate Professor with Tenure, and in 2008, I was promoted to Full Professor.

9. In 2024, I was appointed the William K. Coors Distinguished Chair and Professor in the Department of Chemical and Biological Engineering at the Colorado School of Mines, a position I continue to hold today.

10. My areas of expertise and research interests include catalytic membrane reforming, thin film optoelectronics, solid state battery materials, and purification of hydrogen isotopes pertinent to fusion.

11. I have authored or co-authored over 170 peer-reviewed academic publications in the field of chemical engineering, including ammonia synthesis. In addition, I have been an associate editor for the *Journal of Vacuum Science and Technology A/B* (2010-2019) and a reviewer for numerous chemical engineering journals, including *International Journal of Hydrogen Energy*, *Chemical Engineering and Processing - Process Intensification*, *Journal of Membrane Science*, *Industrial & Engineering Chemistry Research*, *Energy Technology*, *Joule*, *ACS Sustainable Chemistry & Engineering*, *AIChE Journal*, and *ACS Applied Energy Materials*.

12. A few of my research projects most relevant to the technology at issue here include the following: ammonia synthesis, hydrogen production from reforming of ammonia and methanol, and advanced membrane technologies for hydrogen purification.

13. I am a named inventor or co-inventor on eleven United States patents, six United States patent applications, and several foreign patents and applications.

14. My industry experience includes a variety of engineering roles at 3M, Dow Chemical, and Merck, as well as consulting roles for various companies.

15. A copy of my latest *curriculum vitae* (CV) was submitted as Exhibit 2005.

16. I have provided testimony as an expert witness in one other case: *View, Inc. v. Sage Electrochromics, Inc.*, IPR2015-00245. My time is billed at a rate of \$300 per hour in this proceeding. The compensation received from this case is not contingent upon my opinions or performance, the outcome, or any issues involved in or related to the proceeding.

III. MATERIALS CONSIDERED

17. I have reviewed the '168 Patent, the claims of the '168 Patent, and the file history of the '168 Patent, including the *ex parte* reexamination.

18. I have also reviewed the Petition for IPR filed by Topsoe, Inc. ("Petitioner") and all exhibits in support of the Petition, including the Declaration of Dr.

James A. Ritter (EX1005). I have also reviewed the transcript of the April 30, 2026 deposition of James Ritter, Ph.D.

19. In forming my opinions, I have considered the materials listed above and any other documents cited in this declaration. I have also relied on my own education, knowledge, and experience in the relevant art.

20. I have also considered the understanding of a person of ordinary skill in the art around the time of the invention of the Challenged Claims of the '168 Patent.

IV. MY UNDERSTANDING OF LEGAL PRINCIPLES

21. I understand that Petitioner must demonstrate by a preponderance of the evidence that the Challenged Claims are unpatentable. I understand that the preponderance of the evidence standard is one characterized as being more likely than not. As each claim is considered a separate invention, I understand that the Petitioner's burden is applicable individually to each claim.

22. I further understand that determining whether a patent claim is unpatentable requires two steps: first, construction of the meaning and scope of the claim (or individual terms of the claim), and second, comparing the properly construed claim to the prior art. A party may assert unpatentability on the basis of anticipation or obviousness.

23. I understand that my analysis requires an understanding of the scope of the '168 Patent claims and that the disclosures of the '168 Patent and the prior art are judged from the perspective of a person of ordinary skill in the art ("POSA") at the time of the invention. For the purposes of this declaration, I have been instructed to consider the earliest possible priority date for the '168 Patent to be February 15, 2017, and my analysis is based on the perspective of a POSA as of that date.

24. I understand that during an *inter partes* review, claims of an unexpired patent are to be construed according to their ordinary and customary meaning as would be understood by a POSA within the context of the patent record. Unless otherwise noted, I have given the claim terms their plain and ordinary meaning as understood by a POSA at the time of invention.

25. I also understand that a patentee can act as his own lexicographer by defining claim terms in the specification of a patent. The specification of the '168 Patent explains that "the term 'furnace' is understood as meaning an apparatus chosen from among: a steam reformer or a charge preheater or a steam generator or a steam superheater. These apparatus, which operate by means of combustion, are identified by the term 'fired heater.'" EX1001, at 2:47-52. I understand Patent Owner submits that the term "furnace" in Claim 1 should be construed as: "an apparatus chosen from among: a steam reformer or a charge preheater or a steam

generator or a steam superheater.” I agree with this definition in the context of the ’168 Patent.

26. I understand that the Petitioner argues that a furnace and turbine are equivalent. I disagree. A furnace is a relatively simple unit that involves combustion of fuel followed by the transfer of thermal energy from the hot combustion gas to another fluid. A turbine is a much more complex device. In a turbine, air is typically compressed, combusted with fuel at elevated pressure, but instead of transferring heat the energy is converted first into mechanical energy and secondly into electrical energy. Thus while both involve combustion, a furnace simply transfers thermal energy while a turbine transforms thermal energy into mechanical and electrical energy. A gas turbine (which is intended to generate electricity) is not a “furnace” as defined in the specification or based on the ordinary and customary understanding of a person of ordinary skill (which is intended to generate heat and transfer it to another fluid).

27. I understand that a claim is unpatentable if it is anticipated or obvious. I understand that anticipation of a claim requires that every element of a claim is expressly or inherently disclosed in a single prior art reference. I understand that an anticipating reference need not use the exact terms of the claims, but must describe the patented subject matter with sufficient clarity and detail to establish that the

claimed subject matter existed in the prior art and that such existence would be recognized by persons of ordinary skill in the field of the invention. I also understand that an anticipating reference must enable one of ordinary skill in the art to reduce the invention to practice without undue experimentation.

28. I understand that a patent claim is unpatentable if the claimed invention would have been obvious to a POSA at the time of the invention. This means that, even if all requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, the claim can still be unpatentable.

29. I understand that an obviousness analysis involves comparing a claim to the prior art to determine whether the claimed invention would have been obvious to a POSA at the time of the invention in view of the prior art and in light of the general knowledge in the art as a whole. I also understand that obviousness is ultimately a legal conclusion based on underlying facts of four general types, all of which must be considered: (1) the scope and content of the prior art; (2) the level of ordinary skill in the art; (3) the differences between the claimed invention and the prior art; and (4) any objective indicia of non-obviousness.

30. I also understand that obviousness may be established by combining or modifying the teachings of the prior art. Specific teachings, suggestions, or motivations to combine any first prior art reference with a second prior art reference can be explicit or implicit, but if relied upon must have existed before the date of

invention. I understand that prior art references themselves may be one source of a specific teaching or suggestion to combine features of the prior art, but that such suggestions or motivations to combine art may come from the knowledge of a POSA.

31. The Petition states, “All [of the prior art here] are in the same technical field of syngas production and are analogous references to one another and to the ’168 Patent.” Petition at 10. I disagree. A POSA would understand that the technical field of the ’168 Patent is not syngas production generally, but ammonia synthesis. The ’168 Patent is directed to overcoming a challenge that is specific to ammonia synthesis. *See* EX1001 at Abstract; 1:5-9.

32. I further understand that whether there is a reasonable expectation of success from combining references in a particular way is also relevant to the analysis. I understand there may be a number of rationales that may support a conclusion of obviousness, including combining familiar elements according to known methods to yield predictable results or a combination was obvious to try.

33. I understand that it is not proper to use hindsight to combine references or elements of references to reconstruct the invention using the claims as a guide. Rather, I understand that one should analyze obviousness from the perspective of a POSA having no knowledge of the claimed invention or the patent in

question at the time the patent application was filed to determine whether the inventions claimed in the patent would have been obvious in view of the prior art and the knowledge and motivations of a POSA, among other things. My analysis of the prior art is made from the perspective of a POSA at the time of the invention and does not rely on hindsight.

34. I understand that objective indicia of non-obviousness may be relevant to the determination of whether a claim is obvious. Such objective indicia can include evidence of commercial success caused by an invention, evidence of a long-felt need that was solved by an invention, evidence that others copied an invention, skepticism or disbelief by those skilled in the art, failure of others, praise of the invention, evidence that an invention achieved a surprising result, or near-simultaneous invention by multiple parties.

35. I understand that for a reference to be used to show that a claim is obvious, the reference must be analogous art to the claimed invention. I understand that a reference is analogous to the claimed invention if the reference is from the same field of endeavor as the claimed invention, even if it addresses a different problem, or if the reference is reasonably pertinent to the problem faced by the inventor, even if it is not in the same field of endeavor as the claimed invention. I understand that a reference is reasonably pertinent based on the problem faced by the inventor as reflected in the specification.

V. OVERVIEW OF THE '168 PATENT

36. The '168 Patent discloses an improved ammonia synthesis process that minimizes CO₂ emissions by redesigning how synthesis gas is generated and used.

37. Unlike conventional plants that employ natural gas both as furnace fuel and as the feedstock to create CO₂-depleted synthesis gas, the process disclosed in the '168 patent diverts a *portion of CO₂-depleted synthesis gas*—essentially hydrogen-rich gas after decarbonation—as the fuel fraction for furnaces, thereby eliminating most combustion-related CO₂ emissions.

38. As the Abstract of the '168 Patent explains, “a part of the CO₂-depleted synthesis gas...is separated and used as fuel fraction for one or more furnaces of the conversion section.” EX1001 at Abstract.

39. In ammonia production, the synthesis loop is preceded by hydrogen production through hydrocarbon reforming and purification.

40. Synthesis gas (or syngas, for short) is a precursor to many chemicals. For many chemicals (e.g., methanol, hydrocarbons) the amount of hydrogen produced in the former exceeds the requirements of the synthesis loop, and prior art processes focused on efficient utilization of this excess hydrogen to produce steam, electricity, or potentially other chemicals.

41. In contrast, ammonia production capacity is constrained by the amount of hydrogen available. The '168 Patent teaches reducing ammonia production and diverting a portion of the valuable hydrogen reagent back into the front end of the process to decarbonize the hydrogen production process itself.

42. Desulfurized natural gas and steam are first pre-heated in a furnace (AUX) before being converted using a prereformer (PRE) followed by an autothermal reformer (ATR) supplied with oxygen-enriched air (22) to form synthesis gas (primarily a mixture of H_2 and CO), which is then treated in a shift reactor (SHF) which converts CO into CO_2 and produces additional H_2 . The subsequent CO_2 -removal unit (CDR) extracts the majority of the carbon. EX1001, at 12:51-13:8; *id.* at Fig. 1. After decarbonation, part of the resulting CO_2 -depleted syngas (14) is routed back as furnace fuel for AUX, while the remainder (18) proceeds to ammonia synthesis (which requires a methanation treatment (MET) to remove any residual CO and adds nitrogen (19) from the air separation unit (ASU) to create the final product: ammonia (NH_3 , 23) in the synthesis reactor (SYN)). *Id.* at 13:14-17; *id.* at Fig. 1.

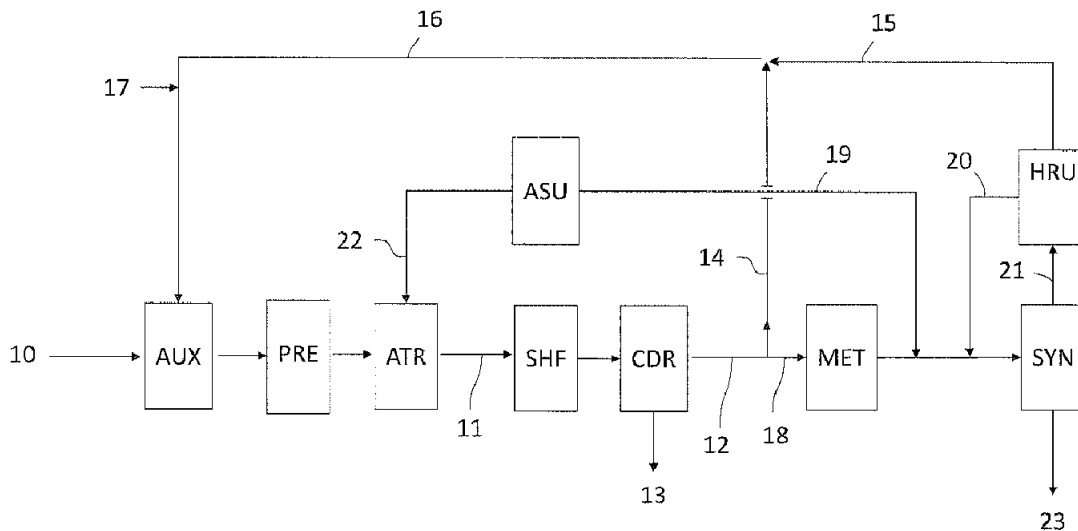


FIG. 1

43. This internal recycling of low-carbon syngas allows the plant to supply its own heat demand without relying on fossil-fuel combustion.

44. The inventors of the '168 Patent recognized that diverting hydrogen-rich process gas—rather than flue-gas scrubbing or external CO₂ capture—can achieve near-zero-emission ammonia production (as low as 0.05 t CO₂ per t NH₃) while maintaining process efficiency and compatibility with plant revamps.

EX1001, at 10:57-60.

VI. CHALLENGED CLAIMS

45. I have listed the challenged claims below, with numbers and letters identifying each element of the claims that are used for clarity throughout this declaration.

Claim 1

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 CO₂, in a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween;”

1[b] – “treatment of said synthesis gas including at least a shift reaction of the carbon monoxide into 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;”

1[c] – “separation of a part of said CO₂-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 CO₂-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.”

Claim 2

2[pre] – “The process of claim 1,”

2[a] – “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.”

Claim 3

3[pre] – “The process of claim 1,”

3[a] – “wherein said fuel fraction is between 1% and 40% of the total amount of said CO₂-depleted syngas.”

Claim 4

4[pre] – “The process of claim 1,”

4[a] – “wherein said fuel fraction is between 10% and 30% of the total amount of said CO₂-depleted syngas.”

Claim 5

5[pre] – “The process of claim 1,”

5[a] – “further comprising a step for methanation of the synthesis gas and/or addition of nitrogen to the synthesis gas.”

Claim 6

6[pre] – “The process of claim 5,”

6[a] – “wherein said fuel fraction is separated upstream of the methanation step or upstream of the nitrogen addition step.”

Claim 7

7[pre] – “The process of claim 1,”

7[a] – “wherein said CO₂-depleted syngas contains no more than 1000 ppm by volume of CO₂.”

Claim 8

8[pre] – “The process of claim 1,”

8[a] – “wherein said enriched air contains at least 50% oxygen.”

Claim 9

9[pre] – “The process of claim 1,”

9[a] – “wherein said enriched air contains at least 90% oxygen.”

Claim 10

10[pre] – “The process of claim 1,”

10[a] – “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.”

Claim 11

11[pre] – “The process of claim 1,”

11[a] – “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.”

Claim 17

17[pre] – “The process of claim 1,”

17[a] – “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.”

Claim 18

18[pre] – “The process of claim 1,”

18[a] – “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.”

Claim 19

19[pre] – “The process of claim 1,”

19[a] – “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.”

46. All but Claim 1 of Challenged Claims are dependent claims, and each dependent claim depends from Claim 1.

VII. LEVEL OF ORDINARY SKILL IN THE ART

47. I understand that several factors are relevant to determining the level of ordinary skill in the art at the time of the claimed invention. I understand that those factors include: (1) the educational level of the inventor(s); (2) type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology; and (6) educational level of active workers in the field.

48. The art of the '168 Patent relates to an ammonia synthesis process. The types of problems encountered in the art include balancing efficient ammonia production with reduction of harmful emissions.

49. The inventors of the '168 Patent are Francesco Baratto and Raffaele Ostuni. Based on publicly available records, it appears that Mr. Baratto¹ and Mr. Ostuni² have advanced degrees (e.g., master's degrees) in chemical engineering.

50. After considering the factors mentioned above, and based on the disclosure of the '168 Patent, a POSA at the relevant time would have had at least a four-year bachelor's degree in chemical engineering, or similar, and at least two

¹ <https://www.linkedin.com/in/francesco-baratto-8a753a2/>.

² <https://www.linkedin.com/in/raffaele-ostuni-22b634160/>.

years of experience working with ammonia production systems, or an advanced degree in chemical engineering or the like. This skill level reflects familiarity with ammonia production systems and emissions reduction processes.

51. Dr. Ritter concludes that a POSA at the relevant time “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.” EX1005 ¶35. Dr. Ritter provides that the “definition is approximate, and more education may substitute for industry experience or vice versa.” *Id.*

52. While I disagree with Dr. Ritter’s definition of a POSA as explained above, for purposes of my analysis herein, I have accepted Dr. Ritter’s conclusion about the level of skill in the art. By February 2017, I held a Ph.D. in Chemical Engineering from MIT and twenty five years of experience in research and development of materials and processing technologies pertinent to energy applications.

VIII. SUMMARY OF THE PROSECUTION HISTORY

53. The application that issued as the ’168 Patent was filed on January 31, 2018.

54. One office action issued during the initial prosecution of the application that issued as the '168 Patent. EX1002 at 290. In response to the office action, Patent Owner argued that the cited prior art did not teach that “said first and second streams [have] the same composition.” *Id.* at 314-15. The Examiner allowed the claims, and the '168 Patent issued on March 29, 2022.

55. In February 2023, Patent Owner submitted a Request for Supplemental Examination. *See* EX1003 (File history for Supp. Exam. No. 96/000,424).

56. This art included Licht (U.S. Patent No. 8,137,422), which Petitioner has asserted in three different Grounds in the petition (Grounds 1E, 2C, and 3D). *See* Petition at 1-2; EX1009.

57. The USPTO found the request raised a substantial new question of patentability and instituted *ex parte* reexamination on May 11, 2023.

58. Patent Owner amended independent claim 1 to recite “a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween.” EX1003, at 631, 638-42, 908, 914-15. The Examiner allowed the amended claims based on his understanding that the prior art did not disclose the features of the amended claim. *Id.* at 1184. Patent Owner also amended dependent Claims 11 and 19. EX1001 at 20. The reexamination certificate issued on July 16, 2024, confirming the patentability of the '168 Patent's claims as amended.

IX. ANALYSIS OF THE ALLEGED PRIOR ART AND PETITIONER'S PROPOSED GROUNDS

A. 2007 IFA (EX1006) (Ground 1)

59. *2007 IFA* is a slide deck on the CO₂ reduction potential in ammonia synthesis. On p.8, *2007 IFA* specifically outlines strategies to reduce CO₂ production in ammonia production. These include CO₂ capture from flue gas, reduced fuel firing requirements through improved heat recovery, and efficiency improvements in ancillary steam and power generation applications.

60. Notably, the *2007 IFA* does not mention the concept of using hydrogen for fueling or heating operations to accomplish CO₂ reduction in the conversion section, which highlights the originality of the '168 Patent. *2007 IFA* only proposes that excess H₂ may be used for electricity production.

1. Public Availability of 2007 IFA

61. I understand that Patent Owner contends *2007 IFA* is not prior art.

62. *2007 IFA* does not appear in Google Scholar or any standard searchable database.

63. *2007 IFA*'s title does not contain terms like ammonia or hydrogen but instead is very generic: "Future Energy Efficiency and CO₂ Reduction Potential." This title could pertain to host of unrelated industries, like solar power, wind energy, or nuclear power.

64. When one searches “ammonia” on the IFA website’s searchable page for IFA resources, the 2007 IFA slide deck does not return as a result, except within a document containing 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.” This file is a combination of more than 10 different presentations consisting of 139 total slides, and the title of the document has no indication that the 2007 IFA slides would be included in the file. Additionally, that search returns more than 90 results, with documents dating back to the 1980s. A person interested and ordinarily skilled in the art exercising reasonable diligence would not be able to locate the key slides in these search results.

2. Claim 1

65. Limitation 1[c] of Independent Claim 1 requires “separation of a part of said CO₂-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 CO₂-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...” The “said CO₂-depleted synthesis gas” is hydrogen-rich synthesis gas based on Claim 1 limitations 1[a] and 1[b].

66. I understand the Petition asserts “*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 (GT) and steam generator (HRSG—Heat Recovery Steam Generator). EX1006 at 8.” Petition at 17.

67. First, a POSA would understand that the order of the slides reflects that *2007 IFA* discloses distinct processes. Page 8 of *2007 IFA* shows a “gas turbine” but does not label any component a “steam generator (HRSG—Heat Recovery Steam Generator).”

68. Page 8 also does not “show[] using CO₂-depleted syngas as fuel.” Throughout the *2007 IFA*, the term “Fuel” is used exclusively to refer to hydrocarbon or natural gas, as defined explicitly on page 7 of *2007 IFA*. Accordingly, the term fuel on page 8 of *2007 IFA* is not labeled as hydrogen and instead, based on the prior slide, refers to “hydrocarbon” fuel (namely, the most common fuel, natural gas).

69. In addition, the first slide of page 9 explicitly shows natural gas being supplied as the fuel to the steam and power production unit. The “GT” and “HRSG” as pictured on page 17 of the Petition are from the second slide on page 9 of the *2007 IFA* which appears to be discussing an entirely different system.

70. Further, there is no link between the slides shown on the bottom of page 8 and the bottom of page 9, respectively, in *2007 IFA*. A POSA would understand that the processes of each of these slides are distinct.

71. The concept of using H₂ as a fuel is not contemplated in the *2007 IFA* until the second slide of page 9 (and only here), where it is labeled “H₂ Fuel” to distinguish it from “Fuel”.

72. When applying the proper construction of “furnace,” as discussed above, the gas turbine of *2007 IFA* is not a “furnace” as recited in limitation 1[c]. It is irrelevant that “a gas turbine operates by means of combustion” because the claimed “furnace” is defined by the ’168 Patent as “a steam reformer or a charge preheater or a steam generator or a steam superheater” “*which* operate by means of combustion.” See EX1001 at 2:47-51.

73. If the Petition is instead, or additionally, pointing to the “HRSG” shown on page 9 of *2007 IFA*, that component is fed with an exhaust gas resulting from the combustion in the gas turbine, and not with a “CO₂-depleted synthesis gas” as required by limitation 1[c]. An “HRSG” is not a furnace as claimed in limitation 1[c] despite including the words “steam generator” in its name. A heat recovery steam generator is a *heat exchanger* that captures waste heat from the gas turbine’s hot exhaust gases to generate steam. It is not “a steam reformer or a

charge preheater or a steam generator or a steam superheater,” at least because unlike those apparatuses a heat exchanger does not “operate by means of combustion.”

3. Claim 10

74. Claim 10 depends from Claim 1 and further claims “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 preheating the charge of the autothermal reformer or natural-gas desulphurization section.”

75. The '168 Patent requires that the relevant “said fuel fraction” is the CO₂-depleted synthesis gas (i.e. hydrogen-rich synthesis gas) of Claim 1, from which Claim 10 depends. As explained with reference to Claim 1 above, the “Fuel” shown on page 8 of *2007 IFA* is a traditional hydrocarbon, not a CO₂-depleted synthesis gas.

76. There is no connection between the figure on page 8 and the figure on page 9, and the slides before slide 8 explain that the “fuel” is “hydrocarbon” (natural gas). Pages 7 and 8 of *2007 IFA* are concerned with using a smaller volume of natural gas as fuel; the slides on page 7 and 8 do not address, and have nothing to do with, the use of “H₂ fuel.” When *2007 IFA* disclosed using H₂ fuel on the slide

on page 9, it was labeled as such. A POSA would understand that the processes shown in the figures on pages 8 and 9 are distinct.

77. *2007 IFA* also does not disclose “feeding the fuel fraction to ‘combustion air preheat to reduce fuel firing.’” “Use combustion air preheat to reduce fuel firing” appears in a bullet point on page 8 of *2007 IFA* – there is no reference to a “fuel fraction” or the required “CO₂-depleted synthesis gas.” This bullet point is also not associated with any figure in *2007 IFA*, and a POSA would not read it to be associated with any figure.

78. As discussed above, any fuel disclosed on pages 7 and 8 of *2007 IFA* is natural gas (“the hydrocarbon”) and the disclosures on these pages are not related to any use of “H₂ fuel.”

79. The Petition asserts that “*2007 IFA* also discloses feeding the fuel fraction to a steam production furnace,” citing to *2007 IFA* at 8-9 and Dr. Ritter’s declaration at ¶ 205. Petition at 20. A POSA would understand that *2007 IFA* proposes only that excess H₂ may be used for electricity production, not as fuel in a furnace of the reforming process. There is a “Steam and Power Production”-labeled component in the top figure on page 9, but that component is receiving “Natural Gas,” not the required “CO₂-depleted synthesis gas.”

B. 2007 IFA (EX1006) alone or in view of the knowledge of a POSA (Ground 1A)

1. Claim 7

80. 2007 IFA does not disclose “wherein said CO₂-depleted syngas contains no more than 1000 ppm by volume of CO₂.” 2007 IFA is silent as to the concentration of CO₂ in the fuel after CO₂ removal.

81. In contrast to the Petition’s assertion at p. 23, a POSA would not have been “motivated to modify 2007 IFA...given the point of 2007 IFA was to reduce carbon emissions, including ‘to reduce the CO₂ emissions to zero.’” The full quote states “[t]echnology exists to integrate the plant [meaning the plant disclosed in 2007 IFA] with the off-sites to reduce the CO₂ emission to zero,” EX1006 at 10, and thus 2007 IFA does not contemplate reducing plant emissions to zero.

82. The “CO₂-depleted syngas” of Claim 7, in contrast, will be combusted as fuel and any of the small amount of CO₂ left in the syngas will therefore be released directly to the atmosphere.

83. The requirement of “no more than 1000 ppm by volume of CO₂” is required to meet the plant emissions targets in Tables 1 and 2 of the ’168 Patent.

2. Claim 11

84. 2007 IFA does not disclose “a purge gas...is treated so as to recover the hydrogen,” nor does it disclose “part of said tail gas is recycled as process gas.”

85. While *2007 IFA* has a bullet point on page 3 referencing potential H₂ recovery (unconnected to any figure in *2007 IFA*, including those on pages 8 and 9), there is no reference in *2007 IFA* to doing anything with a methane-rich component.

86. Further, *2007 IFA* does not show a separation unit or recycle processes for any purge stream, and therefore a POSA looking at the purge gas disclosures in *2007 IFA* (on pages 2 and 6) would assume purge or flaring. *See, e.g.*, EX1012 (*Ji*) at Fig. 2; 5:67-6:2 (“Meanwhile, a portion of the methane-rich purge gas 273 may be routed to flare 325”).

87. Unlike the prior art, Claim 11 requires both “part of the process flow” (from Claim 1) and “at least part of said tail gas” as fuel. EX1001 at 13:18-21; 14:1-4. *2007 IFA* does not disclose allocating either “process flow” or “tail gas” as feed to “said step of conversion.”

88. Moreover, *2007 IFA* does not link the processes shown and otherwise discussed on pages 2-6 to the processes shown on slides 8 and 9, the disclosures from *2007 IFA* on which the Petition relies for Claim 1 above in Ground 1. *See* Petition at 13-18. A POSA would understand these processes are distinct. The processes shown on slides 8 and 9 do not disclose any purge gas or use thereof.

3. Claim 17

89. 2007 IFA does not disclose any part of the “synthesis gas fuel fraction” forming “the fuel of the furnaces used in the conversion section.”

90. Dr. Ritter points to 2007 IFA at 9 for “a process that does not include a fuel source other than the H₂ fuel,” which could only be pointing to the “GT” and/or “HRSG” on page 9. EX1005, at ¶ 222. The “gas turbine (GT)” and/or “HRSG” disclosed in 2007 IFA are not “used in the conversion section” as required by Claim 17. Those components are part of the “power cycle,” not part of the conversion section. See EX1006 at 9.

91. Dr. Ritter’s statement is also wrong. Figure 9 in 2007 IFA shows Natural Gas and Nitrogen added to “H₂ Fuel” before combustion in “GT.” EX1006 at 9. The fuel supplied to the “GT” is not just “H₂ Fuel,” but a mixture with natural gas, where the latter would be expected to be the dominant component based on the typical fuel requirements of gas turbines around the year 2007 as understood by a POSA.

C. Rytter (EX1008) (Ground 2)

92. Similar to 2007 IFA, Rytter is not focused on improvements in the conversion section but targets potential efficiency improvements derived from using the syngas for the co-generation of methanol, dimethyl ether (DME), and electricity.

93. *Rytter* is directed to methanol synthesis (methanol is a carbon compound – CH_3OH) and requires only “at least 5%” of a “substantially H_2 -containing stream” being fed to the synthesis process. EX1008 at 4:10-12.

94. Methanol synthesis, unlike ammonia synthesis, utilizes carbon (the carbon in CO and CO_2) and processes focused on methanol synthesis will therefore have less CO_2 emissions to manage as compared to processes focused on ammonia synthesis.

95. Methanol synthesis requires very little purified H_2 , and when synthesizing methanol using synthesis gas from methane reforming (as disclosed by *Rytter*, EX1008 at 3:64-67) there will be excess H_2 leftover. *Rytter* suggests using that leftover H_2 to create steam and electricity.

96. In contrast, rather than naturally having leftover H_2 , the availability of H_2 is a limiting factor in ammonia synthesis, and the '168 Patent addresses this problem by requiring the production of “an additional quantity of synthesis gas” (EX1001 at 3:1-2) (at an additional cost) – put differently, there is no excess H_2 to find a use for.

97. The '168 Patent counterintuitively teaches that using the “relatively high” fuel fraction is not optimal for synthesis, but it is still worth using valuable H_2 as fuel for reducing CO_2 emissions.

1. Claim 1[a]

98. Limitation 1[a] of Claim 1 requires “a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween.” For this, the Petition points only to *Rytter* at 4:30-33, which states “[p]articularly 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.” Petition at 42.

99. This disclosure of *Rytter* references feeding an ATR with “prereformed natural gas.” It says nothing about the configuration of the conversion section of *Rytter*, including but not limited to whether there is a primary reformer or not, and the location of a primary reformer if included.

100. *Rytter* explains that it “particularly prefer[s] the reforming plant consists of an autothermic reformer combined with a steam reformer and a prereformer.” EX1008 at 4:17-20. A “steam reformer” is a primary reformer.

101. A “prereformed natural gas” could have been treated by both a primary reformer and a prereformer, and *Rytter*’s “particularly preferred” configuration includes both components.

102. If a conversion section includes both a prereformer and a primary reformer, a POSA would understand that the prereformer is upstream of the primary

reformer (the conversion section would not include “an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween”).

2. Claim 1[c]

103. Limitation 1[c] of Claim 1 requires “separation of a part of said CO₂-depleted synthesis gas as fuel fraction, wherein said fuel fraction is fed as fuel to at least one furnace”

104. *Rytter* targets potential efficiency improvements derived from using syngas for co-generation of methanol, dimethyl ether (DME), and electricity. EX1008, at 4:63-67 (“Further, it will be beneficial that the streams from the reformer are distributed between the methanol synthesis reactor and heat generating station depending on the demand of methanol, dimethyl ether and oxidation products thereof and electrical power respectively.”); *id.* at 6:8-12 (“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.”).

105. *Rytter* discloses that the referenced “heat-generating stations” are using fuel for the station’s “gas turbines” “in the production of electrical power.” EX1008 at 1:33-36.

106. The Petition does not identify which of the components of *Rytter* it is citing as the claimed “at least one furnace.” Petition at 42. Moreover, the “hydrogen power station 7” and/or “gas turbines” of *Rytter* are not “furnaces” as that term is defined in the ’168 Patent.

3. Claim 10

107. Claim 10 depends from Claim 1 and further claims “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 preheating the charge of the autothermal reformer or natural-gas desulphurization section.”

108. *Rytter* discloses “a hydrogen power station 7,” which, as explained with respect to Claim 1 above, is not a furnace, and the ability to produce steam (for the express purpose of creating electrical power) does not necessarily make that component a “furnace” as claimed in the ’168 Patent.

4. A POSA would not have looked to *Rytter* (EX1008) to supplement 2007 IFA (EX1006) (Ground 1B)

109. As discussed above, *Rytter* is focused on methanol synthesis (CH_3OH) and would have different operational considerations than 2007 IFA, which is focused on ammonia synthesis (NH_3). For example, as little as 5% of the purified H_2 stream is needed for methanol synthesis while the amount of H_2 available constrains ammonia production.

110. The Petition and Dr. Ritter do not explain why a POSA looking at the complete processes disclosed in *2007 IFA* would have looked at the complete methanol synthesis process in *Rytter* for either percentages of (1) the CO₂-depleted syngas used as the fuel fraction (claims 3 and 4) or (2) oxygen in enriched air (claims 8 and 9), even if those processes have “substantial overlap.” EX1005 at 245. While conceivably possible, it does not follow that “one process that discloses [a step]” *would* “be modified by applying process steps used in another process that discloses the same overlapping steps.” *See id.*

111. The synthesis processes here are at least partially coupled, and the output of each step impacts the input of the next step, so a POSA would not just modify a process step in a complete process to incorporate a step from an unrelated process focused on a different type of synthesis. A POSA would know that changes to an upstream step will impact the downstream steps and would need to carefully consider all steps of the process in considering to make such a change. The Petition and Dr. Ritter simply do not engage in that analysis.

D. *Fjellhaug* (EX1010) (Ground 3)

112. *Fjellhaug* is directed at low CO₂ electricity generation.

1. Claim 1[a]

113. The Petition asserts that a POSA would have understood that the air supplying the ATR is “oxygen-enriched” based on the statement at *Fjellhaug* 3:28-

29 that “at least part of the exhaust from the gas turbine can be recycled to the ATR as an oxygen source or combined with the air supply to the gas turbine.” Petition at 54. I disagree for the reasons explained below.

114. The exhaust from the gas turbine (24) is primarily steam and nitrogen, with minor amounts of oxygen being present only if the turbine was supplied with excess air. The oxygen source referred to in *Fjellhaug* 3:28-29 is primarily in the form of the steam that is required by the ATR unit. The air component of the turbine exhaust would be highly oxygen-deficient, so a POSA reviewing *Fjellhaug* would not expect that the addition of any oxygen from the gas turbine exhaust would create oxygen-enriched air.

115. As explained by *Fjellhaug*, the gas stream 17 fed to the gas turbine 24 “consists mainly of hydrogen and nitrogen, with minor amounts of CO, CO₂, CH₄.” EX1010, at 4:33-37. Air 25 is also supplied to the gas turbine 24. *Id.* Combustion in the gas turbine (“for production of electric energy” (EX1010 at Abstract)) uses the oxygen in Air 25. As explained by *Fjellhaug*, “part of an air supply 29 can be supplied from a gas turbine air compressor” with the remainder being “[a]t least part of the exhaust from the gas turbine.” *Id.* at 3:28-30, 4:6-8. The former has the composition of standard air (25) and as described above the turbine exhaust is highly oxygen deficient. Thus, the resulting air supply 29 (and compressed air supply through conduit 7) is oxygen-deficient air, that is, air that contains less oxygen

than ambient air. A POSA would not expect that adding the turbine exhaust would create “oxygen-enriched air.”

116. The compressor shown between stream 29 and conduit 7 would compress and perhaps heat stream 29; it would not change the composition of stream 29. EX1010, at 3:67-4:1.

117. *Fjellhaug* teaches away from using an oxygen-driven ATR in its process. EX1010, at 2:13-20 (“[I]t was found that the ATR should be an air driven reactor, i.e., not an oxygen driven reactor.”).

118. Even if “it was well-known in the art to supply a conversion section, particularly an ATR, with oxygen or oxygen enriched air,” (Ex. 1005, at ¶ 279), a POSA looking at *Fjellhaug* would not look to make that modification, as the *Fjellhaug* inventors expressly considered and rejected it. “[I]t was decided to investigate further the best way of running the ATR. Contrary to what was taught by the above Japanese patent application, it was found that the ATR should be an air driven reactor, i.e., not an oxygen driven reactor.” EX1010, at 2:13-20.

119. Further, as expressly recognized by *Fjellhaug*, it would increase the cost of the process to use oxygen or oxygen-enriched air, and a POSA looking at *Fjellhaug* would not be looking for ways to make the process more expensive or resource intensive. EX1010, at 1:45-52.

2. Claim 1[c]

120. The Petition also does not identify “at least one furnace” as required by limitation 1[c]. Petition at 55. The Petition points to “[t]he gas stream 17 ... used as fuel.” *Id.* (citing EX1010, at 4:64-65). Limitation 1[c] requires “said fuel fraction is fed as fuel to at least one furnace.” EX1001, at claim 1. *Fjellhaug* discloses that “[t]he gas stream 17 will then be used as fuel for a combined cycle gas turbine 24”—not a “furnace” as that claim term is expressly defined in the ’168 Patent. EX1010, at 4:34-36; *see also* Petition at 55 (annotated version of Fig. 2 of *Fjellhaug* showing a highlighted “gas stream 17” to “gas turbine 24.”).

121. A gas turbine is not a “furnace” as claimed in Claim 1. Rather, just like the gas turbines in *2007 IFA* and *Rytter*, the gas turbine 24 in *Fjellhaug* is used to produce electric energy. *See also* EX1001 at 7:44-53 (gas turbine may be used to produce electricity for the synthesis process).

3. Claim 10

122. Claim 10 depends from Claim 1 and further claims “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.”

123. The Petition asserts: “*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, 4:38-50.” Petition at 57.

124. *Fjellhaug* discloses a “combined cycle gas turbine for the production of electric energy,” EX1010 at 3:15-16, which, as explained with respect to Claim 1 above, is not a furnace. Further, the “gas turbine” disclosed in *Fjellhaug* does not produce steam, rather, “exhaust from the turbine is heat exchanged with water in a steam generator.” EX1010 at 4:43-45.

E. Price (EX1011)

125. *Price* focuses on potential efficiency improvements by using the syngas that emerges from the reforming section for the co-production of ammonia synthesis and hydrocarbons.

126. *Price* is specifically directed to “overcoming problems in the operation of existing ammonia-Fischer-Tropsch integrated plants.” EX1011 at [0019].

127. In Fischer-Tropsch synthesis CO and H₂ are converted into liquid hydrocarbons, thus most of the CO and CO₂ is utilized in the process, not captured or released to the atmosphere.

128. A POSA would not have looked to *Price* to supplement 2007 IFA or *Rytter*.

129. A POSA looking at *2007 IFA* or *Rytter* would not look to a reference focused on “optimizing the production of hydrocarbons and ammonia using a combined” Fischer-Tropsch process plant and ammonia synthesis plant when neither *2007 IFA* or *Rytter* contemplate the production of hydrocarbons or inclusion of a Fischer-Tropsch process plant.

130. *2007 IFA* expressly contemplates a different integration (“Integrated reforming and power cycle”) and *Rytter* is also focused on the “co-generation” of electrical power, not the production of hydrocarbons. EX1006 at 9; EX1008 at 1:33-36.

F. *Licht* (EX1009)

131. *Licht* expressly considers the use of a prereformer alongside and in conjunction with the primary reformer. *See* EX1009 at 6:2-3 (“A prereformer and a reformer may be physically connected.”); 5:56-57 (“FIG. 2 and FIG. 3 show additional optional features, for example a so-called prereformer 80”); 6:34-36 (“Prereforming is a term used to describe reforming before the main reforming step, for example in a fired reformer.”). While the prereformer of *Licht* is expressly “optional,” the primary reformer is not.

132. Additionally, *Licht* teaches away from omitting the primary reformer—“optimizing” the “feedstock processed in the reformer furnace 100” (i.e.,

the primary reformer) suggests that the primary reformer cannot be removed, or at minimum removal is not preferred. EX1009 at 8:40-41.

133. A POSA would not look to *Licht* to supplement 2007 IFA. 2007 IFA and *Licht* contemplate using different equipment in the conversion section and more importantly, 2007 IFA does not contemplate using the “synthesis gas fuel fraction” in the conversion section at all.

134. While *Licht* discloses using H₂ to heat a primary reformer, *Licht* expressly does not consider using H₂ for heat upstream of a prereformer, despite including a prereformer as an optional component and acknowledging that prereformers require preheating. EX1009 at 3:43-46; 5:56-6:18. 2007 IFA’s conversion section, on the other hand, includes a prereformer but no primary reformer. EX1006 at 9.

135. A POSA would also not look to *Licht* to supplement *Rytter* or *Fjellhaug* (or a combination thereof). *Licht* is focused on hydrogen production while *Rytter* and *Fjellhaug* are focused on using excess hydrogen to produce electrical power. EX1009 at 1:31-32; EX1008 at 6:6-12; EX1010 at 1:43-46.

G. Ji (EX1012)

136. *Ji* focuses on the use of membrane processes to improve the performance of a coal gasification unit, specifically membranes for methane separation and recycling the methane-rich stream back to the gasification unit. There are no

shift reactors, CO₂ separation, or H₂ purification steps that are required in ammonia synthesis.

137. A POSA would not have looked to *Ji* to supplement 2007 IFA.

138. *Ji* discloses “a method for gasifying a carbonaceous [solid] feedstock.” EX1012 at 1:6-7; 1:58-60; 5:29-32 (“The embodiment depicted in FIG. 2 begins with a carbonaceous feedstock 163 being pulverized in a mill 182 and combined with water to form a slurry 185.”). Contrary to Petitioner’s assertion, *Ji* is not “directed towards processes for reducing carbon emissions in ammonia synthesis processes.” Petition at 38. Rather, *Ji* discloses “improvements in the efficiency of the gasification process” to “maximiz[e] the production of hydrogen and CO for a given quantity of feedstock.” EX1012 at 1:8-10; 1:45-50.

139. Further, the Petition points to 5:56-6:8 and Figure 2 in *Ji*, which is specifically focused on “a methanol reactor,” while Claim 11 specifically claims “a purge gas of the ammonia synthesis process.” Petition at 38; EX1012 at 2:51-53; 5:41-47. The purge gases produced from these synthesis processes will be different and consideration of the treatment of each will thus vary. *Ji* does not disclose “treating a hydrogen- and methane-containing purge gas of the ammonia synthesis process,” (EX1005 ¶216), it discloses treating a purge gas from methanol synthesis.

140. A POSA starting with *2007 IFA* would not look to *Ji* because *Ji* specifically pertains to a coal-to-methanol process via gasification as opposed to a natural gas ammonia synthesis process via reforming.

141. The excess methane in *Ji* is a particular consequence of coal gasification processes that are not relevant to ammonia synthesis via methane reforming. *See* EX1012 at 1:25-26 (“Synthesis gas produced via the gasification of carbonaceous material commonly contains some methane.”); 5:12-17 (“the raw syngas stream may contain a significant amount of methane (up to 10% by Volume). Methane is not a useful feedstock component for many chemical processes that utilize the H₂ and CO components of synthesis gas as a starting material.”).

142. Further, when discussing *Rytter*, the Petition again points to disclosure in *Ji* that is specifically focused on “a methanol reactor,” while Claim 11 specifically claims “a purge gas of the ammonia synthesis process.” EX1012 at 2:51-53; 5:41-47; Petition at 51 (citing Ground 1D). *Rytter* is also focused on methanol synthesis, so a POSA would not look to *Ji* or *Rytter* (or a combination thereof) for the disclosure of a “purge gas of the ammonia synthesis process.”

X. CONCLUSION

143. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place within the United States. If called for cross-examination, I will appear for cross examination within the United States during the allotted period.

144. I hereby 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 these 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.

Dated: May 11, 2026



Colin A. Wolden
Golden, Colorado

CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. § 42.6(e)(4), the undersigned certifies that on May 11, 2026, a complete and entire copy of this Declaration of Colin A. Wolden in Support of Patent Owner's Response was served on the Petitioner via electronic mail at the following addresses:

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Dated: May 11, 2026

Respectfully submitted,

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