

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 Nos. IPR2025-01454 &
IPR2025-01455

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

TABLE OF CONTENTS

I.	INTRODUCTION	1
II.	QUALIFICATIONS	2
III.	MATERIALS CONSIDERED	4
IV.	MY UNDERSTANDING OF LEGAL PRINCIPLES	5
V.	OVERVIEW OF THE '168 PATENT	10
VI.	CHALLENGED CLAIMS	12
VII.	LEVEL OF ORDINARY SKILL IN THE ART	17
VIII.	SUMMARY OF THE PROSECUTION HISTORY	19
IX.	ANALYSIS OF THE ALLEGED PRIOR ART AND PETITIONER'S PROPOSED GROUNDS	20
A.	<i>2007 IFA</i> (EX1006) (Ground 1)	20
B.	<i>Rytter</i> (EX1008) (Ground 2)	21
C.	<i>Price</i> (EX1011) (as used in Grounds 4 and 5)	21
D.	<i>Fjellhaug</i> (EX1010) (Ground 3)	22
E.	<i>Terrien</i> (EX1007) (Ground 4)	25
F.	<i>Licht</i> (EX1009) (Ground 5)	25
X.	CONCLUSION	28

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 proceedings 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 sponsored by the 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) is submitted herewith as Exhibit 2005.

16. I have testified in two cases by deposition; a complete list is available in my CV. 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 Petitions for IPR filed by Topsoe, Inc. ("Petitioner") and all exhibits in support of those Petitions, including the Declaration of Dr. James A. Ritter (EX1005).

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 purported 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 purported invention.

25. 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.

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 purported invention. I also understand that an anticipating reference must enable one of ordinary skill in the art to reduce the purported 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 purported 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 purported 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 purported 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. 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.

32. 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 purported invention and does not rely on hindsight.

33. 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.

34. 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

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

36. Unlike conventional plants that burn natural gas for furnace fuel, 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.

37. As the Abstract 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.

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

39. Often 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 additional chemicals (e.g. methanol, hydrocarbons) or electricity.

40. In contrast, the '168 Patent teaches the use of this excess hydrogen to decarbonize the hydrogen production process itself.

41. 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, which is then treated in a shift reactor (SHF) and CO₂-removal unit (CDR).

EX1001, at 12:51-13:8; *id.* at Fig. 1. After decarbonation, part of the resulting CO₂-depleted syngas (14) is routed back as furnace fuel for AUX, while the remainder (18) proceeds to ammonia synthesis. *Id.* at 13:14-17; *id.* at Fig. 1.

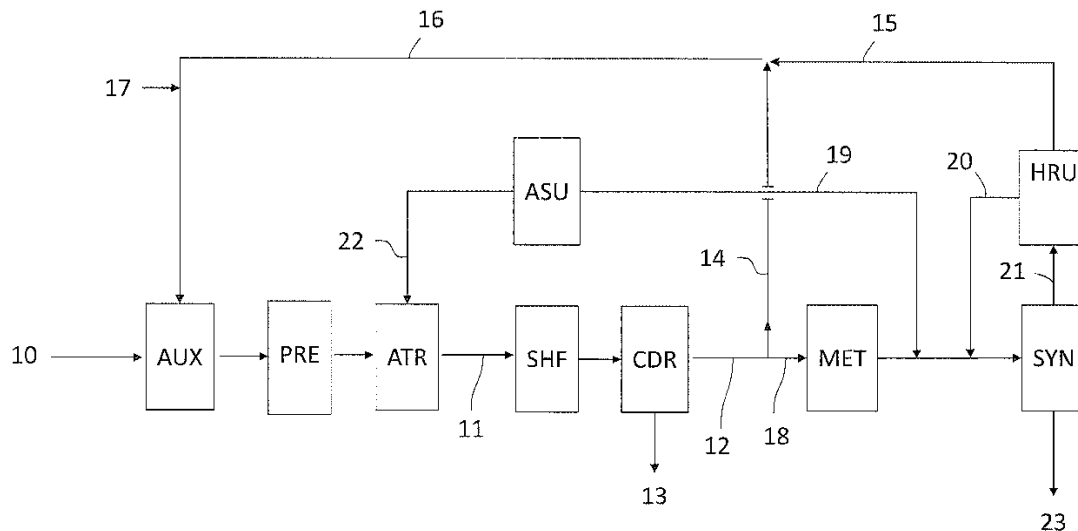


FIG. 1

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

43. 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

44. 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.”

45. All but Claim 1 of Challenged Claims are dependent claims, and each dependent claim depends from Claim 1. While I have reviewed the '168 Patent in its entirety and all of the Challenged Claims, this declaration is focused on Claim 1.

VII. LEVEL OF ORDINARY SKILL IN THE ART

46. 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.

47. 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.

48. 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.

49. 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 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.

50. 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.*

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

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

51. 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 thirty years of experience in research and development of materials and processing technologies pertinent to energy applications.

VIII. SUMMARY OF THE PROSECUTION HISTORY

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

53. 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.

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

55. This art included Licht (U.S. Patent No. 8,137,422), which Petitioner has asserted in three different Grounds in the first petition (Grounds 1E, 2C, and 3D) and as the primary reference for Ground V in the second petition. *See* EX1009; IPR2025-01454, Paper 1 (petition); IPR2025-01455, Paper 1 (petition).

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

57. 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. 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)

58. *2007 IFA* is a presentation on the CO₂ reduction potential in ammonia synthesis. On page 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.

59. 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.

60. I understand that Patent Owner contends *2007 IFA* is not prior art. For the purposes of my analysis in this declaration, I am assuming that *2007 IFA* qualifies as prior art, but I reserve the right to address issues relating to the prior art status of *2007 IFA* at a later time.

B. *Rytter* (EX1008) (Ground 2)

61. 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.

62. Methanol synthesis, unlike ammonia synthesis, utilizes carbon (the carbon in CO and CO₂) and processes focused on methanol synthesis will therefore have less CO₂ emissions to manage as compared to processes focused on ammonia synthesis.

C. *Price* (EX1011) (as used in Grounds 4 and 5)

63. *Price* is analogous to *Rytter* in that it focuses on potential efficiency improvements by using the syngas that emerges from the reforming section for co-production of ammonia synthesis and hydrocarbons. In this case the majority of CO and CO₂ are not captured but utilized in a Fischer-Tropsch process to produce hydrocarbons.

64. *Price* discloses “[t]he reforming section consists of a steam reformer followed by an autothermal reformer.” EX1011 at [0056].

65. A steam reformer and a prereformer are fundamentally distinct components that operate differently and serve different purposes.

66. A prereformer is conducted adiabatically, meaning it requires no heating, while a steam reformer requires heat.

67. A prereformer is typically used to convert heavier hydrocarbons to methane which allows for more efficient reforming downstream (hence the name “pre” reformer), while a steam reformer typically converts lighter hydrocarbons such as methane to syngas.

68. A POSA would not consider the “steam reformer” of *Price* (EX1011 at [0056]) to be a prereformer as required by Claim 1.

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

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

70. 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.

71. The exhaust from the gas turbine 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.

72. 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, CO, CH.” EX1010, at 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.”

73. Further, 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.

74. *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.”).

75. Even assuming as Petitioner’s expert Dr. Ritter does that “it was well-known in the art to supply a conversion section, particularly an ATR, with oxygen or oxygen enriched air,” (Ex. 1005, at ¶ 29), a POSA looking at *Fjellhaug* would not look to make that modification, as the inventors appear to have expressly considered and rejected it: “it 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.

76. 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.

E. *Terrien* (EX1007) (Ground 4)

77. *Terrien* focuses on the use of improved membranes for CO₂ separation to improve the production and purification of hydrogen. *Terrien* does not address ammonia synthesis.

F. *Licht* (EX1009) (Ground 5)

78. *Licht* was considered thoroughly in the re-examination of the '168 Patent which resulted in the subsequent claim modifications.

79. A clear distinction between *Licht* and the '168 Patent is that in *Licht* the majority of the reformation process is conducted by steam methane reforming (SMR). The SMR of *Licht* is a primary reformer. While *Licht* discloses that a pre-reformer and/or secondary oxygen reformer are optional, they are clearly secondary.

80. In contrast, the '168 Patent focuses specifically on a process involving a pre-reformer and an ATR *without* a primary reformer there between. This difference significantly impacts the hydrogen fueling requirements, which is a major differentiator. In conventional steam reforming about 75% of methane is reformed and 25% is used as fuel (EX1006 p.7). On a molecular basis the heat released by hydrogen combustion is only about 1/3 that of methane. As such fueling the steam reformer with hydrogen would require diverting >30% of the hydrogen that exits

the reforming section. The heat requirements of the pre-reformer + ATR are significantly less, which means only a very small fraction (<5%) of the hydrogen is required as fuel. As such, significantly less methane (~7%) would be required to produce an equivalent amount of hydrogen and/or ammonia using the ATR process as opposed to SMR ('168 Patent Table 2).

A second differentiation between *Licht* and the '168 Patent is the quality of the hydrogen that is recycled. *Licht* recycles hydrogen only after it has been completely purified using pressure or temperature swing adsorption. In contrast, the '168 Patent discloses separating the hydrogen rich stream after CO₂ removal but prior to final purification, which could involve pressure swing adsorption, methanation, or a liquid nitrogen wash. These final purification steps are both CapEx and energy intensive. Thus by applying them only to the hydrogen that will be used in ammonia synthesis, it reduces the load on these processes. There will be a slight increase in CO₂ emissions, but this is negligible relative to the overall savings.

81. Furthermore, as discussed above with respect to *Price*, a steam reformer and a prereformer are fundamentally distinct components that operate differently and serve different purposes. A prereformer is conducted adiabatically, meaning it requires no heating, while a steam reformer requires heat. EX1009 at 5:59-6:3 (*Licht*) (prereformer “is characterized by the lack of direct heating by a

combustion flame”). EX1009 at 6:34-6:36 (*Licht*) (“Prereforming is a term used to describe reforming before the main reforming step, for example in a fired reformer.”)

82. A prereformer is typically used to convert heavier hydrocarbons to methane which allows for more efficient reforming downstream (hence the name “pre” reformer), while a steam reformer typically converts lighter hydrocarbons such as methane to syngas. A POSA would not consider the “steam reformer” of Price (EX1011 at [0056]) to be a prereformer as required by Claim 1.

83. *Licht* already 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. Accordingly, a POSA would not look to a reference that omits the primary reformer (even if *Price* disclosed such a configuration, which it does not) to replace the conversion section of *Licht*.

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

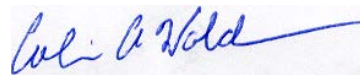
the primary reformer) suggests that the primary reformer cannot be removed, or at minimum removal is not preferred.

X. CONCLUSION

85. 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.

86. 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: December 1, 2025



Colin A. Wolden
Golden, Colorado

CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. § 42.6(e)(4), the undersigned certifies that on December 1, 2025, a complete and entire copy of this Declaration of Colin A. Wolden in Support of Patent Owner's Preliminary Responses was served on the Petitioner via electronic mail at the following addresses:

Robert Riddle: rriddle@reedsmith.com

Jennifer Black: jblack@reedsmith.com

Jonathan Detrixhe: jdetrixhe@reedsmith.com

IPR_Topsoe@reedsmith.com

Dated: December 1, 2025

Respectfully submitted,

/Case Collard/

Case Collard

Registration No. 72,901

DORSEY & WHITNEY LLP

Telephone: +1(303) 629-3400

Attorney for Petitioner