UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

_____

TOPSOE, INC.,
Petitioner

v.

CASALE,
Patent Owner

_____

IPR2025-01454
U.S. Patent No. 11,286,168

_____

DECLARATION OF JAMES A. RITTER, PH.D. IN SUPPORT OF PETITIONER'S OPPOSITION TO PATENT OWNER'S CONTINGENT MOTION TO AMEND

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I. INTRODUCTION AND ENGAGEMENT

1. My name is James A. Ritter, Ph.D. I have been retained by Topsoe, Inc. ("Petitioner") to provide technical analysis and expert opinions in connection with Inter Partes Review No. IPR2025-01454 concerning U.S. Patent No. 11,286,168 ("the '168 patent") (EX1001).

2. I previously submitted a declaration in support of the Petition in this proceeding (EX1005), in which I set forth my qualifications, my understanding of the legal standards, the level of ordinary skill in the art, the technical background of the '168 patent, and my opinions regarding the unpatentability of claims 1-10 and 18 of the '168 patent. I incorporate that declaration by reference. I was deposed in this proceeding on April 30, 2026 (EX2008).

3. I have been asked to provide this supplemental declaration in support of Petitioner's Opposition to Patent Owner's Contingent Motion to Amend (Paper 34) (the "Motion"), in which Patent Owner proposes substitute claims 24, 25, and 26 or, in the alternative, substitute claim 27, to replace challenged claim 10. Specifically, I have been asked to opine on (i) whether the proposed substitute claims would have been anticipated or obvious in view of the prior art, and (ii) whether proposed substitute claim 26 is supported by the written description of the original disclosure.

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4. I am being compensated at my standard consulting rate for my time. My compensation does not depend on the substance of my opinions or on the outcome of this proceeding. I have no financial interest in Petitioner, Patent Owner, or the '168 patent.

II. QUALIFICATIONS AND COMPENSATION

5. My qualifications are set forth in my prior declaration (EX1005 ¶¶4-12) and in my curriculum vitae (EX1004). In brief, I hold a Ph.D. in chemical engineering, and I have decades of academic and industrial research experience in gas separation and purification (including pressure swing adsorption and CO2 capture), hydrogen production, and synthesis gas processing. I am qualified to opine on the subject matter of the '168 patent and the proposed substitute claims from the perspective of a person of ordinary skill in the art ("POSA").

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

III. MATERIALS CONSIDERED

7. In forming the opinions in this declaration, I considered the materials cited herein, including: the '168 patent (EX1001) and its prosecution and

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supplemental examination history (EX1002/EX1003); my prior declaration (EX1005) and the exhibits cited therein, including the 2007 IFA presentation (EX1006), Terrien (EX1007), Rytter (EX1008), and Fjellhaug (EX1010); the Petition (Paper 3); Patent Owner's papers, including its Response (Paper 33) and the Motion (Paper 34); Petitioner's Reply (Paper 13); the transcript of my April 30, 2026 deposition (EX2008); the declaration of Svend Erik Nielsen (EX1045); U.S. Patent No. 5,068,058 to Bushinsky et al. ("the '058 patent") (EX1064); and Aasberg-Petersen et al., "Synthesis Gas Production for FT Synthesis," Chapter 4 of Fischer-Tropsch Technology, Studies in Surface Science and Catalysis Vol. 152 (2004) ("KAP 2004") (EX1065). I also relied on my education, training, and decades of experience in the field.

IV. LEGAL STANDARDS

8. I am not an attorney. Counsel has explained, and I have applied, the following legal standards. I understand that in opposing a motion to amend, Petitioner bears the burden of showing, by a preponderance of the evidence, that the proposed substitute claims are unpatentable, and that the Board considers the entirety of the record, including prior art and argument not presented in the Petition.

9. I understand that a claim is anticipated under 35 U.S.C. § 102 if a single prior art reference discloses, expressly or inherently, every limitation of the

claim arranged as claimed. I understand that a claim is unpatentable as obvious under 35 U.S.C. § 103 if the differences between the claim and the prior art are such that the claimed subject matter as a whole would have been obvious to a POSA at the relevant time, considering the scope and content of the prior art, the differences between the art and the claims, the level of ordinary skill, and any objective indicia of nonobviousness. I understand that obviousness may be supported by, among other rationales, the use of a known technique to improve a similar device in the same way, the simple substitution of one known element for another to obtain predictable results, and the selection from a finite number of identified, predictable solutions with a reasonable expectation of success, and that the analysis asks whether there was an apparent reason to combine the known elements in the fashion claimed.

10. I understand that prior art is "analogous" and available for an obviousness analysis if it is from the same field of endeavor as the claimed invention or is reasonably pertinent to the problem the inventor was addressing. I further understand that a proposed substitute claim must be supported by written description in the original disclosure, meaning the disclosure must reasonably convey to a POSA that the inventors possessed the claimed subject matter as of the filing date; that a disclosure that merely renders claimed subject matter obvious, or

does not exclude it, is not sufficient; and that the question is what the disclosure conveys, not what it might permit.

11. I have applied the same priority date ("Critical Date") as in my prior declaration, February 15, 2017 (EX1005 ¶18), and all references to what a POSA would have known or understood are as of that date unless stated otherwise.

V. LEVEL OF ORDINARY SKILL IN THE ART

12. I apply the same level of ordinary skill set forth in my prior declaration (EX1005 ¶¶32-36): a POSA would have had at least a bachelor's degree, and typically a graduate degree, in chemical engineering or a closely related field, together with several years of experience in the design and operation of processes and systems for synthesis gas production, including reforming, gas treatment, and gas separation, or equivalent combined education and experience. This is the same level of ordinary skill that Petitioner applies in its Opposition; any difference in phrasing between the two is not substantive. My opinions would not change under Patent Owner's articulation of the level of skill.

VI. THE '168 PATENT AND THE PROPOSED SUBSTITUTE CLAIMS

13. Claim 1 of the '168 patent, as amended in reexamination, recites a process for the synthesis of ammonia from natural gas comprising: (a) conversion of a charge of desulphurized natural gas and steam, with oxygen-enriched air or with oxygen, into a synthesis gas containing hydrogen, CO and CO_2, in a

conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween; (b) treatment of said synthesis gas including at least a shift reaction of the carbon monoxide into CO2, and subsequent separation of CO2, obtaining a CO2-depleted synthesis gas and a CO2-rich gaseous flow; (c) separation of a part of said CO2-depleted synthesis gas as fuel fraction, fed as fuel to at least one furnace, wherein the separation includes the split of the CO2-depleted synthesis gas into at least first and second streams having the same composition, the first stream forming the fuel fraction; and (d) the second stream being process gas intended for the synthesis of ammonia. EX1001, Reexamination Certificate, claim 1.

14. Original claim 10 depends from claim 1 and recites that the fuel fraction "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." EX1001, Reexamination Certificate, claim 10. The Motion refers to these alternatives as Option A (steam production and/or superheating furnace), Option B (furnace for pre-heating the charge of the autothermal reformer), and Option C (furnace for pre-heating the charge of the natural gas desulphurization section). Paper 34 at 3-4.

15. Proposed substitute claim 24 recites the process of claim 1 wherein the fuel fraction feeds "a steam production and/or superheating furnace" (Option

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A). Proposed substitute claim 25 recites the process of claim 1 wherein the fuel fraction feeds "said at least one furnace for pre-heating the charge of the autothermal reformer" (Option B). Proposed substitute claim 26 recites the process of claim 1 wherein the fuel fraction feeds "said at least one furnace for pre-heating the charge of a natural gas desulphurization section" (Option C). Proposed substitute claim 27, offered in the alternative, is substantially identical to claim 25. Paper 34, Appendix A; *id*. at 3, 13.

16. Each proposed substitute claim thus carries forward every limitation of claim 1 unchanged and adds a single requirement: the identity of the furnace that the fuel fraction feeds. From a technical standpoint, the question presented by each substitute claim is whether the recited fuel destination—a fired steam generator/superheater, a fired ATR charge preheater, or a fired desulphurization charge preheater—was disclosed by, or would have been an obvious destination in view of, the prior art. As I explain below, each of these destinations was a conventional, decades-old feature of synthesis gas plant design.

VII. CLAIM CONSTRUCTION

17. I understand that Patent Owner contends the term "furnace" should be construed to mean "an apparatus chosen from among: a steam reformer or a charge preheater or a steam generator or a steam superheater." EX1001, 2:47-52; Paper 33 at 9-11; Paper 34 at 17, 20. I understand that this is the construction Patent Owner

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advances, and that Patent Owner does not include as part of its proposed construction the sentence that follows the quoted definition in the specification ("These apparatus, which operate by means of combustion, are identified by the term 'fired heater.'"). Counsel has asked me to apply Patent Owner's construction for purposes of this declaration, and I do so; applying that construction does not reflect my agreement that it is the correct construction. Under Patent Owner's construction, a charge preheater that heats a process charge before it enters downstream equipment is a "furnace," and a boiler that generates and/or superheats steam is a "steam generator" or "steam superheater" and likewise a "furnace."

18. I also understand that claims 25 and 26 recite "said at least one furnace," which Patent Owner explains refers to the "at least one furnace" of claim 1 to which the fuel fraction is fed. Paper 34 at 3, 7-8. I have applied that antecedent reading: in each of my combination opinions below, the furnace that receives the fuel fraction and the furnace that performs the recited pre-heating duty are the same apparatus. As I show, that one-apparatus arrangement is exactly what the prior art discloses.

VIII. TECHNICAL BACKGROUND AND OVERVIEW OF THE PRIOR ART

A. Fired equipment in an ATR-based synthesis gas front end

19. Some technical context frames all of my opinions. In a conventional steam methane reforming ("SMR") plant, the primary reformer is a large fired

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furnace: fuel is combusted in a radiant box to supply the endothermic heat of reforming, and the reformer's burners are the plant's dominant fuel consumer. An autothermal reformer is fundamentally different. In an ATR, the heat for reforming is generated inside the reactor by partial oxidation of the feed with oxygen (or oxygen-enriched air) at a burner internal to the vessel; the ATR consumes oxygen and feed, not external fuel, and it has no externally fired burners. A POSA would have known this as elementary reforming technology. See, e.g., EX1065 at 322-23; EX1064, 1:37-3:62; EX1005 ¶¶37-57.

20. A consequence, well known to POSAs, is that in an ATR-based front end, a plant with no primary reformer, as claim 1 requires, the principal (and frequently the only) fuel-consuming furnace in the process area is the fired heater that pre-heats process streams. The duties of that fired heater are standardized: pre-heating the natural gas feed to the temperature required by the hydrogenation and sulphur-absorption (e.g., zinc oxide) beds of the desulphurization section, typically on the order of 350 to 400°C; pre-heating the desulphurized feed-and-steam mixture ahead of the pre-reformer; and final pre-heating of the pre-reformed charge, typically to roughly 550 to 700°C, before it enters the ATR. Depending on the design, the same heater may also superheat steam. Beyond the fired heater, the other conventional fired consumer in such a plant is the steam system, an auxiliary or package boiler raising and/or superheating steam, and/or a gas turbine with heat

recovery. Because the front-end fired heater is typically the largest, and often the only, point of fuel combustion in the process area of such a plant, it is also the principal source of stack CO_2 there; that is why routing a decarbonized hydrogen fuel to it drives plant CO_2 emissions toward zero, consistent with Terrien's teaching that hydrogen fueling of the feed gas producing unit drives capture toward 100%. EX1007 ¶94. The three "Options" recited in original claim 10 are therefore not an inventive menu; they are a catalogue of the same small set of fired equipment a POSA would find in a conventional ATR-based plant, and isolating them into separate claims does not present distinct technical questions.

21. A second piece of context concerns fuel selection. A POSA would have known that fired heaters and boilers in synthesis gas plants are routinely fired with recycled process offgases—including hydrogen-rich streams from purification units—rather than exclusively with fresh natural gas, both for energy efficiency and, by the Critical Date, increasingly to reduce CO_2 emissions, because combusting a hydrogen-rich, decarbonized fuel emits little or no CO_2 at the stack. Burner technology for hydrogen-containing fuel gases was mature and conventional. *See, e.g.*, EX1064, 9:3-10:51 (PSA offgas fired in feed heater in 1991); EX1007 ¶¶93-95 (hydrogen fueling to maximize CO_2 capture); EX1006 at 8-9 (H_2 fuel substitution to reduce CO_2); EX1008, 6:8-13.

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B. The ’058 patent (EX1064)

22. The ’058 patent, which issued on November 26, 1991, discloses a process for producing ammonia synthesis gas in which natural gas is reformed in an autothermal reformer fed oxygen-enriched air, the raw synthesis gas undergoes water-gas shift conversion, and the shifted gas is purified in a pressure swing adsorption (“PSA”) system that removes CO_2 and other impurities to yield an H_2/N_2 ammonia synthesis gas. EX1064, Abstract; 3:45-4:50. The ’058 patent is thus in the same field as the ’168 patent—ammonia synthesis gas production by autothermal reforming with downstream CO_2 removal—and predates the Critical Date by more than 25 years.

23. The Figure 1 embodiment of the ’058 patent discloses a single fired heater 210 performing the front-end heating duties I described above. First, the natural gas feed (line 204) “is passed through the flue gas stack of a small fuel-fired heater 210 wherein it is preheated to a temperature of about 750° F. (~400° C.) and then desulfurized by being passed through a zinc oxide bed 211.” EX1064, 5:1-5; 13:19-14:28 (Example). That is, heater 210 pre-heats the charge of the natural gas desulphurization section. Second, the major portion of the desulphurized hydrocarbon-and-steam feed (line 215) “is further heated to a temperature in the range of 900° to 1000° F. . . . in the radiant section of heater 210 and is introduced by line 218 into the inlet of an autothermal reactor 220.” *Id*.,

5:16-21; =13:19-14:28. That is, heater 210 pre-heats the charge of the autothermal reformer. Third, the oxygen-enriched air stream fed to the ATR is also heated in the flue stack of heater 210. *Id*., 5:21-27)-.

24. The ’058 patent further discloses the fuel for heater 210: offgas from the PSA purification system. In the described PSA cycle, the rinse and depressurization effluents “may be mixed . . . and the mixture employed as fuel in the gas heater 210 (as indicated by line 254 of FIG. 1).” [1] EX1064, 10:11-18. Figure 1 shows the corresponding “FUEL FROM PSA” input to heater 210 and the “PURGE TO FUEL” output (stream 251) of the PSA system. According to Table 1 of the ‘058 Patent, stream 251 is a H_2-rich, CO_2-depleted, stream containing approximately 6.9 mol% unreacted methane, 47.8 mol% H_2, 1.9 mol% CO, and 43.4 mol% N_2. Disregarding N_2 (which would be substantially inert when fired in heater 210), the relevant fuel portion of stream 251 is approximately 12.1 mol%

[1] The reference to “254” in 10:18 appears to be a typographic error. There is no “line 254” in Fig. 1. Likewise, Table 1 contains no reference to line “254,” and the Table 1 reference to “251” is a gas comprising CH_4, H_2, CO, and N_2, suitable for use as fuel. The example in 13:19-14:24 likewise confirms that CH_4 and CO are removed from the PSA B beds as “stream 251,’ which is consistent with Fig. 1, where line 251 is indicated as “purge to fuel.”

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unreacted methane, 84.5 mol% H_2, and 3.3 mol% CO. This is comparable to the composition of the CO_2-depleted stream 14 in the '168 Patent, including the N_2 composition when enriched air (as opposed to pure oxygen) is used in the ATR. In short, the '058 patent discloses, in one apparatus, a fired charge preheater that (i) pre-heats the desulphurization charge, (ii) pre-heats the ATR charge, and (iii) is fired with a H_2-rich, CO_2-depleted gas recycled from the synthesis gas purification section.

C. KAP 2004 (EX1065)

25. KAP 2004 is a chapter of Fischer-Tropsch Technology, volume 152 of the long-running Studies in Surface Science and Catalysis series, published in 2004. The chapter, "Synthesis Gas Production for FT Synthesis," is a comprehensive treatment of synthesis gas generation technologies, including autothermal reforming, not only for FT synthesis, but also for methanol production and ammonia synthesis all in the same chapter; as such, this chapter reveals the distinct similarities between the front ends of these synthesis gas processes I am familiar with this book and this chapter; the volume was a standard, widely available reference in the synthesis gas field well before the Critical Date, and a POSA designing a synthesis gas front end would have been familiar with it or its content. My understanding is that evidence of the volume's publication and public accessibility is being submitted separately; my opinions treat KAP 2004 as

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representative of what POSAs knew by 2004, which is consistent with my own knowledge of the field in that period.

26. Page 323 of KAP 2004 presents Figure 50, captioned "Typical process flow diagram for synthesis gas production for GTL." The flowsheet is organized under the headings "S-Removal," "Pre-reforming," "Fired Heater," "Autothermal Reformer," and "Steam Production." EX1065 at 45/86. Those headings identify the flowsheet's process blocks; the fired heater's coils serve the feed train at several points along it. As the flowsheet's stream routing shows, the natural gas feedstock is first pre-heated in a coil of the fired heater and then desulphurized; the desulphurized feed, with process steam, is preheated in a second coil of the fired heater and passed to the pre-reformer; and a third coil of the fired heater preheats the pre-reformed charge before it enters the autothermal reformer, which is fed oxygen. The accompanying text tracks the flowsheet from the desulfurization forward: the feed mixture "is passed to a pre-reformer and further, after mixing with carbon rich tail gas from the FT synthesis and preheating, to the ATR," where it reacts with oxygen. EX1065 at 45/86 (p. 323) *see also id*. (p. 322) (feed "is passed to a prereformer and, after preheating to a high temperature, to the ATR, which operates at an outlet temperature of typically 1050°C"). The initial fired heater preheat of the natural gas feed is not separately called out in the text, but it is depicted in the flowsheet itself, which routes the feed through a coil of the

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fired heater upstream of the desulphurization vessels—consistent with the elevated inlet temperature that the hydrogenation and sulphur-adsorption beds require, as I explained above. KAP 2004 thus depicts, and labels as "typical," the fired ATR charge preheater that the '058 patent also discloses: a single fired heater pre-heating the feed at multiple points—including the desulphurization charge and the charge en route to the autothermal reformer—in the standard ATR-based front end.

27. Although Figure 50 appears in a discussion of gas-to-liquids service, the syngas front end it depicts—desulphurization, pre-reforming, fired preheating of the feed streams, autothermal reforming, steam production—is the same front-end technology used for ammonia synthesis gas, and the chapter itself addresses synthesis gas production across applications, including a complete ammonia plant. EX1065 at 324-25 (Fig. 51). The ammonia plant KAP 2004 depicts at Figure 51 uses a fired primary reformer, so it is not the ATR-without-primary-reformer configuration that claim 1 requires; I rely on it only to show that a front end that preheats and desulphurizes the natural gas upstream of reforming is common to ammonia service and that KAP 2004 addresses ammonia synthesis gas, not as a disclosure of the claimed configuration. A POSA working on the problem addressed by the '168 patent, configuring and fueling an ATR-based synthesis gas front end, would naturally have consulted this chapter. In my opinion, KAP 2004 is in the same field of endeavor as the '168 patent (synthesis gas production by

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autothermal reforming) and is reasonably pertinent to the problem the named inventors addressed.

D. Terrien (EX1007)

28. I addressed Terrien in my prior declaration (EX1005 ¶¶98-106) and incorporate that discussion. That analysis was used to support the petition for IPR2025-01455. Terrien, published November 22, 2012, discloses a process for producing hydrogen from natural gas with capture of at least 80% and up to approximately 100% of the CO_2 emissions of a "feed gas producing unit." EX1007 ¶73. Terrien defines the "feed gas producing unit" as any unit producing a feed gas that can be treated for hydrogen removal, expressly including "an ATR unit." *Id*.; *see also* ¶95. Terrien's process includes water-gas shift conversion, id. ¶¶ 72, 78, separation of CO_2 in a CO_2 separation unit yielding a CO_2-rich product and CO_2-depleted streams, *id*. ¶¶36, 78, 93, and purification of hydrogen in a PSA unit. Terrien's front end includes desulfurization and a pre-reformer receiving "desulfurized natural gas preheated to around 600° C." Id. ¶74.

29. Terrien discloses splitting the PSA hydrogen product stream (27), with a portion recovered as product and "a portion of this stream (27) . . . used for hydrogen fueling of the feed gas producing unit (34)." EX1007 ¶¶35, 46; *see also* ¶78. Because the two portions result from the split of a single stream, they necessarily have the same composition at the split. Terrien also states the purpose

of this fuel routing: hydrogen fueling drives the capture rate toward its maximum, "approaching or achieving 100% capture, when hydrogen fueling is utilized," because the fired equipment then emits little or no CO_2. *Id*. ¶94; *see also* ¶93.

E. IFA (EX1006), Rytter (EX1008), and Fjellhaug (EX1010)

30. I described 2007 IFA, Rytter, and Fjellhaug in detail in my prior declaration (EX1005 ¶¶94-97; 109-111) and incorporate that discussion. As relevant here: 2007 IFA is a March 2007 industry presentation on CO_2 reduction in ammonia production (see EX1045); it identifies the plant's fired fuel consumers—including the reformer and an "Auxiliary Boiler" receiving "Fuel" (EX1006 at 7)—proposes options including a gas turbine integrated with a fired "Package HP Steam Boiler" producing HP steam and superheated MP steam and removal of "CO_2 from flue gases (reformer and auxiliary boiler)" (*id*. at 8), and presents an "Integrated reforming and power cycle" flowsheet for an ATR-based ammonia plant (hydrogenator, sulphur absorber, pre-reformer, autothermal reformer, shift, CO_2 removal) in which an "H_2 Fuel" stream is split from the CO_2-depleted synthesis gas downstream of CO_2 removal, upstream of methanation and nitrogen addition, and recycled as plant fuel (*id*. at 9; EX1005 ¶¶ 51-57, 183-85, 205). Rytter discloses reforming natural gas, removing CO_2, separating a surplus hydrogen stream, and passing it "to a hydrogen power station 7, which is also supplied with air for the combustion of the hydrogen gas to steam producing

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electrical power." EX1008, 6:8-13; see also 3:10-16. Rytter also discloses supplying the surplus hydrogen stream "to the reforming plant as fuel." EX1008, claim 11; 4:55-57. Fjellhaug discloses a natural-gas-based process with CO_2 removal in which a decarbonized fuel gas is combusted in a gas turbine whose exhaust raises steam in a steam generator 27 with associated superheating (heat exchanger 30). EX1010, 3:14-15, 4:34-50.

IX. OPINIONS REGARDING PROPOSED SUBSTITUTE CLAIM 24

31. Before turning to the individual claims, I note the structure of my opinions. I understand that Patent Owner's motion is contingent on the Board determining that claims 1 and 10 are unpatentable, and that such a determination could rest on any of the instituted grounds. I have therefore been asked to provide opinions keyed to each of the primary references—2007 IFA, Rytter, and Fjellhaug (alone or in view of Rytter)—as well as opinions based on Terrien that do not depend on the instituted grounds, so that my opinions address each proposed substitute claim on whichever claim 1 foundation the Board adopts. In each combination I address, every limitation of the proposed substitute claim—including the limitations carried forward from claim 1—is disclosed or rendered obvious by the identified references, as set forth in my prior declaration and as summarized herein. Appendix A to this declaration sets forth, in chart form, my element-by-element analysis of each proposed substitute claim against the

combinations addressed below. I prepared Appendix A, and it accurately reflects my opinions.

A. Claim 24 is anticipated by 2007 IFA

32. In my prior declaration, I explained in detail why 2007 IFA discloses every limitation of claim 1. EX1005 ¶¶123, 131, 136-41, 153, 237-39. In brief, and as relevant to the substitute claims: 2007 IFA is directed to ammonia production from natural gas and to reducing its CO_2 emissions, satisfying the preamble. EX1006 at 1, 7, 10 ("Carbon effective ammonia production"). Its "Integrated reforming and power cycle" flowsheet routes natural gas through a hydrogenator and sulphur absorber (desulphurization) and, with process steam, to a pre-reformer and then an autothermal reformer fed oxygen, with no primary reformer between the pre-reformer and the ATR, satisfying limitation 1[a]. *Id*. at 9. The ATR effluent passes to shift conversion and then CO_2 removal, producing the CO_2-depleted synthesis gas and a CO_2-rich flow routed to a CO2 compressor labeled "CO_2 for Injection," satisfying limitation 1[b]. *Id*. Downstream of CO_2 removal—and upstream of methanation and nitrogen addition—an "H_2 Fuel" stream is split from the CO_2-depleted synthesis gas line and recycled as plant fuel. *Id*.; EX1005 ¶131. Because the two resulting streams are produced by a simple split of a single line, they necessarily have the same composition at the split, satisfying the separation and split requirements of limitation 1[c]. EX1005 ¶¶136-41. The remaining stream

continues through the methanator, receives nitrogen, and exits labeled "Ammonia Syngas"—process gas intended for the synthesis of ammonia—satisfying limitation 1[d]. EX1006 at 9; EX1005 ¶153.

33. In my prior declaration, I explained why 2007 IFA discloses every limitation of claim 1 and original claim 10. EX1005 ¶¶123, 131, 136-41, 153, 205. Those opinions apply equally to claim 24, whose added limitation—that the fuel fraction feeds "a steam production and/or superheating furnace"—is disclosed by 2007 IFA. The presentation depicts a fired "Package HP Steam Boiler" receiving a "Fuel" input and generating HP steam and superheated MP steam (EX1006 at 8), and a fired "Auxiliary Boiler" receiving "Fuel" (*id*. at 7). Each is an apparatus in which fuel is combusted to generate and superheat steam—a "steam generator" and "steam superheater," and therefore a steam production and/or superheating furnace under the '168 patent's definition. EX1001, 2:47-52. I further note that because the fired boiler is itself a "steam generator" under that definition, the same apparatus satisfies both the "at least one furnace" requirement of limitation 1[c] and the added limitation of claim 24. My opinion on claim 24 therefore does not depend on how the parties' dispute over whether 2007 IFA's gas turbine is a "furnace" is resolved.

34. A POSA would read the presentation as a whole, because it was delivered as one continuous 25-minute talk to a single audience (EX1045 ¶¶13-15),

and would understand the "H_2 Fuel" recycle of the page 9 flowsheet as the fuel supplied to the plant's fired steam-raising equipment shown on pages 7-8, because substituting decarbonized H_2 fuel for a portion of the hydrocarbon fuel in the plant's fired consumers is the express subject of the presentation. EX1006 at 7-9. This is also confirmed by the lower slide on page 8, whose title requires that the "Fuel" must include the H_2 Fuel shown in the lower slide of page 9, otherwise there would be no "integration" with the ammonia process. Furthermore, as shown in the upper slide on page 7, a POSA would understand that this "Fuel" including the H_2 Fuel can also be used to reduce CO_2 emissions from the Flue Gas of both the Reformer and the Auxiliary Boiler. In my opinion, 2007 IFA discloses feeding the fuel fraction of the synthesis gas to a steam production and/or superheating furnace, and claim 24 is anticipated. If the Board does not credit a single, continuous reading of pages 7 through 9 as disclosing the H_2 fuel feeding the steam boiler, my alternative opinion in Section IX.B establishes that the added limitation of claim 24 would in any event have been obvious over 2007 IFA.

B. Claim 24 would, in any event, have been obvious over 2007 IFA in view of the knowledge of a POSA

35. Even under Patent Owner's reading—that the "Fuel" depicted on pages 7 and 8 is natural gas (Paper 34 at 15-17)—claim 24 would have been obvious from 2007 IFA itself. The presentation identifies exactly two fired, CO_2-emitting fuel consumers in the plant, the reformer and the auxiliary boiler, and

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proposes to "[r]emove CO_2 from flue gases (reformer and auxiliary boiler)." EX1006 at 7-8. Its central teaching is to reduce plant CO_2 emissions by substituting a decarbonized hydrogen fuel fraction, split from the CO_2-depleted synthesis gas, for hydrocarbon fuel. *Id*. at 8-9. A POSA implementing that teaching in the ATR-based flowsheet of page 9—which has no primary reformer—would route the H_2 fuel to the fired steam boiler, because the steam system is the principal remaining fired consumer. Doing so is the application of a known technique (hydrogen-fuel substitution) to a known device (a fired steam boiler) for its intended purpose (eliminating stack CO_2), with predictable results: the boiler raises the same steam while its stack CO_2 is eliminated. The fact that the page 7 boiler's flue gas contains CO_2—the point Patent Owner emphasizes (Paper 34 at 16)—is the motivation, not an obstacle: eliminating that CO_2 is the presentation's stated objective. A POSA would have had a reasonable expectation of success because hydrogen-fired boilers and burners for hydrogen-rich fuel gases were conventional. EX1008, 6:8-13; EX1064, 9:3-10:51.

C. Rytter discloses the claim 24 furnace; claim 24 is anticipated by, or obvious over, Rytter

36. My prior declaration explains why Rytter discloses or renders obvious every limitation of claims 1 and 10. EX1005 ¶¶124, 132, 142-43, 154, 260-61. As to the added limitation of claim 24, Rytter discloses that the separated surplus hydrogen "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." EX1008, 6:8-13. As a technical matter, this passage describes a fired steam generator: fuel (hydrogen) and combustion air are supplied to a combustion unit that raises steam, and the steam is used to produce electrical power—i.e., a boiler supplying a steam cycle. That is a "steam generator," and therefore a steam production furnace, under the '168 patent's definition. EX1001, 2:47-52.

37. I have considered Patent Owner's contention that station 7 is a gas turbine. Paper 34 at 19-21. I disagree. The passage Patent Owner relies on, Rytter's statement that hydrogen "can be used . . . as fuel for gas turbines of heat generating stations" (EX1008, 1:33–36), appears in the background discussion of prior art uses of hydrogen; it does not describe the operation of station 7 in Rytter's process. A gas turbine operates on the Brayton cycle: it compresses air, combusts fuel in the compressed air stream, and produces power by expanding the hot combustion gases through a turbine. It would not be described as combusting fuel "to steam." By contrast, combustion of fuel with supplied air "to steam producing electrical power" (EX1008, 6:8-13) describes boiler duty in a Rankine (steam) cycle: fuel is burned to raise steam, and the steam drives a generator. I have also considered whether the "steam" in this passage could be understood as the water vapor in the exhaust of a hydrogen-fired gas turbine, on the reasoning that combusting hydrogen necessarily produces water. That reading does not fit the sentence. Rytter

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describes combustion of the hydrogen "to steam *producing electrical power*"—the steam produces the power, which is how a boiler-fed steam cycle operates. In a gas turbine, electrical power is produced by expansion of the hot combustion gases through the turbine; the exhaust, whatever its water content, produces no power, and a POSA would not describe a gas turbine as combusting fuel "to steam." Two further aspects of Rytter's disclosure confirm this reading. First, Rytter contemplates firing station 7 with more than hydrogen: "An optional depressurating gas from the methanol plant including hydrogen, carbon monoxide and carbon dioxide may be recycled to the power station as a supplement." EX1008, 6:13-17. If "steam" described the products of combustion, Rytter's single description of station 7 would change meaning with the fuel, because burning that carbon-containing supplement yields carbon dioxide and water, which no engineer would call "steam." On the reading I give the sentence, nothing changes: steam raised on the water side of a boiler is steam whatever is fired in the firebox. Second, Rytter states that "[e]nergy from the hydrogen power station 7 may be used . . . in the separator 6 for separation of hydrogen and carbon dioxide." Id., 6:17-21. Rytter describes that separation as amine absorption in which "stripping steam is usually used" to liberate the carbon dioxide. Id., 8:9-14. That is a heat duty, not shaft power, and Rytter discloses no heat-recovery equipment between station 7 and separator 6. A unit that raises steam and supplies process heat to the

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rest of the plant is a heat generating station in the ordinary engineering sense — that is, a furnace. Rytter also uses the generic label "heat generating station" for this equipment (*see*, e.g., EX1008, cl. 8), but the functional description of station 7 controls its identity under the '168 patent's structural definition, and that description is boiler duty. A POSA reading Rytter's description of station 7 would understand it to disclose, at minimum, a hydrogen-fired steam generator. Rytter's focus on methanol production does not change this analysis. Rytter addresses the same problem as the '168 patent, disposing of a decarbonized, hydrogen-rich fraction of the synthesis gas as combustion fuel to reduce CO_2 emissions from a natural-gas-based syngas plant (EX1008, 3:10-16, 6:8-13), and Rytter itself contemplates directing part of the hydrogen-containing stream to ammonia synthesis and feeding a hydrogen-containing stream to the reforming plant as fuel (EX1008 at claim 11; EX1005 ¶96). In my opinion, a POSA designing the fuel destination for such a decarbonized stream would have consulted Rytter regardless of the downstream synthesis product. Accordingly, if the Board determines that claims 1 and 10 are unpatentable over Rytter, claim 24 presents the same issue and is anticipated by, or at minimum obvious over, Rytter for the same reasons.

D. Claim 24 would have been obvious over Fjellhaug in view of Rytter

38. My prior declaration explains why Fjellhaug, alone and in view of Rytter, discloses or renders obvious the limitations of claims 1 and 10. EX1005

¶¶127, 134, 149-50, 156, 273-77. Rytter supplies the claim 24 furnace (station 7) for the reasons given above. A POSA would have been motivated to combine Fjellhaug and Rytter with a reasonable expectation of success. The references address the same problem in the same field: disposing of a decarbonized, hydrogen-rich fuel fraction from a natural-gas-based synthesis gas process while minimizing CO_2 emissions. EX1010, 3:14-15, 4:34-50; EX1008, 3:10-16, 6:8-13. Fjellhaug already converts the fuel fraction to steam and power—via a gas turbine whose exhaust raises steam in steam generator 27 with superheating at heat exchanger 30 (EX1010, 4:38-50)—and Rytter teaches a directly fired hydrogen steam generator accomplishing the same conversion. Substituting or adding Rytter's fired steam generator is a simple substitution of one known, functionally interchangeable steam-raising means for another, using conventional boiler hardware: fuel gas in, steam and power out, with no CO2 at the stack because the fuel is hydrogen-rich. Nothing about the substitution would have required more than routine engineering, and the result—steam and power from decarbonized fuel—was entirely predictable and directly in service of both references' stated purpose.

E. Claim 24 would have been obvious over Terrien in view of Rytter

39. As set forth in Section XII below, Terrien discloses or renders obvious every limitation of claim 1, including the same-composition split of the PSA

hydrogen product stream with a portion recycled as plant fuel. Rytter supplies the steam production furnace for the reasons given above. A POSA would have combined them: both references concern natural-gas-based synthesis gas production with CO_2 capture and reduction, and both teach recycling the decarbonized hydrogen stream as fuel. EX1007 ¶¶ 35, 46, 93-95; EX1008, 3:10-16, 6:8-13. The destination of that fuel among a plant's few fired consumers is a design choice among a finite set of identified, predictable options; directing Terrien's hydrogen fuel to Rytter's fired steam generator raises useful steam and power while preserving Terrien's near-total capture, with a reasonable expectation of success for the reasons given above. EX1005 ¶¶ 206, 316-19.

X. OPINIONS REGARDING PROPOSED SUBSTITUTE CLAIM 25

A. The '058 patent and KAP 2004 disclose the added limitation

40. Claim 25 adds to claim 1 the requirement that the fuel fraction feed "said at least one furnace for pre-heating the charge of the autothermal reformer." As detailed in Section VIII.B above, the '058 patent discloses exactly that apparatus performing exactly that duty with exactly that class of fuel: fired heater 210, whose radiant section heats the feed to 900-1000°F before it enters autothermal reactor 220, and which is fired with a H_2-rich, CO_2-depleted offgas recycled from the synthesis gas purification train via line 251. EX1064, 5:16-21; 10:16-18; 13:19-14:24; Table 1; Fig. 1. Heater 210 is a fired charge preheater and

therefore a "furnace" under Patent Owner's construction. EX1001, 2:47-52. And because the same heater both receives the recycled fuel and pre-heats the ATR charge, the '058 patent discloses the one-apparatus arrangement that the "said at least one furnace" language requires. KAP 2004 confirms that this configuration was not idiosyncratic but "typical": its Figure 50 flowsheet shows the fired heater pre-heating the pre-reformed charge en route to the ATR in the standard ATR-based front end. EX1065 at 322-23.

B. A POSA would have combined the '058 patent and KAP 2004 with each primary reference, with a reasonable expectation of success

41. Each of the primary references—2007 IFA, Rytter, Fjellhaug (alone or with Rytter), and Terrien—teaches taking a decarbonized, hydrogen-rich fuel fraction from the CO_2-depleted synthesis gas of a natural-gas-based plant and burning it as plant fuel to reduce CO_2 emissions. EX1006 at 7-9; EX1008, 3:10-16, 6:8-13; EX1010, 3:14-15, 4:34-50; EX1007 ¶¶ 35, 46, 93-95. Implementing that teaching in the ATR-based plant that claim 1 requires presents one design question: which fired equipment receives the fuel? The '058 patent and KAP 2004 supply the conventional answer—the front-end fired charge preheater—and the '058 patent shows the claimed arrangement itself, with purification offgas fueling the heater that pre-heats the ATR charge.

42. In my opinion, a POSA would have been led to that answer for at least the following reasons. First, it is the application of a known technique to a known device for its established purpose: the '058 patent had taught, since 1991, fueling the ATR charge preheater with recycled purification gas, and applying that technique to the primary references' plants produces the same predictable result. Second, the universe of destinations is small and fully identified: in an ATR-based plant without a primary reformer, the fired consumers are the front-end fired heater and the steam system—indeed, original claim 10's own list of three Options catalogues them—so directing the fuel to the charge preheater is a selection from a finite number of identified, predictable solutions. Third, the selection directly advances the primaries' express objective: in many ATR-based designs the fired heater is the largest (often the only) point of fuel combustion and hence of stack CO_2 in the process area, so firing it with the decarbonized fuel fraction eliminates that CO_2—which is why Terrien teaches that hydrogen fueling of the feed gas producing unit drives capture toward 100%. EX1007 ¶ 94.

43. A POSA would also have had a reasonable expectation of success. The modification uses a standard fired heater performing its ordinary duty; the only accommodation is burner selection for a hydrogen-rich fuel gas, which was routine and proven, as the '058 patent itself fired its heater with hydrogen-containing PSA offgas in 1991. EX1064, 10:16-18; 14:21-24; Fig. 1; Table 1.

Combustion of hydrogen-rich fuel in refinery and syngas-plant fired heaters was commonplace long before the Critical Date. I am aware of nothing in the primary references or the general knowledge of the art that discouraged, taught away from, or presented any technical obstacle to firing a front-end charge preheater with a decarbonized, hydrogen-rich fuel fraction; to the contrary, the references affirmatively encourage using that fuel to cut CO_2. Nothing about the combination changes the process chemistry of claim 1: the split of the CO_2-depleted synthesis gas, the composition of the streams, and the ammonia process gas are all unaffected by which fired apparatus burns the fuel fraction.

44. I note one further consequence of the combination. In the combined process, the "at least one furnace" of claim 1[c] to which the fuel fraction is fed is the fired charge preheater—a "furnace" under Patent Owner's own construction. EX1001, 2:47-52. Accordingly, my opinions on these combinations do not depend on the parties' dispute over whether the gas turbines of 2007 IFA, Rytter, or Fjellhaug are "furnaces": under the combinations, claim 1[c]'s furnace requirement is satisfied by the charge preheater itself.

45. For completeness, I address the composition of the '058 patent's heater fuel and the structure of my reliance on that reference. The offgas fired in heater 210 is a PSA byproduct stream; its composition differs from that of the PSA's hydrogen/nitrogen product stream. I am aware that, during supplemental

examination of the ’168 patent, Patent Owner distinguished prior art on the ground that a PSA waste stream is not a “fuel fraction” resulting from a split of the CO_2-depleted synthesis gas into first and second streams having the same composition. EX1003 at 570-71, 644, 646, 648. My opinions account for that distinction. In each combination I address, the same-composition split required by limitation 1[c] is supplied by the primary reference—for example, 2007 IFA’s split of the “H_2 Fuel” stream from the CO_2-depleted synthesis gas line, or Terrien’s split of hydrogen product stream 27—and not by the ’058 patent. I do not opine that the ’058 patent anticipates any proposed substitute claim. The ’058 patent is relied upon for what it indisputably discloses: the identity, duty, and fuel supply of the front-end furnace—a fired charge preheater, pre-heating the desulphurization charge and the ATR charge, fired with gas recycled from the synthesis gas purification section—which is the subject matter of the sole limitation the proposed substitute claims add to claim 1.

C. Claim 25 would also have been obvious over Terrien in view of the knowledge of a POSA, the ’058 patent, and KAP 2004

46. Terrien independently renders claim 25 obvious in combination with ordinary knowledge as documented by the ’058 patent and KAP 2004. Terrien expressly directs the hydrogen fuel fraction to fuel the feed gas producing unit: a portion of hydrogen product stream 27 “can be used for hydrogen fueling of the feed gas producing unit (34),” where the feed gas producing unit is defined to

include "an ATR unit." EX1007 ¶¶ 35, 46, 73, 95. As I explained in Section VIII.A, an ATR has no externally fired burners; its heat is generated internally by partial oxidation with oxygen. A POSA reading Terrien's instruction to hydrogen-fuel an ATR-based feed gas producing unit would therefore understand the fuel to be directed to the unit's fired equipment, the fired charge preheater that heats the feed streams, including the pre-reformed charge entering the ATR, as shown by the '058 patent and depicted as "typical" by KAP 2004. Terrien's own description of desulfurized natural gas "preheated to around 600° C." entering the pre-reformer confirms that its front end includes this conventional fired preheat duty. EX1007 ¶ 74. Firing the charge preheater identified in the '058 patent and KAP 2004 to implement Terrien's hydrogen fueling is, in my opinion, the most reasonable reading of Terrien's teaching for the ATR configuration, and at minimum an obvious combination for the reasons and with the reasonable expectation of success set forth above.

47. I acknowledge two points about the scope of Terrien's express disclosure. First, Terrien does not use the word "furnace" in describing hydrogen fueling. Second, an ATR unit is one of several feed gas producing units Terrien identifies, and Terrien's worked hydrogen-fueling embodiment describes a steam methane reformer and water gas shift reactor as the feed gas producing unit rather than an ATR. EX1007 ¶¶73-78. That is why my opinion regarding Terrien and the

pre-heating limitations is presented as a combination rather than as anticipation. Terrien expressly defines the feed gas producing unit to include an ATR unit (EX1007 ¶¶73, 95), so applying Terrien's hydrogen-fueling instruction to that ATR configuration is, at minimum, the selection of one of the small number of feed gas producing units Terrien itself identifies, an obvious choice among a finite set of identified, predictable alternatives. The concrete identity of the fired equipment that receives Terrien's hydrogen fuel in the ATR configuration is supplied by the ordinary knowledge of a POSA, as documented by the '058 patent and KAP 2004, applied to Terrien's express instruction to use the hydrogen fuel fraction to fuel the ATR-based unit and to its express purpose of driving CO_2 capture toward 100%. EX1007 ¶¶ 35, 46, 73, 94-95.

XI. OPINIONS REGARDING PROPOSED SUBSTITUTE CLAIM 26

A. Claim 26 would have been obvious over the same combinations

48. Claim 26 differs from claim 25 only in the recited duty of the furnace: pre-heating the charge of a natural gas desulphurization section. The '058 patent discloses that duty in the same apparatus: the natural gas feed is preheated to about 750°F in the flue gas stack of fuel-fired heater 210 "and then desulfurized" in zinc oxide bed 211. EX1064, 5:1-5; 13:22-26; Fig. 1. From a process-engineering standpoint, this preheat step exists because the desulphurization reactions (hydrogenation of organic sulphur compounds and absorption of H_2S on zinc

oxide) require elevated temperature, so the desulphurization charge must be heated before entering the beds; a fired heater is the conventional means when upstream heat integration is insufficient. KAP 2004 shows a similar process in its Figure 50 flowsheet: the natural gas feed is preheated in a coil of the fired heater before being desulfurized. EX1065 at 45/86 (p. 323, Fig. 50).

49. My opinions on motivation and reasonable expectation of success for claim 25 (Section X.B-C) apply to claim 26 without modification, whichever primary reference is applied: the primary teaches burning the CO_2-depleted fuel fraction in at least one furnace of an ATR-based plant to reduce CO_2; the ’058 patent and KAP 2004 identify the conventional front-end furnace, which pre-heats the desulphurization charge; and directing the fuel there is a selection among the finite, predictable destinations that original claim 10 itself enumerates. In my opinion, claim 26 would have been obvious over 2007 IFA, Rytter, or Fjellhaug (alone or with Rytter) in view of the ’058 patent and KAP 2004, and independently over Terrien in view of the knowledge of a POSA, the ’058 patent, and KAP 2004.

B. Claim 26 is not supported by the written description of the original disclosure

50. I have also been asked whether the original disclosure demonstrates that the inventors possessed a process in which the fuel fraction feeds a furnace “for pre-heating the charge of a natural gas desulphurization section.” In my opinion it does not. The passages the Motion cites (Paper 34 at 12-13) are EP ’305

(EX2012) paragraph [0113], which states that the fuel fraction can be burned "in a furnace in the front end, for example in a charge heater (AUX block)," and paragraphs [0129]-[0130], which concern revamping an existing plant's desulphurization section. Neither passage—nor any other portion of the disclosure I have reviewed—describes a furnace that pre-heats the natural gas upstream of the desulphurization section, much less one fed by the fuel fraction. The specification's figures and description do not show the desulphurization section's feed being heated by a fired, fuel-fraction-fed heater; where the disclosure wished to identify fuel destinations, it did so expressly (steam generators, steam superheaters, charge preheaters, *see*, e.g., EX2012 ¶¶ [0014], [0065], [0113]). Reading the disclosure as a whole, a POSA would understand at most that a desulphurization section exists in the front end and that a furnace exists in the front end—not that the inventors possessed the specific configuration claim 26 recites. In my opinion, the disclosure does not reasonably convey possession of the subject matter of claim 26; it at most fails to exclude it, which I understand is insufficient.

XII. TERRIEN DISCLOSES OR RENDERS OBVIOUS THE CLAIM 1 LIMITATIONS

51. For the combinations above in which Terrien is the primary reference, my opinion that Terrien discloses or renders obvious every limitation of claim 1 is set forth in my prior declaration (EX1005 ¶¶125-26, 133, 144-48, 155, 291-98., addressing what was presented as Grounds 4 and 4A of the petition in IPR2025-

01455) and is summarized here. Terrien's ATR embodiment satisfies limitation 1[a]: the feed gas producing unit includes "an ATR unit" (EX1007 ¶¶73, 95), fed desulfurized natural gas that has passed through a pre-reformer (*id*. ¶ 74), with no primary reformer between them. Terrien's shift conversion and CO2 separation satisfy limitation 1[b]. *Id*. ¶¶ 36, 72, 78, 93. The split of PSA hydrogen product stream 27—one portion recovered, one portion recycled as fuel to the feed gas producing unit—satisfies limitation 1[c]'s separation of a fuel fraction by a split into streams of the same composition, fed as fuel. Id. ¶¶35, 46, 78. To the extent the ammonia-specific limitations of the preamble and limitation 1[d] are deemed not disclosed, it would have been obvious to apply Terrien's capture-and-hydrogen-fueling scheme to ammonia synthesis gas production: ammonia synthesis was, and is, one of the largest and most conventional uses of hydrogen produced from natural gas, the front-end technology is common to both services, and a POSA would have recognized Terrien's near-total-capture approach as directly applicable to the well-known problem of CO2 emissions from ammonia plants—the very problem 2007 IFA addresses. EX1006 at 1, 7; EX1005 ¶¶ 155, 291-93.

XIII. PROPOSED SUBSTITUTE CLAIM 27

52. Proposed substitute claim 27 is, as Patent Owner acknowledges, substantially identical to proposed substitute claim 25. Paper 34 at 3, 13. My

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opinions regarding claim 25 (Section X) apply to claim 27 in full, and in my opinion claim 27 is unpatentable for the same reasons.

XIV. MY DEPOSITION TESTIMONY

53. I understand that Patent Owner relies on portions of my April 30, 2026 deposition testimony, including my testimony that 2007 IFA does not show using the fuel fraction to pre-heat the charge of an autothermal reformer (EX2008, 116:18-20) and my testimony regarding the fired equipment shown in Fjellhaug (*id*., 157:9-19). Paper 34 at 18, 22-23. That testimony was accurate, and nothing in this declaration is inconsistent with it. The questions I was asked, and my answers, concerned what individual references show standing alone. The opinions in this declaration concerning claims 25 and 26 do not rely on 2007 IFA or Fjellhaug for the pre-heating furnace limitations; they rely on combinations in which the '058 patent and KAP 2004 supply those limitations—references about which I was not asked at my deposition. My deposition testimony about the scope of the individual references is fully consistent with, and indeed presupposed by, the combination opinions I offer here.

XV. OBJECTIVE INDICIA

54. I have seen no evidence in the record of objective indicia of nonobviousness—such as commercial success, long-felt but unmet need, failure of others, industry praise, or copying—attributable to the limitations that the proposed

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substitute claims add to claim 1, and the Motion identifies none. Nor, in my opinion, could such a nexus exist: as shown above, the added limitations recite fuel destinations that were conventional in ATR-based synthesis gas plants—disclosed in the '058 patent in 1991 and described as "typical" by KAP 2004 in 2004—long before the Critical Date.

XVI. CONCLUSION

55. For the reasons set forth above, it is my opinion that: proposed substitute claim 24 is anticipated by 2007 IFA and by Rytter, and would have been obvious over 2007 IFA in view of the knowledge of a POSA, over Fjellhaug in view of Rytter, and over Terrien in view of Rytter; proposed substitute claims 25, 26, and 27 would have been obvious over each of 2007 IFA, Rytter, and Fjellhaug (alone or in view of Rytter) in view of the '058 patent and KAP 2004, and independently over Terrien in view of the knowledge of a POSA, the '058 patent, and KAP 2004; and proposed substitute claim 26 is additionally not supported by the written description of the original disclosure.

56. I reserve the right to supplement or amend my opinions in response to any further arguments, evidence, or testimony offered by Patent Owner or its experts, or as additional information becomes available.

XVII. DECLARATION

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

7/28/26
Date

James A. Ritter, Ph.D.

APPENDIX A

1. This Appendix sets forth, in chart form, my element-by-element analysis of Proposed Substitute Claims 24, 25, 26, and 27 against the prior art combinations presented in Petitioner's Opposition to the Motion to Amend and analyzed in the body of this declaration. I prepared this Appendix, and it accurately reflects my opinions. The Appendix addresses only the combinations presented in the Opposition and in the body of this declaration; it presents no additional grounds, references, or combinations.

2. Each Substitute Claim carries forward every limitation of Claim 1 unchanged and adds a single limitation identifying the furnace that the fuel fraction feeds. Chart 1 accordingly collects the record evidence for the Claim 1 limitations under each primary reference or combination; Charts 2, 3, and 4 address the single added limitation of Claims 24, 25/27, and 26, respectively. Claim 27 is substantially identical to Claim 25 (Paper 34 at 3, 13) and is addressed by Chart 3. Bracketed limitation identifiers (1[a]-1[d]) follow the Petition. "Decl. ¶" refers to the numbered paragraphs of the body of this declaration; EX1005 is my prior declaration; "Pet." is the Petition (Paper 3); "Opp." is Petitioner's Opposition. Citations to the '058 Patent (EX1064) and KAP 2004 (EX1065) reflect my review of those references described in the body of this declaration, including my analysis of the stream routing depicted in KAP 2004's Figure 50.

CHART 1—Claim 1

In the contingent posture, the Board will have found the Claim 1 limitations established under at least one instituted ground (Ground 1: 2007 IFA; Ground 2: Rytter; Grounds 3/3B: Fjellhaug alone or with Rytter); the Terrien mapping is independent. The identity of the "at least one furnace" of limitation 1[c] in each combination is addressed in Charts 2-4.

Claim 1 Language	Evidence of Record
1[pre] "Process for the synthesis of ammonia from natural gas comprising:"	**2007 IFA** Directed to ammonia production from natural gas and reduction of its CO_2 emissions. EX1006 at 1 ("Energy efficiency in ammonia plants… CO_2 reduction potential"), 7, 10; Pet. 12-13; EX1005 ¶¶122-23; Decl. ¶¶30, 32. **Rytter** Discloses a process for ammonia synthesis; hydrogen "fed to ammonia synthesis." EX1008, 3:12-16; 4:41-50; Pet. 41; EX1005 ¶122; Decl. ¶¶30, 36-37. **Fjellhaug (alone or with Rytter)** "As feed for an ammonia synthesis may be drawn from the line 17." EX1010, 4:64-65; Pet. 53-54, 58-59; EX1005 ¶122; Decl. ¶¶30, 38. **Terrien** Hydrogen production from a hydrocarbon feed, preferably natural gas; application to ammonia synthesis obvious to the extent the preamble is limiting. EX1007 ¶73; EX1006 at 1, 7; EX1005 ¶¶155, 291-93; Opp. § X; Decl. ¶¶28, 51.

Claim 1 Language	Evidence of Record
1[a] "conversion of a charge of desulphurized natural gas and steam, with oxygen-enriched air or with oxygen, into a synthesis gas containing hydrogen, CO and CO_2, in a conversion section including an autothermal reformer downstream from a pre-reformer and without a primary reformer therebetween"	**2007 IFA** Page 9 flowsheet: natural gas passes through "hydrogenator" and "sulphur absorber" (desulphurization) and, with process steam, to a pre-reformer and then an autothermal reformer fed oxygen, with no primary reformer therebetween. EX1006 at 9; Pet. 14-15; EX1005 ¶131; Decl. ¶¶30, 32. **Rytter** Conversion of desulphurized natural gas and steam with oxygen into synthesis gas; conversion section includes a prereformer followed by an ATR without a primary reformer. EX1008, 1:30-33; 3:64-67; 4:14-29; 4:30-33; 5:26-28; Pet. 42; EX1005 ¶124; Decl. ¶¶30, 36. **Fjellhaug (alone or with Rytter)** Pre-reformer upstream of an ATR with no primary reformer therebetween; ATR supplied with air and supplemental O2 from gas-turbine exhaust (oxygen-enriched air). EX1010, 3:6-7, 3:23-24, 3:28-29, 3:59-4:3; Pet. 54, 59. Desulphurization inherent in ATR service. EX1005 ¶¶44, 126; EX1001, 1:24-45. With Rytter: "substantially pure O_2." EX1008, 4:26-29; Pet. 59-60; Decl. ¶¶30, 38. **Terrien** Pre-reformer receiving "desulfurized natural gas preheated to around 600° C." upstream of the ATR, with no primary reformer therebetween; feed gas producing unit defined to include "an ATR unit." EX1007 ¶¶73-74, 95; Opp. § X; Decl. ¶¶28, 51.

Claim 1 Language	Evidence of Record
1[b] "treatment of said synthesis gas including at least a shift reaction of the carbon monoxide into CO_2, and subsequent separation of CO_2, obtaining a CO_2-depleted synthesis gas and a CO_2-rich gaseous flow"	**2007 IFA** Page 9 flowsheet: shift conversion and CO_2 removal, producing the CO_2-depleted synthesis gas (stream to ammonia synthesis) and a CO_2-rich flow routed to the CO_2 compressor ("CO_2 for Injection"). EX1006 at 9; Pet. 15-16; EX1005 ¶¶132-34; Decl. ¶32. **Rytter** Shift reaction converting CO to CO_2 and subsequent CO_2 removal. EX1008, 4:6-9; 5:48-55; Pet. 42; Decl. ¶36. **Fjellhaug (alone or with Rytter)** Shift reaction and subsequent CO_2 removal. EX1010, 4:14-23; Pet. 54; EX1005 ¶134; Decl. ¶38. **Terrien** Water gas shift conversion; CO_2 separation unit yielding CO_2-rich product and CO_2-depleted streams. EX1007 ¶¶36, 72, 78, 93; Opp. § X; Decl. ¶¶28, 51.
1[c] "separation of a part of said CO_2-depleted synthesis gas as fuel fraction, fed as fuel to at least one furnace, wherein the separation includes the split of the CO_2-depleted synthesis gas into at least first and second streams having the same composition, the first stream forming the fuel fraction"	**2007 IFA** "H_2 Fuel" stream split from the CO_2-depleted synthesis gas line downstream of CO_2 removal (upstream of methanation and nitrogen addition) and recycled as plant fuel; the two streams branch from the same line without intervening treatment and necessarily have the same composition at the split. EX1006 at 9; Pet. 16-18; EX1005 ¶¶51-57, 136-41, 183-85; Decl. ¶¶30, 32. **Rytter** "[P]art of the H_2-containing stream from the separator for the H_2 and CO_2 reformer is supplied as fuel"; surplus hydrogen "may be passed to a hydrogen power station 7"; same composition. EX1008, 4:10-14; 4:55-

Claim 1 Language	Evidence of Record
	57; 6:8-13; cl. 11; Pet. 42-44; EX1005 ¶¶96, 142-43; Decl. ¶¶30, 36-37. **<u>Fjellhaug (alone or with Rytter)</u>** CO_2-depleted syngas split into first stream 17 (fuel fraction) and second streams 38/39 intended for ammonia synthesis; feed "drawn from" line 17 confirms same composition at the split. EX1010, 4:34-5:4; 4:64-65; Fig. 2; Pet. 55-56; EX1005 ¶¶110-11, 149-50; Decl. ¶¶30, 38. **<u>Terrien</u>** Split of PSA hydrogen product stream 27: one portion recovered as product, and "a portion of th[e] stream (27) can be used for hydrogen fueling of the feed gas producing unit (34)"; a single-stream split necessarily yields streams of the same composition. EX1007 ¶¶35, 46, 78; Opp. § X; Decl. ¶¶29, 51. *The apparatus constituting the "at least one furnace" in each Opposition combination and its qualification as a "furnace" under Patent Owner's construction is set forth in Charts 2-4. Decl. ¶¶17-18, 44.*
1[d] "the second stream being process gas intended for the synthesis of ammonia"	**<u>2007 IFA</u>** Second stream passes through the methanator, receives nitrogen, and exits labeled "Ammonia Syngas." EX1006 at 1, 9; Pet. 18; EX1005 ¶¶136-41; Decl. ¶32. **<u>Rytter</u>** Process for ammonia synthesis; hydrogen "fed to ammonia synthesis." EX1008, 3:12-16; 4:41-50; Pet. 44; EX1005 ¶154; Decl. ¶36.

Claim 1 Language	Evidence of Record
	<u>Fjellhaug (alone or with Rytter)</u> "As feed for an ammonia synthesis may be drawn from the line 17." EX1010, 4:64-65; Pet. 56; EX1005 ¶156; Decl. ¶38. **<u>Terrien</u>** To the extent limiting and not disclosed, application of Terrien's scheme to ammonia synthesis gas would have been obvious. EX1006 at 1, 7; EX1005 ¶¶155, 291-93; Opp. § X; Decl. ¶51.

CHART 2—Substitute Claim 24

Claim 24 Language	Evidence of Record
"wherein the fuel fraction feeds a steam production and/or superheating furnace" (Option A)	**2007 IFA** Fired "Package HP Steam Boiler" and fired "Auxiliary Boiler," each receiving "Fuel"; "H_2 Fuel" fraction split from the CO_2-depleted syngas (Chart 1, 1[c]); presentation read as a single continuous talk. EX1006 at 7-9; EX1045 ¶¶13-15. A fired boiler is a "steam generator" and thus a "furnace" under the '168 Patent's definition and Patent Owner's construction. EX1001, 2:47-52; Decl. ¶¶17, 30, 33-34; EX1005 ¶¶183-85, 205. **2007 IFA in view of POSA knowledge** Roughly 25% of plant hydrocarbon burned as fuel; identified fired CO_2 emitters (reformer, auxiliary boiler); "[r]emove CO_2 from flue gases (reformer and auxiliary boiler)"; substitution of the decarbonized H_2 fuel fraction for hydrocarbon fuel in the steam boiler; in the page 9 ATR flowsheet (no primary reformer), the steam system is the principal remaining fired consumer. EX1006 at 7-9; Decl. ¶¶20, 35; EX1005 ¶¶205-06. **Rytter** Surplus hydrogen "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" — an air-supplied, hydrogen-fired steam generator, and thus a steam production furnace under Patent Owner's construction. EX1008, 6:8-13; EX1001, 2:47-52; Decl. ¶¶17, 30, 36. Background reference to gas turbines (EX1008, 1:33-36) describes different, prior-art equipment, not station 7's operation. Decl. ¶37.

Claim 24 Language	Evidence of Record
	<u>Fjellhaug in view of Rytter</u> Fjellhaug burns the fuel fraction to raise steam (steam generator 27; superheater 30). EX1010, 3:14-15, 4:34-50. Rytter supplies the directly fired hydrogen steam generator (station 7). EX1008, 6:8-13. Shared problem and interchangeable, conventional steam-raising equipment. Decl. ¶¶30, 36, 38; EX1005 ¶¶122, 149-50, 156. **<u>Terrien in view of Rytter</u>** Terrien supplies the Claim 1 limitations (Chart 1); Rytter supplies the steam production furnace (station 7). EX1007 ¶¶35, 46, 93-95; EX1008, 3:10-16; 6:8-13; Decl. ¶¶29, 36, 39, 51; EX1005 ¶¶206, 316-19.

CHART 3—Substitute Claims 25 and 27

Claim 25/27 Language	Evidence of Record
"wherein said fuel fraction feeds said at least one furnace for pre-heating the charge of the autothermal reformer" (Option B) *Claim 27 is substantially identical to Claim 25. Paper 34 at 3, 13; Decl. ¶52.*	**The '058 Patent** Fired heater 210 pre-heats the ATR charge: the major feed portion "is further heated to a temperature in the range of 900° to 1000° F. . . . in the radiant section of heater 210 and is introduced by line 218 into the inlet of an autothermal reactor 220." EX1064, 5:16-21; 13:19-14:28; Table 1; Fig. 1; Decl. ¶¶22-23, 40. The same heater is fired with hydrogen-containing offgas recycled from the syngas purification train: the PSA offgas streams "may be mixed . . . and the mixture employed as fuel in the gas heater 210 (as indicated by line 254 of FIG. 1)." EX1064, 9:63-10:3; Fig. 1 ("FUEL FROM PSA"). One apparatus thus both receives the recycled fuel and performs the recited pre-heating duty ("said at least one furnace"). Decl. ¶¶18, 24, 40. Heater 210 is a fired charge preheater and therefore a "furnace" under Patent Owner's construction. EX1001, 2:47-52; Decl. ¶¶17, 40. **KAP 2004** Figure 50, the "[t]ypical process flow diagram for synthesis gas production," depicts a fired heater pre-heating the feed streams, including the pre-reformed charge en route to the ATR; the accompanying text describes the feed as passed "to a prereformer and, after preheating to a high temperature, to the ATR, which operates at an outlet temperature of typically 1050°C." EX1065 at 322-23, Fig. 50; Decl. ¶¶25-27, 40.

	2007 IFA + '058 Patent + KAP 2004 2007 IFA supplies the Claim 1 limitations (Chart 1) and the instruction to burn the decarbonized H_2 fuel fraction as plant fuel to reduce CO_2. EX1006 at 7-9; Decl. ¶¶30, 32. Motivation, KSR rationales, and reasonable expectation of success: Decl. ¶¶41-44; Opp. § VIII.A.3. **Roles of the two secondary references** The '058 patent supplies each component of the added limitation: the apparatus (fired heater 210), the recited duty (pre-heating the ATR charge), and the fuel routing (offgas recycled from the synthesis gas purification section, fired in that same heater). It is also an ammonia synthesis gas reference. EX1064, 5:16-21; Fig. 1; Decl. ¶¶22-24, 40, 45. KAP 2004 supplies the apparatus and the duty, and establishes that this configuration was the industry's "typical" design by 2004. Figure 50 depicts the fired heater's process duties; it does not depict the heater's fuel supply. EX1065 at 322-23, Fig. 50; Decl. ¶¶25-27, 40. My opinions on the added limitation therefore do not rely on KAP 2004 for the fuel routing. If KAP 2004 were not considered, my opinions would be unchanged, because the '058 patent discloses the apparatus, the duty, and the fuel routing. Decl. ¶¶40, 45; see Opp. § VIII.A.4. **Rytter + '058 Patent + KAP 2004** Rytter supplies the Claim 1 limitations (Chart 1) and teaches recycling separated surplus hydrogen as fuel to reduce CO_2 emissions. EX1008, 3:10-16; 6:8-13; Decl. ¶¶30, 36. Same motivation and reasonable-expectation analyses. Decl. ¶¶41-44.

Claim 25/27 Language	Evidence of Record
	<u>Fjellhaug (alone or with Rytter) + '058 Patent + KAP 2004</u> Fjellhaug (alone or with Rytter) supplies the Claim 1 limitations (Chart 1) and teaches recycling the decarbonized fuel fraction as plant fuel to reduce CO_2. EX1010, 3:14-15, 4:34-50; Decl. ¶¶30, 38. Same motivation and reasonable-expectation analyses. Decl. ¶¶41-44. **<u>Terrien + POSA knowledge + '058 Patent + KAP 2004</u>** Terrien expressly directs the hydrogen fuel fraction to fuel the ATR-based feed gas producing unit—"a portion of th[e] stream (27) can be used for hydrogen fueling of the feed gas producing unit (34)"—defined to include "an ATR unit," to drive capture "approaching or achieving 100%." EX1007 ¶¶35, 46, 73, 94-95; Decl. ¶¶28-29. An ATR has no externally fired burners (Decl. ¶¶19, 46); the unit's fired equipment is the charge preheater shown by the '058 Patent and depicted as typical by KAP 2004. Terrien's front end includes the fired preheat duty ("desulfurized natural gas preheated to around 600° C." entering the pre-reformer). EX1007 ¶74; Decl. ¶¶46-47.

CHART 4—Substitute Claim 26

Claim 26 Language	Evidence of Record
"wherein said fuel fraction feeds said at least one furnace for pre-heating the charge of a natural gas desulphurization section" (Option C)	**<u>The '058 Patent</u>** The natural gas feed (line 204) "is passed through the flue gas stack of a small fuel-fired heater 210 wherein it is preheated to a temperature of about 750° F. (~400° C.) and then desulfurized by being passed through a zinc oxide bed 211." EX1064, 5:1-5; 13:19-14:28; Fig. 1; Decl. ¶¶23, 48. Heater 210 thus pre-heats the charge of the natural gas desulphurization section. Heater 210 is the same fired heater whose radiant section pre-heats the ATR charge (Chart 3) and which is fired with recycled PSA offgas. EX1064, 5:1-21; Fig. 1; Decl. ¶¶23-24, 45. One apparatus thus both receives the recycled fuel and performs the recited pre-heating duty ("said at least one furnace"), and is a "furnace" under Patent Owner's construction. EX1001, 2:47-52; Decl. ¶¶17-18, 44. The desulphurization reactions (hydrogenation of organic sulphur compounds; H_2S absorption on zinc oxide) require elevated inlet temperature, so the desulphurization charge must be heated before entering the beds. Decl. ¶¶20, 48. **<u>KAP 2004</u>** Figure 50's "[t]ypical" flowsheet likewise routes the natural gas feed through a coil of the fired heater before it enters the desulphurization ("S-Removal") vessels — i.e., the natural gas feed is pre-heated in the fired heater and then desulphurized. EX1065 at 323, Fig. 50; Decl. ¶¶26, 48.

	Roles of the two secondary references As with claim 25, the '058 patent supplies each component of the added limitation—the apparatus (heater 210), the recited duty (pre-heating the natural gas desulphurization charge), and the fuel routing—and is an ammonia synthesis gas reference. EX1064, 5:1-21; Fig. 1; Decl. ¶¶23-24, 45, 48. KAP 2004 corroborates that the same arrangement was "typical": its Figure 50 routes the natural gas feed through a coil of the fired heater before desulphurization, but does not depict the heater's fuel supply. EX1065 at 323, Fig. 50; Decl. ¶¶26, 48. My opinions on the added limitation would be unchanged if KAP 2004 were not considered. Decl. ¶¶45, 48. **2007 IFA + '058 Patent + KAP 2004** 2007 IFA supplies the Claim 1 limitations (Chart 1) and the fuel-recycle teaching. EX1006 at 7-9; Decl. ¶¶30, 32. The Chart 3 motivation and reasonable-expectation analyses apply without modification to the desulphurization-charge duty; the destinations are the finite alternatives original Claim 10 itself enumerates. EX1001, Reexam. Cert., cl. 10; Decl. ¶¶14, 20, 41-44, 49. **Rytter + '058 Patent + KAP 2004** Rytter supplies the Claim 1 limitations (Chart 1) and the fuel-recycle teaching. EX1008, 3:10-16; 6:8-13; Decl. ¶¶30, 36. Same analyses. Decl. ¶¶41-44, 49. **Fjellhaug (alone or with Rytter) + '058 Patent + KAP 2004** Fjellhaug (alone or with Rytter) supplies the Claim 1 limitations (Chart 1) and the fuel-recycle teaching. EX1010, 3:14-15, 4:34-50; Decl. ¶¶30, 38. Same analyses. Decl. ¶¶41-44, 49.

Claim 26 Language	Evidence of Record
	<u>Terrien + POSA knowledge + '058 Patent + KAP 2004</u> Terrien's express hydrogen-fueling instruction and purpose (Chart 3) apply equally; the '058 Patent and KAP 2004 identify the front-end fired charge preheater, which performs the desulphurization-charge preheat duty. EX1007 ¶¶35, 46, 73-74, 94-95; EX1064, 5:1-5; EX1065 at 323, Fig. 50; Decl. ¶¶46-49, 51.