

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Markus Priske Attorney Docket No.: 55766-0003IP1
U.S. Patent No.: 10,471,380
Issue Date: November 12, 2019
Appl. Serial No.: 15/540,709
Filing Date: June 29, 2017
Title: PROCESS FOR SEPARATION OF GASES WITH REDUCED
MAINTENANCE COSTS

DECLARATION OF DR. RICHARD W. BAKER

I currently hold the opinions explained in this declaration. My analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare 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 the Title 18 of the United States Code.

Dated: 22 February 2014 By: Richard W. Baker
Richard W. Baker

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I. INTRODUCTION

I, Dr. Richard W. Baker, of Redwood City, California, declare that:

1. I am over the age of 18 and competent to make this declaration.
2. I have been retained on behalf of Air Products and Chemicals, Inc. to offer my professional opinions in connection with the *inter partes* review (IPR) of U.S. Patent 10,471,380 (the ‘380 patent). I have no financial interest in the parties or in the outcome of this proceeding. I am being compensated for my work as an expert on an hourly basis. My compensation does not depend in any way on the outcome of the IPR.
3. I understand from Air Products’ counsel that the ‘380 patent (AP-1001) was granted on November 12, 2019, and is based on a patent application filed on December 29, 2014.

II. QUALIFICATIONS AND EXPERIENCE

4. In forming my opinions, I have relied on my knowledge, training and experience with membrane separations and related disciplines.
5. I am an expert in the design, application and commercialization of membrane systems used to separate gas mixtures. I have been an expert in this field since at least 1982.

6. I am currently the principal scientist and founder of Membrane Technology and Research, Inc. My education and experience are described more in my attached curriculum vitae (AP-1004).

7. In 1966, I received a doctorate in physical chemistry from Imperial College, London, where I studied under Professor Richard M. Barrer, a pioneer of membrane science. I later served as postdoctoral fellow at the Brooklyn Polytechnic Institute, New York, from 1968 to 1969.

8. In 1970, I joined Alza Corporation in Palo Alto, California where I collaborated to develop the Ocusert ocular delivery system, a membrane system for drug delivery.

9. In 1974, I left Alza Corporation to co-found Bend Research, Inc. where I served as Director of Research for six years. I then joined the Fraunhofer Research Institute in Stuttgart, West Germany in 1980 as a visiting scientist.

10. In 1982, I left the Fraunhofer Research Institute to found Membrane Technology and Research, Inc. (MTR) in Menlo Park, California.

11. From 1982 to 2007, I served as the president of MTR, overseeing its growth into a leading membrane research, development, engineering, and production company in the field of membranes and membrane systems. Among MTR's successes is its VaporSep membrane system used worldwide to remove organic vapors from air and nitrogen in chemical and petrochemical plants.

12. In 2007, I stepped aside as president of MTR to lead new development programs for MTR's membrane-based biomass/biofuel separation and carbon capture technology. I am still involved with MTR today and remain a board member.

13. In addition to my professional work with MTR, I am also involved in the membrane research community and frequently give presentations and educational workshops at national and international meetings.

14. From 1981 to 1982 I founded and served as president of the International Controlled Release Society, a scientific community that advances research, technology, education, and networking in the field of drug delivery science.

15. From 1986 to 1989 I served on the board of the North American Membrane Society, of which I am a founding member. The North American Membrane Society promotes membrane science and technology from fundamental studies of membrane material science to process application and development.

16. Additionally, I served on the editorial boards of *The Journal of Membrane Science* from 1978–2023, *Industrial & Engineering Chemistry Research* from 2009–2012, *Journal of Controlled Release* from 1984–1996, *Separation and Purification Technology* from 2000–2003, and *Biomedical Polymers, Topics in Controlled Release Science* from 1985–86.

17. Throughout my career I have received a variety of awards.

18. In 1984, Industrial Research Magazine awarded me the Industrial Research 100 Award, awarded to the 100 most technologically significant products of the year, for my work on facilitated transport gas separation membranes.

19. In 1985, the Controlled Release Society awarded me the Founders' Award for contributions to the development of controlled release technology.

20. In 1990, Industrial Research Magazine awarded me a second Industrial Research 100 Award for my work developing MTR's membrane vapor separation technology.

21. In 1997, Chemical Engineering Magazine awarded me its Kilpatrick Chemical Engineering Achievement Award for the most noteworthy chemical engineering technology commercialized in the world in the previous two years, for my work involving monomer recovery in polyolefin plants.

22. In 2002, the American Institute of Chemical Engineer's Separation Division awarded me an annual award for my work in gas separation membrane technology.

23. In 2002, the North American Membrane Society awarded me its Alan S. Michaels Award for Innovation in Membrane Science and Technology, awarded to an individual who has made breakthrough contributions to the membrane field, for my work in several membrane fields including gas separation as well as

achievements in transitioning developments in membrane science into commercial reality.

24. Over the course of my career, I have authored more than 100 papers, which are listed in my CV, and been named as an inventor on over 130 patents, most of which relate to membrane sciences.

25. I am also the author of the book *Membrane Technology and Applications* first published in 2000, with three subsequent editions published in 2004, 2012, and 2024, as well as *Controlled Release of Biologically Active Agents*, published in 1987.

26. Also, I am also the author of “Membrane Technology” in *Kirk-Othmer Encyclopedia of Chemical Technology* (1995); “Membrane Separation” in *Encyclopedia of Separation Science* (2000); “Membrane Technology” in *Encyclopedia of Polymer Science* (2001); “Natural Gas Purification” in *Encyclopedia of Membrane Science and Technology* (2013).

III. LEGAL PRINCIPLES

27. I am not a lawyer but I have been informed by Air Products’ counsel of legal principles that are relevant to my analysis.

A. Independent and dependent patent claims

28. I have been informed by Air Products' counsel that a patent's claims may be independent or dependent claims. I understand the only independent claim in the '380 patent is claim 1, and all the other claims are dependent claims.

29. I have been informed by Air Products' counsel that dependent claims incorporate by reference all the requirements (or "limitations" or "elements") of the claims they depend on. For example, claim 2 in the '380 patent (because it depends on claim 1) contains all the limitations of claim 1 and additionally all the limitations of claim 2; and claim 6 (because it depends on claim 5, which depends on claim 1) contains all the limitations of claims 1 and 5, and additionally all the limitations of claim 6.

B. The meanings of words and terms in patent claims (claim construction)

30. I have been informed by Air Products' counsel that defining the words of, and terms in, a patent's claims is called "claim construction."

31. I also have been informed by Air Products' counsel that the words of, and terms in, a patent's claims should be interpreted as they would have been interpreted by a person of ordinary skill in the art (POSITA) at the time of the invention (not today). Here, I have been asked to assume the time of the invention for the '380 patent was December 2014.

32. I have been informed by Air Products' counsel that the words of and terms in a patent's claims should be given their plain meaning unless that meaning is inconsistent with the patent's specification or the patent's prosecution history (the examination of the patent application by the Patent Office).

33. I also have been informed by Air Products' counsel that features from examples in the patent should not be imported into the definitions of the claims' words and terms if the claim language is broader than the examples.

34. In my analysis, I have applied the plain meaning of the words and terms in the '380 patent's claims as they would have been understood by a POSITA in December 2014 in light of the '380 patent's specification and prosecution history.

C. Patent claim validity

35. I have been informed by Air Products' counsel that the validity of patent claims is assessed on a claim-by-claim basis. In other words, each claim in a patent must be evaluated individually to determine if it is valid or invalid in view of the relevant prior art. Therefore, it is possible that some claims in a patent may be valid and other claims may not be valid in view of the prior art.

36. I have been informed by Air Products' counsel that patent validity must be assessed from the perspective of a POSITA at the time of the invention. I have been asked here to assume the time of the invention was December 29, 2014. I understand, in other words, that in determining whether the '380 patent's claims are

valid, I should assess the state of the art and the teachings and disclosure in the prior art as they would have been understood by a POSITA in December 2014.

D. Legal standards for obviousness

37. I have been informed by Air Products' counsel that documents and materials that qualify as prior art can render a patent claim unpatentable as "obvious."

38. I have been informed by Air Products' counsel that an obviousness evaluation can be based on a single prior art reference or a combination of multiple prior art references.

39. I have been informed by Air Products' counsel that a patent claim can be obvious in light of a single prior art reference, without the need to combine prior art references, if the elements of the claim that are not found explicitly or inherently in the prior art reference can be supplied by the common sense of a POSITA.

40. I have been informed by Air Products' counsel that an obviousness inquiry requires consideration of the following factors: (1) the scope and content of the prior art; (2) the differences between the claims and the prior art; (3) the level of ordinary skill in the pertinent art; and (4) any objective indicia of non-obviousness, such as commercial success, long-felt but unresolved need, failure of others, industry recognition, copying, and unexpected results.

41. I have been informed by Air Products' counsel that a claim is unpatentable for obviousness if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious to a POSITA at the time of the invention.

42. I have been informed by Air Products' counsel that all prior art references are to be looked at from the viewpoint of a POSITA at the time of the invention, and that this viewpoint prevents one from using his or her own insight or hindsight in deciding whether a claim is obvious. In other words, it is improper to use hindsight in an obviousness analysis: a patent's claims should not be used as a "roadmap" in piecing together prior art references.

43. I have been informed by Air Products' counsel that the combination of familiar elements according to known methods is likely to be obvious when it yields predictable results. However, I have been informed by Air Products' counsel that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art.

44. I have been informed by Air Products' counsel that when a patented invention is a combination of known elements disclosed in more than one prior art reference, it must be determined whether there was an apparent reason to combine the prior art references (a "motivation to combine") by considering the teachings of prior art references, the effects of demands known to people working in the field or

present in the marketplace, and the background knowledge possessed by a POSITA. I have been informed by Air Products' counsel that in addition to a motivation to combine, in order for a combination of prior art references to render a patent claim obvious, a POSITA would have to have a reasonable expectation of success in combining the prior art references' teachings.

45. I have been informed by Air Products' counsel that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but that linking two or more prior art references together is sometimes simple common sense. I have been informed by Air Products' counsel that obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

46. I have been informed by Air Products' counsel that secondary indicia may support finding a patent claim non-obviousness. Secondary indicia may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success of processes covered by a patent claim; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art; (5) taking of licenses under the patent by others; (6) deliberate copying of the invention; (7) failure of others to find a solution to the long felt need; and (8) skepticism by experts. I understand from Air Products' counsel that evidence

of secondary indicia of non-obviousness, if available, should be considered as part of the obviousness analysis.

47. I have been informed by Air Products' counsel that there must be a relationship between any such secondary considerations and the invention.

48. I have been informed by Air Products' counsel that contemporaneous and independent invention by others is a consideration supporting a finding that a patent claim is obvious.

49. In sum, my understanding is that prior art teachings are properly combined where a POSITA, having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements in a patent's claim.

50. I have been informed by Air Products' counsel that in an inter partes review, the petitioner has the burden of proving obviousness by a preponderance of the evidence.

IV. MATERIALS CONSIDERED

51. In formulating my opinions, I have considered the following materials, and any other materials referenced in this declaration.

- AP-1001 U.S. Patent No. 10,471,380 ("the '380 patent")
- AP-1002 Prosecution History of the '380 Patent

- AP-1006 U.S. Patent No. 8,999,038 (“Ungerank”)
- AP-1007 M. Scholz et al., *Structural optimization of membrane-based biogas upgrading processes*, Journal of Membrane Science, 474 (Available online 28 September 2014), 1–10 (“Scholz”)
- AP-1008 Japanese Patent Application No. JP2009-242773 (“Tsuchida”)
- AP-1009 Qi, Runhong et al., *Membrane system design for multicomponent gas mixtures via mixed-integer nonlinear programming*, Computers & Chemical Engineering, 24 (2000) (“Qi”)
- AP-1010 Datta, Anjan K., *Optimization of membrane unit for removing carbon dioxide from natural gas*, Journal of Membrane Science, 283 (2006), 291-300 (“Datta”)
- AP-1011 Machine translation of Japanese Patent Application No. JP2009-242773
- AP-1012 Zhang et al., *Current status and development of membranes for CO₂/CH₄ separation: A review*, International Journal of Greenhouse Gas Control, 12 (2013), 84-107 (“Zhang”)
- AP-1013 Baker, Richard W., *Membrane Technology and Application* (3d Ed. 2012)
- AP-1014 U.S. Patent No. 7,968,758
- AP-1015 Baker et al., *Permeability, permeance, and selectivity: A preferred way of reporting pervaporation performance data*, Journal of Membrane Science, 348 (2010), 346-352
- AP-1016 Alshehri et al., *Membrane Systems Engineering for Post-combustion Carbon Capture*, Energy Procedia, 37 (2013), 976-985.

- AP-1017 CAS Registry for Polymers 9046-51-9 and 134119-41-8
- AP-1037 M. Scholz et al., *Structural Optimization of membrane-based biogas upgrading processes*, Journal of Membrane Science, Authors Accepted Manuscript

52. I understand from Air Products' counsel that AP-1006 (Ungerank) and AP-1007 (Scholz) are "prior art" to the '380 patent, which I understand is a term of art in patent law. I also understand AP-1008 (Tsuchida) is a Japanese patent document that was published in 2009.

53. Qi (AP-1009) shows on its first page that it was published in 2000 in *Computers and Chemical Engineering*; Datta (AP-1010) shows on its first page that it was published in 2006 in the *Journal of Membrane Science*; Zhang (AP-1012) shows on its first page that it was published in 2012 in the *International Journal of Greenhouse Gas Control*; Alshehri (AP-1016) shows on its first page it was published in *Energy Procedia* in 2013; and patent US 7,968,758 (AP-1014) shows it was granted on June 28, 2011. The third edition of my book *Membrane Technology and Applications* (AP-1013) was published in 2012, and my paper *Permeability, permeance and selectivity: A preferred way of reporting pervaporation performance data* (AP-1015) was published in 2010.

V. SUMMARY OF MY CONCLUSIONS

54. This declaration explains the conclusions that I have formed based on my analysis.

55. In summary, based on my knowledge and experience and my review of the prior art in light of the state of the art as of December 2014, it is my opinion that claims 1-5, 7, 9 and 11-23 of the '380 patent are obvious because of the combination of Ungerank (AP-1006) and Scholz (AP-1007); and claims 1-13, 16-17, 21 and 23 of the '380 patent are obvious because of Scholz (AP-1007) by itself.

VI. PERSON OF ORDINARY SKILL IN THE ART

56. In preparing this declaration, I have reviewed the '380 patent and its prosecution history (the Patent Office file regarding the application for the patent) (AP-1002), as well as the other documents cited in this declaration, in light of the state of the art as of December 2014. In arriving at my opinions, I have considered the point of view of a POSITA in the field of membrane systems for gas separation in December 2014.

57. I understand that a POSITA is a hypothetical person who, at the time of a patent's invention, is presumed to know of all relevant art and is a person of ordinary creativity. With respect to the '380 patent and its field of three stage membrane systems for gas separation, a POSITA would have education and experience in the field and knowledge of scientific literature in the field.

58. Although education and experience levels may vary, in my opinion a POSITA in December 2014 would have had a Master of Science degree in an academic discipline such as chemistry or chemical engineering and at least three

years of work experience with membrane systems for gas separation, including but not limited to biogas membrane separations.

59. I understand from Air Products' counsel that a POSITA is not necessarily limited to his or her own skills but also may work as part of a team and utilize skills of other team members in order to solve a particular problem.

60. I had attained the qualifications of a POSITA by December 2014, and I have an understanding of the capabilities a POSITA had in December 2014. The opinions I express in this declaration take in to account the knowledge, understanding and capabilities of a POSITA in the field of membrane systems for gas separation in December 2014.

VII. THREE-STAGE MEMBRANE SYSTEMS FOR GAS SEPARATION

61. Gas mixtures (for example, methane and carbon dioxide) are generated in municipal and agricultural waste systems, oil and gas exploration and processing, and other fields. AP-1013, 359.

62. Gas mixtures can be separated into their components using membrane separation systems. AP-1013, 4. In these systems, membranes, typically made of polymers, are used that allow a selected gas in the mixture to pass through the membrane much more readily than the others. AP-1013, 9-10.

63. The membranes do not separate the gases entirely or perfectly. But by using multiple membranes in series or in parallel or both, the final product streams can be of relatively high purity. AP-1013, 345-49.

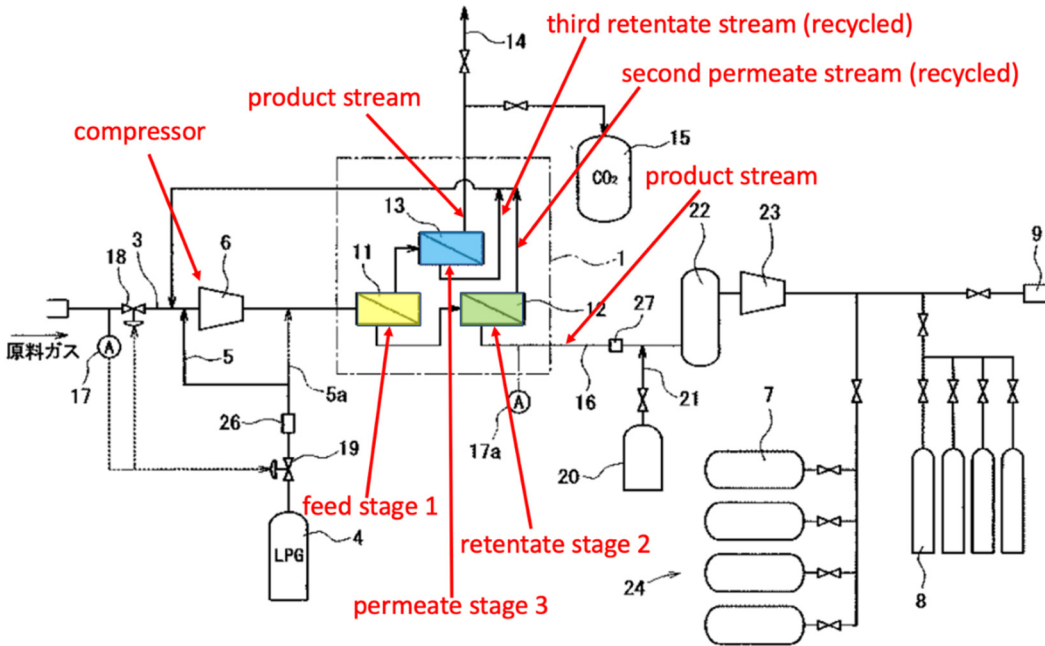
64. The separated gases can be collected or disposed of. For example, when methane and carbon dioxide mixtures are separated, the methane can be injected into the natural gas distribution system and used, for example, in home heaters and stoves. AP-1013, 359.

65. In membrane separation systems, the gas that passes through a membrane is called “permeate” and the gas that does not pass through a membrane is called “retentate.”

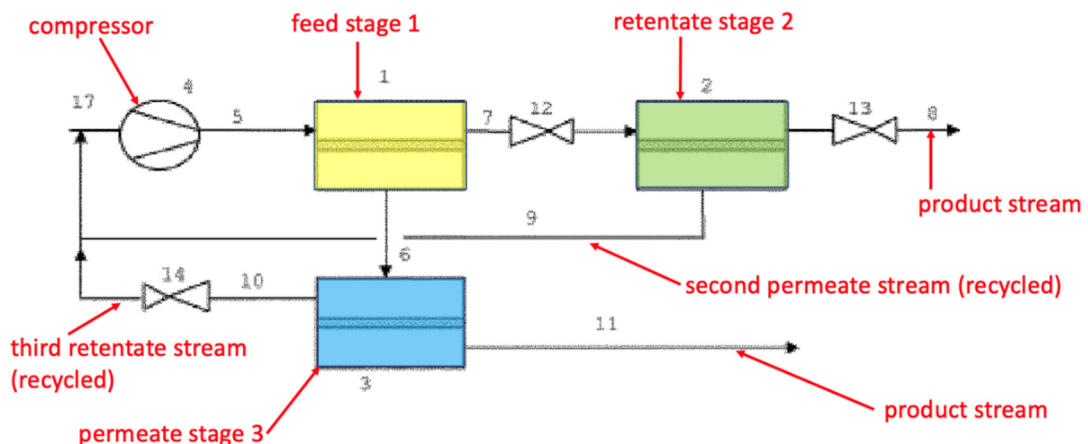
66. Similarly, the gas streams from different stages in a system are also referred to this way, for example, a “second permeate stream” refers to the permeate gas from the second stage in a system, and the “third retentate stream” refers to the retentate gas from the third stage in a system.

67. As I discuss more in Section VIII. below, the ‘380 patent pertains to what are known as “two step, two-stage systems,” or “three-stage” membrane systems. Three stage membrane systems have been known and used since at least 2010, and by that time, generally their advantages and disadvantages were understood.

Figure 1 in the '380 patent, as shown by the highlighting and labels below:



Tsuchida System



Illustrative connection arrangement of several membrane modules according to invention

'380 patent Figure 1

69. By the early 2000's, papers had been published on optimizing membrane gas separation systems, including three stage systems.

70. For example, in 2000, Qi and Henson (Qi) published *Membrane system design for multicomponent gas mixtures via mixed-integer nonlinear programming* (AP-1009). Qi discussed design strategies for “membrane networks separating multicomponent gas mixtures based on an approximate permeator model and mixed-integer nonlinear programming.” AP-1009, Abstract.

71. Among other types of systems, Qi applied the design methodology it discussed to three-stage systems to separate streams containing CH₄ and CO₂:

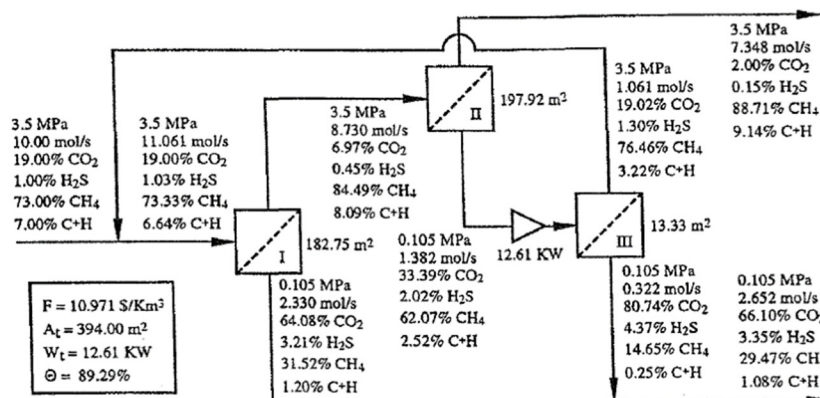
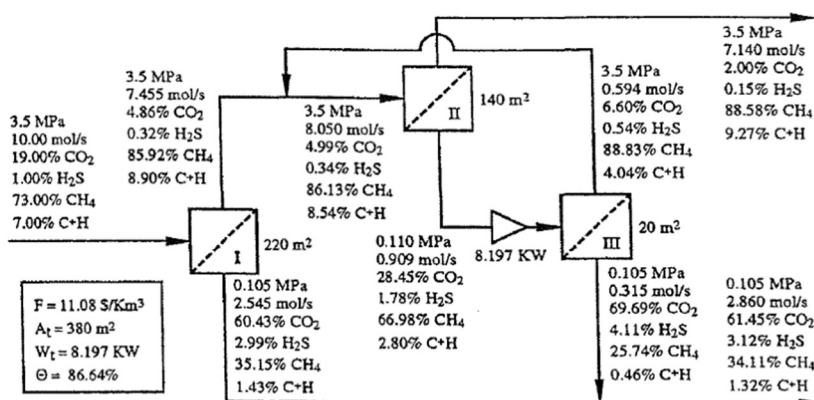


Fig. 4. Three-stage, four-component system with continuous membrane area (natural gas treatment).

Fig. 5. Three-stage, four-component system with membrane element area of 20 m² (natural gas treatment).

Qi Figures 4 and 5

72. Another example is the 2006 paper *Optimization of membrane unit for removing carbon dioxide from natural gas* (“Datta”). AP-1010. Somewhat similarly to Qi, Datta discussed “the optimum configuration and design variables for the asymmetric membrane-based separation of carbon dioxide from natural gas.” AP-1010, Abstract.

73. In its Abstract, Datta explained that optimization, in terms of costs, was analyzed for membrane systems “having up to three stages.” Datta additionally explained that three-stage systems were optimal in many conditions for separating carbon dioxide and methane mixtures. AP-1010, 292.

74. As explained more below, before the ‘380 patent, Ungerank (AP-1006) discussed three-stage systems with the same configuration as in the ‘380 patent; and Scholz (AP-1007) built on the prior optimization papers like Qi and Datta, and explained optimum designs for, among other configurations, three stage systems.

75. In 2014 and before, POSITAs routinely used commercially available computer simulation programs such as Aspen and ChemCad to perform required calculations. For example, a 2011 Evonik patent, 7,968,758, explains that for the examples in that patent, “calculations were carried out using the steady-state simulation program ASPEN Plus (version 12.1 from AspenTech).” AP-1014, 23:8-10. In fact, such programs were first used more than 30 years ago, and by 2000 they were in use throughout the industry.

76. By 2014 (and before), simulation software programs also allowed POSITAs to optimize systems. For example, in 2013, Alshehri discussed using Aspen to design and cost-optimize a multi-component membrane separation system. AP-1016, 981. Scholz described using “General Algebraic Modeling System

(GAMS)” for optimizing multi-unit membrane processes, which in principle is similar. AP-1007, Abstract.

77. In other words, by 2014 (and before) simulation software could be used to test different variations of a particular set of design criteria. That is, simulation software allowed POSITAs to test variables by varying them in the simulations, guided by a POSITA’s experience and knowledge about factors affecting performance. A POSITA could vary a variable and the simulation program would show how doing so affected the other variables in the system. Such characteristics include sizes of the membranes, pressures, sizes of the compression equipment, and the amount of gas that is recycled.

78. In sum, by 2014, performing optimizations to produce the lowest cost and best performing design was routine for POSITAs.

VIII. THE ‘380 PATENT

79. In membrane gas separation systems, as a gas passes through a membrane, its pressure drops. In other words, in these systems, there must be a pressure drop (the retentate pressure minus the permeate pressure) across the membranes to drive the permeate through the membrane. AP-1013, 340-343.

80. To provide the necessary driving force, often the gas mixture must be compressed if it is not already under pressure from its source. Alternatively, a

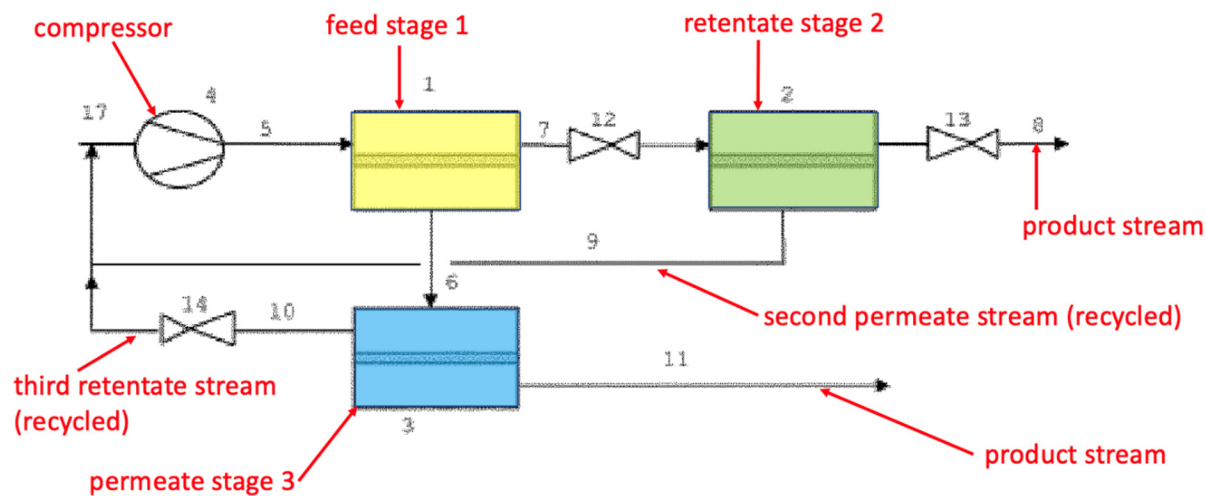
vacuum device can be used to create a pressure drop across a membrane. AP-1013, 342-343.

81. Creating the driving force requires energy (for example, to run a compressor), and energy is often expensive. Often, in designing such systems, the energy used by the compressor(s) is of paramount concern in terms of operating costs. More specifically, the primary operating costs in membrane separation systems are usually energy and membrane replacement costs (and the primary capital costs are usually compressor costs and membrane costs). As explained more below, higher-selectivity membranes are more expensive than lower-selectivity membranes.

82. The '380 patent states that “a new problem has occurred,” which is “some gas separation plants are operated at sites where energy is very cheap” and “the focus ... lies on investment and maintenance costs rather than on an energy saving.” AP-1001, 1:45-51. The '380 patent addresses this problem by using lower-cost, lower-selectivity membranes—i.e., systems that are “advantageous in terms of ... the costs for expendable materials like the membranes” which “should be as low as possible.” AP-1001, 1:60-63.

83. In Figure 1, the '380 patent shows a three-stage “Illustrative connection arrangement of several membrane modules according to the invention,” which,

below, has the three stages colored in yellow, blue and green, and some key parts of the systems are labeled:



Illustrative connection arrangement of several membrane modules according to invention

84. The three stages are the feed separation stage (1) (yellow), the retentate separation stage (2) (green), and the permeate separation stage (3) (blue). AP-1001, 4:54-60. Each stage contains one or more membranes for separating the gases. AP-1001, 29:65-67.

85. As also shown in Figure 1 of the '380 patent:

- the gas mixture that is to be separated is introduced via a “crude” stream (17). AP-1001, 29:62.
- Stream 8 is one of the two product streams. It is called the “second retentate” stream.
- Stream 11 is the second product streams. It is called the “third permeate” stream.

- Stream 9 (the second permeate stream) and stream 10 (the third retentate stream) are recycled and combined with the crude stream (17), which together make up the “feed” stream (5) that is fed to the first stage.
- The feed stream (5) is pressurized by a compressor (4).

86. I understand that claim 1 of the '380 patent is the only “independent” claim in the '380 patent. In addition to a three-stage configuration, claim 1 has three additional requirements (or “limitations” or “elements”):

- claim 1 has a “recycle” limitation: the combined volume of the two recycle streams (9) and (10) must be “from 60 to 100% of the volume” of the crude stream (17). AP-1001, 30:44–46.
- claim 1 has a “capacity” limitation.
 - The '380 patent describes “capacity” as “the product of the membrane surface and the permeance of the membrane” at certain standard conditions. AP-1001, 2:54–47.
 - The '380 patent also explains that “If membranes of identical materials are operated in different separation stages and if the operating temperature is identical, their permeance is identical. As a consequence, the ratio of membrane capacities used in two separation stages correlates to the ratio of the membrane

surfaces.” AP-1001, 3:1-5. It therefore follows that if membranes used in different stages of a system are made of the same material and used at the same temperature, and/or have the same permeance, the ratio of the stages’ capacities is equal to the ratio of the membranes’ surface areas.

- claim 1 requires that the capacity “in the retentate separation stage is higher than” the capacity “in the feed stream separation stage.” AP-1001, 30:47-52.
- Claim 1 contains a “pressure-ratio quotient” limitation. In a particular stage of a system, the pressure of the retentate gas divided by the pressure of the permeate gas is the “pressure ratio.” Claim 1 requires that “the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage is in a range of from 0.5 to 8.” AP-1001, 30:53-55.

87. Regarding the “recycle” limitation in claim 1 of the ‘380 patent, the volume of recycled gas produced in a three step system is mostly determined by the purity of the retentate and permeate product streams required by the application, as well as by the selectivity of the membranes used.

88. For example, the application referred to in the ‘380 patent is separation of methane from a 50/50 methane/carbon dioxide feed. A typical target for the

separation is methane containing less than 2-4% carbon dioxide. Obtaining this low concentration of carbon dioxide generally means that the first separation step is processing a higher concentration CO₂ gas and is almost always relatively small compared to the second separation step which is processing a lower concentration gas.

89. The recycle volume will also be less if higher-selectivity membranes are used, as explained in Ungerank and Scholz (that I discuss more in detail below).

90. These considerations would have been understood by a POSITA in 2014. In other words, it would not have been surprising to a POSITA in 2014 that the systems in the ‘380 patent—with lower-selectivity membranes and relatively high purity product streams—would have relatively high recycle volumes (for example, higher than in the systems described earlier in Ungerank, which had higher-selectivity membranes and relatively high purity product streams).

91. Regarding the “capacity” limitation in claim 1 of the ‘380 patent, as the ‘380 patent describes, capacity is permeance multiplied by surface area. AP-1001, 14:56-15:12. As a result, and as the ‘380 patent explains, if two membranes have the same permeance, the ratio of their capacities is equal to the ratio of their surface areas. AP-1001, 3:1-5.

92. Rephrasing this limitation in simpler language for the case where two membranes have the same permeance (for example, in the systems in Scholz’s

Figure 7 that I discuss below), the membrane area of stage 2 is larger than in stage 1.

93. This limitation is in many ways a restatement of the “recycle” limitation in different words. As described earlier, the relative size of the membranes depends on the target performance required by the application and the selectivity of the membranes used. As I described above, for typical biogas separations, obtaining high purity methane in the second stage retentate stream generally means that the first separation stage is processing a higher concentration CO₂ gas and is almost always relatively small compared to the second separation step which is processing a lower concentration gas.

94. In other words, having a capacity in step 2 that is greater than in step 1 is largely a result of common design criteria for biogas separations—i.e., the composition of the crude stream and requiring relatively high purity methane in the retentate in the second stage. In my opinion, a POSITA would have understood this in December 2014.

95. Regarding the “pressure-ratio quotient” limitation in claim 1 of the ‘380 patent, it is a mathematical term linking the pressure ratio of membrane Units 1 and 3.

96. To discuss the consequences of this limitation, I will use the example calculation given in Example 1.1 of the ‘380 patent (AP-1001, 16:42). In this

example, unit 1 has a feed pressure of 18.2 bara and a permeate pressure of 6.4 bara, while unit 3 has a feed pressure of 6.4 bara and a permeate pressure of 1.0 bara. The pressure ratios are then

$$\frac{18.2}{6.4} = 2.84 \quad \text{for Unit 1} \quad \text{Eq. 1}$$

$$\frac{6.4}{1} = 6.4 \quad \text{for Unit 2} \quad \text{Eq. 2}$$

and the quotient is then

$$\frac{6.4}{2.84} = 2.25 \quad \text{Eq. 3}$$

97. Since the permeate pressure of unit 1 and the feed pressure of unit 3 are the same, 6.4 bara, 6.4 bars in Equations 1 and 3 can be replaced with a more general term, thus

$$\frac{18.2}{6.4} = \frac{18.2}{x}$$

and

$$\frac{6.4}{1} = \frac{x}{1}$$

and the quotient value is then

$$\frac{x^2}{18.2}$$

98. The quotient range of values between 0.5 and 8 can then be calculated.

At a quotient of 0.5, the intermediate pressure x is

$$0.5 = \frac{x^2}{18.2}$$

$$x = 3.02 \text{ bar(a)}$$

and at a quotient of 8, the intermediate pressure x is

$$8 = \frac{x^2}{18.2}$$

$$x = 12.07 \text{ bar(a)}$$

99. Thus, the range of intermediate pressure values are pressures between 3.02 bara to 12.07 bara.

100. For a POSITA in December 2014, the initial obvious starting point for an optimization would have been the middle of the range covered by the third limitation. That is, a POSITA would, for a starting calculation, have picked an intermediate pressure approximately halfway between the maximum possible value (~ 18.2 bara) and the lowest possible value (~ 1.0 bara), which is approximately 9-10 bara. It is also likely that the final optimized result would be within the range of 3-12 bara. A POSITA would have avoided the extreme values because one of the membrane areas would be extremely large as the intermediate pressure goes to an

extreme. In other words, using a pressure ratio quotient near the middle of the range would lead to a minimum area of the two units.

101. In sum, in my opinion, the “pressure-ratio quotient” limitation in claim 1 of the ‘380 patent simply reflects a design choice that a POSITA in 2014 would have made in designing a three-stage system.

102. I understand that all the claims in the ‘380 other than claim 1 are “dependent” claims that add requirements (or “limitations”) to claim 1. In other words, all the other claims have all the requirements of claim 1 incorporated by reference, but also additional requirements, such as the first permeate stream not being additionally compressed (claim 4), and hollow fiber membranes (claim 18).

103. Dependent claims 11 and 12 require that the membranes in the feed stage have certain “pure gas” selectivities. AP-1001, 31:28–33. There are two kinds of relevant selectivities, pure gas and mixed gas. Aside from some possibly highly unconventional systems, for a given membrane and gas mixture, a POSITA would have understood that pure gas selectivity is higher than mixed gas selectivity.

IX. OVERVIEWS OF UNGERANK AND SCHOLZ PRIOR ART

A. Overview of Ungerank

104. Ungerank (AP-1006) addresses three-stage gas membrane separation systems.

105. Ungerank's Figure 11 is exactly the same figure as Figure 1 in the '380 patent; and in both patents the figures are labeled "Illustrative connection arrangement of several membrane modules according to invention":

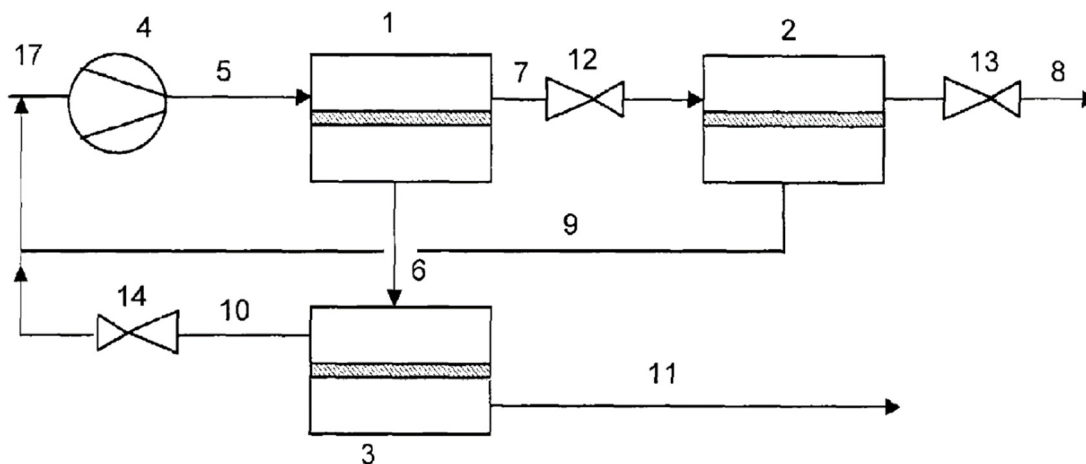


Fig. 11: Illustrative connection arrangement of several membrane modules according to invention

106. Ungerank addresses three stage systems with highly-selective membranes. As Ungerank explains, its “gas separation membrane modules have a mixed gas selectivity of components A and B (=ratio of stream A to stream B through the membrane) of at least 30, preferably at least 35, more preferably at least 40, even more preferably of at least 45 and especially preferably of at least 45 to 80. Membranes of higher selectivity have the advantage that the separation becomes more effective and less permeate has to be recycled from retentate separation stage (2), or less retentate from permeate separation stage (3). Thus, especially in the case of use of a one-stage compressor (4), it is necessary to compress less gas twice,

which entails economic advantages in the operation of the plant.” AP-1006, 9:9-20. Similarly, Ungerank explains “the inventive operation can be conducted in a much more economically viable manner with more selective membranes, and the necessary size of the compressor and the energy required can be reduced.” AP-1006, 9:31-34.

107. Ungerank includes four Examples of the Figure 11 “connection arrangement” with “highly selective” membranes. AP-1006, 11:1-9, 11:53-67, 12:44-60, 13:43-55.

108. Important to my analysis, Ungerank also includes a Comparative Example 1, which serves as a baseline system. Like the four Examples, Comparative Example 1 has the Figure 11 “connection arrangement.” AP-1006, 10:17–24. However, in Comparative Example 1, the membranes have a lower “selectivity for carbon dioxide over methane of 20.” AP-1006, 10:66-67.

109. In Ungerank’s Comparative Example 1, the “sum of recycled gas streams (9) and (10) is therefore 1.544 m³/h or 86.7%.” AP-1006, 10:62-64.

110. Also, even though there are no purity requirements in the ‘380 patent’s claims, it is notable that in Comparative Example 1, “Pure product streams are obtained with a relatively high double compression rate.” AP-1001, 10:64-66. These product streams contain 98.5% methane and 99.0% carbon dioxide, respectively. AP-1006, 10:40-42, 10:56-59.

111. Ungerank's Comparative Example 1 does not describe the membranes' areas, which as I discuss below, is related to their capacities.

B. Overview of Scholz

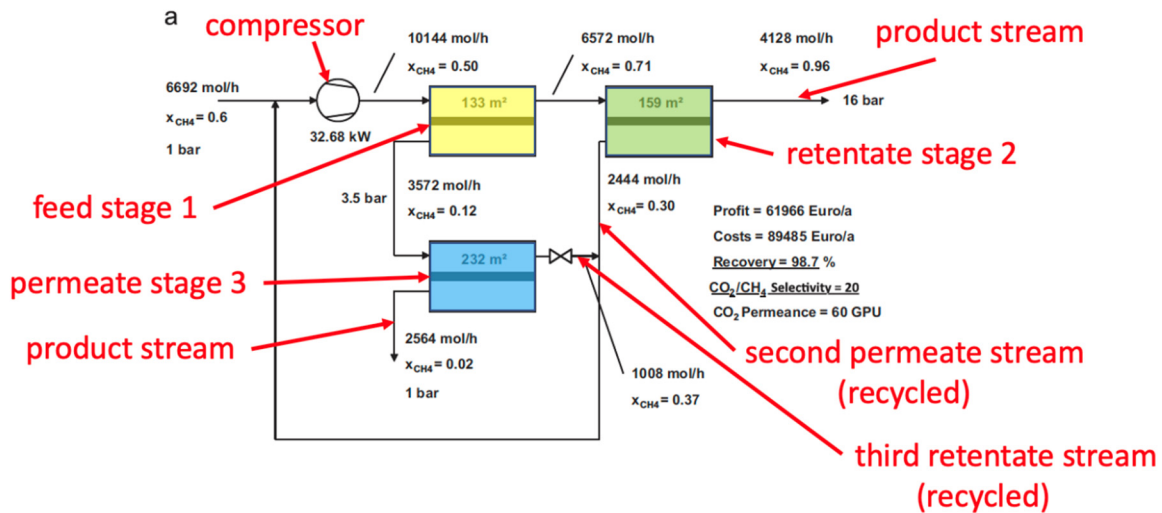
112. Scholz's title is *Structural optimization of membrane-based biogas upgrading processes*. Scholz cites Qi, and like Qi and others before December 2014, Scholz addresses optimization of membrane gas separation systems. AP-1007, 1.

113. More specifically, Scholz's explains that "a structural optimization approach" was used to for "biogas upgrading processes" to determine "the most profitable process layout." AP-1007, Abstract. Scholz further explains that it determined the "most profitable process configuration by taking both, operational cost, mainly caused by electrical energy consumption, and investment costs for the compression equipment and the membrane modules into account." AP-1007, 4.

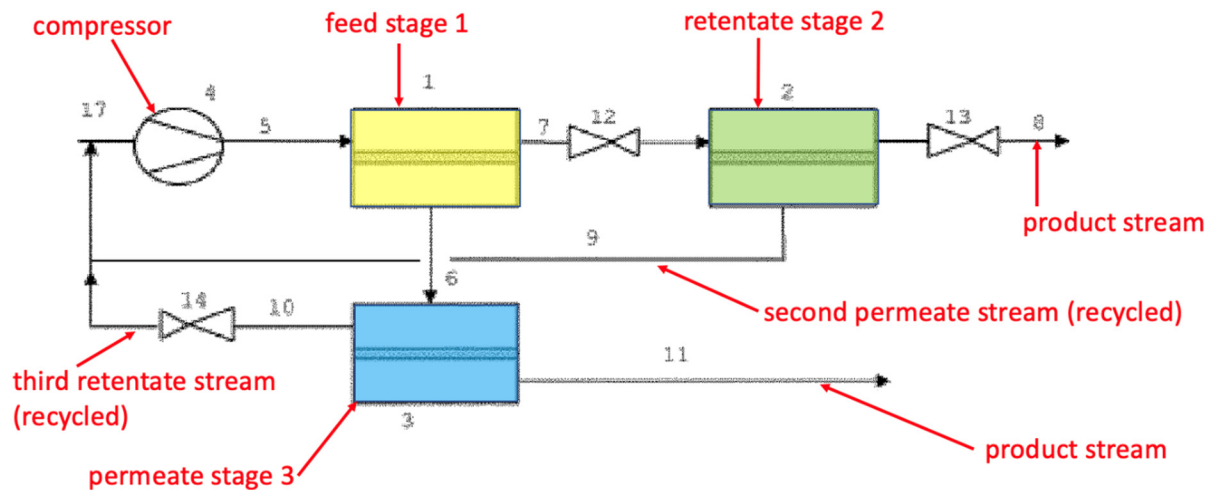
114. Like Ungerank, Scholz explains that lower selectivity membranes "increase the amount of the retained gas species which permeates through the membrane resulting in increased compression duty." AP-1007, 4.

115. Scholz explains that "two commercial membrane materials" were compared, one "with a CO₂/CH₄ selectivity of 60" and another "with a selectivity of 20." AP-1007, 5. Scholz explains that for both membranes, a "three stage membrane process using a single compressor is identified to be the best process configuration." AP-1007, 5-6.

116. Figure 7 shows the optimized results for the lower selectivity membranes in two systems, (a) and (b). The systems' configuration is very similar to the configuration in the '380 patent's Figure 1, as shown by the highlighting and labeling of the two figures below:



Scholz Figure 7 system (a)



Illustrative connection arrangement of several membrane modules according to invention

'380 patent Figure 1

117. In both systems, a compressor compresses the gas introduced to a first “feed” stage (highlighted in yellow). The retentate of the first stage is fed to a second “retentate” separation stage (highlighted in green), and the permeate of the first stage is fed to a third “permeate” separation stage (highlighted in blue). The retentate of the second stage and the permeate of the third stage are the product streams. The permeate of the second stage and the retentate of the third stage are recycled and combined with the “crude” stream upstream of the compressor.

118. Important to my analysis below, Scholz also explains that its optimization method determined “the most profitable process layout including membrane areas.” AP-1007, Abstract. As explained below, in systems like in Scholz’s Figure 7, the membranes’ areas are proportional to their capacities.

X. A POSITA’S MOTIVATION TO COMBINE UNGERANK AND SCHOLZ AND EXPECTATION OF SUCCESS IN DOING SO

A. A POSITA’s Motivation to Combine Ungerank and Scholz

119. A POSITA would have been motivated to design a three-stage system with lower-selectivity membranes based on Ungerank’s Comparative Example 1, combined with the information on membrane surface area ratios (which, as explained below, are proportional to the capacity ratios) in Scholz’s Figure 7.

120. Energy and membrane costs are two of the most significant costs in building and operating membrane-separation systems, and a POSITA would have

understood this in December 2014 and that there are tradeoffs between the two. AP-1013, 346.

121. Ungerank explained that higher-selectivity membranes have an “advantage that the separation becomes more effective and less” gas “has to be recycled” making it “necessary to compress less gas twice, which entails economic advantages in the operation of the plant”; and that “with more selective membranes” the necessary “energy required can be reduced.” AP-1006, 9:14-20, 9:31-34. Scholz similarly discussed how “low selectivities increase the amount of the retained gas species which permeates through the membrane resulting in increased compression duty.” AP-1007, 4; AP-1013, 328-29, 334.

122. Scholz also explained a disadvantage of highly-selective membranes, which is that “permeance drops which increases the required membrane area remarkably,” and as a result, “higher investment costs and membrane replacement costs reduce the profitability.” AP-1007, 4; AP-1013, 328-29, 334. In other words, higher-selective membranes have more membrane area than lower-selectivity membranes, meaning more polymer is needed for their construction. In fact, for this reason, membrane size is usually a primary driver of a membrane unit’s cost.

123. By December 2014, a POSITA would have understood the cost tradeoffs between lower-selectivity and higher-selectivity membranes, which were well known and described, for example by Ungerank and Scholz, as explained

above. Simply put, because of lower permeance, higher-selectivity membranes use more membrane area than lower selectivity membranes (and as a result are more costly), but higher-selectivity membranes result in lower recycle volumes, requiring less compression, which requires less energy. A POSITA not only would have understood this, but also that both types of systems have advantages and disadvantages: using lower-selectivity membranes may be desirable in certain situations whereas using higher-selectivity membranes may be desirable in other situations.

124. The '380 patent discusses how systems with lower-selectivity, higher-permeance (and consequently smaller area) membranes are advantageous for “gas separation plants” that “are operated at sites where energy is very cheap” and “the focus ... lies on investment and maintenance costs rather than on an energy saving.” AP-1001, 1:45-51.

125. For the reasons explained above, it would have been obvious to a POSITA in December 2014 to use lower-selectivity, higher permeance (and therefore smaller area and less costly) membranes in that situation. For example, I described in my book *Membrane Technology and Applications* how membrane systems had been installed on offshore platforms, where small footprint and low weight are important. AP-1013, 363. On offshore platforms, low-cost energy is usually available, for example, hydrocarbon gases that otherwise might be flared.

126. Moreover, before 2014 and since, there were additional reasons to use lower-selectivity membranes. Initial investment costs for membrane-separation systems are relatively expensive. Before 2014 and since, the costs for compressors and membranes, for example, have been significant. Also, when investing in a membrane-separation systems, most initial costs are incurred before the system operates and is providing income or the benefit that is intended. Also, these costs are incurred before it is certain the system will function as intended, once operational.

127. In contrast, operating costs are paid later, and periodically, after a system is operational. Therefore, operating costs may be covered or deferred with income from the systems.

128. For these reasons, before 2014 and since, some operators sought to minimize their initial investment costs (with the consequence that they would incur higher operating costs later). This is reason that would have led POSITAs to use lower-selectivity membranes.

129. The demand in 2014 for systems using lower selectivity membranes is demonstrated, for example, by the fact that Scholz optimized and discussed systems with both higher-selectivity and lower-selectivity membranes. AP-1007, Figures 5 and 7. Another example is the 2012 Zhang paper *Current status and development of membranes for CO₂/CH₄ separation: A review*, which explained that lower-selectivity membranes “dominate” the market “due to their low cost” (among other

reasons). AP-1012, 88. Zhang further noted that lower-selectivity membranes were desirable at that time because they had been the subject of “well-documented research studies.” AP-1012, Abstract. Similarly, in my book *Membrane Technology and Applications*, I described the typical membrane selectivities for CO₂/CH₄ separation “under normal operating conditions” to be “10-20.” AP-1013, 360.

130. Put another way, using lower-selectivity membranes was not inconsistent with Ungerank’s teachings, as Ungerank taught using higher-selectivity membranes to minimize operating costs, but with necessarily increased initial investment costs for higher-selectivity membranes. AP-1006, 3:10-13, 9:9-14. Again, there are tradeoffs, which a POSITA would have understood.

131. In designing a system with lower-cost, lower-selectivity membranes, a POSITA would have looked to Ungerank’s Comparative Example 1, in the first instance because it employs relatively low-selectivity membranes. AP-1006, 10:19–67. A POSITA would have been further motivated to base a design using lower-selectivity membranes on Comparative Example 1 because of the relatively “Pure product streams” in Comparative Example 1. AP-1006, 10:40-42, 10:56-59, 10:64-65.

132. A POSITA would have been further steered towards Comparative Example 1 because it is a three-stage system with a single compressor (AP-1006, 10:24-67, Figure 11) and Scholz had explained by December 2014 that for

“commercial membranes a three stage gas permeation process is the most profitable process which operates with only a single compressor.” AP-1007, Abstract.

133. In addition, Ungerank’s Comparative Example 1 provides detailed information on the gases’ compositions and flowrates, the recycle volume, the pressures (and therefore the pressure ratios); and specifies the type of membranes used (“UBE (NMB01 A Type)”), that have “a moderate mixed gas selectivity for carbon dioxide over methane of 20.” AP-1006, 10:24-67. These details would have further steered a POSITA to Ungerank’s Comparative Example 1 because they are the type of details a POSITA would need as inputs for designing a three-stage system with a single compressor—the type Scholz explained is “the most profitable” for “commercial membranes.” AP-1007, Abstract; AP-1013, 340.

134. However, Ungerank’s Comparative Example 1 does not provide any details on the membranes’ surface areas. A POSITA would therefore have sought guidance elsewhere on membranes’ surface areas (and their ratios) in three-stage, one-compressor systems with relatively low-selectivity membranes.

135. That would have led a POSITA to Scholz because Scholz discusses optimizations of such low-selectivity membrane systems, particularly in Figure 7. AP-1007, Abstract, 6, Figure 7. Indeed, Scholz specifically states that its “systematic method determines the most profitable process layout including **membrane areas**”

and Scholz's Figure 7 provides detailed information on the membrane sizes. AP-1007, Abstract, 2, Figure 7.

136. In addition, and as explained above, the system configuration in Scholz's Figure 7 is very similar to Figure 11 of Ungerank, which would have been further reasons motivating a POSITA to combine Ungerank's and Scholz's teachings on three-stage systems with lower-selectivity membranes.

B. A POSITA's Reasonable Expectation of Success in Combining Ungerank's and Scholz's Teachings

137. A POSITA would have had a reasonable expectation of success in combining the teachings of Ungerank and Scholz on three-stage systems with relatively low-selectivity membranes.

138. Both Ungerank's Comparative Example 1 and Scholz's Figure 7 provide detailed information on the systems' gas compositions, flowrates, membranes etc. These details would have provided a POSITA with necessary inputs for designing a system. As explained above, the initial design could then be optimized using well-known software or in a pilot plant, which POSITAs would have done routinely in December 2014 and before, as I explained above. The detailed system information in Ungerank and Scholz would have provided a POSITA confidence that a design based on these references' teachings would work.

139. Also, Ungerank's Comparative Example 1, by December 2014, was known for several years. This would have given a POSITA additional confidence in designing a system based on Ungerank's Comparative Example 1.

140. Also, in Ungerank's Comparative Example 1, the "crude gas mixture" is 50% methane and 50% carbon dioxide, which Ungerank explains in Comparative Example 1, "corresponds approximately to a gas mixture of biogas." AP-1006, 10:27-29. Scholz's title is *Structural optimization of membrane-based biogas upgrading processes*, and it discusses throughout systems for "separating CO₂ and CH₄." AP-1007, Abstract, Figure 7. Also, in Ungerank's Comparative Example 1, the membranes have "mixed gas selectivity for carbon dioxide over methane of 20," and similarly, in Scholz's Figure 7 the membranes have "a CO₂/CH₄ selectivity of 20." AP-1006, 10:66-67; AP-1007, Figure 7. These similarities between Ungerank's Comparative Example 1 and Scholz's Figure 7 would have given a POSITA additional confidence in combining the two references' teachings.

141. Additionally, Qi discussed optimizing three-stage systems in 2009, years before 2014, as did Datta and others. AP-1009, 2723-24, Figures 4 and 5; AP-1010, Abstract, 292. In fact, Scholz refers to Qi and other prior optimization publications. AP-1007, 1-2. And Scholz explained that its "process model can easily be adapted to other gas separation problems such as ... natural gas upgrading ... to determine the most profitable process configurations." AP-1007, 2.

142. The history of optimizations before December 2014 and Scholz's explanation that its process model can be adapted to other systems would have given a POSITA additional confidence that the optimizations in Scholz were reasonably robust and reliable, and in applying Scholz's teachings to Ungerank's Comparative Example 1.

XI. CLAIMS 1-5, 7, 9 AND 11-23 OF THE '380 PATENT ARE OBVIOUS BASED ON THE COMBINATION OF UNGERANK AND SCHOLZ

Claim 1

Preamble [1pre] - *A method for separating gases from a crude gas stream comprising at least two components wherein in an apparatus comprising a feed stream separation stage, a retentate separation stage and a permeate separation stage, each stage being a membrane separation stage with gas separation membranes*

143. I understand from Air Products' counsel that this portion of claim 1 of the '380 patent is referred to as the claim's "preamble."

144. Ungerank's Comparative Example 1 meets the requirements in claim 1's preamble.

145. In Ungerank's Comparative Example 1, the Figure 11 "connection arrangement was used." AP-1006, 10:24. This system configuration in Figure 11 was used in Ungerank's Comparative Example 1 to separate "a crude gas mixture of 50% methane and 50% carbon dioxide." AP-1006, 10:27-28. In Ungerank's Comparative Example 1, there is a "feed stream separation stage (1)," "retentate

separation stage (2)” and a “permeate separation stage (3).” AP-1006,10:25-53. Ungerank also explains that each of the “three membrane separation stages” “consists of one or more physical gas separation modules, which are connected in parallel and/or in series within one stage” and the “membranes are preferably used in the form of hollow fiber membranes” “assembled into modules.” AP-1006, 4:57-61, 9:1-4. A POSITA would therefore have understood Ungerank’s Comparative Example 1 to meet the language in the ‘380 patent’s claim 1 preamble.

[1a] – a feed stream is separated in the feed stream separation stage into a first permeate stream and a first retentate stream

146. In Ungerank’s Comparative Example 1, “a crude gas mixture” together with recycled streams (9) and (10) “is applied to the feed stream separation stage (1)”; the “retentate of the feed stream separation stage (1) is” “passed via the first retentate stream (7)” to “separation stage (2)”; and the “permeate of the feed stream separation stage” is “passed via the first permeate stream (6)” into “separation stage (3).” AP-1006, 10:27–53. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [a] of claim 1 of the ‘380 patent.

[1b] – the first retentate stream is separated in the retentate separation stage into a second permeate stream and a second retentate stream

147. In Ungerank’s Comparative Example 1, the “retentate of the feed stream separation stage (1)” is passed to “separation stage (2)”; the “retentate of the retentate separation stage (2) has a content of 98.5% methane”; and the “permeate

of retentate separation stage (2) has a” flow rate “of 0.743 m³/h.” AP-1006, 10:33–48. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [b] of claim 1 of the ‘380 patent.

[1c] – the first permeate stream is separated in the permeate separation stage into a third retentate stream and a third permeate stream

148. In Ungerank’s Comparative Example 1, the “permeate of the feed stream separation stage (1)” is passed into “the permeate separation stage (3)”; which “gives a third permeate stream (11)” and a “third retentate stream (10) from the permeate separation stage (3).” AP-1006, 10:49-62, Fig. 11. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [c] of claim 1 of the ‘380 patent.

[1d] – the second retentate stream is removed as a first product.

149. In Ungerank’s Comparative Example 1, “a crude gas mixture of 50% methane and 50% carbon dioxide” was separated; the “retentate of the retentate separation stage (2) has a content of 98.5% methane”; and Ungerank explains that “Pure **product streams** are obtained.” AP-1006, 10:27-32, 10:40-42, 10:64-66. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [d] of claim 1 of the ‘380 patent.

[1e] – the third permeate stream is removed as a second product

150. In Ungerank’s Comparative Example 1, “a crude gas mixture of 50% methane and 50% carbon dioxide” was separated; the “third permeate stream (11)”

has “a composition of 99.0% carbon dioxide”; and Ungerank explains that “Pure *product streams* are obtained.” AP-1006, 10:27-28, 10:56-59, 10:64-67. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [e] of claim 1 of the ‘380 patent.

[1f] – the second permeate stream and the third retentate stream are combined with the crude gas stream to give the feed stream

151. Ungerank’s Comparative Example 1 explains that “a crude gas mixture of 50% methane and 50% carbon dioxide” is “introduced into a mixing chamber” “together with recycled gas composed of gas streams (9) and (10)”; the “permeate of retentate separation stage (2)” is “recycled via the second permeate stream (9) into the mixing chamber”; and the “third retentate stream (10) from the permeate separation stage (3)” is “recycled into the mixing chamber.” AP-1006, 10:27-32, 10:43-48, 10:59-62. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet limitation [f] of claim 1 of the ‘380 patent.

[1f.i] – wherein the combined gas volume of the second permeate stream and the third retentate stream is from 60 to 100% of the volume of the crude gas stream

152. Ungerank’s Comparative Example 1 explains that the volumetric flowrate of the crude gas is 1.78 m³/h and the “sum of recycled gas streams (9) and (10) is therefore 1.544 m³/h or 86.7% based on the amount of gas to be separated supplied.” AP-1006, 10:27-32, 10:62–64. A POSITA would have understood this,

along with Figure 11 in Ungerank, to meet limitation [1f.i] of claim 1 of the '380 patent.

[1f.ii] – the total capacity of the gas separation membranes in the retentate separation stage is higher than the total capacity of the gas separation membranes in the feed stream separation stage, the total capacity being measured for nitrogen Grade 4.8 under standard conditions as defined in the description,

153. As I discussed above, a POSITA would have been motivated to combine the information in Scholz's Figure 7 regarding surface area ratios (and therefore by extension, capacity ratios) for optimized three-stage systems with low-selectivity membranes with Ungerank's teachings on three-stage systems using lower-selectivity membranes, since Ungerank does not provide details on the membranes' areas in Comparative Example 1.

154. As the '380 patent explains, capacity is the product of permeance and surface area, and measuring capacity at standard conditions is the result of and depends on measuring permeance at those conditions. AP-1001, 14:55-15:18. It would have been obvious to a POSITA to measure permeances at standard conditions because measuring variables at a set of standard conditions, so that performance characteristics between two membranes can be compared more easily, has been known and practiced for decades. For example, I previously discussed the use of membrane permeance at standard temperature and pressure to describe permeation through gas separation membranes. AP-1015, 347. The specific standard

condition in limitation [1f.ii] of the ‘380 patent also would have been obvious to a POSITA because choosing a set of standard conditions is somewhat arbitrary and would have been well within the capabilities of a POSITA in 2014.

155. The ‘380 patent also explains that that when membranes used in two stages have the same permeance, “the ratio of membrane capacities” “correlates to the ratio of the membrane surfaces.” AP-1001, 3:1-5. In other words, in certain situations, capacity is proportional to membrane area, and consequently, in such systems, capacity ratios are proportional to area ratios.

156. Scholz explains that for “a membrane reflecting the characteristics of a cellulose acetate membrane with a CO₂/CH₄ selectivity of 20 the results are depicted in Fig. 7.” AP-1007, 6. Figure 7 explains that it shows the “Optimal process design and process conditions for gas permeation membranes with a CO₂/CH₄ selectivity of 20 and a CO₂ permeance of 60 GPU.” A POSITA would have understood from this that all the membranes in Scholz’s Figure 7 systems are the same material and have identical selectivity and permeance.

157. From this, a POSITA would have understood that the permeances of the membranes in the Figure 7 systems measured at any given set of conditions, including “at operating temperature that is determined for nitrogen (Grade 4.8) under standard conditions,” all necessarily would be identical. AP-1001, 2:53-57.

158. As the ‘380 patent explains, a “consequence” of having permeance that is identical is “the ratio of membrane capacities used in two separation stages correlates to the ratio of the membrane surfaces.” AP-1001, 3:1-5. Therefore, in Scholz’s Figure 7 systems, the ratios of membrane capacities “measured for nitrogen Grade 4.8 under standard conditions as defined in the description,” are proportional to the ratios of the membranes’ surface areas.

159. Limitation [1f.ii] in the ‘380 patent requires, among other things, that the “total capacity¹ of the gas separation membranes in the retentate separation stage is higher than the total capacity of the gas separation membranes in the feed stream separation stage.” In other words, the capacity ratio of the retentate stream separation stage to the feed stream separation stage must be greater than 1.

160. In system (a) in Scholz’s Figure 7, the surface areas of the retentate and feed stages are 159 m² and 133 m², respectively; and in system (b), the surface areas

¹ There does not appear to be any distinction in the ‘380 patent between “capacity” and “total capacity.” Total capacity likely refers to stages that include more than one membrane. AP-1001, 6:32-35. As Scholz explains, the areas shown in Figure 7 are the total membrane areas. For example, for system (b) in Figure 7, Scholz describes how “21 gas permeation modules have to be installed in case that a single module contains 25 m² membrane area.” AP-1007, 6.

of the retentate and feed stages are 382 m² and 57 m², respectively. AP-1007, Figure 7. Scholz therefore would have taught a POSITA surface area ratios for the retentate and feed stages that as a matter of mathematics, for the systems in Figure 7, meet the greater than 1 capacity ratio for limitation [1f.ii] of claim 1 of the '380 patent.

161. For these reasons, the combination of Ungerank's and Scholz's teachings would have made limitation [1f.ii] of the '380 patent obvious to a POSITA.

[1f.iii] – the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage is in a range of from 0.5 to 8.

162. Ungerank's Comparative Example 1 explains that a “reducing valve (13) on the retentate side of the retentate separation stage (2) is set to 18.2 bara and thus determines the driving force through the membrane of membrane separation stages (1) and (2).” AP-1006, 10:36-39. Also, Ungerank's Comparative Example 1 explains that the “pressure drop over the membrane of stage (1) does not extend to ambient pressure, but is limited to 4.2 bara by a reducing valve (14).” AP-1006, 10:53-56.

163. In other words, in Ungerank's Comparative Example 1, the pressure on the retentate side of the feed stage is 18.2 bara and the pressure on the permeate side of the feed stage (and therefore also on the retentate side of the permeate stage) is

4.2 bara. The pressure ratio over the feed stream separation stage is therefore 4.33 (18.2 bara $\div$ 4.2 bara).

164. In Ungerank's Comparative Example 1, the Figure 11 "Connection arrangement was used." AP-1006, 10:24. A POSITA would have understood that the pressure on the permeate side of the permeate separation stage is 1 bara, because (unlike stream 8, with pressure-reducing valve 13), there is no pressure-reducing valve in stream 11, the third permeate stream. Without a pressure-reducing valve, a POSITA would have understood that the stream pressure would be atmospheric pressure or very close—i.e., very close to 1 bara.

165. In other words, in Ungerank's Comparative Example 1, the pressure ratio over the permeate separation stage is 4.2 (4.2 bara $\div$ 1 bara).

166. Therefore, in Ungerank's Comparative Example 1, and the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage is $4.2 \div 4.33 = 0.97$. A POSITA would therefore have understood Ungerank's Comparative Example 1 to meet limitation [1 fiii] of claim 1 of the '380 patent.

Claim 2 – The method of claim 1, wherein the apparatus comprises a compressor arranged up-stream of the feed stream separation stage.

167. In Ungerank's Comparative Example 1, the Figure 11 "Connection arrangement was used." AP-1006, 10:24. Figure 11 shows a compressor "arranged up-stream of the feed stream separation stage" and Ungerank explains that in

Comparative Example 1, the gas which has been compressed” “is applied to the feed stream separation stage (1).” AP-1006, 4:59-60, 10:32-33. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet the limitation in claim 2 of the ‘380 patent.

Claim 3 – *The method of claim 1, wherein the apparatus comprises at least one vacuum device arranged in at least one permeate stream of the feed stream separation stage, the retentate separation stage and/or the permeate separation stage.*

168. In Ungerank’s Comparative Example 1, the Figure 11 “Connection arrangement was used.” AP-1006, 10:24. Ungerank explains that Figure 11 is an example of the “inventive apparatus,” and that in the inventive apparatus, “the partial pressure differential can be generated” by “vacuum pump(s)” “in the second permeate stream (9) on the permeate side of the retentate separation stage (2) and/or in the third permeate stream (11) on the permeate side permeate separation stage (3).” AP-1006, 4:57-5:4. A POSITA would have therefore understood Ungerank’s teachings above and in Comparative Example 1 to meet the limitation in claim 3 of the ‘380 patent or at least make it obvious.

Claim 4 – *The method of claim 1, wherein the first permeate stream is not subjected to a recompression.*

169. In Ungerank’s Comparative Example 1, the Figure 11 “Connection arrangement was used.” AP-1006, 10:24. In Ungerank’s Figure 11, there is no recompression in the first permeate stream (6). AP-1006, Figure 11, 10:24-67.

Ungerank also explains that it overcomes a “disadvantage of” the prior art, which is that “there are no processes which do not need a recompression unit.” AP-1006, 2:59-3:3. A POSITA would have understood this, along with Figure 11 in Ungerank, to meet the limitation in claim 4 of the ‘380 patent.

Claim 5 – *The method of claim 1, wherein the ratio of the total capacity of the gas separation membranes in the retentate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage is in a range of from 1.05 to 10.*

170. Above, for limitation [1f.ii] in claim 1, I explained that (i) for Scholz’s Figure 7 systems, the capacities are proportional to the membrane areas; (ii) in system (a) in Figure 7, the surface areas of the retentate and feed stages are 159 m² and 133 m² respectively (the ratio therefore being 1.2 (159 m² ÷ 133 m²)); and (iii) in system (b), the surface areas of the retentate and feed stages are 382 m² and 57 m² respectively (the ratio therefore being 6.7 (382 m² ÷ 57 m²)). Both ratios are from 1.05 to 10. Scholz therefore would have taught a POSITA surface area ratios for the retentate and feed stages that as a matter of mathematics, for the systems in Figure 7, meet the capacity ratio limitation in claim 5 of the ‘380 patent.

171. For these reasons, the combination of Ungerank’s and Scholz’s teachings would have made the limitation in claim 5 of the ‘380 patent obvious to a POSITA.

Claim 7 – *The method of claim 1, wherein the ratio of the total capacity of the gas separation membranes in the permeate separation stage to the total capacity of the*

gas separation membranes in the feed stream separation stage is in a range of from 0.5 to 3.

172. Above, for limitation [1f.ii] in claim 1, I explained that for the systems in Scholz's Figure 7, the capacities are proportional to the membrane areas. In Figure 7 system (a), the surface areas of the permeate and feed stages are 232 m² and 133 m² respectively, (the ratio therefore being 1.7 (232 m² ÷ 133 m²)). Scholz therefore would have taught a POSITA surface area ratios for the permeate and feed stages that as a matter of mathematics, for the Figure 7 system (a), meet the capacity ratio limitation in claim 7 of the '380 patent. For these reasons, the combination of Ungerank's and Scholz's teachings would have made the limitation in claim 7 of the '380 patent obvious to a POSITA.

Claim 9 – The method of claim 1, wherein the combined gas volume recycled with the second permeate stream and the third retentate stream is from 65 to 85% of the volume of the crude gas stream.

173. Above, for limitation [1f.i] in claim 1, I explained that that the recycle volume in Ungerank's Comparative Example 1 is 86.7%. AP-1006, 10:62-64. 86.7% is 2% higher than 85%.

174. A POSITA would have expected that varying the recycle volume by 2% would not have a significant effect on a system's performance because a 2% difference is a relatively small difference, and within the tolerances under which membrane systems are designed and operated. In other words, a 2% difference in recycle rate may result from variations in such things as ambient temperature or

pressure, or membrane aging and fouling, which routinely affect the performance of membrane systems, but minor variations (like 2% ones) do not typically cause substantial differences in performance.

175. Also, as I explained above, by December 2014 and before, a POSITA would have used simulation software such as Aspen and ChemCad to optimize systems. Using such software would have allowed a POSITA to test recycle volumes across various ranges, and a POSITA would have been motivated to test recycle rates within the range of 65% to 85% because in Ungerank's Comparative Example 1, the recycle volume is close to that range, and a POSITA would have known of the potential economic benefits of reducing the recycle volume, as discussed in Ungerank and Scholz and elsewhere, namely, decreased energy requirements.

176. A POSITA would therefore have found the range of 65% to 85% in claim 9 of the '380 patent obvious based on the 86.7% recycle volume in Ungerank's Comparative Example 1.

Claim 11 – *The method of claim 1, wherein the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of at least 10.*

177. Ungerank's Comparative Example 1 explains that the membranes exhibit "mixed gas selectivity for carbon dioxide over methane of 20." AP-1006, 10:66-67. For the conventional type of membranes in Comparative Example 1, their pure-gas selectivity is higher than their mixed gas selectivity for CO₂/CH₄, which a POSITA in December 2014 would have understood. A POSITA would therefore

have understood Ungerank's Comparative Example 1 to meet the limitation in claim 11 of the '380 patent.

Claim 12 – *The method of claim 11, wherein the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of from 20 to 100.*

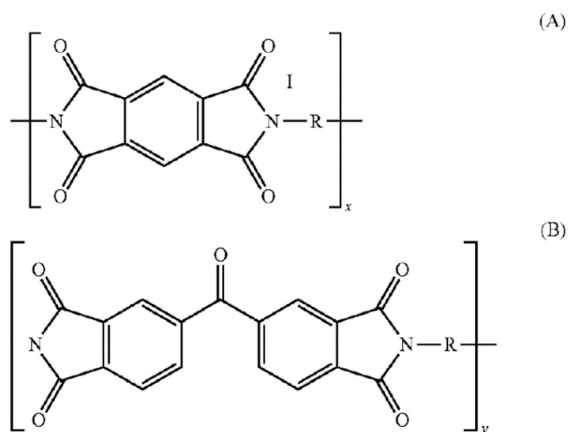
178. Above, for claim 11, I explained that in Ungerank's Comparative Example 1, the membranes have a mixed-gas selectivity for CO₂/CH₄ of 20, and therefore a pure-gas selectivity for CO₂/CH₄ of at least 20. AP-1006, 10:66-67. A POSITA in December 2014 would have known that a membrane's pure-gas selectivity is higher than its mixed-gas selectivity, but nonetheless the pure-gas selectivity for the types of membranes in Comparative Example 1 would not be more than 500% higher than the mixed-gas selectivity for CO₂/CH₄. AP-1013, 334-335. A POSITA would therefore have understood Ungerank's Comparative Example 1 to meet the limitation in claim 12 of the '380 patent.

Claim 13 – *The method of claim 1, wherein the gas separation membranes comprise a separation-active layer of a material selected from the group consisting of polyamides, polyetherimides, polyaramides, polybenzoxazoles, polybenzothiazoles, polybenzimidazoles, polysulfones, cellulose acetate, cellulose acetate derivatives, polyphenylene oxides, polysiloxanes, polymers with intrinsic microporosity, mixed matrix membranes, facilitated transport membranes, polyethylene oxides, polypropylene oxides and polyimides.*

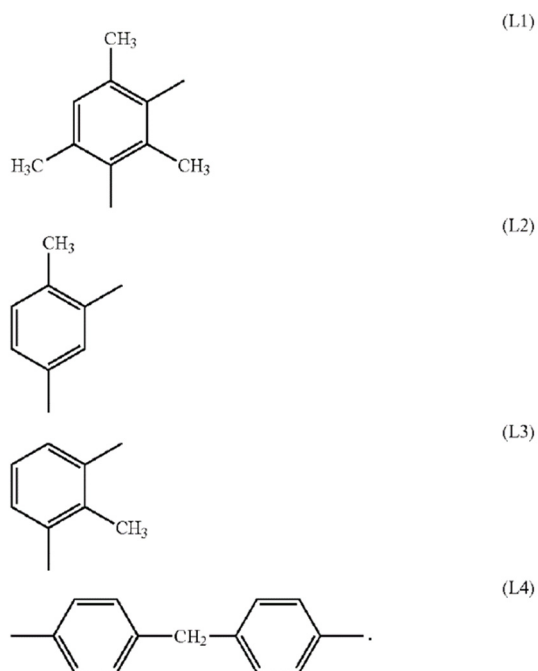
179. Ungerank's Comparative Example 1 explains that each "stage consisted of a hollow fiber membrane module consisting of hollow *polyimide* fibers." AP-

1006, 10:25-26. A POSITA would therefore have understood Ungerank's Comparative Example 1 to meet the limitation in claim 13 of the '380 patent.

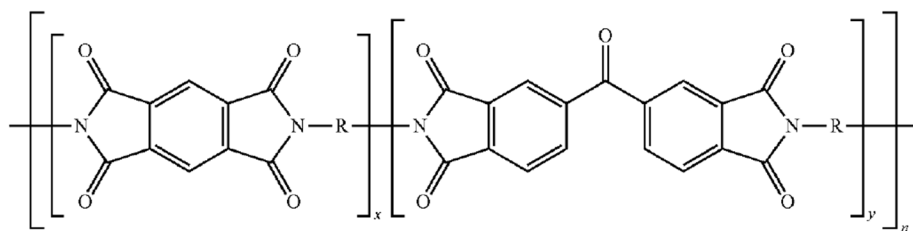
Claim 14 – The method of claim 13, wherein the gas separation membranes comprise a separation-active layer of a polyimide consisting of monomer units A and B



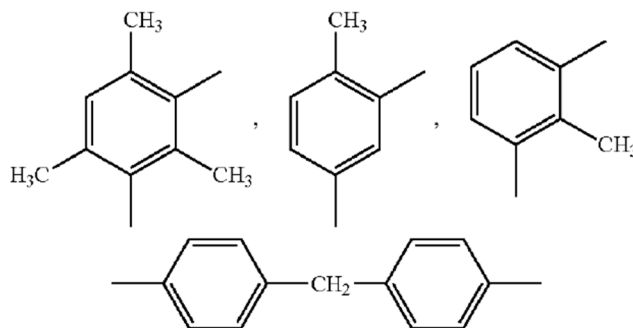
with $0 \leq x \leq 0.5$ and $1 \geq y \geq 0.5$, wherein each R is an identical or different radical selected from the group consisting of radicals L1, L2, L3 and L4



180. Ungerank's Comparative Example 1 has the Figure 11 "connection arrangement" and Ungerank explains that Figure 11 is an example of the "inventive apparatus." AP-1006, 10:24. Ungerank also explains in column 8, lines 17-57, that in the "inventive apparatus," "Particularly preferred membranes comprise, as materials for the separation-active layer or as a material for the complete membrane, a polyimide of the general formula:



R is selected from the group consisting of



x,y: mol fraction where $0 < x < 0.5$ and $1 > y > 0.5$.

181. This "general formula" is nearly identical to the formula in claim 14 of the '380 patent, the only difference is that in Ungerank's "general formula," " $0 < x < 0.5$ and $1 > y > 0.5$," but in claim 14 of the '380 patent, $0 \leq x \leq 0.5$ and $1 \geq y \geq$

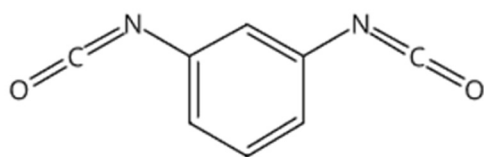
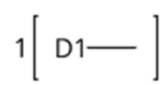
0.5. In other words, all the structures in Ungerank's "general formula" are also covered by formula in claim 14 of the '038 patent. Additionally, even though less structures are included within Ungerank's "general formula" than the formula in claim 14 of the '038 patent, the "general formula" in Ungerank encompasses a very large number of structures, therefore includes ones having different selectivities.

182. A POSITA would have therefore understood Ungerank's teachings above to meet the limitation in claim 14 of the '380 patent or at least make it obvious.

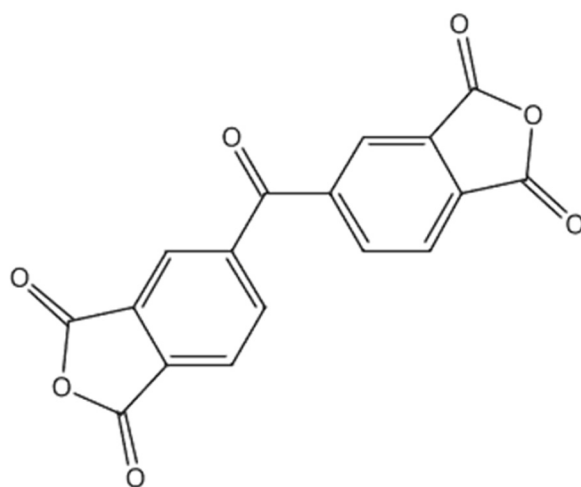
Claim 15 - The method of claim 13, wherein the gas separation membranes comprise a separation-active layer of a polyimide selected from the group of polyimides with CAS number 9046-51-9 and polyimides with CAS number 134119-41-8.

183. Above, for claim 14, I explained that in Ungerank's Comparative Example 1, the Figure 11 "connection arrangement" was used; Ungerank explains that Figure 11 is an example of the "inventive apparatus"; and that Ungerank also explains in column 8, lines 17-57, that in the "inventive apparatus," "Particularly preferred membranes comprise, as materials for the separation-active layer or as a material for the complete membrane, a polyimide of the general formula" shown in Ungerank's column 8.

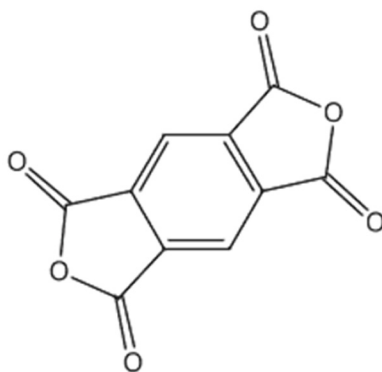
184. I obtained the Chemical Abstracts Registry File's information for CAS number 134119-41-8 (AP-1017), which shows among other information, the three monomers used to make the polymer:



1

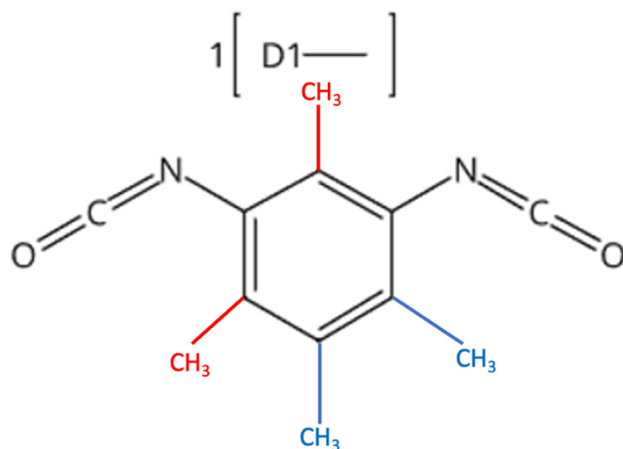


2

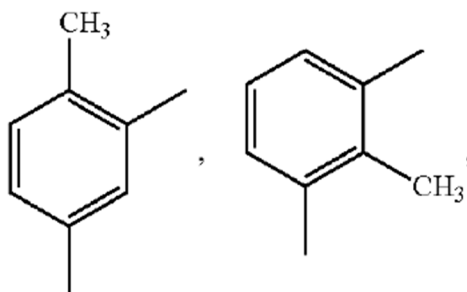


3

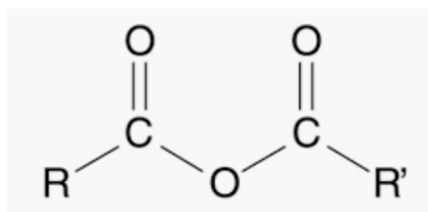
185. The 1[D1—] in the first structure denotes that there can be one methyl substituent on this monomer, and this substituent can be on any open position on the benzyl ring, as shown below:



186. The two permutations in red above correspond to the second and third “R” groups listed in Ungerank’s “general formula”:



187. The isocyanate groups (N=C=O) on the first monomer react with the anhydride groups



on the second and third monomers to form polyimide bonds, or in other words, to form the polymer. Monomers 2 and 3 correspond to the “y” and “x” copolymer structures, respectively, in Ungerank’s “general formula”; and monomer 1 covers the “R” groups in the “general formula.”

188. Therefore, Ungerank’s “general formula” includes polyimides with CAS number 134119-41-8. A POSITA would therefore have understood polyimides with CAS number 134119-41-8 to be within Ungerank’s teachings, and a POSITA would have therefore understood Ungerank’s teachings above to meet the limitation in claim 15 of the ‘380 patent or at least make it obvious.

Claim 16 – *The method of claim 2, wherein the second permeate stream and the third retentate stream are combined with the crude gas stream on the suction side of the compressor.*

189. In Ungerank’s Comparative Example 1, the Figure 11 “Connection arrangement was used.” AP-1006, 10:24. Figure 11 shows that the second permeate stream (9) and the third retentate stream (10) are combined with the crude gas stream (17) on the suction side of the compressor (4). AP-1006, Figure 11, 10:27-62. A POSITA would have understood Ungerank’s Comparative Example 1, along with Figure 11 in Ungerank, to meet the limitation in claim 16 of the ‘380 patent.

Claim 17 – *The method of claim 2, wherein the compressor is a multistage compressor and the second permeate stream, the third retentate stream, or both are introduced into the compressor between two compression stages.*

190. In Ungerank's Comparative Example 1, the Figure 11 "Connection arrangement was used." AP-1006, 10:24. Ungerank explains that the compressor (4) in Figure 11 can be a "One-stage or multistage compressor" and that in Figure 11, if "a multistage compressor is used," "it is preferable that" "the second permeate stream (9)" and "the third retentate stream (10)" are "introduced into the compressor between two compression stages." AP-1006, 6:40-46, 7:8-13, 15:11. A POSITA would have therefore understood Ungerank's teachings above and in Comparative Example 1 to meet the limitation in claim 17 of the '380 patent or at least make it obvious.

Claim 18 – *The method of claim 1, wherein the gas separation membranes are hollow fiber membranes.*

191. Ungerank's Comparative Example 1 explains that each stage "consisted of a hollow fiber membrane module consisting of hollow polyimide fibers." AP-1006, 10:25-26. Also, in Ungerank's Comparative Example 1, the Figure 11 "Connection arrangement was used" and Ungerank explains that in the Figure 11 "connection arrangement" each stage "consists of one or more physical" modules "connected in parallel and/or in series within one stage." AP-1006, 10:24, 4:58-61, 9:1-3. A POSITA would have therefore understood Ungerank's teachings above and in Comparative Example 1 to meet the limitation in claim 18 of the '380 patent or at least make it obvious.

Claim 19 – *The method of claim 1, wherein the retentate pressure of the feed stream separation stage and of the retentate separation stage are adjusted with a pressure reducing valve in the second retentate stream to a value of from 1 to 100 bar.*

Claim 20 – *The method of claim 19, wherein the retentate pressure of the feed stream separation stage and of the retentate separation stage are adjusted to a value of from 10 to 70 bar.*

192. Ungerank's Comparative Example 1 explains that a "reducing valve (13) on the retentate side of the retentate separation stage (2) is set to 18.2 bara and therefore determines the driving force through the membrane" of "stages (1)" (the feed stream separation stage) "and (2)" (the retentate separation stage). AP-1006, 10:24, Figure 11, 10:37-40. A POSITA would have therefore understood Ungerank's Comparative Example 1, along with Figure 11 in Ungerank, to meet the limitations in claims 19 and 20 of the '380 patent.²

² Claims 19 to 22 of the '380 patent do not specify bara (absolute) or barg (gauge) pressures. Ungerank's Comparative Example 1 meets the limitations in these claims regardless because the relevant pressures in Ungerank's Comparative Example 1 are more than 1 bar away from the ends of the ranges in claims 19 to 22. So regardless of whether claims 19 to 22 are in bara or barg, the relevant pressures in Ungerank's Comparative Example 1 fall within the ranges in claims 19 to 22. For example, for claims 19 and 20, the relevant pressure in Ungerank's Comparative Example 1 is

Claim 21 – *The method of claim 1, wherein the pressure on the permeate side of the feed stream separation stage is adjusted with a pressure reducing valve on the retentate side of the permeate separation stage to a value of from 1 to 30 bar.*

193. Ungerank's Comparative Example 1 explains that the "pressure drop over the membrane of stage (1)" (the feed stream separation stage) "is limited to 4.2 bara by a reducing valve (14) on the retentate side of the permeate separation stage (3)." AP-1006, 10:24, 10:53-56, Figure 11. A POSITA would have understood this to mean the pressure on the permeate side of the feed stream separation stage is 4.2 bara. A POSITA would have therefore understood Ungerank's Comparative Example 1 to meet the limitation in claim 21 of the '380 patent.

Claim 22 – *The method of claim 19, wherein the pressure on the permeate side of the feed stream separation stage is adjusted to a value of from 2 to 10 bar.*

194. For the reasons explained above for claims 19 and 21, a POSITA would have understood Ungerank's Comparative Example 1 to meet the limitation in claim 22 of the '380 patent.

Claim 23 – *The method of claim 1, wherein the crude gas stream is selected from the group consisting of biogas, natural gas, air, a gas mixture comprising carbon dioxide and methane, a gas mixture comprising hydrogen and methane, a gas mixture comprising carbon monoxide and methane, a gas mixture comprising helium and methane, a gas mixture comprising helium and nitrogen, a gas mixture comprising hydrogen and carbon monoxide, a gas mixture comprising a permanent gas having a boiling point of less than 110 Kelvin at 1 atm and a non permanent gas having a boiling point above or equal to 110 Kelvin at 1 atm, a gas mixture*

18.2 bara, and the ranges in claims 19 and 20 are "1 to 100 bar" and "10 to 70 bar," respectively.

comprising carbon dioxide and a hydrocarbon, and a gas mixture comprising nitrogen and a hydrocarbon.

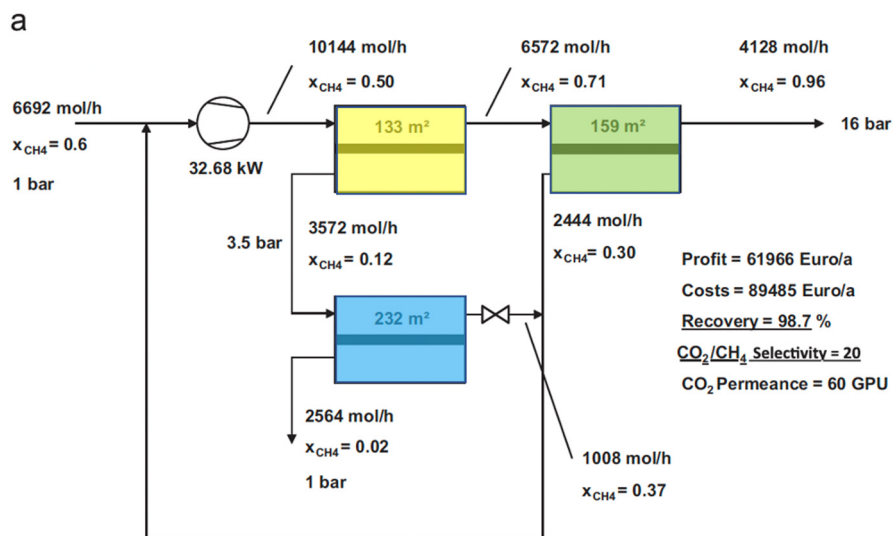
195. In Ungerank Comparative Example 1, there is “a crude gas mixture of 50% methane and 50% carbon dioxide, which corresponds approximately to a gas mixture of biogas.” AP-1006, 10:27-32. A POSITA would have therefore understood Ungerank’s Comparative Example 1 to meet the limitation in claim 23 of the ‘380 patent.

XII. CLAIMS 1-13, 16-17, 21 AND 23 OF THE ‘380 PATENT ARE OBVIOUS BASED ON SCHOLZ

Claim 1

Preamble [1pre] - A method for separating gases from a crude gas stream comprising at least two components wherein in an apparatus comprising a feed stream separation stage, a retentate separation stage and a permeate separation stage, each stage being a membrane separation stage with gas separation membranes

196. Scholz discusses systems that use “Gas permeation membranes” that “are well known for separating CO₂ and CH₄.” AP-1007, Abstract. In Figures 5 and 7, Scholz depicts such systems, separating inlet (crude) streams containing CO₂ and CH₄. AP-1007, 5-7. The apparatuses in Scholz’s Figure 7 comprise a feed stream separation stage (in yellow below), a retentate separation stage (in green below) and a permeate separation stage (in blue below):



Scholz's Figure 7

197. Scholz explains that in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz also explains that Figure 5 (and therefore also Figure 7) shows a “three stage membrane process.” AP-1007, 5. Scholz also discusses using multiple “25 m²” membrane modules in various stages in the Figure 7 systems. AP-1007, 6. A POSITA would therefore have understood Scholz's Figure 7 to meet the language in the '380 patent's claim 1 preamble or at least make it obvious.

[1a] – a feed stream is separated in the feed stream separation stage into a first permeate stream and a first retentate stream

198. Scholz explains that in Figure 7, the “process layout does not change compared to” the systems shown in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), the “raw gas” is “fed to the first membrane

stage” (the feed stream separation stage in yellow above in Figure 7); the “retentate of the first stage is fed to a second stage”; and the “third stage polishes the permeate of the first stage.” AP-1007, 5-6. A POSITA would have understood this, along with Scholz’s Figure 7, to meet limitation [a] of claim 1 of the ‘380 patent.

[1b] – the first retentate stream is separated in the retentate separation stage into a second permeate stream and a second retentate stream

199. Scholz explains that for the systems shown in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), the “retentate of the first stage” (in yellow above in Figure 7) “is fed to a second stage” (the “retentate separation stage in green above in Figure 7) “in which the final product purity is obtained” and the “permeate of the second stage is recycled.” AP-1007, 5-6. A POSITA would have understood this, along with Scholz’s Figure 7, to meet limitation [b] of claim 1 of the ‘380 patent.

[1c] – the first permeate stream is separated in the permeate separation stage into a third retentate stream and a third permeate stream

200. Scholz explains that for the systems in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), the “third stage” (the “permeate separation stage” in blue in Figure 7 above) “polishes the permeate of the first stage.” AP-1007, 6. A POSITA would have understood the “third stage polishes the

permeate of the first stage” to mean further removing the desired retentate from the stage 1 permeate, or in other words, separating the first permeate stream in a permeate separation stage into a third retentate stream and a third permeate stream. A POSITA would have therefore understood this, along with Scholz’s Figure 7, meet limitation [c] of claim 1 of the ‘380 patent.

[1d] – the second retentate stream is removed as a first product

201. Scholz’s Abstract explains that its topic is membrane systems for “separating CO₂ and CH₄.” AP-1007, Abstract. Scholz explains that for the systems in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. In Figure 5 (and therefore in Figure 7), the “retentate of the first stage is fed to a second stage in which the **final product** purity is obtained.” AP-1007, 5. Figure 7 shows the second retentate streams have 0.96 mol fraction of CH₄. AP-1007, 7. Additionally, Figure 7 does not show any additional processing of the second retentate stream. AP-1007, 7. A POSITA would have understood this, along with Figure 7, to meet limitation [d] of claim 1 of the ‘380 patent.

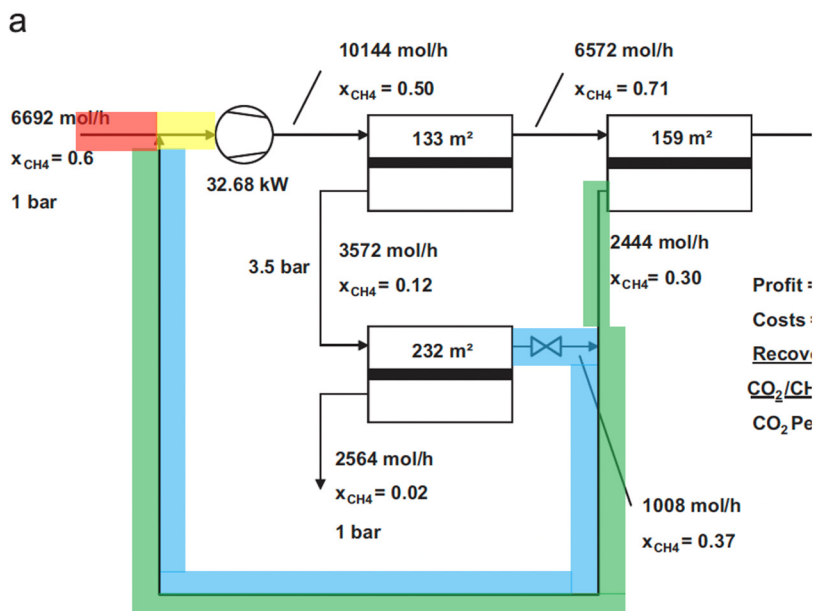
[1e] – the third permeate stream is removed as a second product

202. Scholz pertains to membrane systems for “separating CO₂ and CH₄.” AP-1007, Abstract. Scholz explains that for the systems in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. In Figure 5 (and therefore in Figure 7) the “third stage polishes the permeate of the first stage.”

AP-1007, 5-6. Figure 7 shows the third permeate streams have 0.02 and 0.008 mol fraction of CH₄. AP-1007. A POSITA would have understood this to mean that the third permeate streams are predominantly CO₂. Also, Figure 7 does not show any additional processing of the third permeate streams. A POSITA would have understood this, along with Figure 7, to meet limitation [e] of claim 1 of the ‘380 patent.

[1f] – the second permeate stream and the third retentate stream are combined with the crude gas stream to give the feed stream

203. Scholz explains that for the systems in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), the “permeate of the second stage is recycled and mixed with the raw gas stream” and “the retentate of the third stage is also recycled.” AP-1007, 5-6. As shown below, in Figure 7, the second permeate stream (in green) and the third retentate stream (in blue) are combined with the crude gas stream (in red) to give the feed stream (in yellow):



204. A POSITA would have understood this to meet limitation [1f] of claim 1 of the ‘380 patent.

[1f.i] – wherein the combined gas volume of the second permeate stream and the third retentate stream is from 60 to 100% of the volume of the crude gas stream

205. In Scholz’s Figure 7 (a) system “the combined gas volume of the second permeate stream and the third retentate stream” as a percentage “of the volume of the crude gas stream” (“recycle percentage”) is $51.5\% = 100 \times ((2444 \text{ mol/hr} + 1008 \text{ mol/hr}) \div 6692 \text{ mol/hr})$. In Scholz’s Figure 7 (b) the recycle

percentage is $135\% = 100 \times ((8492 \text{ mol/hr} + 533^3 \text{ mol/hr}) \div 6692 \text{ mol/hr})$. The range between these values encompasses the 60-100% range in claim limitation [1f.i] of the '380 patent.

206. A POSITA would have understood that in the Figure 7 systems, varying the recycle percentage affects, among other things, product recovery and operating costs, and this would have motivated a POSITA to optimize the recycle percentage for the particular design criteria. For example, Scholz explains that in the Figure 7 (b) system, the CH₄ recovery is higher than in system (a), but the “high[er] recovery can only be obtained on cost of an increased recycle flow rate.” AP-1007, 6. Similarly, Ungerank explains that having less permeate recycled “entails economic advantages in the operation of the plant,” and teaches a recycle rate of 86.7% in its

³ In Scholz's Figure (b) system, the flowrate of the stream entering the permeate separation stage 3 is 3063 mol/hr, and the two streams leaving that stage are 2530 mol/hr and 198 mol/hr, which does not sum to 3063 mol/hr. The 198 mol/hr appears to be in error and should be 533 mol/hr. This is consistent with the mass balance for the feed separation stage 1. The flow rate entering the feed separation stage is 15716 mol/hr, which is equal to 6692 mol/hr in the feed + 8492 mol/hr recycle from stage 2 + 533 mol/hr recycle from stage 3.

Comparative Example 1. AP-1006, 9:14-20, 10:62-64. A POSITA would also have understood that varying the recycle percentage within and around the range between the Figure 7 systems (a) and (b) (51-135%) would have a predictable effect on product recovery and operating costs, as for example, the language above from Scholz and Ungerank explains.

207. Also, as I have explained above, a POSITA in December 2014 would have routinely used simulation software such as Aspen or Chemcad to optimize systems and would have done so in part to test recycle volumes, for the reasons I explained above.

208. A POSITA would have done so with recycle percentages in the range of 60%-100% based on the recycle percentages in Scholz Figure 7 (51-135%). In other words, a POSITA would have been guided by Scholz to test within the range encompassed by the systems in Scholz's Figure 7 systems (a) and (b) (51-135%), and 60-100% lies within that range. Moreover, the midpoint between 51-135% is 93%, which is within the range of 60-100%, and it would have been logical for a

POSITA in implementing the data in Scholz, in the first instance, to test near the middle of the range encompassed by the systems in Scholz's Figure 7.⁴

209. In addition, in system (b) in Scholz's Figure 7, the mole fraction of methane in the third permeate stream is 0.008, meaning that stream has very high purity CO₂. For some applications, while it is environmentally beneficial to have a certain level of CO₂ purity in the permeate, a CO₂ purity need not be this high, and a POSITA would have been motivated to use a lower recycle percentage to save on energy costs if lower purity CO₂ was sufficient. This is further reason a POSITA would have been steered towards using a lower recycle percentage than in system (b), and towards the range of 60-100% recycle percentage.

210. A POSITA would have therefore found the 60-100% recycle percentage in limitation [1fi] of claim 1 of the '380 patent obvious because of Scholz's Figure 7.

[1f.ii] – the total capacity of the gas separation membranes in the retentate separation stage is higher than the total capacity of the gas separation membranes in the feed stream separation stage, the total capacity being

⁴ As explained above, Scholz's Figure 7 systems are similar to Ungerank's Comparative Example 1 system. The 86.7% recycle percentage in Ungerank's Comparative Example 1 is consistent with a POSITA being led by Scholz to a recycle percentage in 60-100% range.

measured for nitrogen Grade 4.8 under standard conditions as defined in the description

211. Above, in the section on the Ungerank Scholz combination, I explained Scholz's teachings for claim limitation [1f.ii] in claim 1 of the '380 patent, and for those reasons, Scholz's teachings would have made limitation [1f.ii] obvious to a POSITA.

[1f.iii] – the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage is in a range of from 0.5 to 8.

212. In Scholz's Figure 7 (a) system, "the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage" ("3/1 pressure ratio quotient") is $0.77 = ((3.5 \text{ bar} \div 1 \text{ bar}) \div (16 \text{ bar} \div 3.5 \text{ bar}))$. A POSITA would have understood system (a) in Scholz's Figure to meet limitation [1f.iii] of claim 1 of the '380 patent.

213. The 3/1 pressure ratio quotient in system (b) in Scholz's Figure 7 is $0.42 = ((2.6 \text{ bar} \div 1 \text{ bar}) \div (16 \text{ bar} \div 2.6 \text{ bar}))$. The range between the values in Scholz's systems (a) and (b) (0.42-0.77) overlaps the 0.5-8 range in limitation [1f.iii] of the '380 patent.

214. A POSITA would have also understood that in systems like in Scholz's Figure 7, varying pressure ratios (and therefore 3/1 pressure ratio quotients) affects costs. As I explained above, this claim limitation pertains to the intermediate pressure in a three stage system with no recompression—i.e., the pressure on the

permeate side of stage 1, which is equal to the pressure on the retentate side of stage 3.

215. If the 3/1 pressure ratio quotient is very high, that means the pressure ratio in stage 1 is low, requiring a large membrane in stage 1; and conversely, if the 3/1 pressure ratio quotient is very low, that means the pressure ratio in stage 3 is low, requiring a large membrane in stage 3. In other words, as the 3/1 pressure ratio quotient goes to extremes, that necessitates very large (and therefore very costly) membranes in either stage 1 or stage 3, significantly driving up costs—which a POSITA would have understood and tried to avoid. This is why, as I explained above, a POSITA would generally choose an intermediate pressure somewhere close to the middle of the range between the feed stage retentate pressure and the permeate stage permeate pressure.

216. A POSITA would have been motivated to test 3/1 pressure ratio quotients in the range in limitation [1f.iii] of claim 1 of the '380 patent (0.5-8) because the values in Scholz's systems (a) and (b) (0.42-0.77) overlap that range, and the median of the range encompassed by systems (a) and (b) in Scholz's Figure 7 is $= 0.59 (0.42 + 0.77) \div 2$, which is within the 0.5-8 range in limitation [1f.iii] of claim 1 of the '380 patent. Therefore a POSITA would have been led by Scholz's teachings to test 3/1 pressure ratio quotients in the 0.5-8 range in limitation [1f.iii] of the '380 patent.

217. A POSITA would have therefore found the 0.5-8 3/1 pressure ratio quotient in limitation [1f.iii] of claim 1 of the '380 patent obvious because of Scholz's Figure 7.

Claim 2 – The method of claim 1, wherein the apparatus comprises a compressor arranged up-stream of the feed stream separation stage.

218. Scholz explains that in Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), “a single compressor is” used. AP-1007, 5. In Figure 7, there is a compressor shown up-stream of the feed stage. A POSITA would have understood this, along with Figure 7 in Scholz, to meet the limitation in claim 2 of the '380 patent.

Claim 3 – The method of claim 1, wherein the apparatus comprises at least one vacuum device arranged in at least one permeate stream of the feed stream separation stage, the retentate separation stage and/or the permeate separation stage.

219. Scholz Explains that “a vacuum pump” can be used “to generate the driving force for permeation.” AP-1007, 6. A POSITA would have understood generating a “driving force for permeation” to mean a vacuum pump in a permeate stream. A POSITA would have therefore understood Scholz's teachings above and in Figure 7 to meet the limitation in claim 3 of the '380 patent or at least make it obvious.

Claim 4 – The method of claim 1, wherein the first permeate stream is not subjected to a recompression.

220. Scholz explains that for Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz explains that in Figure 5 (and therefore in Figure 7), “a single compressor is” used. AP-1007, 5. In Figure 7 the compressor is in the feed line, not in the first permeate stream. A POSITA would have understood this, along with Figure 7 in Scholz, to meet the limitation in claim 4 of the ‘380 patent.

Claim 5 – *The method of claim 1, wherein the ratio of the total capacity of the gas separation membranes in the retentate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage is in a range of from 1.05 to 10.*

221. Above, for claim 5 in the combination of Ungerank and Scholz section, I explained that Scholz’s Figure 7 would have taught a POSITA surface area ratios for the retentate and feed stages that as a matter of mathematics meet the capacity ratio limitation in claim 5 of the ‘380 patent. That explanation that I provided in the earlier section also applies here.

Claim 6 – *The method of claim 5, wherein the ratio of the total capacity of the gas separation membranes in the retentate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage is in a range of from 1.5 to 6.*

222. As I explained above, in Scholz’s Figure 7, the membranes’ capacities are proportional to their surface areas. In Scholz’s Figure 7 (a) system, “the ratio of the total capacity of the gas separation membranes in the retentate separation stage to the total capacity of the gas separation membranes in the feed stream separation

stage” (“2/1 capacity ratio”) is $1.2 = 159 \text{ m}^2 \div 133 \text{ m}^2$. In system (b) in Figure 7 that 2/1 capacity ratio is $6.7 = 382 \text{ m}^2 \div 57 \text{ m}^2$. The range between these values (1.2-6.7) encompasses, and is fairly close to, the 1.5-6 range in claim 6 of the ‘380 patent.

223. A POSITA would have also understood that in Scholz’s Figure 7 systems—where, as I have explained, capacity is proportional to surface area—varying the areas in stages 1 and 2 (and therefore varying the 2/1 capacity ratio) affects costs. Scholz explained that increasing the “required membrane area” results in “higher investment costs and membrane replacement costs,” reducing the profitability. AP-1007, 4, 7. In other words, a POSITA would have understood that varying the surface area ratios of stages 1 and 2 (and therefore varying the 2/1 capacity ratio) within and around the range encompassed by Scholz’s systems (a) and (b) (1.2-6.7) has a predictable effect on cost. That is, the more total surface area, the higher the cost.

224. A POSITA would have been motivated to use simulation software such as Aspen or ChemCad to test the areas in stages 1 and 2 such that they were within the 2/1 capacity ratio range in claim 6 of the ‘380 patent because the area ratios (and therefore the 2/1 capacity ratios) in the range encompassed by systems (a) and (b) in Scholz’s Figure 7 (1.2-6.7) overlaps the range in claim 6 of the ‘380 patent (1.5-6). Also, the midpoint between the Scholz range ($3.9 = (1.2+6.7) \div 2$) is near the middle of the range in claim 6 in the ‘380 patent (1.5-6) and a POSITA would have been

motivated by Scholz's optimizations to, in the first instance, test values near the midpoint of the range encompassed by the two systems in Scholz's Figure 7.

225. A POSITA would have found that the 2/1 capacity ratio range in Scholz's Figure 7 makes the 2/1 capacity ratio range in claim 6 of the '380 patent obvious.

Claim 7 – *The method of claim 1, wherein the ratio of the total capacity of the gas separation membranes in the permeate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage is in a range of from 0.5 to 3.*

226. Above, for claim 7 in the Ungerank Scholz combination section, I explained that in Scholz Figure 7 system (a), "the ratio of the total capacity of the gas separation membranes in the permeate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage" ("3/1 capacity ratio") is 1.7. That earlier explanation also applies here as well. Therefore, a POSITA would have understood the Figure 7 system (a) meet the limitation in claim 7 of the '380 patent.

227. In Scholz's Figure 7 system (b), the 3/1 capacity ratio is $22.8 = 1300 \text{ m}^2 \div 57 \text{ m}^2$. Therefore the range encompassed by systems (a) and (b) in Scholz's Figure 7 is 1.7-22.8, which overlaps the 0.5-3 range in claim 7 of the '380 patent.

228. Above, I explained for claim 6 that a POSITA would have understood that in Scholz's Figure 7 systems, capacity is proportional to surface area, and varying surface areas (and therefore surface area ratios and capacity ratios) affects

costs. A POSITA would have understood that varying the surface area ratios of stages 1 and 3 (and therefore the 3/1 capacity ratio) within and around the range encompassed by systems (a) and (b) in Scholz has a predictable effect on cost: the more total surface area, the higher the cost.

229. A POSITA would have been motivated to use simulation software such as Aspen or ChemCad to test the areas in stages 1 and 3 such that they were within the 3/1 capacity ratio range in claim 7 of the '380 patent because the area ratios (and therefore the 3/1 capacity ratios) in the range encompassed by systems (a) and (b) Scholz's Figure 7 (1.7-22.8) overlaps the range in claim 7 (0.5-3). A POSITA would have been motivated by Scholz's optimizations to test values within the range encompassed by the systems (a) and (b) in Figure 7, which would have led a POSITA to the range in claim 7 of the '380 patent.

230. For these reasons, Scholz's Figure 7 would have made the limitation in claim 7 of the '380 patent obvious to a POSITA.

Claim 8 – The method of claim 7, wherein the ratio of the total capacity of the gas separation membranes in the permeate separation stage to the total capacity of the gas separation membranes in the feed stream separation stage is in a range of from 0.8 to 1.

231. For similar reasons to those I explained above for claim 7, a POSITA would have been motivated to use simulation software such as Aspen or ChemCad to test the areas in stages 1 and 3 such that they were within the 3/1 capacity ratio range in claim 8 of the '380 patent. In other words, membrane surface areas is one

of the variables a POSITA would have varied in optimizing a system. The 3/1 capacity ratio range in system (a) in Scholz (1.7) is somewhat near the high end of the 3/1 capacity ratio range in claim 8 of the '380 patent. A POSITA would have been motivated by Scholz's optimizations to test values close to and around the systems in Figure 7, which would have made the range in claim 8 of the '380 patent obvious to a POSITA.

Claim 9 – The method of claim 1, wherein the combined gas volume recycled with the second permeate stream and the third retentate stream is from 65 to 85% of the volume of the crude gas stream.

232. Above I explained that systems (a) and (b) in Scholz's Figure 7 encompass a range of 51-135% for the recycle percentage. This range encompasses the 65-85% range in claim 9 of the '380 patent.

233. Similar to what I explained above for limitation [1f.i], a POSITA would have been guided by Scholz to test within the range encompassed by the systems in Scholz's Figure 7 systems (a) and (b) (51-135%), and 65-85% lies within that range.

234. In addition, as I explained above, in system (b) in Scholz's Figure 7, the mole fraction of methane in the third permeate stream is 0.008, meaning that stream has very high purity CO₂. For most applications, CO₂ purity need not be this high, and a POSITA would have been motivated to use a lower recycle percentage to save on energy costs if lower purity CO₂ was sufficient. This is further reason a

POSITA would have been steered towards using a lower recycle percentage than in system (b), and towards the range of 65-85% recycle percentage.

235. A POSITA would have therefore found the 66-85% recycle percentage in claim 9 of the '380 patent obvious because of Scholz's Figure 7.

Claim 10 – *The method of claim 1, wherein the quotient of the pressure ratio over the permeate separation stage to the pressure ratio over the feed stream separation stage is in a range of from 1 to 3.*

236. Above, I explained for limitation [1f.iii] in claim 1 of the '380 patent system (a) in Scholz's Figure 7 has a 3/1 pressure ratio quotient of 0.77. This is not within the 1-3 range in claim 10 of the '380 patent.

237. As I have explained, a POSITA would have been motivated to use simulation software such as Aspen or ChemCad to test 3/1 pressure ratio quotient across various ranges. In other words, testing pressure ratios is one of the variables a POSITA would have varied in optimizing a system. A POSITA would have been motivated by Scholz to test values near and between the ones in systems (a) and (b) in Scholz's Figure 7. The 3/1 pressure ratio quotient range in claim 10 of the '380 patent would have been obvious to a POSITA from the 3/1 pressure ratio quotient in system (a) in Scholz's Figure 7.

Claim 11 – *The method of claim 1, wherein the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of at least 10.*

238. Scholz explains that the membranes in its Figure 7 systems have "a CO₂/CH₄ selectivity of 20." AP-1007, Figure 7. Scholz does not specify if this

selectivity is mixed gas or pure gas. If it is mixed gas selectivity, a POSITA would have understood that the pure gas selectivity would be higher than the mixed gas selectivity, and therefore higher than 20. A POSITA would therefore have understood Scholz's Figure 7 to meet the limitation in claim 11 of the '380 patent.

Claim 12 – *The method of claim 11, wherein the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of from 20 to 100.*

239. Scholz explains that the membranes in its Figure 7 systems have “a CO₂/CH₄ selectivity of 20.” AP-1007, Figure 7. As I explained above for claim 11, Scholz does not specify if this selectivity is mixed gas or pure gas. If it is mixed gas selectivity, a POSITA would have understood that the pure gas selectivity would be higher than the mixed gas selectivity, and therefore higher than 20. A POSITA would have understood nonetheless that the pure gas selectivity would not be 500% or more higher. A POSITA would therefore have understood that in the systems in Scholz' Figure 7, the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of from 20 to 100. A POSITA would therefore have understood Scholz's Figure 7 to meet the limitation in claim 12 of the '380 patent.

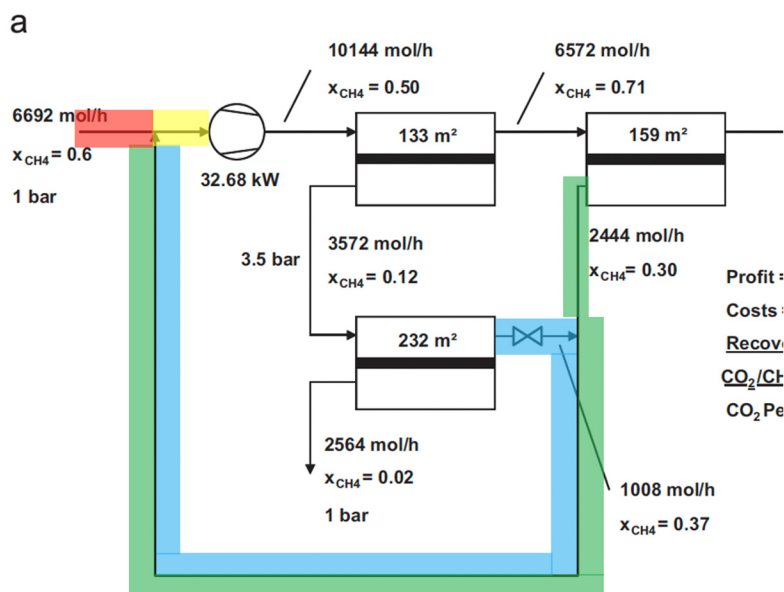
Claim 13 – *The method of claim 1, wherein the gas separation membranes comprise a separation-active layer of a material selected from the group consisting of polyamides, polyetherimides, polyaramides, polybenzoxazoles, polybenzothiazoles, polybenzimidazoles, polysulfones, cellulose acetate, cellulose acetate derivatives, polyphenylene oxides, polysiloxanes, polymers with intrinsic microporosity, mixed*

matrix membranes, facilitated transport membranes, polyethylene oxides, polypropylene oxides and polyimides.

240. Scholz explains that “a membrane reflecting the characteristics of a cellulose acetate membrane” is “depicted in Fig. 7.” AP-1007, 5, 6, Figure 7. A POSITA would therefore have understood Scholz to meet the limitation in claim 13 of the ‘380 patent or make it obvious.

Claim 16 – The method of claim 2, wherein the second permeate stream and the third retentate stream are combined with the crude gas stream on the suction side of the compressor.

241. As shown in Scholz’s Figure 7, the second permeate stream (in green below) and third retentate stream (in blue below), are combined with the crude stream (in red below) on the suction side of the compressor. AP-1007, Figure 7. A POSITA would have therefore understood Scholz’s Figure 7 to meet the limitation in claim 16 of the ‘380 patent.

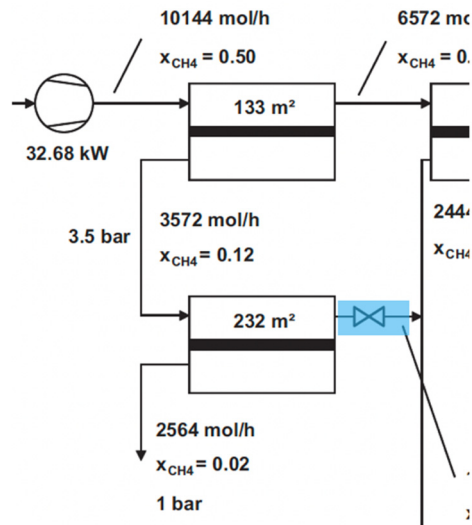


Claim 17 – The method of claim 2, wherein the compressor is a multistage compressor and the second permeate stream, the third retentate stream, or both are introduced into the compressor between two compression stages.

242. Scholz explains that “the application of a multistage compressor would further reduce the energy demand for the gas permeation processes.” AP-1007, 6. A POSITA would have understood this to mean that the recycled stream(s) would be introduced between two compression stages, as that is how multistage compressors reduce energy demand. By introducing recycle streams between two compression stages, their pressure is not reduced all the way down to the inlet stream pressure, and as a result, the recycle stream(s) do not need to be recompressed as much. A POSITA would have understood Scholz’s teachings above to meet the limitation in claim 17 of the ‘380 patent or at least make it obvious.

Claim 21 – The method of claim 1, wherein the pressure on the permeate side of the feed stream separation stage is adjusted with a pressure reducing valve on the retentate side of the permeate separation stage to a value of from 1 to 30 bar.⁵

243. In Scholz's Figure 7, there is a pressure reducing valve on the retentate outlet of the third permeate stage (in blue below):



244. In Scholz's Figure 7, the pressure on the permeate side of the feed stage is 3.5 bar in system (a), and it is 2.6 bar in system (b). AP-1007, Figure 7. Also, Scholz explains that in Figure 7, the “process layout does not change compared to”

⁵ As I explained above, claim 21 of the '380 patent does not specify bara (absolute) or barg (gauge) pressures. The systems in Scholz's Figure 7 also do not specify bara (absolute) or barg (gauge) pressures. The systems in Scholz's Figure 7 meet the limitation in claim 21 regardless because the relevant pressures in Figure 7 are more than 1 bar away from the ends of the range in claim 21.

the systems in Figure 5. AP-1007, 6. Scholz also explains that in Figure 5 (and therefore also in Figure 7), the “pressure valve on the retentate outlet of the third stage controls the feed pressure in the third stage” (which is also the pressure on the permeate side of the feed stage). AP-1007, 6. A POSITA would have therefore understood Scholz’s Figure 7 to meet the limitations in claim 21 of the ‘380 patent.

Claim 23 – *The method of claim 1, wherein the crude gas stream is selected from the group consisting of biogas, natural gas, air, a gas mixture comprising carbon dioxide and methane, a gas mixture comprising hydrogen and methane, a gas mixture comprising carbon monoxide and methane, a gas mixture comprising helium and methane, a gas mixture comprising helium and nitrogen, a gas mixture comprising hydrogen and carbon monoxide, a gas mixture comprising a permanent gas having a boiling point of less than 110 Kelvin at 1 atm and a non permanent gas having a boiling point above or equal to 110 Kelvin at 1 atm, a gas mixture comprising carbon dioxide and a hydrocarbon, and a gas mixture comprising nitrogen and a hydrocarbon.*

245. Scholz explains that for Figure 7, the “process layout does not change compared to” the systems in Figure 5. AP-1007, 6. Scholz also explains that in Figure 5 (and therefore also in Figure 7), the “raw gas is compressed” and “fed to the first membrane stage. The first stage performs a bulk separation of CO₂ and CH₄.” AP-1007, 5. Also, Scholz’s Figure 7 shows systems that are separating a CO₂ and CH₄ crude gas stream. A POSITA would have therefore understood Scholz’s Figure 7 to meet the limitation in claim 23 of the ‘380 patent.

XIII. THE JOURNAL OF MEMBRANE SCIENCE AND SCHOLZ

246. Over the course of my career, I have had over twenty papers published in the *Journal of Membrane Science*. AP-1004. In addition, I served on the Editorial

Board of the *Journal of Membrane Science* from 1978-1987 and from 1991 until 2023.

247. In my opinion and experience, the *Journal of Membrane Science* is the dominant journal in the membrane separation technology industry, and was the dominant journal in this industry in 2014. Since the very beginning, the *Journal of Membrane Science* has been a robust, peer-reviewed journal frequented by those persons looking to stay abreast of current developments in the industry. The Journal only accepts about 40% of the papers that are submitted.

248. In my experience, the ScienceDirect website is now, and was in 2014, a resource for searching the *Journal of Membrane Science*, among other journals. The website may be searched through keywords, author information, subject, affiliation, etc., including by searching the full text in articles.

249. Over the course of my career, through both publishing with the *Journal of Membrane Science* and serving on its Editorial Board, I became familiar with the submission, review, revision, and publication practices at the Journal. I was also familiar with those practices as of 2014.

250. In my experience with the *Journal of Membrane Science*, as of at least 2014, after an article has been submitted, revised, and accepted for publication, the accepted article was made available to the public on the ScienceDirect website, generally for a purchase fee.

251. It is my understanding, based on my experience with the *Journal of Membrane Science*, including as of 2014, that once an article is accepted, no substantive changes are made to the article other than typographical or formatting changes, before the article is published in the assigned journal volume. Once the article is accepted and placed on the ScienceDirect website, in my experience, including as of 2014, any interested person could access the website and purchase the article if they so desired.

252. I was able to confirm this understanding through a physical copy of the Scholz paper that I had in my possession. AP-1037. Specifically, I have in my possession a copy of this article that has a cover page identifying it as “Author’s Accepted Manuscript.” The cover page notes that the article was received on February 17, 2014, was revised on August 8, 2014, and was accepted on August 14, 2014. A citation is provided for citations made to the article prior to publication. The cover page further explains that:

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting galley proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

AP-1037, 1.

253. I note that the first full page of the “Accepted Manuscript” Scholz copy has the date of September 25, 2014 at the bottom righthand corner of the page. AP-1037, 2.

254. I have personally reviewed and compared the Scholz reference I rely upon above (AP-1007) and this “Accepted Manuscript” copy (AP-1037), and the only changes I observed between the two versions were the correction of several typographical errors and some formatting changes that lay the figures out more clearly. I observed no substantive differences between the two versions, including no substantive differences in the sections addressing systems (a) and (b) in Figure 7 and their underlying discussion.