

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

AIR PRODUCTS AND CHEMICALS, INC.,
Petitioner

v.

EVONIK OPERATIONS GMBH and EVONIK CORPORATION,
Patent Owner.

Case IPR2024-00611

Patent 10,471,380 B2

DECLARATION OF GEOFFREY GEISE

EVONIK 2008
AIR PRODUCTS v. EVONIK
IPR2024-00611

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I. INTRODUCTION

1. I have been retained as an expert consultant by counsel for Patent Owner, Evonik Operations GMBH and Evonik Corporation (“Evonik”) in connection with the Inter Partes Review of U.S. Patent No. 10,471,380 (AP1001) before the United States Patent and Trademark Office.

2. I submit this Declaration in support of Patent Owner’s Response in connection with these proceedings.

II. QUALIFICATIONS AND PROFESSIONAL EXPERIENCE

3. My complete qualifications and professional experience are described in my academic curriculum vitae (Appendix A). The following is a brief summary of my relevant qualifications and professional experience.

4. I am an associate professor in the Department of Chemical Engineering and, by courtesy, in the Department of Materials Science and Engineering at the University of Virginia. I specialize in membranes for separation applications. Attached as Appendix A to this declaration is my current curriculum vitae, which includes a listing of my education, work experience, and publications. The following paragraphs briefly summarize my relevant experience.

5. I hold a B.S. in Chemical Engineering from the Pennsylvania State University and a M.S.E. in Chemical Engineering from the University of Texas at

Austin. I also hold a Ph.D. in Chemical Engineering from the University of Texas at Austin.

6. I am currently an associate professor in the Department of Chemical Engineering and, by courtesy, in the Department of Materials Science and Engineering at the University of Virginia. In this position, I conduct research in small molecule transport through polymeric materials, and I teach courses at the undergraduate and graduate levels on topics including mass transfer and separations. In these courses, I specifically teach topics related to membrane separations, and I teach gas separations via membranes in a Ph.D.-level chemical engineering course on mass transfer. I publish papers relating to membrane-based separations, and I routinely give invited seminars and presentations on topics related to membranes and separations. I have chaired national meeting technical sessions focused on membrane separations.

7. Prior to my position at the University of Virginia, I conducted postdoctoral research in the Department of Materials Science and Engineering at the Pennsylvania State University. Prior to that, I was a graduate research assistant in the Department of Chemical Engineering at the University of Texas at Austin.

8. My work in membrane separations has been recognized via several awards and honors. The North American Membrane Society (NAMS), which is the premier professional society for membrane scientists and engineers in North

America, has recognized my research via the Young Membrane Scientist Award.

My papers on membranes for separation applications have won awards and recognition including a Journal of Membrane Science Editors' Choice Award, Best ACS ES&T Engineering Paper for 2022, Best ES&T Letters Paper for 2019, and the 2020 Class of Influential Researchers from Industrial & Engineering Chemistry Research. Additionally, I led a research team to a runner-up win in the American-Made Geothermal Lithium Extraction Prize for a separation process, which included membranes, to extract lithium from geothermal brine.

9. I have personal knowledge of the matters set forth in this declaration and, if called upon as a witness, would testify competently thereto. I have used my education and my years of experience working in the field of chemical engineering and membrane-based separations, and my understanding of the knowledge, creativity, and experience of a person of skill in the art in performing the analysis expressed in this declaration.

III. SCOPE OF WORK

10. I understand that a petition was filed with the United States Patent and Trademark Office for inter partes review of U.S. Patent No. 10,471,380 (AP1001 ("Priske-'380")).

11. I understand that in IPR2024-00611, the Patent Trial and Appeal Board ("PTAB" or the "Board") has decided to institute inter partes review of

claims 1-23 of the Priske-'380 patent under 35 U.S.C. §§ 102 and 103 based on the disclosures of U.S. Patent No. 8,999,038 to Ungerank et al. (AP1006 (the "Ungerank patent")) and Scholz et al., Structural optimization of membrane-based biogas upgrading processes, Journal of Membrane Science 474, 1–10 (2015) (AP1007 ("Scholz")).

12. In forming my opinions, in addition to my knowledge and experience, I have considered the materials listed in Appendix B.

13. Unless otherwise indicated, all statements made herein are based on my knowledge and experience in the field.

14. I am being compensated for my work on this declaration at a rate of \$300 per hour. My compensation is not contingent on the outcome of this matter or the contents of my testimony.

IV. PERSON OF ORDINARY SKILL IN THE ART

15. I understand that the person of ordinary skill in the art ("POSITA") is a hypothetical person from whose perspective patentability analysis is performed. I also understand that the POSITA is presumed to have known the relevant art at the time of the invention.

16. I understand that for the purposes of the Patent Owner Response only, Patent Owner is utilizing Petitioner's proposed level of skill in the art: an individual with "a Master of Science degree in physical chemistry, chemistry,

chemical engineering, or a related field, and at least three years of work experience in membrane gas-separation systems, including but not limited to biomembrane gas-separations.”

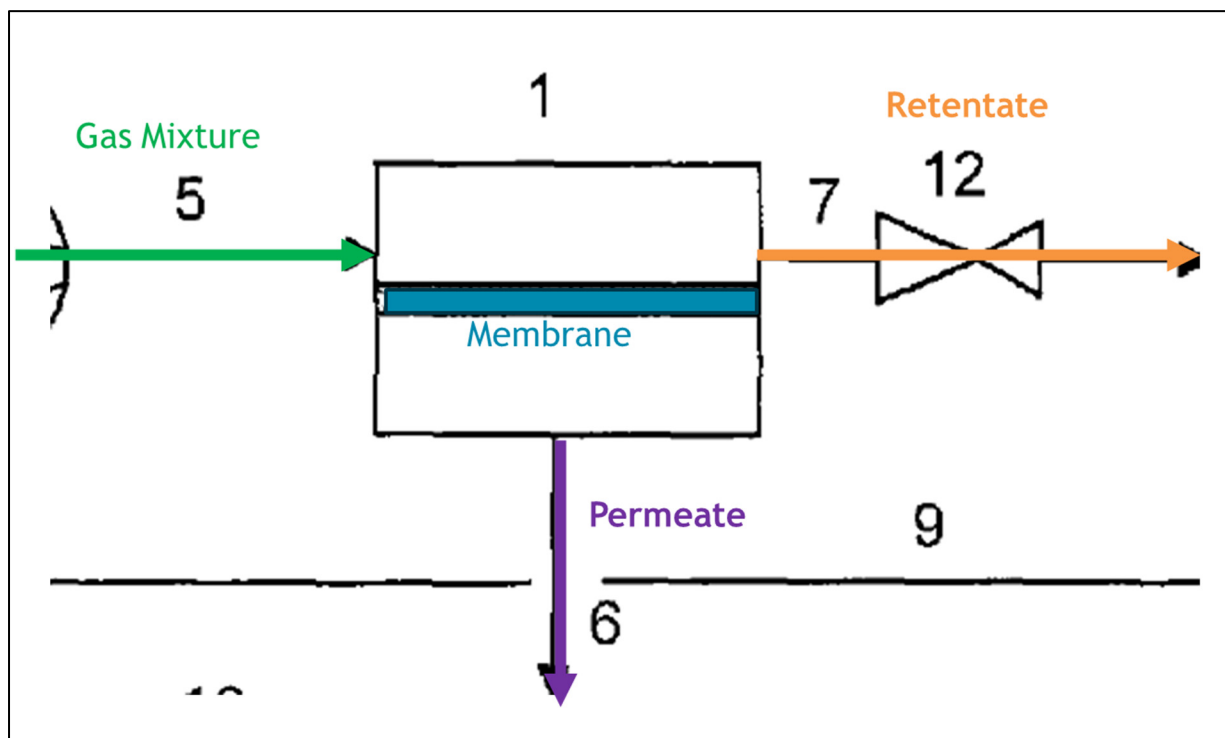
17. I have a Master's degree and a Ph.D. in chemical engineering, and I worked in a research group engaged in gas separation membrane research for more than three years prior to 2014 and taught courses on gas separation topics over a period of several years. As such, under this definition, I consider my education and work experience to meet the threshold of a POSITA (and to have done so since before 2014). I provide my analysis from the perspective of a POSITA.

V. BACKGROUND OF THE TECHNOLOGY

18. The invention of Priske-'380 relates to a process and apparatus for separation of gas mixtures using membranes. Gas separation membranes can be used in a wide variety of scenarios, including for separating biogas streams.

19. The overall principle of operation of gas separation membranes is as follows: a mixture of gases is introduced to a membrane, and the gases pass through the membrane at different rates. The transport of gas from one side of the membrane to the other side occurs through a process called permeation. The gas flow that passes through the membrane is called the “permeate,” while the gas that remains on the feed side of the membrane is called the “retentate.” Since one gas component, in a two-gas mixture, permeates more rapidly than the other gas

component, both the permeate stream and retentate stream are enriched with the different component gases after introduction to the membrane.



20. Membrane gas-separation processes have many variables that can be altered depending on the goals of the process. The output of a process depends, for example, on the structure of the system (such as the number of stages, membrane sizing, recycle stream locations, compressor and/or vacuum location, etc.) and the process conditions used (such pressure ratios, gas and membrane temperatures, etc.).

21. There are several different concepts that define a membrane gas-separation process, which are described below.

22. *Selectivity* of a membrane is a measure of the membrane's relative permeance for one gas over another gas. For a given membrane, permeance typically varies for different gases, and selectivity is defined relative to two different gases (e.g., selectivity of CO₂ over CH₄). EX2010-White; *see also* EX2011-Matteucci. Selectivity is defined as the ratio of permeances of the two gases in question, and thus selectivity has no units. High selectivity membranes may be more effective at separating one gas from another, but higher selectivity generally comes at the cost of decreased overall permeability, increased energy consumption, and higher membrane costs. EX2012-Robeson; *see also* EX2010-White.

23. *Permeance* is a measure of how effectively a membrane can move a specific gas through the membrane under a given set of conditions. Permeance is often described in terms of gas permeation units (GPU) with units of $1 \text{ GPU} = 10^{-6} \text{ cm}^3(\text{STP}) \text{ cm}^{-2} \text{ sec}^{-1} (\text{cm Hg})^{-1}$. Gas permeance can be measured using different gases or mixtures thereof. For example, Priske-'380 discusses membrane permeance in terms of Nitrogen Grade 4.8 under the standard conditions defined in Priske-'380. Increasing the permeance of a membrane generally increases the amount of gas that the membrane can handle in a process, and thus, permeance can affect a process's throughput, among other characteristics.

24. The *chemical composition* of a membrane affects its permeability, selectivity and cost. For example, a membrane made using tightly packed polymer chains typically offers higher selectivity but lower permeability, while a membrane made from more loosely packed polymer chains may provide higher permeability at the expense of selectivity. EX2009-Baker Dep.; EX2012-Robeson; EX2013-Freeman. Membranes made of the same material often exhibit similar properties, but differences can still exist depending on the specifics of the manufacturing process, membrane construction, and other factors. For example, membrane permeance depends both on permeability and a measure of membrane thickness. EX2011-Matteucci.

25. A membrane separation's *pressure ratio* defines the difference in pressure between the feed (or retentate) side and the permeate side of the membrane. This difference in pressure is the driving force behind gas permeation. A higher pressure ratio generally leads to faster permeation of gases.

26. The *recycle volume* refers to the amount of gas that is taken from the end of a separation process and reintroduced into a feed stream. Recycling of gas streams generally allows for a more effective separation at the expense of increased energy costs (for example, due to recompression of the recycled gas) and increased capital costs (for example, due to need for a higher capacity compressor).

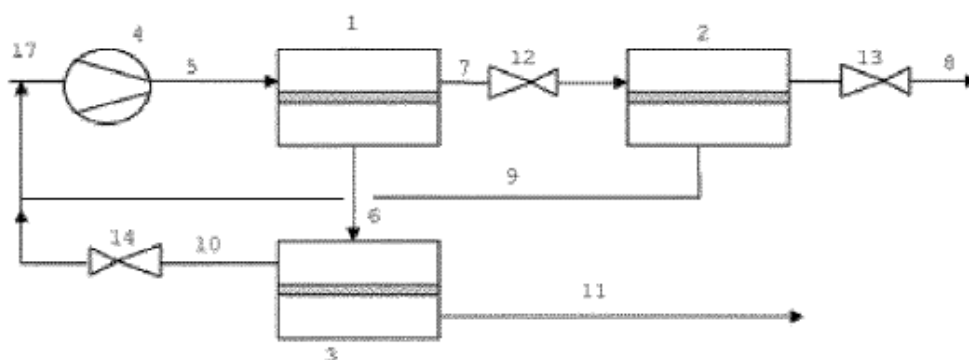
27. These process variables are highly interdependent in a membrane separation system. For example, all else being equal, a change in a membrane's permeance could lead to changes in the optimal pressure ratio over the membrane, a change in selectivity can cause a change in the optimal recycle volume, and a change in membrane capacity can also cause a change in the optimal recycle volume. Alteration of system variables can have effects on any (or all) other process variables. Care must be taken in altering process variables as a result.

28. The parameters used in a particular process depend on the goals of the process. For example, a process may aim to separate two gases at the lowest possible cost. Some gas membrane systems may be required to achieve certain purities, or recoveries, due to jurisdictional regulations legislation. Meeting such criteria may come with at the expense of cost reduction. A process can be limited by several other constraints, such as the amount of physical space available or a required pressure for a product stream.

29. In some cases, process modeling software can be used to simulate process performance. Real world utility of these simulations can vary drastically depending on factors such as the assumptions used in constructing the model, the computational methods used, and user sophistication.

VI. SUMMARY OF THE PRISKE-'380 PATENT

30. The Priske-'380 patent relates to a specific process and apparatus for separation of gas mixtures with reduced maintenance costs. Priske-'380, Abstract. The claims of Priske-'380 relate to a three stage membrane gas-separation process with certain process parameters specified. Figure 1 of Priske-'380 depicts an “illustrative connection arrangement” of the process:



Illustrative connection arrangement of several membrane modules according to invention

31. The specification describes the then-existing state of the art and explained that a new problem had developed, which was that some separation processes were often located where energy was cheap, and thus were cost-dominated by maintenance and investment costs. AP1001-Priske-'380, 1:45-53. The invention of Priske-'380 is a three-stage membrane gas-separation process that is advantageous in terms of maintenance costs (e.g., membrane costs) and can

achieve high purity for both product gas streams with reduced membrane capacity.

Id., 2:13-26.

32. Priske surprisingly found that the claimed invention “can afford pure streams of permeate and retentate without requiring more than one compressor ... without further purification of the permeate or retentate stream by other methods” and with a “significantly reduced overall membrane capacity” to achieve streams of high purity. *Id.* He also surprisingly found that, using the claimed invention, “a maintenance cost optimum for three stage membrane separation” could be achieved. *Id.* 2: 27-30. The claimed invention involves three key features: 1) “increasing the total gas volume recycled in sum with the second permeate stream and the third retentate stream”, 2) “increas[ing] of the total membrane capacity of the retentate separation stage compared to the total membrane capacities of separation stage (1)”, and 3) using “a specific quotient of the pressure ratios of the permeate separation stage over the feed stage separation stage.” *Id.* 2:30-40.

33. Priske-'380 describes several terms used in the claims, including membrane capacity, permeance, selectivity, permeate, retentate, crude gas, raw gas, and feed stream. *Id.*, 2:51-4:14. I have reviewed these definitions, and they are consistent with my understanding of the terms.

34. The specification provides 12 examples of the claimed invention and compares each of these examples to a reference example. Reference Examples 1-3

are reproduced from WO 2012/000727 (the “Ungerank PCT application”), which I understand is the PCT application that ultimately resulted in the Ungerank patent.

35. Reference Example 1 of Priske-’380 is a reproduction of Comparative Example 1 from the Ungerank PCT application. AP1001-Priske-’380, 16:28-40. Priske-’380 then describes Example 1.1, which modified the reference process by increasing the recycle rate, the membrane capacity of stage 2, and the pressure ratio quotient of stage 3 to stage 1, according to the claims of Priske-’380. *Id.*, 16:44-50. Priske-’380 then explains that, using the claimed process, the system could achieve similar results to the reference example while reducing the total membrane capacity of the system by 14.9% relative to Reference Example 1. *Id.*, 17:36-46.

36. Reference Example 2 is a reproduction of Example 1 from the Ungerank PCT application. *Id.*, 19:8-19. Priske-’380’s Example 2 modified Reference Example 2 to meet the claimed process conditions by increasing the recycle rate, the membrane capacity of stage 2, and the pressure ratio quotient of stage 3 to stage 1. The resulting process achieved similar results to Reference Example 2 and had a total membrane capacity that was reduced by 15% compared to Reference Example 2. *Id.*, 19:60-62.

37. Reference Example 3 is a reproduction of Example 3 from the Ungerank PCT application. *Id.*, 20:7-19. Example 3 modified Reference Example

3 to meet the claimed process conditions by increasing the recycle rate, the membrane capacity of stage 2, and the pressure ratio quotient of stage 3 to stage 1. *Id.*, 20:23-26. The resulting process achieved similar results to Reference Example 3 and had a total membrane capacity that was reduced by 8% compared to Reference Example 3. *Id.*, 21:6-10.

38. Examples 4-10 compare processes with the inventive features of the Priske-'380 claims to various other reference processes, and show "that [the] process and apparatus of the invention are applicable for a wide range of operating pressures, membrane selectivities and for different gas mixtures." *Id.*, 27:64-28:58. In each case, "the inventive combination of 'recycling rates', 'increased membrane capacity in stage (2)' and 'quotient of pressure ratio of stage (3) over pressure ratio of stage (1)', in all cases led to a saving of overall membrane capacity compared to the corresponding comparative examples." *Id.*, 28:1-8.

39. Example 11 depicts a process with different selectivities in different separation stages, and Example 12 depicts a process with similar parameters to that of Example 11, except the selectivity is the same for each stage. Examples 11 and 12 reveal that "the inventive process and apparatus is applicable with membranes with different selectivities in different separation stages but also with membranes with identical selectivities in all separation stages." *Id.*, 29:27-31.

VII. SUMMARY OF THE CHALLENGED CLAIMS

40. The claims of Priske-'380 relate to methods for separating gases from a crude gas stream comprising at least two components, with an apparatus comprising a feed stream separation stage, a retentate separation stage, and a permeate separation stage, with each stage being a membrane gas-separation stage.

41. Independent claim 1 of Priske-'380 recites values for the three key features of the claimed method:

(i) “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,”

(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,” and

(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.”

(AP1001-Priske-'380 claim 1[f][i]–[iii].) Dependent claims 2 through 23 claim various other aspects, including additional hardware features in the process such as

a compressor, a vacuum device, and a pressure reducing valve (dependent claims 2-4, 16-17), the membrane material (dependent claims 13-15, 18), the specific crude gas stream (dependent claim 23), the ratio of the membrane capacity in the retentate separation stage to the feed stream separation stage (dependent claims 5-8), the selectivity of the of the membrane for CO₂/CH₄ (dependent claims 11-12), the volume of the recycled gas (dependent claim 9), various process pressures (dependent claims 19-22), and the quotient of the pressure ratio of the permeate separation stage to the pressure ratio of the feed separation stage (dependent claim 10).

VIII. SUMMARY OF THE ASSERTED ART

A. The Ungerank Patent

42. I understand that the Ungerank patent is a U.S. Patent that issued on April 7, 2015, and shares a common inventor with the Priske-'380 patent, Markus Priske. I have been informed that as of the priority date of Priske-'380, December 29, 2014, both the application for the Ungerank patent and the application for Priske-'380 were assigned to Evonik Fibres GmbH.¹ I have been informed that the Ungerank PCT application was considered and cited by the Examiner of the Priske-'380 patent. As discussed above, Comparative Example 1, Example 1 and Example 3 of the Ungerank PCT application are directly disclosed in the

¹ I understand that the Ungerank patent and Priske-'380 were assigned from Evonik Fibres GMBH to Evonik Operations GMBH on September 20, 2022.

specification of Priske-'380 and compared against the "inventive teachings" of Priske-'380.

43. The Ungerank patent teaches one-stage, two-stage, and three-stage processes for the separation of gas mixtures through membranes. *See, e.g.*, AP1006-Ungerank patent, Figs. 1-11.

44. The Ungerank patent further teaches that "[m]embranes 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)." *Id.*, 9:14-17. The Ungerank patent also teaches that "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." *Id.*, 9:30-34.

45. There are five different examples in the Ungerank patent, "Comparative Example 1" and "Examples" 1-4.

46. Example 1 is compared to Comparative Example 1; the Ungerank patent states that "[t]he high selectivity of 45 [in Example 1] compared to 20 in [Comparative Example 1] therefore enables a more economically favorable process by a lower recompression." *Id.*, 11:49-51. Said differently, the Ungerank patent teaches that higher selectivity membranes are ultimately more economical than lower selectivity membranes.

47. Examples 2-4 teach that “[i]n order to satisfy various legislators, it is necessary to minimize the methane loss into the atmosphere.” *See, e.g., id.*, 11:62-63. These Examples all require a methane content in the third permeate stream of less than 0.5% by volume. *See, e.g., id.*, 11:63-66. Both Comparative Example 1 and Example 1 have methane content in the third permeate stream of greater than 0.5% by volume. *Id.*, 10:57-58, 11:41-42.

B. Scholz

48. Scholz is a journal article titled “Structural optimization of membrane-based biogas upgrading processes” published in the Journal of Membrane Science in 2015 (“Scholz”). Scholz states that it was available online as of September 28, 2014. Scholz teaches a “structural optimization approach to biogas upgrading processes” that uses a “process modeling” system. Scholz, Abstract. Scholz investigates the “most profitable process layout including membrane areas and pressures.” AP10007-Scholz, 1. This investigation is done in different scenarios, including with two different “commercial membranes,” and with apparently non-commercial membranes that have “optimal selectivity and CO₂ permeance following the upper bound of the Robeson plot.” *Id.* Scholz also investigated “[t]he impact of changed feed conditions and required product purity.” *Id.*

49. In each of these models, certain assumptions about the economic costs and other conditions are kept constant, whereas other parameters are modified for evaluation. Table 3 of Scholz shows at least some of the economic assumptions used in its modeling:

Table 3
Economic parameters used for optimization of a membrane based biogas upgrading plant.

Costs	Unit	Value
Membrane module costs	$\frac{\text{Euro}}{\text{m}^2}$	55
Electrical costs	$\frac{\text{Euro}}{\text{kWh}}$	0.08
Commission of purified gas	$\frac{\text{Euro}}{\text{m}^3}$	0.2
Membrane lifetime	year	4
Annual operation	h	8,000
Interest rate	–	0.09
Amortization period	years	8

50. Scholz keeps the cost of electricity constant at 0.08 Euro/kWh in each of its analyses. AP1007-Scholz, 4.

51. While some details are disclosed, Scholz does not disclose the method used to calculate a process's profit. In my opinion, the exact details of the profit model are not apparent to a POSITA after reviewing Scholz. As a result, a POSITA would not be able to directly determine the effect that altering process parameters would have on the profit in Scholz's models.

52. As mentioned, Scholz investigated several different scenarios. Figure 5 depicts an “optimal process layout together with the process parameters” using a “commercial” membrane that has a selectivity for CO₂/CH₄ of 60, and a CO₂ permeance of 60 GPU. AP1007-Scholz, 5-6.

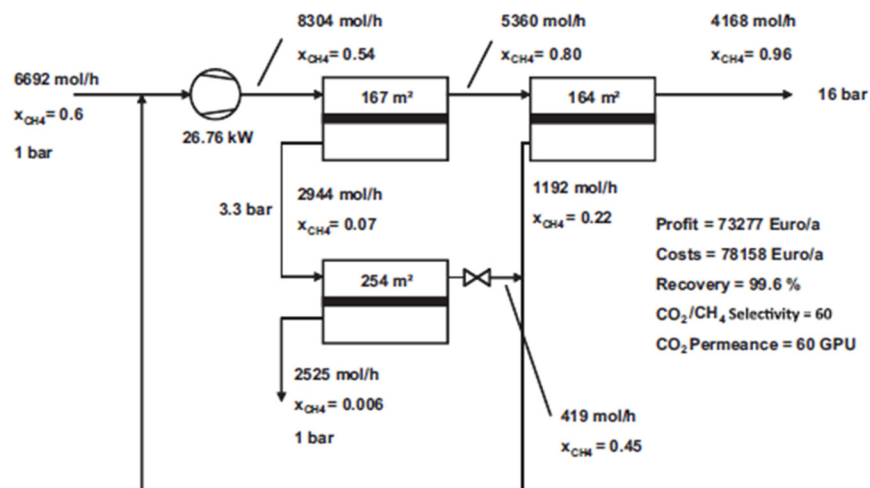


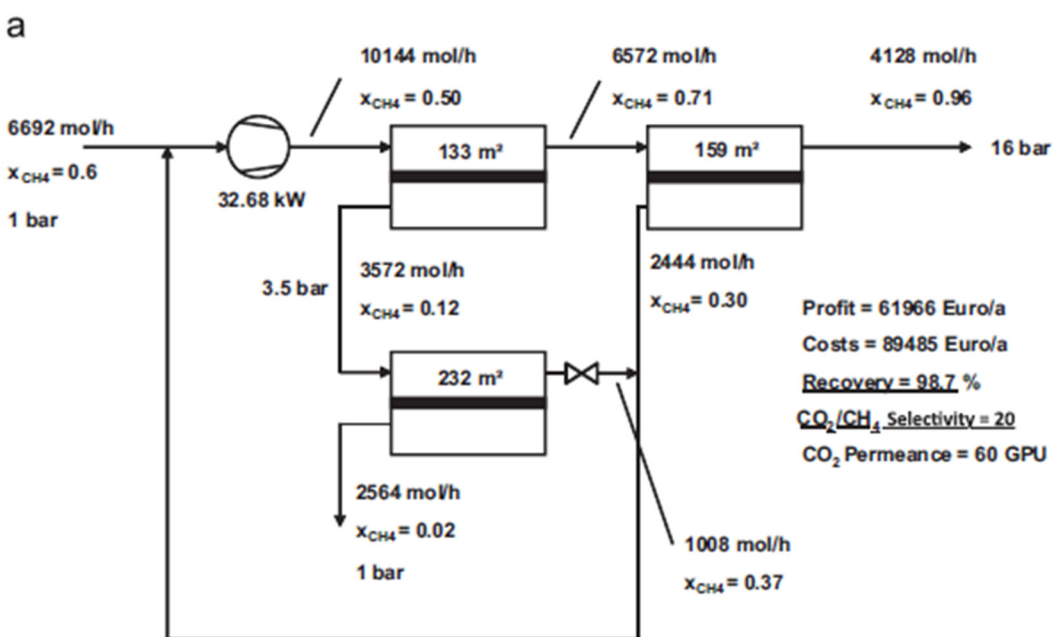
Fig. 5. Optimal process design and process conditions for gas permeation membranes with a CO₂/CH₄ selectivity of 60 and a CO₂ permeance of 60 GPU.

53. The process of Figure 5 resulted in a CH₄ recovery of 99.6% which was slightly higher than the requirement of 99.5%. *Id.* It achieved an annual profit of 73,277 euros, which is the highest annual profit of any process modeled using “commercial” membranes.

54. Using the information provided by Scholz, particularly on page 4, it would be clear to a person of ordinary skill that the capital cost of the compressor is the dominant cost in the process. Further, using Guthrie’s method and the information provided in Scholz Tables 2 and 3, it is readily apparent that

compressor cost scales with the required compressor volume, and thus, increasing the recycle volume of the system will increase the compressor capital cost.

55. Figure 7 includes scenarios (a) and (b) and depicts “optimal process design and process conditions” using a cellulose acetate membrane with a CO_2/CH_4 selectivity of 20 and CO_2 permeance of 60 GPU. Figure 7(a) reflects the output where the lower bound for methane recovery is set to 95%:

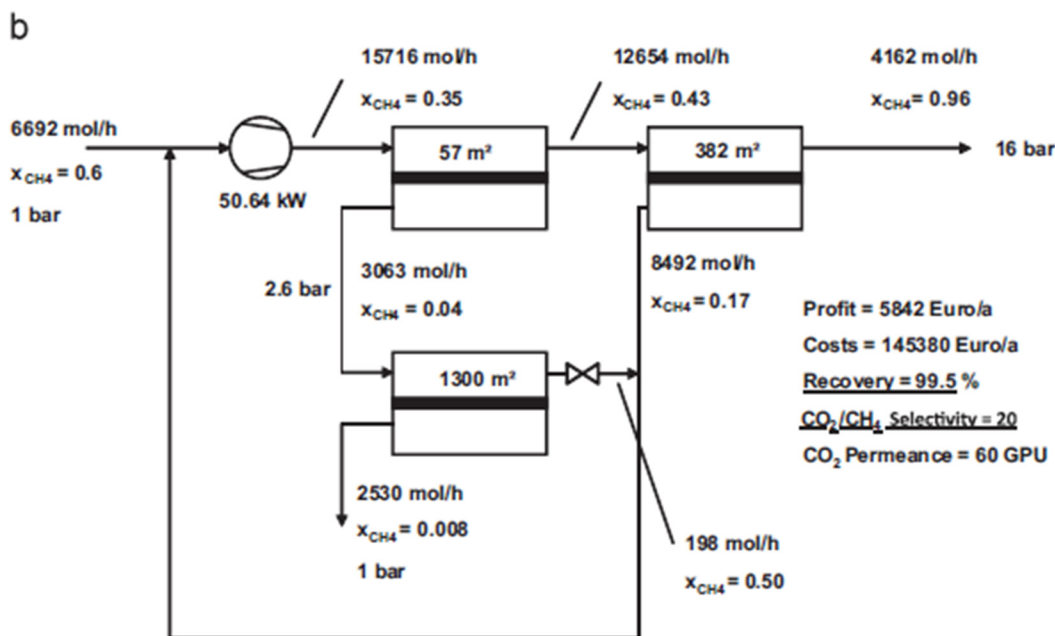


56. As shown, the model there reached an optimal point with methane recovery at 98.7%, higher than the 95% requirement, and achieved an annual profit of 61,966 euros.

57. However, Scholz states that such a low level of methane recovery would have a prohibitively detrimental impact on the environment. AP1007-

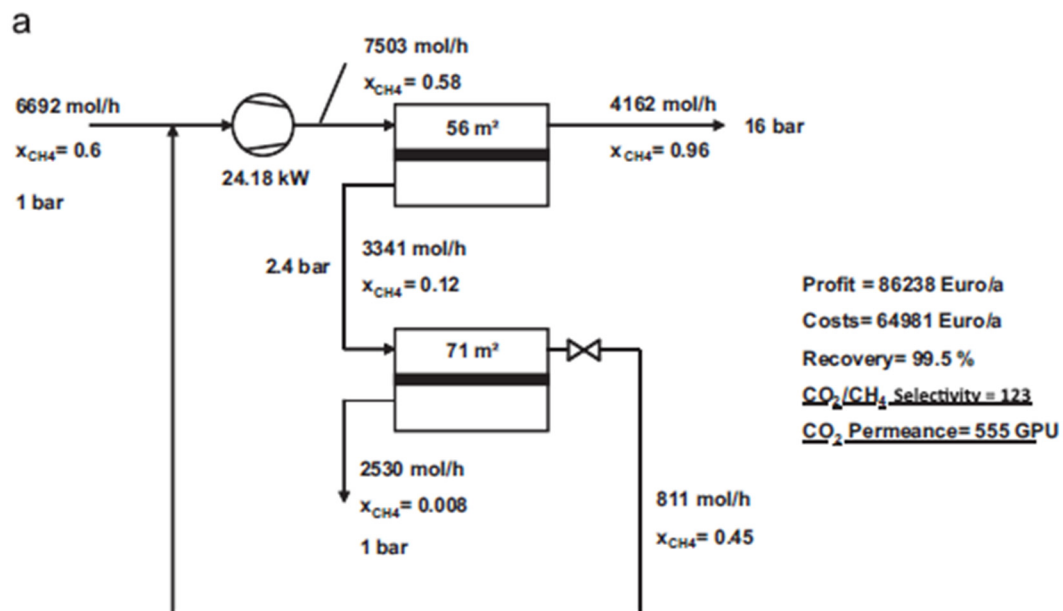
Scholz, 6 (“For the processes considered here, the CH₄ recovery should be at least 99.5% to minimize the environmental impact caused by extensive CH₄ losses.”).

58. In Figure 7(b), the CH₄ recovery requirement was raised to an ecologically acceptable 99.5%.



59. As shown, the optimal process in 7(b) achieved a methane recovery of 99.5% and an annual profit of 5,842 euros, which is the lowest profit achieved in any process taught in Scholz.

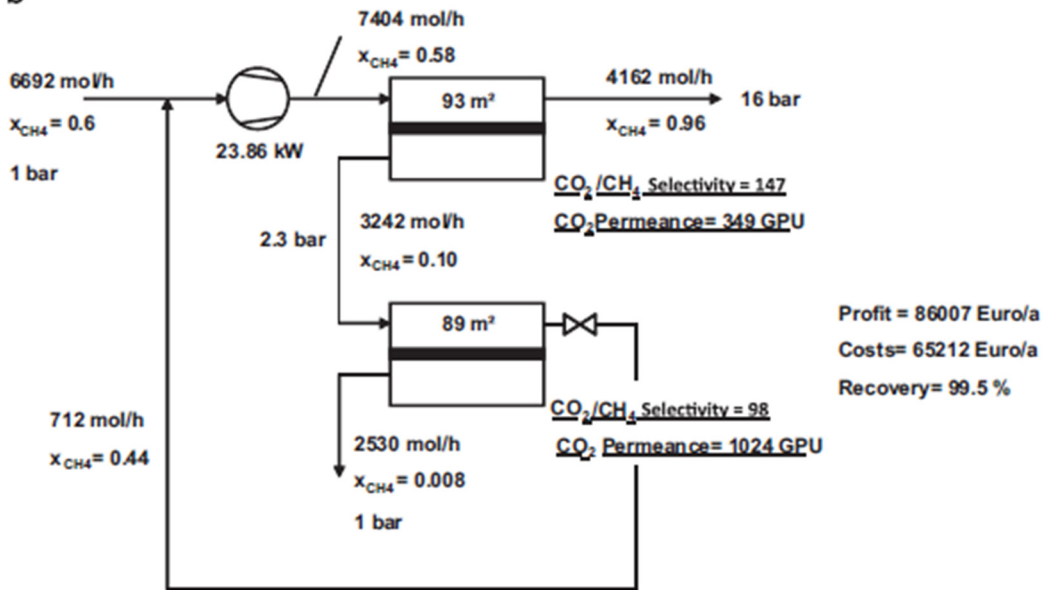
60. Figure 8 reflects an attempt by Scholz to optimize the process layout and conditions, as done before, and also to optimize the selectivities of the membranes. Figure 8(a) shows the optimal process where a single selectivity is applied to all membrane stages:



61. As shown, optimal process includes two stages in this scenario. The selectivity was optimized to 123, CH₄ recovery was 99.5%, and the annual profit was 86,238 euros.

62. Figure 8(b) shows the optimal process where the membrane properties for each stage are determined individually (i.e., the selectivities and permeances are allowed to differ between stages):

b



63. As shown, the optimal process included only two stages in this scenario. The optimal selectivities were 98 and 147, CH₄ recovery was 99.5%, and the annual profit was 86,007 euros.

64. Scholz concludes “[c]omparing two types of membrane materials the process equipped with membrane materials with a CO₂/CH₄ selectivity of 60 has a higher profit and lower costs than the process with low selective materials.”

AP1007-Scholz, 9.

IX. CLAIM CONSTRUCTION

65. I understand that when considering the meaning of patent claims, one must consider the language of the claims, the specification, and the prosecution history of the patent. I also understand that claim terms are typically given their ordinary and customary meanings as would have been understood by a person of

ordinary skill in the art at the time of the invention for the patent. For the Priske-'380 patent, as I explained above in Section IV, the relevant time that I have been asked to consider is around December 29, 2014. For purposes of my opinions in this declaration, subject to the further discussion in the next paragraph, I have been asked to consider the challenged claims under their plain and ordinary meanings as understood by a person of ordinary skill in the art at the time of the alleged invention, and I have applied such understandings in my analysis of the Priske-'380 patent and the prior art.

66. I understand that where a patent defines a claim term, the definition provided in the patent governs. Accordingly, I understand that the claim terms “capacity” and “standard conditions as defined in the description” should be applied as they are defined in Priske-'380. Priske-'380 defines membrane “capacity” as “the product of the membrane surface and the permeance of the membrane at operating temperature that is determined for nitrogen (Grade 4.8) under standard conditions”; and defines “standard conditions as defined in the description” to mean the conditions as set forth at column 14, line 51 through column 15, line 23. AP1001-Priske-'380, 2:53-57, 14:51-15:23.

X. OPINIONS REGARDING DR. BAKER'S DECLARATION

A. Ungerank And Scholz

1. Claim 1

a) Scholz Does Not Teach Limitation 1[f][iii]

67. I disagree with Dr. Baker at paragraphs 153 through 161, that Scholz teaches “the total capacity of 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.” This claim requirement is not disclosed by Scholz under Priske-’380’s definitions of “capacity” and “standard conditions as defined in the description,” and is not disclosed even if those terms are not construed.

68. As an initial matter, Scholz does not mention or discuss membrane capacity within the article. As I understand it, Dr. Baker is arguing that a person or ordinary skill “would have understood from [the disclosure in Scholz] that all the membranes in Scholz’s Figure 7 systems are the same material and have identical selectivity and permeance.” AP1003-Baker Decl., 156. Total capacity, however, is defined in Priske-’380 as “the product of the membrane surface and the permeance of the membrane at operating temperature that is determined for *nitrogen (Grade 4.8) under standard conditions*” “described in detail in [the patent’s] section [on] measurement methods.” AP1001-Priske-’380, 2:51-59 (emphasis added). Dr. Baker’s argument only works if the permeance of the membrane at operating temperature for ***nitrogen (Grade 4.8)*** under standard conditions is the same for the

two membranes. The permeance for nitrogen is not disclosed in Scholz under any conditions, let alone at the “standard conditions” specifically described in Priske-’380.

69. Dr. Baker’s circular argument (at paragraphs 156-158)—that identical *CO₂ permeances* must mean the ratio of membrane capacities correlate to the ratio of membrane surface areas, and thus the ratio of membrane surface capacities *measured under nitrogen (Grade 4.8)* must correlate to the ratio of membrane surface areas—ignores the fact that the permeances of the different gases, e.g., CO₂ and nitrogen, and the ratios of those permeances may vary.

70. Even where two membranes are composed of cellulose acetate and have a permeance for CO₂ of 60 GPU, the permeance for nitrogen (Grade 4.8) may not be identical between the two membranes as discussed in further detail below. Permeance values can vary significantly depending on chemical composition of the membrane, the size of the permeating molecule, the thickness of the membrane—even the membrane manufacturing process or operational conditions (e.g., partial pressures of specific gases exposed to the membrane) can affect the membrane’s permeance for one type of molecule versus another. For example, a POSITA would have known that CO₂ can plasticize cellulose acetate membranes and that the permeability (and, thus, permeance) of cellulose acetate is sensitive to the history of how the membrane is exposed to partial pressures of CO₂. EX2014-

Puleo, Table 9. Exposure of cellulose acetate to elevated CO₂ pressures was known to lead to a hysteresis effect where the permeability of CO₂, at a given pressure, remains higher after the membrane is exposed to high pressures of CO₂, and a POSITA would expect this hysteresis to affect the permeability of all gases. *Id.*, Fig. 13. Furthermore, different variants of cellulose acetate have different CO₂/N₂ selectivity values, meaning that cellulose acetate membranes could be made to have the same CO₂ permeance but could have different N₂ permeance. *Id.*, Table 9. Simply saying that each membrane was composed of cellulose acetate and had a permeance for CO₂ of 60 GPU does not establish that the membrane capacity “measured for nitrogen Grade 4.8 under standard conditions” is identical, either under Priske-’380’s definitions of “capacity” and “standard conditions as defined in the description” or if those terms are not construed.

71. Dr. Baker’s analysis fails to address any of the assumptions included in the definition of permeance defined by Priske-’380.

b) Dr. Baker Has Not Established Any Problem Or Design Pressures That Would Have Led To The Claimed Solution

72. Dr. Baker generally alludes to “trade-offs” between “energy and membrane replacement costs” as the problem motivating a person of ordinary skill to arrive at the claimed invention. AP1003-Baker Decl., ¶81. This is not the

problem identified in the Priske-'380 patent and even if it was, it would not lead a person of ordinary skill to the claimed invention.

73. Dr. Baker argues the claims of Priske-'380 would have been obvious to a person of ordinary skill in the art because of a need for “lower-selectivity, higher permeance membranes (and therefore smaller area and less costly membranes)” as a solution. AP1003-Baker Decl., ¶125. However, the claims of the Priske-'380 patent do not mention “lower-selectivity, higher permeance membranes” at all. Rather, the Priske-'380 patent teaches that it addresses the scenario where gas separation plants are operated at sites where energy is very cheap, and the focus of the separation process economics are on investment and maintenance costs, rather than energy costs. AP1001-Priske-'380, 1:45-52.

74. Dr. Baker does not identify any teachings in the Ungerank patent or Scholz that discuss this problem. Neither do they note where the references teach how a person of ordinary skill would arrive at the claimed invention in light of this problem.

75. Further, the Ungerank patent and Scholz do not address scenarios where the energy cost is different. Scholz assumes a fixed cost of 0.08 euros per year, and Ungerank is silent as to electrical cost. *See* AP1007-Scholz, Table 3.

76. Scholz states that “operational cost” is “mainly caused by electrical energy consumption.” AP1007-Scholz, 4. This statement indicates that Scholz

considered electrical cost as the primary driver behind the cost of operating the system and did not contemplate scenarios where the energy cost could be lower.

77. The Ungerank patent does not discuss scenarios where lower energy cost is present. Instead, the Ungerank patent focuses on the benefits of high selectivity membranes because these allow the separation to “be conducted in a more economically viable manner,” because “the necessary size of the compressor and the energy required can be reduced.” AP1006-Ungerank patent, 9:30-34.

78. Therefore, I disagree with Dr. Baker’s assertion that there was a recognized need in the references to design a membrane gas separation plant focused on scenarios with low energy cost.

79. In fact, there was no market pressure or “need” for “lower-selectivity, lower-cost membranes” in 2014 as Dr. Baker suggests. Membrane gas separation processes using membranes with a selectivity of 20, which is relatively low, were quite common in 2014.

**c) Dr. Baker Has Not Established Why A POSITA
Would Start With The Ungerank Patent**

80. Even if there were a need for systems with “lower-selectivity, lower-cost membranes,” a person of ordinary skill would not start with Ungerank’s Comparative Example 1 (“CE1”) as the base teaching for that new system.

81. The Ungerank patent uses CE1 as an undesirable system compared to the other systems in that patent. For example, the Ungerank patent teaches that the recycle volume in CE1 is not economically desirable. AP1006-Ungerank patent, 11:49-52. Further, the Ungerank patent later identifies that a 99.5% purity of CO₂ in the third permeate stream is necessary to “satisfy various legislators,” and CE1 does not achieve this CO₂ purity level. AP1006-Ungerank patent, 11:40-43, 62-63; *see also* AP1007-Scholz, 6 (“For the processes considered here, the [methane] recovery should be at least 99.5% to minimize the environmental impact caused by extensive [methane] losses.”). For these reasons alone, a person of ordinary skill would not identify CE1 as a good starting point for designing a new process.

82. Dr. Baker asserts four reasons that a person of ordinary skill, in his view, would start with Ungerank CE1 when designing a new process: (1) it has low selectivity membranes, (2) it produces relatively pure product streams, (3) it is a three stage system with a single compressor, and (4) it provides detailed information on the process parameters including gas composition, flowrates, recycle volume, pressures, and it specifies the types of membrane used. AP1003-Baker Decl., ¶¶131-133; EX2009-Baker Dep., 105:18-107:4. However, Dr. Baker admitted that the systems in Scholz Figure 7 have all of these characteristics as well. EX2009-Baker Dep., 108:3-24. As a result, Dr. Baker has not identified any

specific reason that a person of ordinary skill would have started with CE1 when designing a new separation process.

83. In fact, the Ungerank patent's CE1 would not be a good example to start with. First, the system in CE1 only processes 1.787 cubic meters per hour. AP1006-Ungerank patent, 10:24-32. A person of ordinary skill would recognize that Comparative Example 1 would have been a small scale system and that the system would not have been representative of larger-scale or commercial scale processes (e.g., processes that would require much more compression). Likewise, the membranes used in Comparative Example 1 were less common at the time and were not as commonly available from the major membrane suppliers as cellulose acetate. Thus, the example shown in CE1 has no distinguishing features that would lead a person of ordinary skill to start with this example, and then modify it to meet the claimed invention of Priske-'380.

d) A Person Of Ordinary Skill In The Art Would Not Be Motivated To Combine Scholz With The Ungerank Patent

84. I disagree with Dr. Baker's opinion (paragraphs 119-136) that a person of ordinary skill in the art would have been motivated to combine the teachings of the Ungerank patent and Scholz, for several reasons.

85. *First*, I disagree with Dr. Baker's assertion that a person of ordinary skill would look to Scholz because "Ungerank's Comparative Example 1 does not

provide any details on the membranes' surface areas" (or their ratios). AP1003, Baker Decl., ¶134. CE1 specifies that "[e]ach stage consisted of a hollow fiber membrane module consisting of hollow polyimide fibers from UBE (NM B01 A type)." AP1006-Ungerank patent, 10:24-27. A person of ordinary skill would recognize that this refers to a specific UBE membrane module. A "module" refers to a membrane unit, which has a common size to other modules of the same type. *See* EX2009-Baker Dep., 77:11-81:4; *see also* AP1007-Scholz, 6 ("assuming a gas permeation module size of 25 m² per module, 24 modules have to be installed."). This is a common use of the term "module" that a person of ordinary skill would understand. Since CE1 says each stage had "a...module," then, a person of ordinary skill would understand each stage had the same area, and the area ratio between all stages would be 1:1.

86. A person of ordinary skill would understand that the membrane area of this specific UBE module is information that UBE could provide to its customers. If UBE does not provide this information, then a person of ordinary skill could determine an estimated membrane area by physical inspection of the membrane fibers within the module (e.g., by determining the length, diameter, and number of fibers present in the module).

87. Further, if a person of ordinary skill wanted to understand more about the membrane's capacity or permeance, they could do so. The membrane capacity

of this UBE module could be determined by obtaining the module and testing the permeation of Nitrogen (grade 4.8) at the standard conditions defined in Priske-'380 through the membranes in the module. The information obtained from this measurement would enable a person of ordinary skill to calculate the capacity; a person of ordinary skill could then calculate permeance from the capacity and membrane area information determined above. Understanding these characteristics of the membrane module used in CE1, a person of ordinary skill would have enough information to model the process in process simulation software such as Aspen or ChemCad.

88. *Second*, Ungerank's CE1 works for its intended purpose. There is no supplemental information that a person of ordinary skill would need to implement the system described in CE1, so there would be no motivation for a person of ordinary skill to combine the process of CE1 with the process of Scholz.

**(1) There Is No Reason A Person Of Ordinary Skill
Would Have Selected The Specific Features
Identified In The Ungerank Patent And Scholz**

89. I disagree with Dr. Baker's analysis concerning which elements a person of ordinary skill would take from the Ungerank patent's CE1 and the processes of Scholz. The analysis from Dr. Baker on this topic appears to be based on what a person of ordinary skill arguably *could* do, rather than what that person *would* in fact do, given these references.

90. There is no suggestion in the Ungerank patent that if energy costs are low, a person of ordinary skill should turn to the process described in CE1 as opposed to any of the other examples in the Ungerank patent. Further, there is no teaching that a person of ordinary skill should take a different approach to process design if energy costs are low, and no guidance towards the specific recycle volumes, capacity ratios, or pressure ratios claimed in the Priske-'380 patent.

91. Further, Dr. Baker does not provide any reason why a person of ordinary skill would turn to Scholz and only use the membrane areas taught there. Scholz used the General Algebraic Modeling System (GAMS) to identify optimal process configurations to maximize profits for certain process requirements or conditions, such as methane recovery and while making certain assumptions such as a fixed electric cost, constant membrane permeance, and isothermal operation. The results of the optimization detail the process parameters required, such as membrane areas, pressure ratios, different gas flows and compositions, etc. The membrane areas themselves have no special significance outside of the context of the Scholz optimization exercise. Further, a person of ordinary skill would understand that they could not simply implement these membrane areas into the CE1 process without likely disturbing other parameters of the processes due to the highly interdependent nature of process optimization.

92. Dr. Baker does not explain why a person of ordinary skill would be motivated to select information from Figure 7 of Scholz when Figures 5 and 8 provide better profits, lower costs and better or similar methane recovery. Dr. Baker asserts that one reason a person of ordinary skill would use the processes from Figure 7 is that these systems use membranes with a selectivity of 20. However, Dr. Baker then notes that Scholz does not teach whether the selectivity values identified therein are pure gas or mixed gas selectivity values, obviating his own argument.

93. As discussed, the Ungerank patent states that the third permeate stream must have CO₂ purity levels of above 99.5% in order to “satisfy various legislators.” Scholz’s 7(a), with a CO₂ purity of 98% in the third permeate stream, does not meet this standard. Nor does it meet the standard of 99.5% methane recovery that Scholz identifies as needed to “minimize the environmental impact caused by extensive CH₄ losses.” AP1007-Scholz, 6. Finally, 7(a) of Scholz has a lower annual profit than any process in Figures 5 or 8 of Scholz.

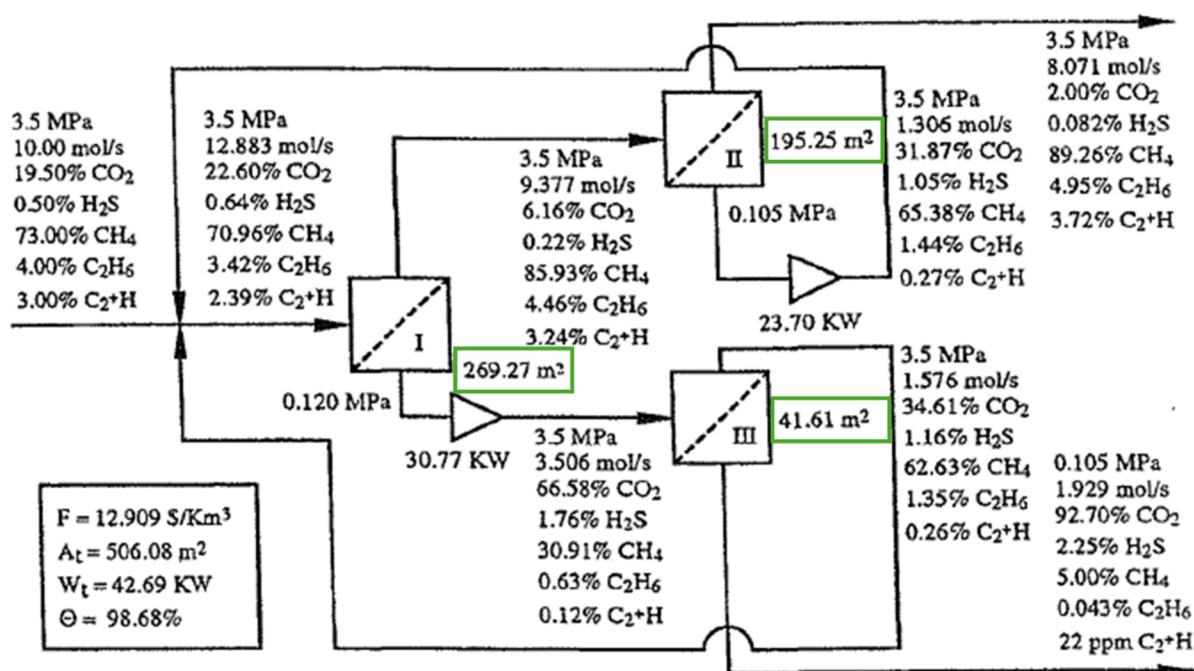
94. 7(b) of Scholz has the lowest annual profit of any process in Scholz. While this process does meet the required methane recovery identified by Scholz, it also does not meet the CO₂ purity requirement to “satisfy various legislators” identified in the Ungerank patent. Thus, a person of ordinary skill would not select information from 7(b) to incorporate into a new process based on these flaws.

e) A Person Of Skill In The Art Would Not Have Had A Reasonable Expectation Of Success In Combining The Ungerank Patent And Scholz

95. I disagree with Dr. Baker's opinion (paragraphs 137-142) that a person of ordinary skill in the art would have had a reasonable expectation of success combining the disparate teachings of the Ungerank patent with those of Scholz and achieving the claimed invention.

(1) Performance Of A System Depends On A Large Number Of Variables

96. Depending on the particular design constraints imposed on a given system, there are a very large number of considerations that must be taken into account and potentially a large number of solutions that could be considered. Even within the references that Dr. Baker identifies—a large number of *potential parameter modifications* are taught that could be considered—for example, while the model in Scholz suggests that under the conditions used to generate Figures 7(a) and 7(b) a three-stage separation system where the feed stage has a smaller membrane surface area than that of the second separation stage is the optimal configuration; Qi and Henson (Exhibit 1009) suggests the opposite in Figure 9:

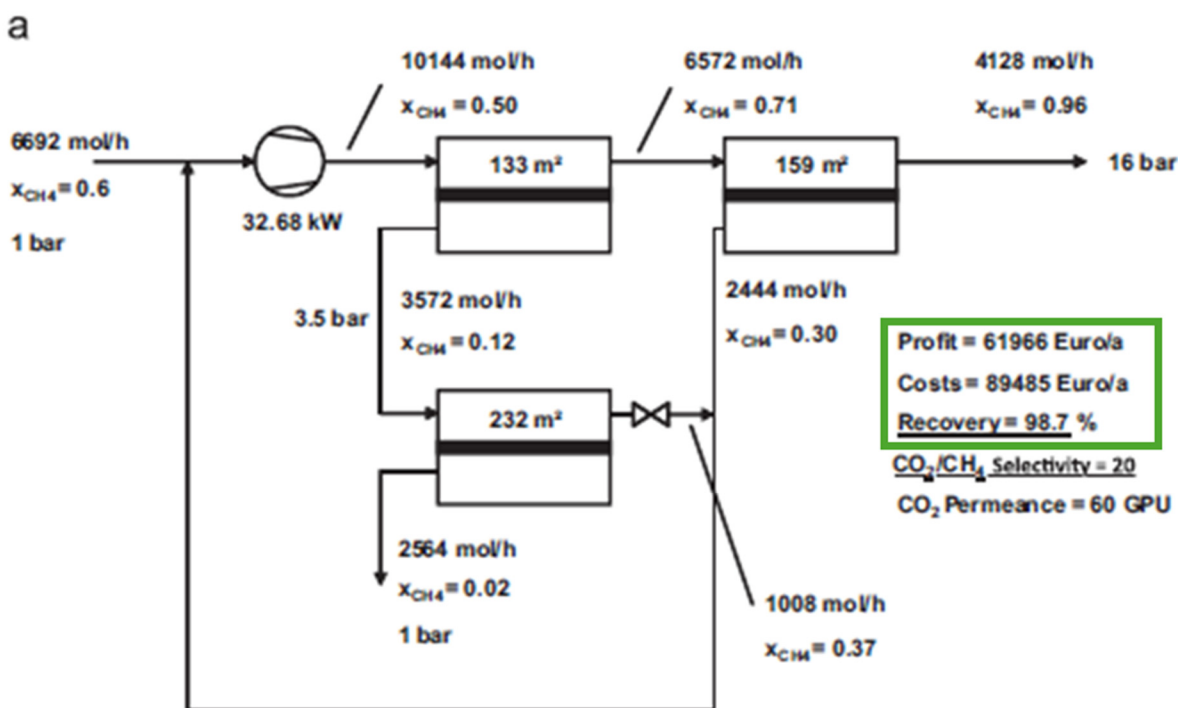


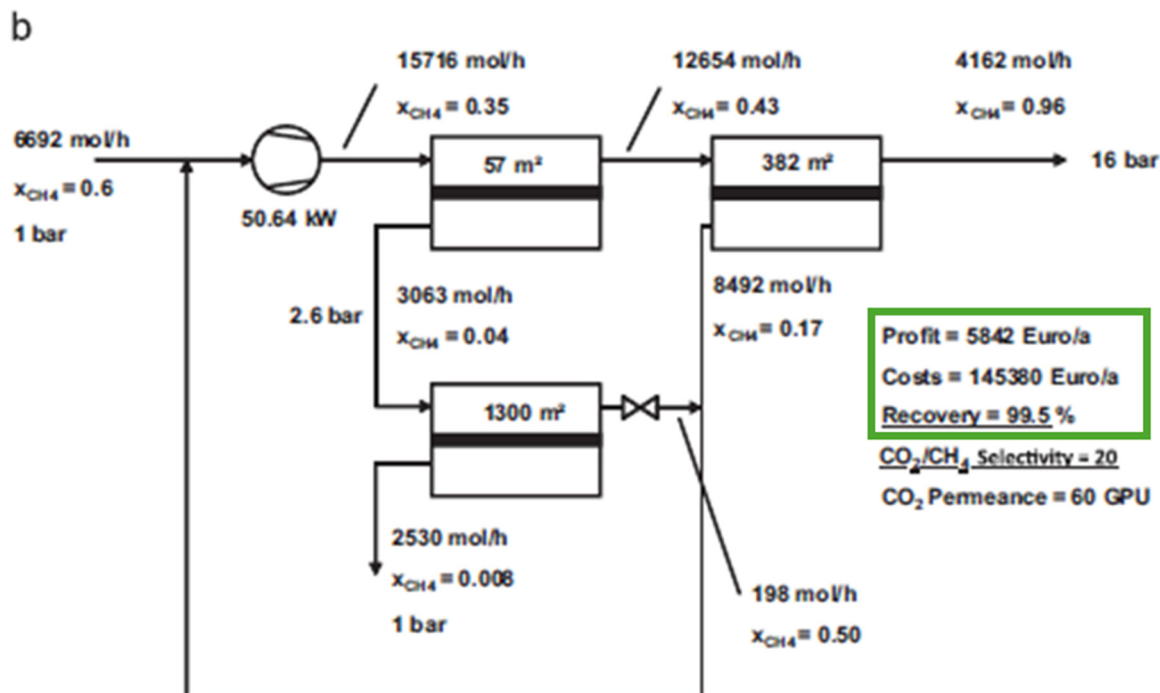
97. Given the large number of variables that could be modified, and that the effect of each of these variables on system optimization may depend in a complex manner on a number of other variables, assumptions or other design constraints—absent further guidance—a person of ordinary skill in the art would not have had a reasonable expectation of success at selecting the surface membrane ratios taught in Figures 7(a) and/or 7(b) for combination with another system with a reasonable expectation of success.

(2) Small Design Choices Can Have Large Effects

98. Even small design choices can have a significant effect on the overall system. This concept is exemplified by the differences between Figure 7(a) and Figure 7(b) of Scholz. For both models described in Scholz, the same membrane

CO₂/CH₄ Selectivity and CO₂ permeance were selected, and the economic and other assumptions were kept constant as well. The only difference between the output of Figure 7(a) and Figure 7(b), was that for Figure 7(a) the recovery was required to be at least 95% and while the recovery for Figure 7(b) was required to be at least 99.5%. This difference is seemingly small, but it is important because of environmental concerns leading to the design of methane recovery systems with a minimum methane recovery of 99.5%. What Scholz teaches is that meeting this more stringent emissions target using a membrane with these particular characteristics comes with a very large cost in terms of profitability and costs of the overall system:





Thus, even small changes to a system requirement, like recovery in Scholz's Figures 7(a) and (b) can lead to significant changes to the feasibility or the optimum configuration of a membrane gas-separation system.

(3) The Assumptions Of Scholz Differ From Those Of Ungerank

99. Further, the Scholz model includes a number of assumptions and fixed constants that are not the same as the Ungerank patent, nor necessarily reflective of real-world conditions. For example, Scholz assumes isothermal conditions across the entire membrane gas-separation system. This is rarely if ever true in real life, and it is not the assumption of the Ungerank patent Comparative Example 1. For example, Comparative Example 1 discusses gas pressures of 25 bar, 18.2 bara, 4.2 bara, and implies that the permeate stream resulting from stage 3 (stream 11 in Fig.

11) is at ambient pressure. A POSITA would recognize that these reductions in gas pressure would lead to reductions in gas (and thus stage) temperature. Temperature control is only mentioned in relation to (stream 5 in Fig. 11), and as such, a POSITA would recognize that the stage temperatures would be affected by these pressure differences.

100. As explained in Priske-'380, temperature is a variable that can affect the total capacity of each membrane—where temperature varies across the different membrane stages, total capacity *will not* correlate directly with the surface area of the membrane as it would in the strictly isothermal case. AP1001-Priske-'380, 3:1-6.

(4) Scholz Assumes Ideal Gases

101. Moreover, the Scholz model assumes that the system involves ideal gases—a condition rarely encountered in real-world applications involving CO₂ and CH₄—and does not account for concentration polarization or variations in selectivity for mixed gas transport, both of which are critical factors in the separation of mixed gas systems. Gas concentration polarization is the phenomena “[w]hen a mixture is brought to a membrane surface by any driving force, there is an accumulation of the less permeable species and a depletion of the more permeable components in the boundary layer adjacent to the membrane and this causes a concentration gradient building up in the boundary layer.” EX2015-He,

243. Concentration polarization can lead to performance losses by creating concentration gradients that reduce the driving force for separation, and changes in membrane selectivity can significantly impact the efficiency and effectiveness of the membrane in a gas separation process.

102. The literature suggests that the difference between selectivities calculated from pure gas measurements and *selectivity values measured using mixed gas measurements* can be large. AP1013-Baker Textbook, 345 (citing Lee, S.Y., Minhas, B.S., and M.D. Donohue, Effect of Gas Composition and Pressure on Permeation through Cellulose Acetate Membranes, New Membrane Materials and Processes for Separation, AiChE Symposium Series Number 261, Vol., 84, p. 183 (1988)):

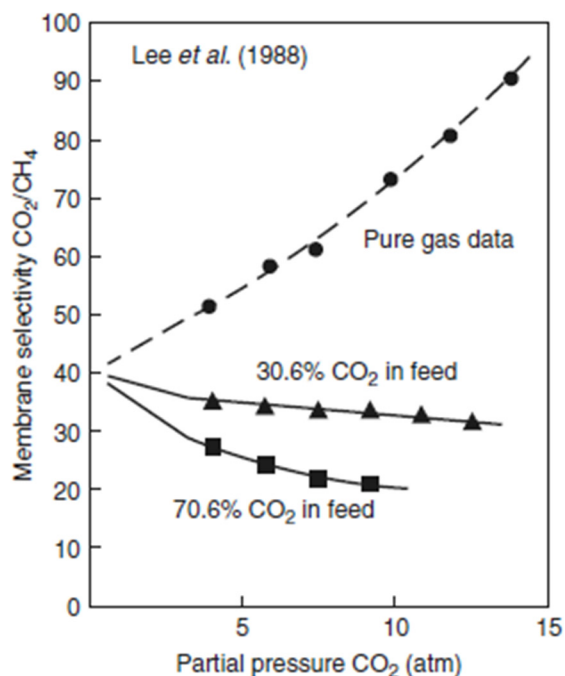


Figure 8.8 The difference between selectivities calculated from pure gas measurements and selectivities measured with gas mixtures can be large. S.Y. Lee, B.S. Minhas and M.D. Donohue, *Effect of Gas Composition and Pressure on Permeation through Cellulose Acetate Membranes*, in *New Membrane Materials and Processes for Separation*, K.K. Sirkar and D.R. Lloyd (eds), AIChE Symposium Series Number 261, Vol. 84, p. 93 (1988). Reproduced with permission of the American Institute of Chemical Engineers. Copyright © 1988 AIChE. All rights reserved.

As can be seen from the Lee et al. study, the selectivity measured with a CO₂/CH₄ mixture can be one-half or less of the selectivity calculated from pure gas measurements. A person of ordinary skill in the art, would understand that failing to account for these differences results in an overestimation of the ability of a membrane to separate a target gas mixture. Thus, a person of skill in the art would not have simply expected the calculated membrane areas and the given selectivities to have successfully translated to a system that was practically combinable with Ungerank with any expectation of success.

**(5) A Membrane Scientist Would Not Extract
Features From Output From A Model**

103. It would not be reasonable from the perspective of a POSITA to extract the specific surface area membrane values from *any figure generated by the Scholz optimization process* and combine them with another system while maintaining a reasonable expectation of success, as the approach taken by Scholz (i.e., assumptions and omissions) fails to reflect the complexities of real-world gas separation processes. Dr. Baker's analysis fails to consider how a person of skill in the art would read and apply an academic journal article like Scholz. Instead of selecting disparate features from the output generated by the Scholz models—a person of skill in the art would have simply read Scholz at face value for what it taught—namely the qualitative variation of characteristics such as membrane selectivity, permeance and desired methane recovery *can have an impact* on process design and the economics (profits/costs) of a given system. But as explained above, Scholz does not teach *specifically how* these variables impact the output - it does not provide the details of all its calculations, and even recommends *against* the use of experience or heuristics for selecting membrane surface area parameters. *See* AP1007-Scholz, 1. Given these limitations, there would be no basis for a person of ordinary skill in the art to have a reasonable expectation of success in adjusting these parameters from the optimal values established by Scholz.

104. Finally, the Scholz optimization produced results that are undesirable to a POSITA, particularly in terms of the membrane areas calculated. Dr. Baker even indicated he would have altered the pressures instead of using a membrane of 1,300 m² in Scholz 7(b). EX2009-Baker Dep., 124:12-126:8

2. Claim 9

105. I disagree with Dr. Baker's declaration at paragraphs 173 through 176, that Ungerank's Comparative Example 1 renders obvious "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."

106. First, a 2% change in recycle volume would not result in the same separation process. Such a change would affect the purity of the process's product streams. While real world processes may have tolerances that can accept swings of 2% in recycle volume, that does not mean that setting the target recycle volume 2% higher or lower would not result in different process performance. Accordingly, a person of ordinary skill would understand that changing the recycle volume by 2% would not result in the same system.

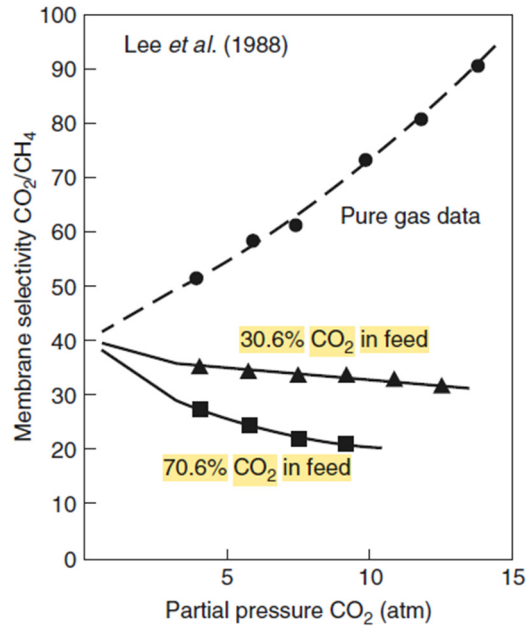
3. Claim 12

107. Claim 12 requires that "the gas separation membranes in the feed stream separation stage have a pure gas selectivity for CO₂/CH₄ of from 20 to 100." AP1001-Priske-'380, cl. 12. Dr. Baker asserts that the Ungerank patent's

disclosure of a mixed-gas selectivity of 20 in Comparative Example 1 would translate to a pure gas selectivity that is “not ... more than 500% higher”—i.e., no more than 100. AP1003-Baker Decl., ¶178. This position is unsupported.

108. First, Comparative Example 1 uses polyimide membranes, but the data Dr. Baker relies on to demonstrate a relationship between mixed-gas selectivity and pure gas selectivity relates to cellulose acetate membranes. AP1013-Baker Textbook, 345-46. Dr. Baker does not state that the relationship would be the same for different materials, let alone offer any evidence or reasoning for this conclusion.

109. Second, even if the data Dr. Baker cites was relevant, that data is insufficiently detailed to indicate what the pure gas selectivity would be for a mixed-gas selectivity of 20 and a feed stream including 61.2% CO₂, as in Ungerank's Comparative Example 1. The graph Dr. Baker relies on, reproduced below, does not include data pertaining to a 61.2% CO₂ feed stream.



AP1013-Baker Textbook, Fig. 8.8.

110. As a result, Dr. Baker's evidence does not indicate what the pure gas selectivity would be for a mixed-gas selectivity of 20, or whether the pure gas selectivity would be less than (or equal to) 100 as claim 12 requires. AP1003-Baker Decl., ¶178.

4. Claim 17

111. Dr. Baker's opinion that CE1 teaches claim 17 fails because CE1 does not teach or suggest a "multistage compressor" where the "second permeate stream, third retentate stream, or both are introduced into the compressor between the two compression stages." As Dr. Baker conceded, Comparative Example 1 "is [a] very small" system, and that "multistage compressor[s]" are for use with a "big system[s]" not small ones like that of Comparative Example 1. EX2009-Baker

Dep., 117:22-120:14. I agree. Dr. Baker's testimony is in direct contradiction with his opinion that Comparative Example 1 can include a multistage compressor.

AP1003-Baker Decl., ¶190.

112. A person of ordinary skill would understand that compressors are a significant cost component of a membrane gas separation system and would not simply seek to introduce a multistage compressor without explicit motivation. Further, since the recycle streams shown in Ungerank are combined with the crude gas stream that is at or near atmospheric pressure, it is assumed that the recycle streams are also at or near atmospheric pressure. Thus, there would be no need for a multistage compressor since the crude and recycle streams are at the same pressure. Finally, if the pressure of the recycle streams (or the crude stream) were raised to enable use of a multistage compressor, this would directly impact the pressure ratios of the system (and the quotients of them), thus significantly modifying the process.

113. For these reasons, I disagree that the proposed combination of Ungerank and Scholz renders any of the claims of Priske-'380 obvious.

B. Scholz Alone

114. I disagree with Dr. Baker regarding Scholz for a number of reasons. Scholz fails to teach limitations 1[f][i] and 1[f][ii], a person of ordinary skill would

not be motivated to modify Scholz as asserted, and a number of dependent claims are not taught or suggested by Scholz.

1. Claim 1

a) Limitation 1[f][i]

115. Limitation [1f.1] recites “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.” AP1003-Baker Decl., ¶205. Scholz does not provide any examples of processes meeting the recycle volume in this limitation. Dr. Baker notes that Scholz teaches a recycle volume of 51% in 7(a) and 135% in 7(b). *Id.* However, I disagree with Dr. Baker that Scholz teaches or suggests the claimed range of 60-100%.

116. First, a person of ordinary skill would not see Figure 7 of Scholz and understand that the figure teaches a range of acceptable recycle volume limitations. The systems in 7(a) and 7(b) are different systems, as evidenced by their different methane recovery targets. Each system incorporates the specific conditions that the Scholz optimization approach used for the desired design criteria, including recycle volume as well as other parameters such as pressure and membrane area, among others. As a result, a person of ordinary skill would not understand from Scholz that simply any value between the two values taught, 51% and 135%, is desirable. Changing the recycle volumes would result in reduced performance

relative to the Scholz optimization for the respective systems because the membrane areas, pressures, and other process parameters are interdependent. As such, the recycle volume in each system cannot be seen in a vacuum—the entire process must be considered.

117. Second, a person of ordinary skill in the art would understand that incorporating the claimed range of recycle volumes, 60-100%, into the Scholz model would produce significantly different outcomes in the Scholz optimization process. A change to the recycle volume would result in other changes to the system, such as different membrane areas, different pressure ratios, different methane recovery or some combination of these factors. This is particularly true if the changes are relatively large, such as going from 51% to the low end of the range, 60% (a 17.5% increase), or from 135% to the high end of the range, 100% (a 25.9% reduction). Simply put, a person of ordinary skill would understand that the values of 51% and 135% in Scholz are significantly different from the claimed range of 60-100%.

118. Third, Dr. Baker has not identified any reasons that a person of ordinary skill in the art would modify the systems of Scholz Figure 7 to achieve a recycle volume in the claimed range. To start, Scholz explains that these are the optimized systems. The models in Scholz Figure 7 have different recovery requirements, 7(a) targets 95% and 7(b) targets 99.5%. Put differently, these

recovery targets are the variable that changes between 7(a) and 7(b). Dr. Baker has not suggested that a person of ordinary skill in the art would be motivated to pursue a different methane recovery target. Table 3 of Scholz shows that the sale of methane is the only source of revenue for the process, so lower methane recovery will lead to lower amounts of methane for sale, and thus lower revenue.

119. Dr. Baker does suggest that a person of ordinary skill would understand that lowering the CO₂ purity requirement in 7(b) could lead to a lower recycle volume. However, Dr. Baker does not suggest a different CO₂ purity that would achieve this result, and there is no support in the Scholz reference that there was a high CO₂ purity requirement in the first place. Scholz states at page 5 that “[i]n the optimization a *product gas purity of at least 96%* together with a CH₄ recovery of more than 95% and 99.5%, respectively, have to be met.” AP1007-Scholz, 5 (emphasis added). A person of ordinary skill would understand that this means the required CO₂ purity was at least 96%. Dr. Baker notes the CH₄ purity in 7(b) is 0.008 (meaning the CO₂ purity is 0.992, or 99.2%), and states that “a POSITA would have been motivated to use a lower recycle percentage to save on energy costs if lower purity CO₂ was sufficient.” AP1003-Baker Decl., ¶209. In fact, in Figure 7(a) and 7(b), a lower purity CO₂ *was* sufficient since the *requirement was only to have the CO₂ purity above 96%, and the optimization still*

arrived at 98% and 99.2% as the desired CO₂ purity value in Figures 7(a) and 7(b), respectively. See AP1007, Scholz, Fig. 7.

120. Dr. Baker also does not properly handle the concepts of purity and recovery. A person of ordinary skill would understand methane purity, for example, refers to the concentration of methane in one stream. Methane recovery refers to the fraction of methane from the crude gas stream that is present, or “recovered,” in the methane product stream. The methane recovery calculation depends on the purity of the two product streams *and* the flow rates of the two streams. For example, the methane purity in the methane product stream can be moderate while still achieving a reasonably high recovery, provided that there is not much methane leaving the system in the third stage permeate stream (e.g., through a low permeate flow rate from the third stage).

121. Dr. Baker also suggests that a person of ordinary skill would use Aspen or ChemCad to optimize the results of Scholz. *See, e.g., AP1003, ¶207.* However, Dr. Baker does not identify an example of a simulation arriving at the claimed recycle range. The Scholz reference already used an optimization software package, GAMS, to arrive at its results, and as Dr. Baker notes, Scholz did not arrive at a process within the claimed recycle volume range.

b) Limitation 1[f][ii]

122. For the same reasons discussed with respect to the Ungerank patent, Dr. Baker has failed to demonstrate that Scholz teaches the Total Capacity Ratios of Limitation 1[f][ii].

c) Motivation To Modify

123. A person of ordinary skill reading Scholz would not be motivated to modify the processes to arrive at a process according to the claims of the Priske-'380 patent, as discussed in relation to the challenged claims above and below.

2. Claim 8

124. Claim 8 further recites that “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.” AP1001, Claim 8. I disagree with Dr. Baker’s opinion that claim 8 would have been obvious in light of Scholz

125. As Dr. Baker notes, assuming his analysis is correct, the relevant capacity ratio in Scholz 7(a) is 1.7. AP1003-Baker Decl., ¶231. The relevant capacity ratio in 7(b) would be 22.8 ($130/57=22.8$). Dr. Baker apparently suggests that a person of ordinary skill would arrive at the claimed capacity ratio range through mere experimentation. Going from Scholz’s closest value to the closest point in the claimed range constitutes a 41% reduction in the capacity ratio ([1.7-

1]/1.7). While a person of ordinary skill can simulate processes using programs such as Aspen, ChemCad, or GAMS, changing capacity ratios by 41% is more than mere experimentation, it is more like reworking the entire system. Using Scholz as a guide, a person of ordinary skill would understand that the model in 7(a) achieved its goal of 95% methane recovery, and thus would not have a motivation to rework the entire process.

126. Dr. Baker does not provide any actual reason a person of ordinary skill would be motivated to rework the systems either. Dr. Baker simply states the claimed range is “close” to that of 7(a). AP1003-Baker Decl., ¶231. There is no other discussion of a specific reason a person of ordinary skill would target the modification of this capacity ratio. In fact, references in the art suggest that further decreasing the capacity ratio (away from the claimed range) is viable. *See* AP1009-Qi, Fig. 9. Dr. Baker cited to Figures 4 and 5 of the Qi reference in paragraph 141 of his declaration, but he admitted later that Figure 9 of the Qi reference is more relevant to the systems in Scholz and Ungerank. EX2009, Baker Dep., 165:18-168:15. Figure 9 shows a capacity ratio of the permeate stage to the feed stage of 0.155, according to Dr. Baker’s calculation method ($41.61/269.27=0.155$). *See id.*; AP1009-Qi, Fig. 9.

127. Further, Dr. Baker has provided no evidence that modifying this capacity ratio as proposed would result in a system otherwise meets the

requirements of the claim (and the claim it depends from). Finally, I note that Dr. Baker has not actually performed this modification using simulation software, or at the least has not shared it.

3. Claim 9

128. Claim 9 recites “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.” AP1001-Priske-’380, cl. 9. Dr. Baker asserts that this claim limitation would have been obvious in light of Scholz. I disagree.

129. First, Dr. Baker asserts that Scholz discloses “a range of 51-135% for the recycle percentage,” which is a misinterpretation of the information in Scholz. AP1003-Baker Decl., ¶232. As discussed, the processes in 7(a) and 7(b) of Scholz are aimed at different outcomes for methane recovery. Accordingly, the processes disclosed there are not the same, and the recycle volumes disclosed there are not properly seen as the bounds of a range that would work as intended. In 7(a) a recycle volume of 51% is taught, along with the other process conditions, to achieve a recovery of at least 95% with the highest profit. Likewise, in 7(b) a recycle volume of 135% along with other, different, process conditions are taught to achieve a recovery of 99.5% with the highest profit.

130. A person of ordinary skill in the art would not expect that the claimed recycle volume range, 65-85%, would have the same results as a system with 51%

or 135% recycle volume. In fact, a person of ordinary skill would understand that the processes would be different.

131. Due to this and the reasons explained above in paragraphs 115-121, claim 9 would not have been obvious in view of Scholz.

4. Claim 10

132. Claim 10 recites “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.” AP1001-Priske-'380, cl. 10. Dr. Baker asserts that this claim limitation is obvious in light of Scholz. I disagree.

133. First, I note that Dr. Baker again asserts that Scholz discloses a “range” of pressure ratio quotients, from the values in 7(a) and 7(b) of 0.42 and 0.77, respectively. AP1003-Baker Decl., ¶213. For the reasons I already stated in [Claim 9], these disclosures in Scholz are not properly considered a range, but they are in fact two discrete values of the pressure ratio quotient.

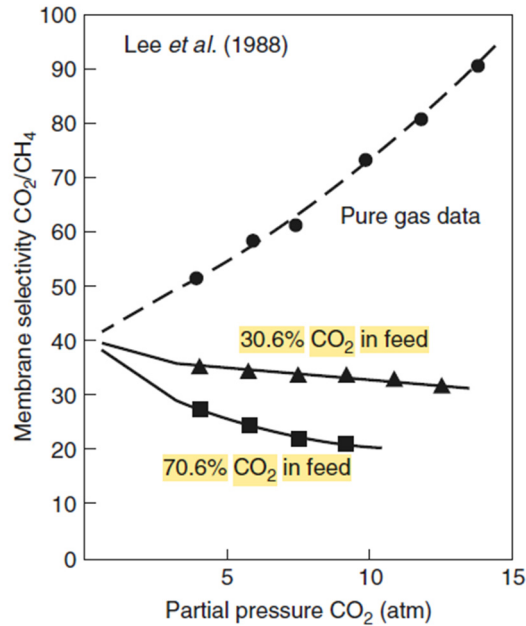
134. Further, Dr. Baker argues again that a person of ordinary skill would arrive at the claimed values of 1 to 3 by mere experimentation, starting from the values disclosed in Scholz. I disagree. Modifying the closest value of Scholz to arrive at the closest end of the claimed range would constitute a 30% increase in the pressure ratio quotient ($(1-0.77)/0.77$). Again, while a person of ordinary skill can manipulate processes using programs such as Aspen, ChemCad, or GAMS,

changing pressure ratios by 30% is more than mere experimentation, it is more like reworking the entire system. Such a change to the pressure ratio would require significant changes to other process parameters too. Since the process in Scholz 7(a) was shown to achieve its required purity of at least 95% and optimized for the highest profit, a person of ordinary skill would understand this process works for its intended purpose and have no motivation to modify it.

135. Finally, I note that Dr. Baker has not provided a software simulation showing the claimed pressure ratios in the process of Scholz, let alone showing that the process incorporating these ratios would arrive at the rest of the claimed limitations.

5. Claim 12

136. As Dr. Baker acknowledges, Scholz does not specify whether its disclosure of a selectivity of 20 refers to mixed-gas or pure gas. EX2009-Baker Decl., ¶239. Petitioner does not identify a reason a person of ordinary skill would interpret Scholz to refer to the latter. Even if the selectivity value of 20 disclosed in Scholz refers to mixed-gas selectivity, Dr. Baker's cited graph, reproduced below, does not include data relating to a 50% or 65% CO₂ feed stream such as that of Scholz 7(a) and 7(b), respectively.



AP1013-Baker Textbook, Fig. 8.8.

137. Therefore, this evidence does not indicate what the pure gas selectivity would be for a mixed-gas selectivity of 20, or whether the pure gas selectivity would be less than (or equal to) 100 as claim 12 requires. AP1003-Baker Decl., ¶239. Thus, claim 12 would not have been obvious to a POSITA based on Scholz.

6. Claim 17

138. Claim 17 requires use of a multistage compressor. A multi-stage compressor is more expensive than a single-stage compressor. EX2009-Baker Dep., 109:14-22. Dr. Baker provides no articulation of why a multistage compressor would be used in connection with either the Figure 7(a) or Figure 7(b) embodiment as contemplated by Scholz, beyond stating that doing so would

“reduce energy demand.” AP1003-Baker Decl., ¶242. Dr. Baker provides no explanation why a POSITA would have believed that any offset in energy demand would justify the use of a more expensive compressor for a system with a recycle rate in the claimed range or with membranes with the required relative capacities. *See* AP1003-Baker Decl., ¶242.

139. A person of ordinary skill would understand that compressors are a significant cost component of a membrane gas separation system and would not simply seek to introduce a multistage compressor without explicit motivation. Further, since the recycle streams shown in Scholz are combined with the crude gas stream that is at or near atmospheric pressure, it is assumed the recycle streams are also at or near atmospheric pressure. Thus, there would be no need for a multistage compressor since the crude and recycle streams are at or are nearly at the same pressure. Finally, if the pressure of the recycle streams (or the crude stream) was raised to enable use of a multistage compressor, this would directly impact the pressure ratios of the system (and the quotients of them), thus significantly modifying the process.

XI. CONCLUSION

140. For the reasons stated above, I disagree with Dr. Baker that either the combination of the Ungerank patent and Scholz, or Scholz alone, renders obvious any of the challenged claims of Priske-’380.

XII. AVAILABILITY FOR CROSS-EXAMINATION

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

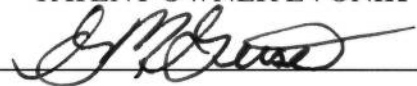
XIII. RIGHT TO SUPPLEMENT

142. I reserve the right to supplement my opinions in the future to respond to any arguments that Petitioner raises and to take into account new information as it becomes available to me.

XIV. JURAT

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

Dated: 12/12/2024

By: 

Geoffrey Geise, Ph.D.

APPENDIX A

GEOFFREY MATTHEW GEISE

Associate Professor, Department of Chemical Engineering, University of Virginia
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EDUCATION:

Ph.D.	Chemical Engineering, The University of Texas at Austin – Austin, Texas	August 2012
M.S.E.	Chemical Engineering, The University of Texas at Austin – Austin, Texas	December 2010
B.S.	Chemical Engineering (with High Distinction) The Pennsylvania State University – University Park, Pennsylvania	May 2007

APPOINTMENTS:

- ◆ **The University of Virginia** – Charlottesville, Virginia
Associate Professor, Department of Chemical Engineering 2020 to Present
Associate Professor, Department of Materials Science & Engineering (by courtesy) 2020 to Present
Assistant Professor, Department of Chemical Engineering 2014 to 2020
- ◆ **Commonwealth Scientific and Industrial Research Organisation (CSIRO)** – Clayton, Victoria, Australia
Visiting Scientist, Applied Porous Materials Area Spring 2023
- ◆ **Lawrence Berkeley National Laboratory** – Berkeley, California
Visiting Professor, Energy Technologies Area Fall 2022
- ◆ **The Pennsylvania State University** – University Park, Pennsylvania
Postdoctoral Scholar, Materials Science and Engineering 2012 to 2014
Research Advisors: Prof. Michael A. Hickner and Prof. Bruce E. Logan
- ◆ **The University of Texas at Austin** – Austin, Texas
Graduate Research Assistant, Department of Chemical Engineering 2007 to 2012
Thesis Advisors: Prof. Donald R. Paul and Prof. Benny D. Freeman

HONORS / AWARDS:

Journal of Membrane Science Editors' Choice Article	2024
Robert A. Moore, Jr. Award in Chemical Engineering	2024
Best ACS <i>ES&T Engineering</i> Paper for 2022 (https://doi.org/10.1021/acsestengg.3c00503)	2023
Led UVA-based Team TELEPORT to a runner-up win in the American-Made Geothermal Lithium Extraction Prize (managed by NREL)	2023
American Chemical Society Petroleum Research Fund Excellence in Peer Review	2023
Selected by the U.S. National Academy of Sciences as a Delegate for the 1 st U.S.-Africa Frontiers of Science, Engineering, and Medicine Symposium	2022
Robert A. Moore, Jr. Award in Chemical Engineering	2021
2020 Class of Influential Researchers (<i>Industrial & Engineering Chemistry Research</i>)	2020
Best <i>ES&T Letters</i> Paper for 2019 (https://doi.org/10.1021/acs.estlett.0c00347)	2020
Hartfield Excellence in Teaching Award (Jefferson Scholars Foundation)	2019
University of Virginia Student Council Teaching Award	2019
All-University Teaching Award from the University of Virginia	2019
Selected by the U.S. National Academy of Sciences as a Delegate for the 6th Arab-American Frontiers of Science, Engineering, and Medicine Symposium	2018
Robert A. Moore, Jr. Award in Chemical Engineering	2018
National Science Foundation Faculty Early Career Development Program (CAREER) Award	2018
University of Virginia SEAS Research Innovation Award	2018
ACS Excellence in Review Award (<i>Industrial & Engineering Chemistry Research</i>)	2018
University of Virginia SEAS Research Innovation Award	2017
Ralph E. Powe Junior Faculty Award	2016

Engineering Conferences International New Professor Travel Award	2016
North American Membrane Society (NAMS) Young Membrane Scientist Award.....	2015
Excellence in Diversity Fellowship (University of Virginia).....	2014
First Prize Poster Presentation in the Penn State University Postdoc Research Exhibition	2013
The Pennsylvania State University Office of Postdoctoral Affairs Travel Award.....	2013
University of Texas Office of Graduate Studies Professional Development Award	2011
International Congress on Membranes & Membrane Processes (ICOM)	
Outstanding Oral Presentation Award.....	2011
North American Membrane Society (NAMS) Travel Award	2011
University of Texas Office of Graduate Studies Professional Development Award	2010
University of Texas Graduate Engineering Council Travel Grant	2010
University of Texas Graduate Fellowship in Engineering	2007 – 2011
Selected to represent the Pennsylvania State University Class of 2007	
B.S. Chemical Engineers as Student Marshall at Commencement	2007
Merck & Co. Inc. Student Fellowship.....	2006

PUBLICATIONS:

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[Invited Special Issue Contribution]

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INVITED LECTURES:

33. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Department of Chemistry & Polymer Science, Stellenbosch University* (Stellenbosch, South Africa), November 15, 2024.
32. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Lenfest Center for Sustainable Energy, Columbia University* (New York, NY), October 3, 2024.
31. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Polymers & Membranes for Clean Energy & Resource Recovery Workshop, National Renewable Energy Laboratory* (Golden, CO), August 22, 2024.
30. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Department of Chemical Engineering, University of Florida* (Gainesville, FL), February 6, 2024.
29. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *University of Melbourne* (Melbourne, VIC Australia), March 17, 2023.
28. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Commonwealth Scientific and Industrial Research Organisation – CSIRO* (Clayton, VIC Australia), March 2, 2023.
27. G.M. Geise, “Structure/property relationships in desalination polymer membranes” *Stanford University Water Group* (Stanford, CA), November 11, 2022.
26. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *National Renewable Energy Laboratory (NREL)* (Golden, CO), September 15, 2022.

25. G.M. Geise, “Controlling desalination via polymer membrane chemistry” *Role of Polymer Science in Water Purification Membranes*, American Chemical Society (ACS) Division of Polymer Chemistry, May 5, 2022.
24. G.M. Geise, “Engineering ion transport in polymer membranes for water purification and energy applications” *Department of Materials Science & Engineering, University of Virginia* (Charlottesville, VA), September 21, 2020.
23. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical Engineering, University of Virginia* (Charlottesville, VA), July 15, 2020.
22. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Joint Center for Artificial Photosynthesis (JCAP) Polymers Group, Lawrence Berkeley National Laboratory* (Berkeley, CA), July 8, 2020.
21. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Departments of Chemical Engineering and Earth and Environmental Engineering, Columbia University* (New York, NY), February 28, 2020.
20. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical & Biomolecular Engineering, University of Connecticut* (Storrs, CT), November 21, 2019.
19. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical and Biological Engineering, University at Buffalo* (Buffalo, NY), October 9, 2019.
18. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Ralph E. Martin Department of Chemical Engineering, University of Arkansas* (Fayetteville, AR), September 12, 2019.
17. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical and Biomolecular Engineering, University of Notre Dame* (South Bend, IN), April 9, 2019.
16. G.M. Geise, “Structure/property relationships in polymers for membrane applications” *DOW Water & Process Solutions* (Edina, MN), August 10, 2018.
15. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Don Paul 50 Years Symposium, University of Texas at Austin* (Austin, TX), October 13, 2017.
14. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical & Biological Engineering, Colorado School of Mines* (Golden, CO), September 29, 2017.
13. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Department of Chemical & Biomolecular Engineering, Clemson University* (Clemson, SC), March 2, 2017.
12. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Materials Science & Engineering Division, National Institute of Standards and Technology* (Gaithersburg, MD), September 23, 2016.
11. G.M. Geise, “Structure/property relationships in polymer membranes for water purification and energy applications” *Center for Nanophase Materials Sciences (CNMS) at Oak Ridge National Laboratory* (Oak Ridge, TN), January 14, 2016.

10. G.M. Geise, “Grand challenges for fresh water availability and emerging polymer membrane technologies for water purification and energy” *National Science Foundation Workshop: FEWS: Food-Energy-Water Systems Challenging Chemists in the 21st Century* (Arlington, VA), October 15, 2015.
9. G.M. Geise, “Structure/property relationships in polymer membranes for water and energy” *Virginia Commonwealth University, Department of Chemical and Life Science Engineering* (Richmond, VA), February 11, 2015.
8. G.M. Geise, B.D. Freeman, D.R. Paul, “Structure/Property relationships in polymer membranes for water purification and power generation” *The Pennsylvania State University, Department of Materials Science & Engineering* (University Park, PA), February 28, 2012.
7. G.M. Geise, J.E. McGrath, B.D. Freeman, D.R. Paul, “Fundamental salt sorption and permeability properties of polymeric membrane materials” *DOW Water & Process Solutions* (Edina, MN), October 18, 2011.
6. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for desalination applications” *Université Paul Cézanne* (Aix-en-Provence, France), May 7, 2010.
5. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for desalination applications” *Université Paul Sabatier* (Toulouse, France), May 5, 2010.
4. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for desalination applications” *The University of Melbourne Department of Chemical Engineering* (Melbourne, VIC Australia), March 11, 2010.
3. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for desalination applications” *Victoria University* (Werribee, VIC Australia), March 4, 2010.
2. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes” *The University of New South Wales* (Sydney, NSW Australia), February 16, 2010.
1. G.M. Geise, B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes” *Commonwealth Scientific and Industrial Research Organisation – CSIRO* (Clayton, VIC Australia), January 29, 2010.

PRESENTATIONS:

117. Y.T. Bimbatti (Presenting), D. Ipekçi, X. Wang, I. Oliveira do Carmo Nascimento, A. Harris, V. Yang, H. Gerber, B. Li, G.M. Geise, P. Kohl, J.R. McCutcheon, “Thin film composite ion exchange membranes by electrospray” (Oral Presentation) *2024 AIChE Annual Meeting* (San Diego, CA), October 30, 2024.
116. D. Ipekçi (Presenting), Y.T. Bimbatti, X. Wang, I. Oliveira do Carmo Nascimento, A. Harris, G.M. Geise, B. Li, J.R. McCutcheon, “Sulfonated polyamide thin film composite cation exchange membrane (CEM) synthesis by electrospray” (Oral Presentation) *2024 AIChE Annual Meeting* (San Diego, CA), October 30, 2024.
115. S.M. Bannon, G.M. Geise (Presenting), “Engineering and modeling ion transport in sulfonated polysulfone” (Oral Presentation) *2024 AIChE Annual Meeting* (San Diego, CA), October 29, 2024.

114. G.M. Koenig Jr. (Presenting), G.M. Geise, J. Wang, A. Hawkins, A.T. Saasi, “Selective extraction of lithium from brines via chemical reduction of intercalation materials” (Poster Presentation) *2024 AIChE Annual Meeting* (San Diego, CA), October 29, 2024.
113. G.M. Geise (Presenting), “Microwave dielectric relaxation spectroscopy: A technique to inform ion transport in hydrated polymer membranes” (Oral Presentation) *Telluride Science – Water: Grand Challenges for Molecular Science and Engineering* (Telluride, CO), June 13, 2024. **[Invited Contribution]**
112. S.M. Bannon (Presenting), G.M. Geise, “The influence of Donnan-Manning and dielectric exclusion on ion partitioning in sulfonated polysulfone” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 15, 2024.
111. P.M. McCormack, G.M. Koenig Jr., G.M. Geise (Presenting), “Selective ion conducting polymers for non-aqueous redox flow battery applications” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 15, 2024.
110. G.M. Geise (Presenting), “Microwave dielectric relaxation spectroscopy: A technique to inform ion transport in hydrated polymer membranes” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 14, 2024.
109. N. Sreedhar (Presenting), B. Tremblay, R. Lee, K. Gaffrey, G.M. Geise, M. Paul, M. Kumar, A. Roy, “Fabrication of asymmetric nanofiltration membranes prepared from sulfonated poly(arylene ether sulfone) for monovalent-divalent ion separation” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 13, 2024.
108. D. Ipekçi (Presenting), Y.T. Bimbatti, X. Wang, I. Oliveira do Carmo Nascimento, A. Harris, G.M. Geise, B. Li, J.R. McCutcheon, “Sulfonated polyamide thin film composite membranes for electrodialysis” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 13, 2024.
107. Y.T. Bimbatti (Presenting), D. Ipekçi, X. Wang, I. Oliveira do Carmo Nascimento, A. Harris, V. Yang, H. Gerber, B. Li, G.M. Geise, P. Kohl, J.R. McCutcheon, “Thin film composite ion exchange membranes by electrospray” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 13, 2024.
106. S.M. Bannon (Presenting), E. Kutner, B. Garretson, G.M. Geise, “Understanding the influence of external sodium chloride concentration on ion diffusion in sulfonated polymers” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 13, 2024.
105. D. Ipekçi (Presenting), Y.T. Bimbatti, X. Wang, I. Oliveira do Carmo Nascimento, A. Harris, G.M. Geise, B. Li, J.R. McCutcheon, “Sulfonated polyamide thin film composite membranes for electrodialysis” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Santa Fe, NM), May 13, 2024.
104. P.M. McCormack, J. Wang, C.G. Morin, G.M. Koenig Jr., G.M. Geise (Presenting), “Advanced materials for green energy & sustainable electrification” (Poster Presentation) *2nd U.S.-Africa Frontiers of Science, Engineering, and Medicine Symposium* (Rabat, Morocco), January 16, 2024. **[Invited Contribution]**
103. G.M. Geise (Presenting), “Microwave dielectric relaxation spectroscopy: A technique to inform ion transport in hydrated polymer membranes” (Oral Presentation) *2023 AIChE Annual Meeting* (Orlando, FL), November 8, 2023. **[Invited Contribution]**
102. D. Ipekçi (Presenting), Y. Bimbatti, A. Harris, I. Oliveira do Carmo Nascimento, G.M. Geise, J.R. McCutcheon, “Polyamide-based thin film cation exchange membrane synthesis” (Oral Presentation) *2023 AIChE Annual Meeting* (Orlando, FL), November 7, 2023.

101. S.M. Bannon (Presenting), G.M. Geise, “The superposition of dielectric and Donnan exclusion and their influence on sodium chloride transport in sulfonated polysulfone” (Oral Presentation) *2023 AIChE Annual Meeting* (Orlando, FL), November 7, 2023.
100. A. Harris (Presenting), I. Oliveira do Carmo Nascimento, D. Ipekçi, J.R. McCutcheon, G.M. Geise, “Analysis of manufacturing methods of ion exchange membranes for desalination” (Poster Presentation) *2023 AIChE Annual Meeting* (Orlando, FL), November 6, 2023.
99. B.M. Tremblay (Presenting), S. Bannon, G.M. Geise, M. Paul, A. Roy, “Monovalent ion transport in sulfonated poly(arylene ether sulfone) membranes” (Poster Presentation) *2023 AIChE Annual Meeting* (Orlando, FL), November 6, 2023.
98. P.M. McCormack, G.M. Koenig Jr., G.M. Geise (Presenting), “Selective ion conducting polymers for non-aqueous redox flow battery applications” (Oral Presentation) *244th ECS Meeting* (Gothenburg, Sweden), October 11, 2023.
97. G.M. Geise (Presenting), “Microwave dielectric relaxation spectroscopy: A technique to inform ion transport in hydrated polymer membranes” (Oral Presentation) *244th ECS Meeting* (Gothenburg, Sweden), October 10, 2023. **[Invited Contribution]**
96. J.M. Kim (Presenting), Y.-h. Lin, S.M. Bannon, G.M. Geise, B.S. Beckingham, “Co-transport of methanol and formate in crosslinked phenyl acrylate-based ion exchange membranes: Effect of steric hindrance” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 17, 2023.
95. S.M. Bannon (Presenting), C. Leroux, B.M. Tremblay, G.M. Geise, “Characterizing dielectric permittivity properties and water molecule dynamics using dielectric relaxation spectroscopy” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 16, 2023.
94. C. Leroux (Presenting), P.M. McCormack, G.M. Koenig Jr., G.M. Geise, “Transport property modulation via non-aqueous solvent specific behavior in cross-linked membranes” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 16, 2023.
93. B.M. Tremblay (Presenting), J.M. Kim, S.M. Bannon, G.M. Geise, “Lithium and sodium sorption in crosslinked bisphenol A ethoxylate diacrylate-based cation exchange membranes” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.
92. A. Harris (Presenting), I. Oliveira do Carmo Nascimento, D. Ipekçi, J.R. McCutcheon, G.M. Geise, “Analysis of manufacturing methods of ion exchange membranes for desalination” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.
91. S.M. Bannon (Presenting), C. Leroux, B.M. Tremblay, G.M. Geise, “Characterizing dielectric permittivity properties and water molecule dynamics using dielectric relaxation spectroscopy” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.
90. C. Leroux (Presenting), P.M. McCormack, G.M. Koenig Jr., G.M. Geise, “Transport property modulation via non-aqueous solvent specific behavior in cross linked membranes” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.

89. Y.T. Bimbatti (Presenting), D. Ipekçi, X. Wang, A. Harris, I. Oliveira do Carmo Nascimento, G.M. Geise, B. Li, J.R. McCutcheon, "Printed ultrathin film Nafion™ composite membranes by electrospray" (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.
88. D. Ipekçi (Presenting), A. Harris, I. Oliveira do Carmo Nascimento, D. Ipekci, Y.T. Bimbatti, G.M. Geise, J.R. McCutcheon, "Polyamide-based ion exchange membrane synthesis" (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Tuscaloosa, AL), May 15, 2023.
87. C.J. Piccolo (Presenting), S.M. Bannon, G.M. Geise, "Salt sorption in Nafion-212 membranes exposed to high salinity environments" (Poster Presentation) *Virginia Experiential Learning Conference for Community College Students* (Annandale, VA), April 15, 2023.
86. S.M. Bannon (Presenting), G.M. Geise, "Engineering polymers to study structure/property relationships in desalination membranes" (Poster Presentation) *Polymer Reaction Engineering XI* (Scottsdale, AZ), December 12, 2022.
85. J.M. Kim (Presenting), S. Bannon, P.M. McCormack, G. Geise, "Co-transport of lithium, sodium, and potassium ions in pegylated sulfonated polysulfones" (Oral Presentation) *2022 AIChE Annual Meeting* (Phoenix, AZ), November 17, 2022.
84. L. Keesecker (Presenting), G. Geise, "Understanding polymer membrane interactions with contaminants" (Poster Presentation) *2022 AIChE Annual Meeting* (Phoenix, AZ), November 14, 2022.
83. J.M. Kim (Presenting), Y.-h. Lin, Y. Wang, T. Huang, J. Yoon, S. Bannon, C. Leroux, P. McCormack, G. Koenig Jr., G. Geise, D.-J. Kim, M. Auad, B. Beckingham, "Novel crosslinked ion exchange membranes with phenyl acrylate for direct urea fuel cell and nonaqueous flow battery applications" (Oral Presentation) *2022 AIChE Annual Meeting* (Phoenix, AZ), November 13, 2022.
82. G.M. Koenig Jr. (Presenting), P.M. McCormack, G.M. Geise, "Assessing and modifying selective transport for nonaqueous flow battery membranes" (Oral Presentation) *242nd ECS Meeting* (Atlanta, GA), October 12, 2022.
81. K. Chang, P.M. McCormack, W.-A.S. Agata, H. Luo, K. Bahati, G.M. Koenig Jr., G.M. Geise (Presenting), "Advanced polymer materials to enable clean energy and efficient water purification" (Poster Presentation) *1st U.S.-Africa Frontiers of Science, Engineering, and Medicine Symposium* (Nairobi, Kenya), October 10, 2022. **[Invited Contribution]**
80. K. Chang, P.M. McCormack, H. Luo, K. Bahati, T. Xue, G.M. Koenig Jr., G.M. Geise (Presenting), "Engineering selective transport in polymer membranes" (Poster Presentation) *Chemical Separations Gordon Research Conference* (Ventura, CA), October 3, 2022.
79. P.M. McCormack, G.M. Koenig Jr., G.M. Geise (Presenting), "Selective ion conducting polymers for non-aqueous redox flow battery applications" (Oral Presentation) *Polymers for Fuel Cells, Energy Storage, and Conversion* (Napa, CA), May 17, 2022. **[Invited Contribution]**
78. G.M. Geise (Presenting), "Selective ion conducting polymers for non-aqueous redox flow battery applications" (Oral Presentation) *AIChE Fall National Meeting* (Boston, MA), November 11, 2021.
77. G.M. Geise (Presenting), "Engineering ion transport in polymer membranes for water purification and energy applications" (Oral Presentation) *AIChE Fall National Meeting* (Boston, MA), November 11, 2021.

76. P. Verma (presenting), M. Kuenen, M. Bannon, S. Bannon, G. Geise, R. Letteri, G. Giri, “UIO-66 mixed matrix membranes for water desalination and ion-transport studies” (Oral Presentation) *AIChE Fall National Meeting* (Boston, MA), November 9, 2021.
75. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *TechConnect World Innovation Conference & Expo* (Washington DC), October 19, 2021. **[Invited Contribution]**
74. P.M. McCormack, G.M. Koenig Jr., G.M. Geise (Presenting), “Decoupling ionic conduction and cross-over in membrane separators for non-aqueous redox flow batteries” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Estes Park, CO), September 1, 2021.
73. G.M. Geise (Presenting), “Engineering selective desalination membrane materials via polymer backbone rigidity and functional group position” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Estes Park, CO), August 30, 2021.
72. L. Huelsenbeck (Presenting), H. Luo, P. Verma, J. Dane, R. Ho, E. Beyer, H. Hall, G.M. Geise, Gaurav Giri, “Generalized approach for rapid aqueous MOF synthesis by controlling solution pH” (Oral Presentation) *AIChE Fall National Meeting* (Virtual), November 17, 2020.
71. P.M. McCormack, H. Luo, G.M. Koenig Jr., G.M. Geise (Presenting), “Selective ion conducting membranes for non-aqueous redox flow battery applications” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Virtual), May 21, 2020.
70. H. Luo (Presenting), K. Chang, K. Bahati, G.M. Geise, “Engineering selective desalination membranes by controlling functional group configuration” (Oral Presentation) *North American Membrane Society (NAMS) Meeting* (Virtual), May 21, 2020.
[Invited Contribution – NAMS Student Fellowship Award (H. Luo)]
69. Y. Ji, H. Luo, K. Chang, G.M. Geise (Presenting), “Controlling water and ion transport in hydrated polymer membranes via chemical functionality” (Oral Presentation) *2019 MRS® Fall Meeting & Exhibit* (Boston, MA), December 4, 2019. **[Invited Contribution]**
68. Y. Ji, H. Luo, K. Chang, G.M. Geise (Presenting), “Controlling water and ion transport in hydrated polymer membranes via chemical functionality” (Oral Presentation) *ACS Fall National Meeting & Exposition* (San Diego, CA), August 28, 2019. **[Invited Contribution]**
67. H. Luo, K. Chang, T. Xue, W.A. Morris, G.M. Geise (Presenting), “Structure/property relationships in polymers for membrane applications” (Oral Presentation) *Tech Connect World* (Boston, MA), June 19, 2019. **[Invited Contribution]**
66. K. Chang (Presenting), H. Luo, G.M. Geise, “Relative permittivity properties of hydrated polymer membranes for desalination applications” (Poster Presentation) *North American Membrane Society (NAMS) Meeting* (Pittsburgh, PA), May 13, 2019.
65. G.M. Geise (Presenting), “Ion transport in charged polymers for electromembrane applications” (Oral Presentation) *ACS Spring National Meeting & Exposition* (Orlando, FL), April 4, 2019.
64. P. McCormack (Presenting), G. Koenig Jr., G. Geise, “Poly(phenylene oxide) based ion conducting polymers for electrochemical applications” (Oral Presentation) *ACS Spring National Meeting & Exposition* (Orlando, FL), April 4, 2019.
63. G.M. Geise (Presenting), “Influence of relative permittivity properties on ion transport in hydrated polymer membranes” (Oral Presentation) *ACS Spring 2019 National Meeting & Exposition* (Orlando, FL), April 3, 2019.

62. Y. Ji, H. Luo, K. Chang, G.M. Geise (Presenting), “Ion transport in and permittivity properties of hydrated polymer membranes” (Oral Presentation) *Polymers for Fuel Cells, Energy Storage, and Conversion* (Pacific Grove, CA), February 26, 2019. **[Invited Contribution]**
61. G.M. Geise (Presenting), “Engineering advanced water purification membranes using fundamental structure/property relationships” (Poster Presentation) *6th Arab-American Frontiers of Science, Engineering, and Medicine Symposium* (Kuwait City, Kuwait), November 4, 2018. **[Invited Contribution]**
60. Y. Ji (Presenting), H. Luo, G.M. Geise, “Ion specific effects in charged polymers for membrane applications” (Oral Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), November 1, 2018.
59. K.C. Chang (Presenting), A. Korovich, W.A. Morris, T. Xue, L.A. Madsen, B. Frieberg, C.M. Stafford, G.M. Geise, “Influence of polymer backbone rigidity on the water and ion transport properties of low water content membrane polymers” (Oral Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), October 30, 2018.
58. G.M. Geise (Presenting), K.C. Chang, H. Luo, “Relative permittivity properties of hydrated polymers for desalination membrane applications” (Poster Presentation) *10th Conference on Broadband Dielectric Spectroscopy and its Applications* (Brussels, Belgium), August 29, 2018.
57. Y. Ji, H. Luo, G.M. Geise (Presenting), “Ion specific effects in charged polymers for electromembrane applications” (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Lexington, KY), June 13, 2018.
56. H. Luo, K. Chang, Y. Ji, T. Xue, W.A. Morris, G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Lexington, KY), June 11, 2018.
55. K. Chang, T. Xue, W.A. Morris, G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *255th ACS National Meeting* (New Orleans, LA), March 20, 2018. **[Invited Contribution]**
54. A. Korovich (Presenting), K. Chang, T. Xue, W.A. Morris, L.A. Madsen, G.M. Geise, “Investigating multi-scale transport in random copolymer membranes for use in molecular separations” (Oral Presentation) *255th ACS National Meeting* (New Orleans, LA), March 18, 2018.
53. L.A. Madsen (Presenting), A. Korovich, L.M. Thieu, L. Zhu, K. Chang, G.M. Geise, M.A. Hickner, “Measuring multi-scale tortuosity in polymer membranes” (Oral Presentation) *255th ACS National Meeting* (New Orleans, LA), March 18, 2018.
52. Y. Ji, H. Luo, G.M. Geise (Presenting), “Ion specific effects in charged polymers for membrane applications” (Oral Presentation) *255th ACS National Meeting* (New Orleans, LA), March 18, 2018. **[Invited Contribution]**
51. G.M. Geise (Presenting), “Ion specific effects in charged polymer membranes for water purification and energy applications” (Oral Presentation) *AIChE Fall National Meeting* (Minneapolis, MN), October 31, 2017.
50. G.M. Geise (Presenting), “Ion specific effects in charged polymers for membrane applications” (Oral Presentation) *International Congress on Membranes and Membrane Processes (ICOM)* (San Francisco, CA), August 3, 2017.

49. G.M. Geise (Presenting) and Y. Ji, “Ion specific effects in charged polymer membranes for water purification and energy applications” (Oral Presentation) *American Physical Society (APS) March Meeting* (New Orleans, LA), March 6, 2017.
48. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *AIChE Fall National Meeting* (San Francisco, CA), November 16, 2016.
47. H. Zhang, T. Xue, G.M. Geise (Presenting), “Influence of polymer backbone rigidity on water and salt transport properties of low water content membrane polymers for desalination” (Oral Presentation) *Engineering Conferences International: Advanced Membrane Technology VII* (Cork, Ireland), September 14, 2016.
46. Y. Ji (Presenting), G.M. Geise, “Specific ion effects in charged polymer membranes” (Oral Presentation) *252nd ACS National Meeting* (Philadelphia, PA), August 24, 2016.
45. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Poster Presentation) *Gordon Research Conference on Membranes: Materials and Processes* (New London, NH), August 1-2, 2016.
44. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Poster Presentation) *Gordon Research Conference on Polymer Physics* (South Hadley, MA), July 27-28, 2016.
43. Y. Ji, T. Xue, A.M. Biedermann, G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *American Physical Society (APS) March Meeting* (Baltimore, MD), March 17, 2016.
[Invited Contribution]
42. G.M. Geise (Presenting), “Ion transport structure/property relationships in charged polymer membranes” (Oral Presentation) *Pacificchem 2015* (Honolulu, HI), December 18, 2015.
[Invited Contribution]
41. T. Xue, G.M. Geise (Presenting), “Water/salt selectivity properties of hydrophilic polymer membranes” (Oral Presentation) *Pacific Polymer Conference 14* (Koloa, HI), December 10, 2015. **[Invited Contribution]**
40. G.M. Geise (Presenting), “Ion transport structure/property relationships in charged polymer membranes” (Oral Presentation) *AIChE Fall National Meeting* (Salt Lake City, UT), November 10, 2015.
39. G.M. Geise (Presenting), “Ion Sorption And Transport in Charged Polymers for Membrane Applications” (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Boston, MA), June 3, 2015. **[Invited Contribution]**
38. G.M. Geise (Presenting), “Material Properties of Chlorine Tolerant Sulfonated Polysulfone for Water Purification Applications” (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Boston, MA), June 2, 2015. **[Invited Contribution]**
37. G.M. Geise (Presenting), “Ion Sorption And Transport in Charged Polymers for Membrane Applications” (Oral Presentation) *Advances in Materials and Processes for Polymeric Membrane Mediated Water Purification* (Pacific Grove, CA), February 16, 2015.
[Invited Contribution]
36. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water and energy” (Oral Presentation) *Macromex 2014* (Nuevo Vallarta, Mexico), December 6, 2014.
[Invited Contribution]

35. G.M. Geise (Presenting), “Structure/property relationships in polymer membranes for water purification and energy applications” (Oral Presentation) *AIChE Fall National Meeting* (Atlanta, GA), November 18, 2014.
34. G.M. Geise (Presenting), H.J. Cassady, M.A. Hickner, B.E. Logan, “Ionic resistance and permselectivity of ion exchange membranes” (Poster Presentation) *North American Meeting of the International Society for Microbial Electrochemistry and Technology, NA-ISMET* (University Park, PA), May 14, 2014.
33. G.M. Geise (Presenting), M.A. Hickner, B.E. Logan, “Ion transport in anion exchange membranes for water purification and power generation applications” (Oral Presentation) *AIChE Fall National Meeting* (San Francisco, CA), November 8, 2013.
32. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Salt transport structure/property relationships in polymer membranes for water purification and power generation” (Oral Presentation) *AIChE Fall National Meeting* (San Francisco, CA), November 4, 2013. **[Invited Contribution]**
31. G.M. Geise (Presenting) “Structure/Property relationships in polymer membranes for water purification and energy applications” (Poster Presentation) *AIChE Fall National Meeting* (San Francisco, CA), November 3, 2013.
30. G.M. Geise (Presenting), B.E. Logan, M.A. Hickner, “Ion transport in anion exchange membranes for power generation applications” (Poster Presentation) *Penn State Postdoc Research Exhibition* (University Park, PA), September 13, 2013.
29. G.M. Geise (Presenting), B.E. Logan, M.A. Hickner, “Ion transport in anion exchange membranes for power generation applications” (Poster Presentation) *Gordon Research Conference on Polymers* (South Hadley, MA), June 13, 2013.
28. G.M. Geise (Presenting), C.L. Willis, C.M. Doherty, A.J. Hill, T.J. Bastow, J. Ford, K.I. Winey, B.D. Freeman, D.R. Paul, “Characterization of aluminum-neutralized sulfonated styrenic pentablock copolymer films” (Oral Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), October 31, 2012.
27. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Diffusive water transport: Relating hydraulic permeability to the apparent water diffusion coefficient in water-swollen polymers” (Oral Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), October 30, 2012.
26. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Salt transport structure/property relationships and modeling in polymer membranes for water purification and power generation” (Oral Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), October 30, 2012.
25. G.M. Geise (Presenting) “Structure/property relationships in polymer membranes for water purification and power generation” (Poster Presentation) *AIChE Fall National Meeting* (Pittsburgh, PA), October 28, 2012.
24. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Structure/property relationships in polymer membranes for water purification and power generation” (Oral Presentation) *244th ACS National Meeting* (Philadelphia, PA), August 19, 2012. **[Invited Contribution]**
23. G.M. Geise (Presenting), J.E. McGrath, B.D. Freeman, D.R. Paul, “Fundamental salt sorption and permeability properties of polymeric membrane materials” (Oral Presentation) *AIChE Fall National Meeting* (Minneapolis, MN), October 18, 2011.

22. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, "Salt transport characteristics of a sulfonated styrenic pentablock copolymer for desalination applications" (Oral Presentation) *The International Congress on Membranes and Membrane Processes - ICOM* (Amsterdam, The Netherlands), July 28, 2011.
21. G.M. Geise (Presenting), H. Ju, W. Xie, A.C. Sagle, C.M. Doherty, J.I. Mardel, A.J. Hill, J.E. McGrath, B.D. Freeman, D.R. Paul, "Positron annihilation lifetime spectroscopy (PALS) characterization of polymeric membrane materials for desalination applications" (Oral Presentation) *The International Congress on Membranes and Membrane Processes - ICOM* (Amsterdam, The Netherlands), July 27, 2011.
20. C.H. Lee, K. Lee, B. Sundell, O. Lane, J. Cook, W. Xie, G. Geise, B.D. Freeman, J.E. McGrath (Presenting), "Crosslinkable chlorine resistant membranes for reverse and forward osmosis (RO,FO)" (Keynote Presentation) *The International Congress on Membranes and Membrane Processes - ICOM* (Amsterdam, The Netherlands), July 25, 2011. **[Invited Contribution]**
19. Y.-H. Na (Presenting), R. Sooriyakumaran, R.D. Allen, G. Geise, B. Freeman, "Enhanced RO performance of polyamide bi-layer membranes prepared by sequential interfacial polymerization" (Oral Presentation) *Advances in Materials and Processes for Polymeric Membrane Mediated Water Purification* (Pacific Grove, CA), March 1, 2011.
18. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, "Characterization of novel sulfonated styrenic pentablock copolymer materials for desalination applications" (Poster Presentation) *Advances in Materials and Processes for Polymeric Membrane Mediated Water Purification* (Pacific Grove, CA), February 28, 2011.
17. G.M. Geise (Presenting), H. Ju, W. Xie, A.C. Sagle, C.M. Doherty, J.I. Mardel, A.J. Hill, J.E. McGrath, B.D. Freeman, D.R. Paul, "Positron annihilation lifetime spectroscopy characterization of membrane polymers" (Oral Presentation) *The International Congress of Pacific Basin Societies – Pacifichem* (Honolulu, HI), December 18, 2010.
16. G.M. Geise (Presenting), L.K. Passaniti, J.E. McGrath, B.D. Freeman, D.R. Paul, "Understanding the ion sorption and salt transport differences between highly charged and less-highly charged membrane polymers" (Oral Presentation) *The International Congress of Pacific Basin Societies – Pacifichem* (Honolulu, HI), December 16, 2010.
15. G.M. Geise (Presenting), A.J. Hill, B.D. Freeman, D.R. Paul, "Fundamental water transport properties of a sulfonated styrenic pentablock copolymer" (Oral Presentation) *AIChE Fall National Meeting* (Salt Lake City, UT), November 11, 2010.
14. G.M. Geise (Presenting), L.K. Passaniti, J.E. McGrath, B.D. Freeman, D.R. Paul, "Characterization of individual cation and anion sorption related to salt transport in highly charged sulfonated polymers for desalination applications" (Oral Presentation) *AIChE Fall National Meeting* (Salt Lake City, UT), November 11, 2010.
13. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, "Understanding the effect of ion exchange on water and salt transport properties of a highly-charged sulfonated pentablock copolymer" (Oral Presentation) *240th ACS National Meeting* (Boston, MA), August 24, 2010. **[Invited Contribution]**
12. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, "Water and salt transport in a sulfonated pentablock copolymer for desalination applications" (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Washington, DC), July 21, 2010.

11. G.M. Geise (Presenting), A.J. Hill, B.D. Freeman, D.R. Paul, “Water transport in a novel sulfonated pentablock copolymer analyzed using positron annihilation lifetime spectroscopy (PALS)” (Oral Presentation) *North American Membrane Society (NAMS) National Meeting* (Washington, DC), July 19, 2010.
10. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Characterization of novel sulfonated styrenic pentablock copolymer materials for desalination applications” (Poster Presentation) *North American Membrane Society (NAMS) National Meeting* (Washington, DC), July 19, 2010.
9. G.M. Geise (Presenting), J.E. McGrath, B.D. Freeman, D.R. Paul, “Water and salt transport in novel sulfonated polymer materials for desalination applications” (Oral Presentation) *Advances in Science and Engineering for Brackish Water and Seawater Desalination* (Cetraro, Italy), May 10, 2010. **[Invited Contribution]**
8. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Characterization of novel sulfonated styrenic pentablock copolymer materials for desalination applications” (Poster Presentation) *Advances in Science and Engineering for Brackish Water and Seawater Desalination* (Cetraro, Italy), May 9, 2010.
7. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport properties of Nexar™: A novel sulfonated pentablock copolymer for desalination applications” (Oral Presentation) *239th ACS National Meeting* (San Francisco, CA), March 21, 2010.
6. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport characterization of a novel sulfonated pentablock copolymer for desalination membrane applications” (Oral Presentation) *Membrane Society of Australasia Student Symposium* (Wollongong, Australia), February 19, 2010.
5. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport in a novel sulfonated pentablock copolymer” (Oral Presentation) *34th Annual Condensed Matter and Materials Meeting* (Auckland, New Zealand), February 4, 2010.
4. G.M. Geise (Presenting), L.K. Passaniti, J.E. McGrath, B.D. Freeman, D.R. Paul, “Ion transport through sulfonated polymer membranes for desalination applications” (Oral Presentation) *AIChE Fall National Meeting* (Nashville, TN), November 12, 2009.
3. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for desalination applications” (Oral Presentation) *238th ACS National Meeting* (Washington, DC), August 17, 2009. **[Invited Contribution]**
2. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for reverse osmosis applications” (Oral Presentation) *67th Annual Technical Conference – Society of Plastics Engineers* (Chicago, IL), June 22, 2009. **[Peer-Reviewed Conference Paper]**
1. G.M. Geise (Presenting), B.D. Freeman, D.R. Paul, “Water and ion transport through sulfonated styrenic pentablock copolymer membranes for reverse osmosis applications” (Poster Presentation) *Advances in Materials and Processes for Polymeric Membrane Mediated Water Purification* (Pacific Grove, CA), February 23, 2009.

PATENTS:

5. G.M. Koenig Jr., G.M. Geise, J. Wang, “Systems and Methods of Processing Brine to Capture Lithium Ions” *International Patent Application No. PCT/US2024/57438*
Filed on November 26, 2024.

4. G.M. Koenig Jr., G.M. Geise, J. Wang, "Selective Lithium Extraction from Brine via Chemical Reduction of Iron Phosphate with Aqueous Iron Compounds" *U.S. Provisional Patent Application Serial No. 63/604,965*
Filed on December 1, 2023.
3. G. Giri, P.K. Verma, G.M. Geise, A.F. Clarens, H.E. Hall, "Enhancing Polymers for Carbon Capture Using Metal Organic Frameworks as Cages" *International Patent Application WO 2024/163331 A1*
Published on August 8, 2024.
2. G.M. Koenig Jr., G.M. Geise, P.M. McCormack, "Transport Property Modulation via Solvent Specific Behavior in Crosslinked Non-Aqueous Membranes" *International Patent Application WO 2024/081943 A2*
Published on April 18, 2024.
1. G.M. Koenig Jr., G.M. Geise, P.M. McCormack, "Ion Selective Membranes for Organic Electrochemical Processes" *U.S. Patent Application US 2023/0099030 A1*
Published on March 30, 2023.

PROFESSIONAL ACTIVITIES:

Editor, *Journal of Membrane Science Letters* (Elsevier) (2024 – present)

Programming Committee & Session Chair, North American Membrane Society (NAMS) Annual Meeting (2024)

Editorial Advisory Board Member, *Membranes* (MDPI) (2022 – present)

Editorial Advisory Board Member, *Polymer* (Elsevier) (2021 – present)

Editorial Advisory Board Member, *Journal of Membrane Science Letters* (Elsevier) (2021 – 2024)

UVA Chemical Engineering Undergraduate Program Director (2018, 2020 – 2022, 2023 – present)

Engineering Character Strength Initiative (ECSI), Steering Committee Member (2024 – present)

UVA Chemical Engineering HHMI (Howard Hughes Medical Institute) Driving Change Committee (2024 – present)

Undergraduate Curriculum Committee, UVA Engineering (Chair, 2021 – 2022; CHE Rep., 2018, 2020 – 2022, 2023 – present)

Libraries Committee, University of Virginia (2019 – 2021)

ChE Undergraduate Awards Committee, University of Virginia (2021 – 2022)

Virginia Community College System – Chemical Engineering Transfer Student Working Group (2020 – present)

UVA Engineering Continuity of Operations Committee (2020 – 2021)

2015 & 2019 Co-Organizer and Session Chair for the Virginia Soft Matter Workshop
-A day-long meeting (funded by a 4-VA grant) of soft materials researchers from Virginia Tech, Virginia Commonwealth University, and James Madison University

Volunteer Pipeline Committee Member (2016 – 2019), American Chemical Society (ACS) Division of Polymeric Materials: Science and Engineering (PMSE)

Discussion Leader, 2018 Gordon Research Conference – Membranes: Materials and Processes

2018 Committee on Academic Standards, UVA School of Engineering and Applied Science

Guest Editor, Special Issue: *New Polymeric Materials and Characterization Methods for Water Purification*, Volume 103, 2016, Polymer (Elsevier)

2015-2016 Ignite Program at the University of Virginia

2015 Invited Participant and Speaker at the National Science Foundation workshop titled, “FEWS: Food-Energy-Water Systems Challenging Chemists in the 21st Century”

2015 Course Design Institute at the University of Virginia

2014-2016 Department of Chemical Engineering Safety Committee Co-Chair

2014 Excellence in Diversity Fellowship at the University of Virginia

2011 Graduates Linked with Undergraduates in Engineering (GLUE)

- Part of the Women in Engineering Program (WEP) at the University of Texas at Austin
- Volunteered as a graduate student mentor

2007-2009 ExploreUT Community Outreach Open House at the University of Texas at Austin

- Organized and volunteered for the ‘Playing with Plastic!’ exhibit in 2009
- Volunteered for the ‘Playing with Plastic!’ exhibit in 2007 and 2008

2008 International Congress on Membranes and Membrane Processes (ICOM)

Proceedings Committee Chairperson and Administrative Student Staff Member

- Coordinated the compilation, editing, and production of proceedings material
- Responsible for leading the proceedings committee that consisted of 7 graduate students
- Assisted with logistics for running the largest membrane science conference in the world

Research Mentor/Advisor

- Graduate student advisees (15):
Wendy-Angela Saring Agata (Ph.D., 2021), Sean Bannon (M.E., 2022), Kevin Chang (Ph.D., 2020), Rachel Fetter (M.E., 2023), Yuanyuan Ji (Ph.D., 2019 & M.S., 2017), Thomas Lam, Charlie Leroux (M.E., 2022), Hongxi Luo (Ph.D., 2021), Patrick M. McCormack (Ph.D., 2022 & M.E., 2018), Caroline Morin (M.E., 2023), Inara Oliveira do Carmo Nascimento, Phu Phan, Amin Tia Saasi, Tianyi Xue (M.S., 2016), Huan Zhang (M.E., 2015)
- Visiting professors/scholars hosted (1):
Dr. Rueben Pfukwa (Dept. of Chem. and Polym. Sci., Stellenbosch University, South Africa)
- Post-doctoral scholar advisees (2):
Dr. William A. Morris, Dr. Jung Min (Luca) Kim
- Mentored/Advised 36 undergraduate students as they completed individual research projects
- Hosted and mentored 3 visiting French engineering interns & 1 M.S. student at UT Austin

North American Membrane Society (NAMS) – Member

American Chemical Society (ACS) – Member

American Institute of Chemical Engineers (AIChE) – Member

American Physical Society (APS) – Member

Materials Research Society (MRS) – Member

OTHER CERTIFICATIONS:

U.S. Federal Aviation Administration Private Pilot Certificate and Instrument Rating

APPENDIX B

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

- AP1001 U.S. Patent No. 10,471,380
- AP1002 Prosecution History of Priske-'380
- AP1003 Declaration of Dr. Richard W. Baker
- AP1004 Curriculum Vitae of Dr. Richard W. Baker
- AP1006 U.S. Patent No. 8,999,038
- AP1007 M. Scholz et al., *Structural optimization of membrane-based biogas upgrading processes*, Journal of Membrane Science, 474, 1-10 (2015)
- AP1008 Japanese Patent Application No. JP2009-242773
- AP1009 Qi, Runhong et al., *Membrane system design for multicomponent gas mixtures via mixed-integer nonlinear programming*, Computers & Chemical Engineering, 24 (2000)
- AP1010 Datta, Anjan K., *Optimization of membrane unit for removing carbon dioxide from natural gas*, Journal of Membrane Science, 283 (2006), 291-300
- AP1011 Machine translation of Japanese Patent Application No. JP2009-242773
- AP1012 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
- AP1013 Baker, Richard W., *Membrane Technology and Application* (3d Ed. 2012)
- AP1014 U.S. Patent No. 7,968,758
- AP1015 Baker et al., *Permeability, permeance, and selectivity: A preferred way of reporting pervaporation performance data*, Journal of Membrane Science, 348 (2010), 346-352
- AP1016 Alshehri et al., *Membrane Systems Engineering for Post-combustion Carbon Capture*, Energy Procedia, 37 (2013), 976-985
- AP1017 CAS Registry for Polymers 9046-51-9 and 134119-41-8
- AP1034 Declaration of June Ann Munford

- AP1035 Declaration of Nathaniel E. Frank-White
- AP1036 Declaration of Luaine Bandounas
- AP1037 M. Scholz et al., *Structural Optimization of membrane-based biogas upgrading processes*, Journal of Membrane Science, Author Accepted Manuscript
- AP1038 US20130098242A1
- EX2001 Expert Declaration of Dr. Markus Ungerank
- EX2003 Linde Engineering – Membrane Plants
- EX2004 Anderson, Case Study – Membrane CO₂ Removal from Natural Gas
- EX2009 Deposition Transcript of Dr. Richard W. Baker
- EX2010 White, L. S. *Evolution of Natural Gas Treatment with Membrane Systems*, Membrane Gas Separation, Freeman, B., Yampolskii, Y. Eds.; John Wiley & Sons, Ltd, 2010.
- EX2011 Matteucci et al., *Transport of Gases and Vapors in Glassy and Rubbery Polymers*, Materials Science of Membranes for Gas and Vapor Separation, 2006; pp 1-47.
- EX2012 Robeson, L. M., *The upper bound revisited*, Journal of Membrane Science (2008) 320, 390-400.
- EX2013 Freeman, B. D., *Basis of permeability/selectivity tradeoff relations in polymeric gas separation membranes*, Macromolecules 1999, 32 (2), 375-380.
- EX2014 Puleo et al., *The effect of degree of acetylation on gas sorption and transport behavior in cellulose acetate*, Journal of Membrane Science, 47, 301-332, 1989.
- EX2015 He et al., *Theoretical study on concentration polarization in gas separation membrane processes*, Journal of Membrane Science, 153, 243-258, 1999.