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Transcript of Joseph D. Smith, Ph.D.

Date: July 7, 2026

Case: Topsoe, Inc. -v- L'Air Liquide Société Anonyme (PTAB)

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Conducted on July 7, 2026

1 (1 to 4)

1 UNITED STATES PATENT AND TRADEMARK OFFICE 2 ----- 3 BEFORE THE PATENT TRIAL AND APPEAL BOARD 4 ----- 5 TOPSOE, INC., 6 Petitioner 7 v. 8 L'AIR LIQUIDE, SOCIETE ANONYME POUR L'ETUDE ET 9 L'EXPLOITATION DES PROCEDES GEORGES CLAUDE, 10 Patent Owner 11 ----- 12 Case IPR2025-01173 13 Patent No. 11,673,805 14 ----- 15 16 HIGHLY CONFIDENTIAL - ATTORNEYS' EYES ONLY 17 18 ORAL DEPOSITION OF 19 JOSEPH D. SMITH, Ph.D. 20 Austin, Texas 21 July 7, 2026 - 9:04 a.m. 22 21 Reported by: 22 Micheal A. Johnson, RDR, CRR Job No. 641166	3 1 APPEARANCES 2 ON BEHALF OF THE PETITIONER: 3 Jeffrey J. Phillips 4 SPENCER FANE LLP 5 3040 Post Oak Boulevard, Suite 1400 6 Houston, Texas 77056 7 (713) 212-2710 8 jphillips@spencerfane.com 9 10 ON BEHALF OF THE PATENT OWNER: 11 Eagle Robinson 12 Sophia Poirier 13 NORTON ROSE FULBRIGHT US LLP 14 98 San Jacinto Boulevard, Suite 1100 15 Austin, Texas 78701 16 (512) 474-5201 17 eagle.robinson@nortonrosefulbright.com 18 sophia.poirier@nortonrosefulbright.com 19 20 ALSO PRESENT: 21 Kyril Talanov 22
2 1 ORAL DEPOSITION OF JOSEPH D. SMITH, Ph.D., 2 produced at the instance of the Petitioner, in the 3 above-styled and numbered cause on the 7th day of 4 July, 2026, at 9:04 a.m., before Micheal A. 5 Johnson, RDR, CRR, Notary Public in and for the 6 State of Texas, reported by realtime stenographic 7 means, at the offices of Norton Rose Fulbright, 98 8 San Jacinto Boulevard, Suite 1100, Austin, Texas, 9 pursuant to Notice of Oral Deposition, and 10 pursuant to 37 C.F.R. 42.6(e). 11 12 13 14 15 16 17 18 19 20 21 22	4 1 INDEX 2 JOSEPH D. SMITH, Ph.D. 3 July 7, 2026 4 APPEARANCES 3 5 PROCEEDINGS 6 6 7 EXAMINATION OF JOSEPH D. SMITH, Ph.D.: 8 BY MR. PHILLIPS 6 9 BY MR. ROBINSON 205 10 BY MR. PHILLIPS 208 11 REPORTER'S CERTIFICATION 215 12 13 14 15 16 17 18 19 20 21 22

1	DEPOSITION EXHIBITS	5	1 dozen.	7
2	JOSEPH D. SMITH, Ph.D.		2 Q. A dozen?	
3	July 7, 2026		3 A. Yeah.	
4	NUMBER	DESCRIPTION	4 Q. Well, then, you probably know this, but	
5	Exhibit 1001	11	5 I'm going to go over a few ground rules. So I'm	
6	Exhibit 1003	120	6 going to be asking you questions today. Your	
7	Exhibit 1005	98	7 attorney, Mr. Robinson, will be making objections	
8	Exhibit 1018	126	8 on the record as well. The court reporter is	
9	Exhibit 2021	11	9 typing everything that we say, so it's important	
10	Exhibit 2022	11	10 you don't talk over me, and I will try my	
11	Exhibit 2023	164	11 darnedest not to talk over you, because he can	
12			12 only take down one person at a time.	
13			13 If you don't understand one of my	
14			14 questions, please ask. I'm not perfect, and this	
15			15 area is a little bit of a tough area, so I want to	
16			16 make sure that I'm clear, I want to make sure that	
17			17 you're answering -- you know what you're answering	
18			18 in terms of the question.	
19			19 We'll try to take a break every 45 minutes	
20			20 to an hour, but if you need to go to the restroom,	
21			21 let me know. The only thing I ask is if we're in	
22			22 the middle of a question, let's finish the Q and A	
1	PROCEEDINGS	6	1 at that point, and then we can take a break and go	8
2	JOSEPH D. SMITH, Ph.D.,		2 off the record.	
3	called as a witness, having been duly sworn by a		3 Do you have any questions --	
4	Notary Public, was examined and testified as		4 A. I do not.	
5	follows:		5 Q. -- for me? Okay.	
6	EXAMINATION		6 Dr. Smith, are there any reasons you can't	
7	BY MR. PHILLIPS:		7 provide complete and truthful testimony here	
8	Q. Good morning, Dr. Smith. Can you please		8 today?	
9	state your name for the record.		9 A. There's not.	
10	A. Joseph D. Smith.		10 Q. So what have you done to prepare for	
11	Q. And do you know why you're here today?		11 today's deposition?	
12	A. I do.		12 A. So I've read and studied the patents in	
13	Q. Why are you here today?		13 question. I have also reviewed SMR, or steam	
14	A. To be deposed.		14 methane reforming the process, the technology	
15	Q. Okay. Do you know why you're being		15 behind the process, things that I've practiced,	
16	deposed?		16 but it's nice to review again.	
17	A. I'm being deposed regarding certain		17 I have read the previous deposition given	
18	patents.		18 by Mr. Klein and his report, expert report. And	
19	Q. Have you ever been deposed before?		19 that's what I've done, basically, to prepare for	
20	A. I have.		20 this deposition.	
21	Q. How many times, roughly?		21 Q. So when you said the patents involved in	
22	A. Several. Several dozen. Probably a		22 this IPR, you're talking about the '805 patent?	

9 1 A. '805 patent, the Reinertsen patent, the 2 Rytter patent and the Darde patent. 3 Q. You had mentioned that you reviewed 4 documents relating to SMR? 5 A. Yeah. 6 Q. So that's steam methane reforming. 7 A. Yes. 8 Q. What type documents did you review? 9 A. So as a chemical engineer, again, we're 10 trained in reaction engineering. And so there are 11 certain reactions that are involved in steam 12 methane reforming that are energetics, either 13 endothermic or exothermic. They generate energy 14 or they consume energy. So I reviewed those 15 again, just to be clear in my mind what's -- we're 16 talking about and what Mr. Klein had talked about. 17 Q. Did you review documents relating to 18 the -- so after the reaction portion of an SMR 19 process, so the separation of hydrogen, CO₂, more 20 of the downstream processes, did you look at those 21 as well? 22 A. I did. I did.	11 1 documents, and we're going to make a nice little 2 pile in front of you, and we're going to switch 3 back and forth. I apologize for that. 4 The first one I'm going to hand you is 5 your declaration. It's marked as Exhibit 2021 in 6 this IPR. 7 MR. PHILLIPS: Eagle, do you need a copy? 8 BY MR. PHILLIPS: 9 Q. I'm also going to hand you Exhibit 2022. 10 This is the CV that you submitted that accompanies 11 your declaration. 12 And I'm going to give you what's been 13 marked as Exhibit 1001. This is US patent number 14 11,673,805. This is the patent that is at issue 15 in the IPR. 16 A. Yes. 17 Q. So you've seen these documents before? 18 A. I've seen these documents before. 19 Q. And these are some of the documents that 20 you reviewed in preparation for today? 21 A. They are. 22 Q. So I guess let's start by discussing your
10 1 Q. So what did you look at with respect to 2 those? 3 A. Pressure swing adsorption technology that 4 we had practiced at Dow Chemical when I worked 5 there. Steam methane reforming itself, both 6 autothermal reforming or partial oxidation, which 7 is what another term for that is, and catalytic 8 reforming, which is an endothermic process that 9 requires heat. So I reviewed that. I also 10 reviewed amine scrubbing, using an amine -- 11 ethanolamine, for example, to absorb various 12 materials, carbon dioxide mainly, but something 13 that we produced at Dow Chemical when I was -- 14 worked for Dow. 15 Q. You had mentioned partial oxidation. Is 16 partial oxidation and steam methane reforming the 17 same thing? 18 A. Partial oxidation is part of the 19 autothermal reforming process. And it's a way to 20 provide the energy required for the reforming 21 reaction itself. 22 Q. So I'm going to start to hand you some	12 1 professional background. 2 A. Okay. 3 Q. So I don't want to go -- you have an 4 impressive CV. I don't want to go over every 5 detail of it. I want to try to get to the 6 relevant parts. 7 I see you have a bachelor's degree, a 8 master's degree and a Ph.D. in chemical 9 engineering all from BYU; is that right? 10 A. That is correct. 11 Q. What was your Ph.D. research? What was 12 the focus of that research? 13 A. Combustion of coal and gasification of 14 coal for power generation. 15 Q. So you said -- okay. So I want to break 16 that down a little bit. The combustion of coal 17 and the gasification of coal, what are the 18 difference between -- what's the difference 19 between those two processes? 20 A. So coal combustion is when you have coal, 21 and generally it's ground, and so it's very fine 22 particles, and it's injected into a furnace or a

13 1 chamber, and it burns completely, you know, over 2 fired air, and so we have excess oxygen. And so 3 it completely burns. And that's used in power 4 generation, electric power generation. And at 5 Brigham Young University I was part of the 6 National Science Foundation Energy Research Center 7 dealing with combustion. And so that was one of 8 the things that we focused on. 9 The second one, gasification, is also coal 10 gasification, but this is, again, a partial 11 oxidation of coal. So it's not full combustion. 12 It's gasification, which is to generate syngas 13 from the coal that is then used to fire a gas 14 turbine to generate electricity. 15 Q. So in the coal combustion process, does 16 that process produce a syngas? 17 A. No, it -- it burn -- it produces water and 18 carbon dioxide mainly. There are some CO 19 emissions that are generated during the process 20 because of incomplete combustion. Mostly that's 21 in parts-per-million levels. And so full 22 combustion generates -- of hydrocarbons, and coal	15 1 objection? Thanks. 2 A. So there's sulfur in coal, like there's 3 nitrogen in coal. So when those react with the 4 environment, you can get H₂S, and that's what's 5 referred to as acid gas. You can also get SO₂, 6 which is a full oxidation of the sulfur. And so 7 they have sulfur scrubbers on the back end of coal 8 plants to remove that, because it's an emission. 9 Acid rain, we talked about that and its impact on 10 the environment. That comes from coal combustion 11 also. 12 BY MR. PHILLIPS: 13 Q. We're going to talk about this in a lot 14 more detail later, steam methane reforming, but 15 the products that -- from steam methane reforming 16 versus the products from coal gasification, is it 17 the same type of -- strike that. Let me start 18 over. 19 Coal gasification, after the gasification 20 process, are we trying to -- do those type of 21 plants try to recover the hydrogen and CO₂ from 22 the --
14 1 is a hydrocarbon, generates carbon dioxide and 2 water. 3 Q. So for gasification, though, what are the 4 products in the gasification process? 5 A. Again, they're partial oxidation. So you 6 still get some carbon dioxide and water, but 7 mostly you get carbon monoxide, CO, and hydrogen, 8 and then you have some methane that's formed and 9 then there's some nitrogen oxides that are formed 10 because nitrogen and coal also reacts with the 11 oxygen and forms NO and NO₂ H₂O, NO_x. 12 Q. So for coal gasification -- I mean, coal 13 is somewhat of a complex, I guess, feedstock. I 14 mean, is there -- there's other products that come 15 from the -- from that coal gasification process, 16 right? Aren't there acid gases as well? 17 MR. ROBINSON: Objection, form. 18 A. Well, it -- 19 MR. PHILLIPS: Sorry. 20 BY MR. PHILLIPS: 21 Q. I think you can go ahead and answer. 22 MR. ROBINSON: Yeah, just -- you have my	16 1 A. They can. They can. You know, there are 2 lots of different flavors of coal combustion 3 plants. In the 1970s, you know, I was in high 4 school in the '70s and then in the '80s I was in 5 college. The focus on the environment, the focus 6 on -- acid rain was the main, you know, interest, 7 and so they -- so the coal plants at that point 8 were designed for that. More recently with focus 9 on climate change and carbon emissions, CO₂ 10 capture, CO₂ sequestration, have become a lot more 11 part of the industry. 12 Q. Okay. Again, we'll come back to steam 13 methane reforming processes a little bit later, 14 and I may do some comparisons with gasification in 15 terms of the processes used. 16 I noticed in your declaration that you 17 have several references in your background section 18 to computational fluid dynamics. 19 A. Yes. 20 Q. Or CFD. 21 A. Yes. 22 Q. What is that?

17 1 A. So "computational" obviously refers to 2 computers. Computer simulation of the combustion 3 process. And so CFD is computational fluid. And 4 then dynamics, again, is because it's time 5 dependent. And so some of this -- the computer 6 models, computer codes, are transient, and so they 7 solve the conservation equations that describe 8 coal combustion or coal gasification in terms of 9 mass and energy and momentum transport. And so 10 CFD is solving those equations to simulate what 11 happens inside a coal furnace or any kind of 12 furnace. 13 Q. Can CFD be used to model the process units 14 described in the '805 patent? 15 A. I suspect they can, yes. 16 Q. Have you ever used -- sorry. Have you 17 ever used CFD to simulate or model the process 18 units described in the '805 patent? 19 A. So I have in the past, yes. 20 Q. Which units? 21 A. Well, the catalytic oxidizer, the 22 autothermal oxidizer, the -- those are the main	19 1 employed? 2 A. University of Missouri in Rolla, Missouri. 3 Q. And what is your current position there? 4 A. I'm a professor of chemical engineering, 5 chemical and biochemical engineering. 6 Q. How long have you been professor of 7 chemical engineering at Missouri Rolla? 8 A. I have been there since 2011. 9 Q. And what is your current research focus? 10 A. Current research focus is in 11 energy-related technologies, with a main focus in 12 sustainability. 13 Q. Sustainability, what do you mean by 14 sustainability? 15 A. So renewable energy, biofuels, combustion, 16 gasification. We've done -- I have a gasifier, 17 and we use it to gasify biomass to make syngas. 18 We've done biodiesel production. So we form 19 biodiesel from waste cooking oil. Again, reactive 20 chemical engineering process. Solar energy 21 combined with nuclear energy for nuclear hybrid 22 systems. I've done a lot of systems analysis, and
18 1 focuses that I've had when I worked for Dow 2 Chemical. We did a lot of CFD in developing their 3 coal gasification process. And so those types 4 of -- same types of processes, it's reactive 5 chemistry, so that's what we're simulating. 6 Q. So you used CFD with respect to the 7 reaction-type unit operations; is that right? 8 A. That's right. 9 Q. So something like pressure swing 10 adsorption, you wouldn't use CFD for modeling that 11 process? 12 A. So pressure swing adsorption is a 13 transport process, so we can certainly use CFD to 14 simulate it. I have not in -- to my recollection 15 simulated a PSA or pressure swing adsorption unit. 16 Q. Would CFD be able to model the adsorption 17 kinetics from a PSA unit? 18 A. Yes. 19 Q. But you haven't -- that's not been a focus 20 of your research; is that right? 21 A. That is correct. 22 Q. Dr. Smith, where are you currently	20 1 that's kind of the focus of my area. 2 Q. Do you do any research in the area of 3 steam methane reforming? 4 A. So the gasification work that I'm doing 5 involves steam methane reforming, yes. 6 Q. So you're saying it's the gasification of 7 biofuels? 8 A. So gasification of biomass to make 9 biofuels. 10 Q. Okay. But in terms of the steam methane 11 reforming, so the steam reforming of natural gas, 12 that's not an area of research for your group? 13 A. So the work that I have done at the 14 university has not focused on steam methane 15 reforming, per se. 16 Q. Do you teach any undergraduate classes -- 17 A. I do. 18 Q. -- at Missouri Rolla? 19 A. I do. 20 Q. Which ones? 21 A. Currently I'm teaching process control. 22 I'm also teaching process intensification, I'm

21 1 teaching energy in engineering and economics, I'm 2 teaching -- let's see. What else? That's it. 3 Those are the ones I'm teaching right now. 4 Q. Have you taught any other -- since 2011, 5 have you taught any other undergraduate classes? 6 A. I have. I've taught process design, I 7 have taught separation sciences, I have taught 8 computer modeling, numerical methods. The 9 computer modeling class I taught was -- uses a 10 book that I wrote on computational fluid dynamics 11 for the process industry. The energy economics 12 class that I taught, I developed with the 13 department chair for economics and we teach it 14 together. We have taught it together now for 14 15 years. So those are the classes I've taught since 16 joining. 17 Q. I'm interested in -- you had mentioned a 18 separation sciences class. 19 A. Yeah. 20 Q. So I'm a chemical engineer also. So 21 University of Texas I took Unit Ops 1 and 2 -- 22 A. Okay.	23 1 the topics. Was pressure swing adsorption -- 2 A. Yes. 3 Q. -- a topic that's taught in that class? 4 A. Yes. 5 Q. What about membrane separations? 6 A. Membrane separation as well. 7 Q. Cryogenic separations? 8 A. Yes, cryogenic separations. 9 Q. So these are all processes that your 10 undergraduate students are familiar with? 11 A. Well, hopefully. We would do the exam, we 12 would test them to see how familiar they are with 13 them, yes. 14 Q. What about graduate-level classes, what 15 graduate-level classes do you teach? 16 A. Yeah, yeah. So I've taught, again, the 17 computational fluid dynamics class is a graduate 18 level class, 6180. That's a course, again, I 19 developed and the book I wrote for it. I've 20 taught modeling, again, which is the basic process 21 of modeling, how you model a process, something 22 that I co-taught with Professor Erdogan Gulari at
22 1 Q. -- which covered -- Unit Ops 1 was more 2 fluid flow, Ops 2 was more of a separations class. 3 Can you tell me more about that separation 4 science class? What was the subject matter for 5 that class? 6 A. So chemical engineering, the undergraduate 7 separations focuses on distillation mostly, but it 8 also focuses on adsorption, stripping. So those 9 are scrubbing technologies. We did liquid -- 10 looked at extraction and learned about 11 tri-diagonal -- or tri -- diagrams and trying to 12 understand the different phase separations, and so 13 it included that. 14 We spent time learning Aspen to do process 15 simulation. We learned about physical property 16 prediction to try to make sure that you could 17 account for the polarity of molecules and the 18 effect that has on physical properties, which are 19 important to process simulation. 20 Learned how to write, supposedly, and to 21 communicate. 22 Q. So as -- and I appreciate the long list of	24 1 University of Michigan when I was on faculty at 2 University of Michigan. 3 Q. So real quick, though, that model -- I 4 didn't mean to cut you off, but that modeling 5 class, I mean, is that using Aspen to simulate -- 6 A. No. 7 Q. -- kind of a process or -- 8 A. No. The modeling class is learning how to 9 develop models. So you start with the algorithm 10 and you develop the algorithm, and then you -- 11 whatever model fit -- whatever software fits or 12 whatever tools you need to use to model. And so 13 it's a general process of learning how to model 14 something. 15 Q. And so -- so you're -- is that a -- is 16 that a required class for graduate level -- 17 (Simultaneous discussion interrupted by 18 reporter.) 19 BY MR. PHILLIPS: 20 Q. -- masters level engineers? 21 Sorry, I'll repeat the question. So is -- 22 in those -- in graduate classes -- actually,

25 1 strike that. 2 So you're -- I guess the question I was 3 asking is, are -- is this type of modeling type of 4 class required for your graduate students? 5 A. Modeling class is an elective class. They 6 can take -- they have to have a certain number of 7 electives in their masters or Ph.D. programs. And 8 so that's a class that they take for that. 9 Q. The Aspen process simulation, is that 10 required for your undergraduate students? 11 A. The separation sciences class is a 12 required class and that's where that is taught, 13 yes. 14 Q. You also mentioned that they're -- the 15 undergraduates take a design -- a process design 16 course as well? 17 A. Yes. And I'm sure you took it. 18 Q. I took it at the end. Is that -- so is 19 that a class -- correct me if I'm wrong. That's a 20 class where the -- I think in my class we were -- 21 we were in teams and we were presented -- each 22 team had their own process to stimulate. Is that	27 1 A. I accepted his definition, yes. 2 Q. So that definition has a graduate degree 3 in chemical engineering; is that right, in part? 4 A. What it says is while I do not necessarily 5 agree with every aspect of Dr. Klein's explanation 6 of a level of ordinary skill in the art, I do not 7 currently believe the aspects of that explanation 8 I would change or clarify would impact the 9 analysis set forth in this declaration. For the 10 purposes of this declaration, my opinions are 11 therefore provided from the perspective of a 12 POSITA described in paragraph 55 of Dr. Klein's 13 declaration, and this is what he says: Three to 14 five years of experience with steam methane 15 reforming, partial oxidation, water-gas shift 16 process and synthesis gas separation, and a 17 graduate degree in chemical engineering, master's 18 of science level. 19 Q. So you said that you don't agree with 20 every aspect of this definition. What do you not 21 agree with? 22 A. So I would -- I would also say that there
26 1 how it works -- 2 A. Yes. 3 Q. -- at Missouri Rolla as well? 4 A. Yes. 5 Q. So by the time an undergraduate student 6 graduates from Missouri Rolla with a chemical 7 engineering degree, they've at least been exposed 8 to simulating processes? 9 A. Yes. 10 Q. If we can look real quick at your 11 declaration. So this is Exhibit 2021. If you can 12 turn to paragraph 26 of your declaration. Do you 13 see it? 14 A. Yes. 15 Q. So this is a paragraph concerning the 16 level of skill in the relevant art; is that right? 17 A. That's what I read, yeah. 18 Q. So I don't know if you reviewed this in 19 your preparation for today, but it appears that 20 you adopted Dr. Klein's definition for a person of 21 skill in the art, which I'm going to call it POSA 22 today; is that correct?	28 1 are some of the things that are required to 2 understand these patents that maybe -- maybe if 3 he's a graduate of the University of Texas, he 4 would have that, maybe if he's from another 5 school, wouldn't have it. So that's right on the 6 edge. I'm not sure that somebody with three to 7 five years' experience would be able to opine or 8 to understand exactly the nuances involved here, 9 mostly because of the way a process works. As a 10 chemical engineer, you understand that chemical 11 processes interact with each other. The chemical 12 reactions are dependent on temperature and 13 pressure, they're related to the composition of 14 the feed stocks. And so just in the chemical 15 reactor itself, the processes are coupled. And 16 the equations to describe those processes are 17 coupled. These are nonlinear partial differential 18 equations that describe the transport of mass 19 momentum and energy -- 20 THE REPORTER: Please, slow down. 21 A. Partial differential equations that 22 describe the transport of the mass momentum and

29 1 energy. And those are coupled with the velocity, 2 the temperature, the composition that appear in 3 those equations. And so just the very processes 4 themselves are coupled, the transport processes. 5 So then when you combine different types of 6 processes of steam methane reforming in an 7 autothermal reactor with partial oxidation with a 8 process -- pressure swing adsorption unit, with a 9 cryogenic separation unit, those processes 10 themselves are coupled. And so somebody that has 11 three to five years' experience with steam methane 12 reforming or partial oxidation may not have the 13 understanding required to really understand what 14 the coupled process, how they work together. And 15 that's an important part of this. And so whereas 16 I don't think it's going to change my analysis, 17 that was where I had problems with Dr. Klein's 18 description. 19 BY MR. PHILLIPS: 20 Q. So you'd agree with me, I'm just trying to 21 digest what you said. You think that someone 22 needs to have a -- a person of ordinary skill in	31 1 the company recognizes the effects that graduate 2 work has on your understanding is reflected in 3 their titles. And so I would say that, you know, 4 three to five years with a bachelor's degree would 5 be equivalent to a Ph.D., basically. That's how 6 Dow defines it, and that's how I would define it. 7 There's some experience that you gain working in a 8 plant that you can't get in a graduate program 9 generally, but that -- that experience is 10 important. And so graduate level adds to that 11 experience and so, yes. 12 BY MR. PHILLIPS: 13 Q. I want to turn to your CV for a second. 14 This is Exhibit 2022. And if you could turn to 15 the second page. 16 A. Okay. Page 3? 17 Q. Page 2. 18 A. Page 2. 19 Q. I'm sorry, I have it -- they're two-sided. 20 I was trying to save the trees -- 21 A. Yeah, good. 22 Q. -- for this deposition.
30 1 the art needs to have a deeper understanding of 2 these processes? 3 MR. ROBINSON: Objection, form. 4 A. I would -- I would say that a person 5 that -- a normal, you know, skilled-in-the-art 6 person needs to understand how systems interact, 7 the coupling between systems. 8 BY MR. PHILLIPS: 9 Q. Do you agree that this needs to be a 10 graduate-level engineer, a graduate degree -- 11 A. Yes. 12 Q. -- engineer? 13 Do you think that it could be a bachelor's 14 degree engineer with more experience? 15 MR. ROBINSON: Objection, form. 16 A. So when I -- when I joined the Dow 17 Chemical Company, I came in with my Ph.D. And so 18 I was given the title of senior research engineer. 19 Undergraduate chemical engineer from UT Austin 20 that would be hired by Dow Chemical to work down 21 in Freeport, Texas would be given the term as an 22 engineer. And so that -- the titles and the way	32 1 You identify 16 cases where you provided 2 expert testimony. Do you see that? 3 A. I do. 4 Q. Were any of these patent cases? 5 A. They were. 6 Q. Which ones? 7 A. So case No. 5, Kingsford Product Company 8 versus Creative Spark, involved charcoal 9 production and that was -- Kingsford is owned by 10 Clorox, and that patent case took place in 11 Washington, D.C. where I was deposed. Kilpatrick 12 Townsend & Stockton was the law firm from 13 San Francisco that I worked with. We did a lot of 14 testing related to combustion and pyrolysis that 15 are involved in producing charcoal. 16 Q. It also says in this description that you 17 testified relating to flare performance; is that 18 correct? 19 A. Yes. Yeah. 20 Q. What -- what -- tell me -- tell me a 21 little bit about flare performance. What is a 22 flare?

33 1 A. A flare in -- general usage of flare is 2 something that's used to dispose of waste gases. 3 Q. So was this case relating to the charcoal 4 briquets themselves, or was this related to the 5 flare system? 6 A. Both. 7 Q. So the charcoal briquets, is that more of 8 an example of coal combustion as opposed to coal 9 gasification? 10 A. Again, you refer to coal. It's a 11 carbonaceous material, and charcoal is produced 12 from wood, a biomass, but as you heat up wood, it 13 charcoal -- it turns into charcoal, which is a 14 carbonaceous material similar to coal. Coal that 15 comes out of the ground has been subject to high 16 temperature and pressure over millions of years 17 that has carbonized it. So here in Texas we have 18 a lot of lignite. Up in Utah we have a lot 19 of bituminous coal. There are different qualities 20 of coal that depend on the temperature and 21 pressure that they've been exposed to. Charcoal 22 is the same. So you can have different types of	35 1 the process, yes. 2 Q. Was it related -- did this relate at all 3 to separating a high-purity hydrogen or CO₂ 4 product from the syngas? 5 A. So you used the term "high-purity." 6 Again, you have to define that, but certainly pure 7 hydrogen and CO for subsequent use as a feedstock. 8 Q. So still looking at your CV, if you could 9 turn to page 8. 10 A. Okay. 11 Q. You identify 12 patents -- 12 A. Yeah. 13 Q. -- which looks like actually ten patents 14 and a couple of -- actually maybe nine patents and 15 three patent applications. 16 Do you see that? 17 A. I do. 18 Q. Do any of these patents relate to the 19 steam reforming of natural gas? 20 A. Patent No. 9,114,984 B2, system and 21 process for upgrading hydrogens -- or 22 hydrocarbons, August 25, 2015, does.
34 1 charcoal. If you go to Lowe's or Home Depot, you 2 can buy Kingsford charcoal. You can buy it -- you 3 know, they advertise mesquite charcoal for 4 smoking, you know. And so, yeah, different types 5 of charcoal that are prepared differently. So 6 that was, again, part of this case. 7 Q. Do any of the 16 cases that you testified 8 relate to steam methane reforming -- steam 9 reforming of natural gas? 10 A. Let me review my cases here. Case No. 1 11 was an arbitration that took place in Vienna, 12 arbitration between Clarke-Rajchel Engineering, 13 which is out of Wyoming, and Stercorat, Hungary. 14 This was related to producing chemicals, 15 thiosulfate chemicals, and that involves steam 16 methane reforming. 17 Q. Did it involve the recovery of hydrogen 18 and CO₂ products from the resulting syngas? 19 A. It included the separation of gases, 20 including hydrogen and CO, that they were used 21 later in the process. But it wasn't -- they 22 weren't captured, but they were certainly part of	36 1 Q. And what did that patent -- can you -- do 2 you recall what that patent was related to? 3 A. I do. That has to do with molten salt 4 gasification. The work was conducted at Idaho 5 National Laboratory and was subsequently licensed 6 to a company in Canada that was recovering 7 hydrogen and CO from the gasification process. 8 Q. I noticed this patent was assigned to 9 Battelle Energy Alliance? 10 A. That was who I worked for. 11 Q. Okay. 12 A. That was when it was managed by Battelle 13 Energy Alliance. 14 Q. When was -- when was your employment with 15 Battelle? 16 A. From 2009 to 2011, just before I went to 17 Missouri. 18 Q. And what was your primary responsibility 19 at Battelle? 20 A. I was a group leader and senior research 21 scientist. 22 Q. And what were the areas that your group

37 1 was researching? 2 A. Hydro energy and, again, biofuels, 3 bioenergy, nuclear energy, and then systems that 4 involved those. 5 Q. Also on page 8 of your CV you identify, 6 looks like 11 books and book chapters in which 7 you're an author; is that right? 8 A. That's correct. 9 Q. Do any of these books or book chapters 10 relate to the steam reforming of natural gas? 11 A. Yes, they do. 12 Q. Which ones? 13 A. So let's look -- let me review here. 14 No. 2, Chemistry and Modeling of Biomass 15 Combustion; No. 5, Impact of Densified Biomass 16 Feedstocks on Biofuel Production from Biomass 17 Gasification; No. 6, Thermal Energy Conversion and 18 Utilization, Perry's Chemical Engineers' Handbook; 19 No. 7, Computational Fluid Dynamics for Chemical 20 and Petrochemical Process Industries; No. 10, 21 Henneke, Computational Fluid Dynamics Based 22 Combustion Modeling; No. 11, Mathematical Modeling	39 1 exchange CO to make hydrogen, and there's water 2 and -- involved in that. So water and CO2. So in 3 the combustion process a water-gas shift reaction 4 occurs. It's part of the reaction process that's 5 going on. So when you model it, you have to 6 include all those reactions. And so that's 7 included in the combustion modeling. 8 Q. In No. 6, this is the chapter from Perry's 9 handbook? 10 A. Yes. 11 Q. This is a -- the 2019 edition. I'll be 12 honest, I have on my desk a 1984 edition, so I 13 wasn't able to look at your article. Can you tell 14 me something about the chapter that you wrote for 15 Perry's? 16 A. Yes. So, again, chapter 24 -- Section 24 17 is about thermal conversion or combustion or 18 gasification. Those are all thermal energy 19 conversions. So the chapter that I wrote, again, 20 referred to that specifically. The 1984, I have 21 that same edition on my shelf. It's what I had 22 when I went to school, too. There is a -- there's
38 1 of Combustion Systems. 2 Q. So No. 2 that you had mentioned, the 3 Chemistry and Modeling of Biomass Combustion, 4 that's not steam methane reforming. That was a 5 biomass combustion process? 6 A. Again, steam methane reforming, that 7 reaction that involves methane and water occurs in 8 the combustion process. And so when you model it, 9 you have to include all the reactions that are 10 involved. And so that was included in that work. 11 Q. So does biomass combustion create a 12 similar syngas to steam methane reforming? 13 A. It certainly does. I mean, it -- syngas 14 is CO and hydrogen. So CO and hydrogen are 15 produced in the process. 16 Q. So typically in biomass combustion, where 17 you have CO and hydrogen as the products, is there 18 typically a water-gas shift reaction to convert CO 19 to CO2? 20 A. Absolutely. Again, the water-gas shift 21 involves the balance between CO and hydrogen. You 22 either exchange hydrogen to make CO or you	40 1 a section in there that -- the way Perry's 2 handbook has evolved over the years has been -- 3 those sections are added to and modified and 4 upgraded. So my contribution to Perry's handbook 5 was to do that and expand it to include more 6 current research and work that had been done in 7 thermal energy conversion and utilization. So 8 that's what I contributed. 9 Q. Let's shift gears a little bit. Go back 10 to your declaration, Exhibit 2021. And I want to 11 direct you to paragraph No. 2. 12 A. 2? 13 Q. 2. And I specifically wanted to direct 14 you to the last sentence where you say: In 15 forming my opinions, I relied on my knowledge and 16 experience in designing, developing, researching 17 and teaching the technology referenced in this 18 declaration. 19 Do you see that? 20 A. I do. 21 Q. So let's break that down a little bit. 22 What do you consider to be the technology

41 1 referenced in this declaration? 2 A. Reaction -- reaction chemistry. 3 Q. That's a fairly broad topic. So in 4 particular, though, I mean, are there specific 5 technologies related to the '805 patent? 6 A. There are. Steam methane reforming. 7 Q. Any others? 8 A. The '805 patent also talks about some 9 separation technologies, and as I mentioned to you 10 before, the experience that I have, not just in 11 teaching material to undergraduate students, but 12 in practicing the technology while working for the 13 Dow Chemical Company, for Cabot Corporation and 14 for Koch Industries. 15 Q. Let's -- I want to break down, you had 16 mentioned designing, developing, researching and 17 teaching. So I want to kind of break those down. 18 Your designing experience, what do you 19 mean by designing? 20 A. So in developing a chemical process, 21 there's designs that are involved. A lot of the 22 work that I've done in industry, again, for those	43 1 design processes, size lines, size reactors, 2 choose catalysis? What was your role in designing 3 that process? 4 A. One of the -- one of the challenges that 5 reactor has is that it fires coal-water slurry 6 with pure oxygen through two nozzles that are 7 directly opposed. And so the fluid dynamics of 8 those reactors -- those injectors interact. And 9 because it's coal, you have abrasive material that 10 erodes the refractory that lines that reactor. 11 And so one of the projects that I worked on for 12 Dow, again, which is not published, it's not 13 public knowledge, is that we actually developed 14 the angles that those injectors were placed at to 15 minimize the erosion and refractory wear. That 16 cost the company, when that reactor was operating, 17 over a million dollars every six months to replace 18 that refractory. 19 So that -- part of that design involved 20 the reactor and how the reactor was built, and the 21 refractory in that reactor is probably the most 22 expensive part of that process. It's really a
42 1 companies that I mentioned, involve designing. 2 For Dow Chemical I was part of the design team 3 that developed, starting in Louisiana, the LGTI 4 gasification process that was later then 5 commissioned in Wabash, Indiana as the Dow 6 gasifier. That was later sold to ConocoPhillips, 7 and practiced by ConocoPhillips for many years and 8 then sold to Chicago Bridge & Iron, who now own 9 that technology, that involved a lot of CFD 10 modeling used to design that reactor, used to 11 analyze that reactor, to troubleshoot that 12 reactor, used to optimize that reactor. And so 13 that experience that I gained working for Dow, 14 which is not published in the public -- in the 15 public literature, but is technology that the 16 company owned and then sold and is practiced 17 today. So that's what that means. 18 Q. So you -- in answering my question about 19 designing, you morphed in the concept of 20 developing in that as well, which is the second 21 term in that list. So I guess my question for you 22 is, with respect to designing, did you actually	44 1 refractory, and each block is numbered, and it's 2 like a work of art. You go inside that reactor 3 and those blocks are put in by number, and wearing 4 out that refractory, as I said, is very expensive 5 and very time-consuming to repair. So that's why 6 the design was such an important thing. So we had 7 an initial design, we tested it, it looked like it 8 would work, we built it, it didn't work, we had to 9 go back in and redesign it, and so -- and then 10 implement it, and then it worked. 11 Q. So you're describing the design of a 12 particular reactor. Did you have any involvement 13 or experience in designing an overall process in 14 which that reactor is a part of? 15 A. Okay. So the reactor is the first step in 16 that process. 17 Q. Okay. 18 A. And so you -- you know, grinding the coal, 19 forming the slurry and developing the nozzles and 20 injecting those nozzles -- or injecting the slurry 21 through those nozzles, that's all part of that 22 process design. And my portion of that -- like

45 1 any chemical plant that's designed, you have 2 experts that do specific things. But my process 3 started with the nozzles. And so how those 4 nozzles are designed and how those -- the oxygen 5 stream and the slurry stream mix and all the 6 mixing processes, that was part of that design. 7 And then the process itself, I've already 8 described one problem that I helped in, helped 9 refine the design, develop the design for the 10 reactor itself. And then the effluent from that 11 reactor goes to a large heat exchanger, which has 12 a refractory header atop of a -- heat transfer 13 tubes so that the coal doesn't erode the tubes. 14 So analyzing that -- analyzing the heat transfer 15 inside that -- that heat exchanger, that was part 16 of my design. And then after that, then it goes 17 to, again, the gas cleanup where you remove the 18 sulfur and take the CO₂ out, and we worked with a 19 company in Houston, Gas Spec, to actually do 20 pressure swing adsorption and temperature swing 21 adsorption, both of those, in this gasification 22 process.	47 1 swing adsorption were both part of that process. 2 Were these -- was PSA in this instance used to 3 separate hydrogen? 4 A. CO₂. 5 Q. CO₂. What about the temperature swing 6 adsorption? 7 A. Same thing. 8 Q. Was -- was hydrogen recovered as a product 9 from this process? 10 A. Hydrogen was burned in a gas turbine. 11 This gasifier was developed to produce power with 12 a minimum emission, including CO₂. But the CO₂ 13 was separated, again, through PSA and TSA, and 14 then recovered. The hydrogen and CO, the syngas, 15 was burned in a GE Frame 5 gas turbine to make 16 115 megawatts of power over in Indiana. 17 Q. Do you have any other experiences 18 designing and developing related to the technology 19 referenced in this declaration? 20 A. So there are several processes with other 21 companies. Probably the one that's most relevant 22 is with Cabot Corporation, where I was, again, a
46 1 And then subsequently, what happens with 2 that -- the coal ash that comes out of that and, 3 you know, capturing that through these refractory 4 candle, basically -- refractory candle baghouses, 5 because they're not the typical baghouse because 6 of the coal, it would -- the ash would just erode 7 it. So designing that, that was another one of 8 the really big problems we had with that design, 9 so I got involved in that. 10 So I did the whole process, simulated the 11 entire process, and worked on different parts of 12 that whole process. 13 Q. So you had mentioned that pressure swing 14 adsorption -- 15 A. Yes. 16 Q. -- and temperature swing adsorption were 17 both process that were involved -- 18 (Simultaneous discussion interrupted by 19 reporter.) 20 BY MR. PHILLIPS: 21 Q. So I'll start over. You had said that 22 pressure swing adsorption, PSA, and temperature	48 1 group lead, corporate development, process 2 development lead for the company, and we were 3 interested in fumed metal oxides. One of my 4 patents is related to producing ceria for 5 autocatalysis. That's a fuming process that we 6 used that I developed. The work I did at Cabot 7 related to hydrogen production and storage. It 8 used hydrogen formed with PSA and separated with 9 PSA. We had a hydrogen plant in our facility in 10 Tuscola, Illinois that was used -- it was built in 11 Tuscola, Illinois because it was next to an 12 ethylene furnace that had excess hydrogen. So we 13 would recover that hydrogen and then use it in the 14 fumed metal oxide process. 15 Q. Switching gears one more time back to your 16 CV, this is Exhibit 2022, on the very first page 17 you have a section marked Specialized Professional 18 Competence. 19 Do you see that? 20 A. I do. 21 Q. I don't see steam methane reforming or 22 autothermal reforming in this section. Am I

49 1 missing something? 2 A. As a chemical engineer, you will 3 understand that reactive chemical evaluation, 4 extensive experience evaluating potential reactive 5 chemical hazards in chemical manufacturing 6 processes has led to several explosion 7 investigations to identify and mitigate reactive 8 chemical issues for Dow Chemical and Cabot 9 Corporation. That's where that falls. 10 Q. So evaluating -- so your work regarding 11 reactive chemical evaluation and explosion 12 investigations relates to steam methane reforming? 13 A. Absolutely. 14 Q. And that's both for your work at Dow 15 Chemical and Cabot Corporation? 16 A. Those are two examples, yes. 17 Q. We've been going about 55 minutes. Let's 18 take a ten-minute break. Are you good with that? 19 A. I'm fine. 20 Q. Then we can continue. I think we're at a 21 good breaking point. 22 (Recess taken from 9:54 a.m. to 10:08 a.m.)	51 1 producing -- if you're gasifying to produce 2 hydrogen for a fuel cell to make electricity, one 3 of the groups that I worked with, ProtonPower in 4 Oak Ridge, Tennessee, that was their focus. And 5 so certainly in that gasification system the same 6 types of separation operations that are used in a 7 stem methane reformer were used in that 8 gasification process because they had the same 9 objectives. 10 In the coal gasification process that I 11 described earlier, the objective was to produce 12 power. And so there was no need to separate the 13 hydrogen and the CO₂, per se. We separated the 14 CO₂ because we didn't want to have that extra mass 15 going into the gas turbine. And so that 16 separation was certainly done. But -- and I 17 mentioned how we did that. So those unit 18 operations were included, and they're similar to 19 what's used in the steam methane reformer. 20 But depending on the application, whether 21 it's for power generation, whether it's for 22 chemical production or whether it's for, you know,
50 1 BY MR. PHILLIPS: 2 Q. Dr. Smith, we're coming back from the 3 break. I just want to remind you you're still 4 under oath. 5 I wanted to go back to coal gasification. 6 I had a few more questions there. You described 7 the coal gasification process produces a syngas 8 and that there's the recovery of CO₂ and hydrogen 9 from that as well. 10 A. Yes. 11 Q. Do you agree with that? Are those the 12 same type of process units for recovering hydrogen 13 and CO₂ that you would find in a steam methane 14 reforming plant? 15 A. So each unit operation that you referred 16 to earlier that you learn in undergraduate 17 education has a specific application. In the 18 steam methane reformer there are several unit 19 operations that are involved, and separation is a 20 big part of that. And in gasification there are 21 separation technologies used where necessary 22 depending on the application. If you're	52 1 electricity, not power production, per se, but 2 fuel cell operation. 3 Q. My understanding is for coal gasification, 4 though, there's a, I don't want to say a 5 significant amount, but there are certainly acid 6 gases that are created besides CO₂. There's H₂S, 7 there's COS; is that right? 8 A. Depends on the goal that you gasify. The 9 lignite coals from Texas, they have a lot more 10 sulfur than -- they bituminous coals in Illinois 11 and Kentucky, a lot more sulfur. In West 12 Virginia, a lot more sulfur. So acid gas is a 13 significant issue that they have to deal with. 14 And so they have both dry scrubbing, they have wet 15 scrubbing that are used to remove the sulfur. 16 They have H₂S that's converted in a sulfur 17 reactor. They have a Claus process they usually 18 use to form elemental sulfur from that H₂S. 19 I mentioned also the project I worked on 20 in Slovakia to make thiosulfates. Again, they're 21 using the H₂S from a refinery. 22 So certainly there is acid gases that are

53 1 produced in coal gasification, coal combustion. 2 Depending on the coal that's used, those different 3 processes will vary. When I was in China, in 4 Chongqing, China, they had a coal plant there. 5 They had 1200 PPM SO₂ at the stack, and you -- 6 although they had a sulfur -- you know, 7 desulfurization step in their coal process, it was 8 not functioning. So they were just emitting it. 9 And they could do it in China because it's a 10 different country. But here in the US we do have 11 acid scrubbing to remove that acid gas. But 12 that's not every coal plant. Some of them do 13 because they burn bituminous high-sulfur -- 14 low-sulfur Utah coal, Wyoming coal, Powder River 15 Basin coal from Wyoming, those are low-sulfur 16 coals. 17 Q. Isn't it true, though, that in a coal 18 gasification plant it's a different type of CO₂ 19 removal than what you would find in a steam 20 methane reforming plant? And so let me get 21 specific about that. 22 I think my understanding is is that you	55 1 Q. In a coal gasification plant where 2 hydrogen is recovered, isn't it true that CO₂ 3 removal would happen before that hydrogen removal? 4 A. It can be that way. It doesn't have to be 5 that way. Most of the plants I worked on, it was 6 that way, but it is -- what it comes down to is 7 best practices involved in separation science. 8 Generally when you -- when you're designing a 9 separation train that has multiple columns, if you 10 have three components and a mixture A, B and C, 11 and in -- the compositions maybe are 70, 20 and 12 10, you take out the 70 percent material first to 13 separate the 20 and 10 percent material second, 14 just because it makes the separation easier. And 15 so many times in a -- in a process that really 16 dictates how the -- the order in which the 17 separation occurs. 18 Q. So in the case of CO₂ and hydrogen with 19 coal gasification, coal gasification produce -- 20 strike that. 21 In coal gasification there's a -- there's 22 more CO₂ produced relative to hydrogen --
54 1 would use an absorbent-like Rectisol or Selexol or 2 MDEA as part of that CO₂ removal step, and that 3 would also remove some of the acid gases. Is that 4 a fair statement? 5 A. That's a fair -- 6 MR. ROBINSON: Objection, form. 7 A. That's a fair statement. 8 BY MR. PHILLIPS: 9 Q. And in the '805 patent we're talking about 10 a different type of CO₂ absorption -- 11 MR. ROBINSON: Objection, form. 12 BY MR. PHILLIPS: 13 Q. -- process; is that right? 14 A. The specific process is different than in 15 the Selexol process. As you mentioned in -- the 16 physics involved are the same. The different 17 application of those physics, the adsorption of a 18 gas from the gas phase to a liquid phase is mass 19 transfer using packing, you know, surface area is 20 a big deal. So in terms of modeling it, not a lot 21 of difference. In terms of application and usage, 22 there are some differences, yes.	56 1 A. That's correct. 2 Q. -- than you would find in a steam methane 3 reforming process? 4 A. Depends on how the gasification or the 5 methane reformer was operated, but generally 6 speaking, yes. 7 Q. And based on that, you're saying a person 8 of ordinary skill in the art would utilize best 9 practices -- 10 A. Correct. 11 Q. -- to determine how to appropriately order 12 the processes. Is that a fair statement? 13 A. That's a fair statement. 14 Q. How are these best practices developed? 15 MR. ROBINSON: Objection, form. 16 A. So as with everything in engineering, best 17 practices come from years of experience, and 18 process safety is a big part of that. And in 19 chemical engineering, you know, of all the 20 engineering disciplines, process safety has become 21 one of the hallmarks of chemical engineering. The 22 CCPS through AIChE is a worldwide organization

57 1 that focuses on process safety. So those best 2 practices are related to that. API, the American 3 Petroleum Institute, have developed over the years 4 for refineries best practices, and in terms of how 5 you do different processes. And so that's how 6 best practices are developed, both experience, 7 safety and technology. 8 BY MR. PHILLIPS: 9 Q. I'm just -- again, I know you appreciate 10 this. Part of this case has to do with the order 11 of process separation. So I'm just trying to 12 understand what a person of ordinary skill in the 13 art -- what they consider. You had mentioned best 14 practices, you mentioned process safety; is that 15 right? 16 A. Correct. 17 Q. I had mentioned differences in the amount 18 of CO2 versus hydrogen. Is that also a 19 consideration for the order of separations? 20 A. As I mentioned, one of the parts of best 21 practices is relative composition of a gas and gas 22 mixture. And so the order can be determined based	59 1 Again, they had all the processes related 2 to a steam methane reformer, with a guard reactor, 3 to remove that sulfur because it poisons the 4 catalyst. And not necessarily -- it didn't happen 5 in the CO2 removal step, it happened as a specific 6 unit operation with a guard reactor. It was a 7 catalytic reactor that the sulfur gas would 8 absorb, and then they would -- it's a zinc oxide 9 catalyst. So then they would take that out and 10 regenerate the catalyst. But that's a guard 11 reactor specifically for desulfurization. 12 Q. Is cryogenic CO2 removal used in a coal 13 gasification separation process? 14 A. Cryogenic separation is one separation 15 step. It can be used. It is an expensive 16 process, because you've got compression involved. 17 And any cryogenic operation that you do is very 18 expensive. Air separation units, for example, 19 that separates nitrogen from oxygen, is an 20 expensive step in carbon capture and sequestration 21 that relies on oxygen combustion. It can make up 22 as much as 30 percent of the cost of electricity
58 1 on that. 2 Q. So coal gasification that has -- I'm going 3 to pick on pressure swing adsorption, PSA. My 4 understanding is you would want to remove sulfur 5 before a pressure swing adsorption process. Is 6 that right? 7 A. Absolutely. And it's not just for PSA, 8 but for the reforming step. In a catalytic 9 reformer, sulfur is a poison for the catalyst as 10 you know. So they do desulfurization prior to the 11 reformer itself for that reason. 12 Q. So the CO2 removal step is one step in 13 removing the sulfur before a hydrogen purification 14 step; is that accurate? 15 A. Not necessarily accurate, I wouldn't say. 16 I think that a guard reactor in a steam methane 17 reformer, which is very common, and again, in 18 methanation, when you build a plant to make 19 methane -- now, we don't do it anymore because 20 methane is so cheap now, but back in the '80s 21 methanation was a big deal. The 1984 AIChE 22 problem was a methanation plant.	60 1 because of the cost of that separation step. And 2 so cryogenic separation is a process separation 3 technology, can be used. When it's absolutely 4 necessary it is used. Cryogenic CO2 separation is 5 an effective way to remove CO2. It's not the most 6 common in the chemical industry. Most power 7 plants use amine separators, and there are 8 scrubbing towers that use an ethanol amine to pull 9 out the CO2, and then they can desorb the CO2 10 under different conditions. 11 So cryogenic separation is a process. 12 It's very expensive. It can be used, and it is 13 used when necessary. 14 Q. You say when necessary. When would it be 15 necessary? 16 A. Yeah. It's necessary depending on the 17 design. And so to understand which technologies 18 work best, whether it's cryogenic CO2 separation, 19 whether it's amine separation, it comes down to 20 the system that you built -- put together a 21 chemical process from. And so if you have five 22 different units that are part of this process,

61 1 then you do economic analysis and process safety 2 analysis to see which one makes the most sense. 3 And that's how you come up with a design. That's 4 standard chemical engineering process development. 5 And so, again, a steam methane reformer, 6 the ones that are talked about in these patents, 7 that's what they've done. They've gone through 8 and they've looked at and they've come up with 9 designs. So they put them in order. They're 10 not -- it's not like labels. You can't just cut 11 and paste, but they're based on a system analysis 12 to come up with that design. And that's how you 13 pick cryogenic CO2 separation versus amine 14 separation. 15 Q. Would this fall under your category of 16 best practices, how a person of ordinary skill in 17 the art, a chemical engineer, would choose between 18 different process options? 19 A. I think that that is part of best 20 practice. It's not necessarily spelled out. Best 21 practices don't specify the type of packing you 22 would use in a scrubbing tower. It specifies	63 1 Q. When it's not recovered as a product, I 2 believe you said it was used as a fuel? 3 A. It can be used as a fuel, correct. 4 Q. When it's not used as a fuel, is it then 5 recovered as a product or is there a third option 6 for where the hydrogen may -- 7 MR. ROBINSON: Objection, form. 8 A. The -- whether or not hydrogen is 9 recovered, period, depends on the application. 10 That's what I said. And when you're generating 11 electricity, as they do with the Dow gasification 12 process -- or any of them, the GE process, the 13 Texaco process or the Shell process, there are 14 several of those processes, but if they're using 15 it to produce power, then they'll burn the 16 hydrogen. So they don't necessarily separate it 17 out. They burn the CO2 -- or the CO1 hydrogen as 18 syngas. 19 In the case of powering fuel cells or 20 running the fuel cell with hydrogen, the hydrogen 21 is separated out for that application. It's not a 22 fuel, necessarily, and it's also not burned to
62 1 scrubbing. It doesn't specify cryogenic versus 2 amine separation. It specifies separation order 3 and how things are, you know, organized. 4 Q. But the separation order is a -- can be a 5 best practice? 6 A. Absolutely. 7 MR. ROBINSON: Objection, form. 8 BY MR. PHILLIPS: 9 Q. So in a -- going back to coal gasification 10 plants. Hydrogen recovery, when it happens, is 11 that typically pressure swing adsorption? 12 A. Can you rephrase the question again? 13 Q. Sure. So we were talking about coal 14 gasification plants. You had testified earlier 15 CO2 is often recovered for environmental reasons 16 today. You said hydrogen, H2, is not necessarily 17 recovered as a product. Is that -- do you -- is 18 that accurate? 19 A. I don't think so. 20 Q. Okay. Is it always recovered as a 21 product? 22 A. No.	64 1 make electricity. It's -- they take the electron 2 from the hydrogen in the fuel cell and they make 3 electricity that way. So it's used -- so that's a 4 third option. That's not -- that doesn't fit into 5 your description. 6 BY MR. PHILLIPS: 7 Q. In those situations, is hydro -- is 8 hydrogen purified first; in other words, is 9 hydrogen separated away from CO or CO2 or 10 unreacted carbon, other reacted carbon molecules? 11 Is that -- is that accurate? 12 A. That is -- 13 MR. ROBINSON: Objection, form. 14 A. That is accurate. CO2 -- or hydrogen is 15 purified -- because, again, you're limited by mass 16 flow in a fuel cell. The stack, that is where 17 it's generating electricity, can only handle a 18 certain amount through the membrane. And so you 19 don't want to have extra gases going in to foul 20 the membrane or to block the membrane, so you 21 purify the hydrogen for a fuel cell, yes. 22

65 1 BY MR. PHILLIPS: 2 Q. Is that hydrogen purification typically 3 pressure swing adsorption? 4 MR. ROBINSON: Objection, form. 5 A. It can be. I don't say it's 100 percent 6 of the cases a PSA, but certainly membrane 7 separation is another way that they can remove the 8 hydrogen out. Zeolites, for example, are a great 9 example of different types of membranes that are 10 designed to remove a specific compound from a gas 11 mixture. And hydrogen is one of those examples. 12 BY MR. PHILLIPS: 13 Q. I know you're aware one of the prior art 14 references, Reinertsen, teaches palladium membrane 15 separation of hydrogen. Are you aware of any 16 applications of palladium membrane separations to 17 recover or purify hydrogen? 18 A. I am. 19 Q. Where? 20 A. Fuel cells. Fuel cell applications. 21 Q. And why would that make sense in that 22 application?	67 1 permeate, one comes out as a retentate, and that's 2 the typical separation process in the membrane 3 system. 4 Q. Let's switch gears and take a look at the 5 '805 patent. I think that's one of the ones I 6 gave you at the beginning. 7 A. Yeah. 8 Q. This, for the record, it's US patent 9 number 11,673,805 and it's marked as Exhibit 1001. 10 I think you said this earlier, I just wanted to 11 confirm, you reviewed this patent in preparation 12 for your deposition today, right? 13 A. Yes. 14 Q. I want to turn, if you will, to Figure 3 15 of the '805 patent. I believe this is the 16 relevant process flow scheme for this IPR 17 proceeding, which is the series arrangement for 18 the reformers. 19 Do you agree with that? 20 A. Yes. 21 Q. And just for your reference so that -- I 22 don't want to, you know -- I don't want you to
66 1 A. Because it's designed specifically for 2 hydrogen separation. As I mentioned, there are 3 different membranes that are designed for specific 4 molecules. Zeolites are often used in the 5 chemical industry for separations. And different 6 types of zeolites have different pore size that 7 are designed for specific molecules. When you're 8 separating crown ethers, for example, they have a 9 specific zeolite for that because of the molecular 10 dimension in the pore size for the zeolite. 11 So membrane design is specific to those 12 molecules that you're interested in. And so 13 palladium membranes are common in cases where you 14 need to purify, you're not interested in using 15 other techniques, so you use membrane separation. 16 Q. What -- in those instances, what are we 17 separating hydrogen from? 18 A. In the steam methane reformer you can use 19 the palladium membrane to separate hydrogen from 20 CO₂, from methane and CO, different types of gases 21 now. The key is large molecules, CO₂, small 22 molecule hydrogen, and so one comes out as a	68 1 miss this piece. I think the relevant discussion 2 of Figure 3 begins at column 12 of the patent, 3 just for your reference. 4 Column 12, line 65 is where there's -- the 5 discussion of Figure 3 begins. I'm going ask you 6 some questions about Figure 3, so I just want to 7 make sure you have that -- 8 A. Okay. 9 Q. -- have that available, the actual text. 10 So looking at Figure 3, there's a -- 11 starting on the left of the process flow -- first 12 off, let me start with Figure 3. This is what I 13 would characterize as a high-level process flow 14 diagram. Would you agree with that? 15 MR. ROBINSON: Objection, form. 16 A. High-level. 17 BY MR. PHILLIPS: 18 Q. Okay. 19 A. High-level. 20 Q. What do you mean by high-level? I know 21 what I mean by high-level. What do you mean by 22 high-level?

69 1 A. High-level means there's a general 2 characterization of a process. There are boxes 3 with numbers. Those numbers represent something. 4 There's streams. Those streams are numbered. 5 They represent something. So in that case, it's a 6 process flow diagram. 7 Q. As opposed to a more -- can there be more 8 detailed flow process diagrams? 9 A. There generally is. 10 Q. And then I think you and I both know 11 there's detailed P&ID, piping and instrument 12 diagrams, and I think that's the most -- the 13 ultimate in detail; is that right? 14 A. That's correct. 15 Q. So each of these boxes represents a -- I'm 16 going to call it a unit operation within this 17 process flow. I guess would you agree with me 18 that inside each box there could be multiple 19 actual operations going on to achieve whatever 20 that box is -- is designed to do; is that fair? 21 A. That is correct. 22 Q. Okay. So looking at Figure 3, starting on	71 1 reactor. 2 Q. The second box, 201, is an autothermal 3 reformer. Are you familiar with autothermal 4 reformers? 5 A. I am. 6 Q. Can you describe what occurs, what happens 7 in an autothermal reformer? 8 A. Another term for autothermal reformer is a 9 partial oxidation reactor, where part of the 10 incoming stream is oxidized. So, again, methane 11 oxidation, CH₄ plus oxygen, goes to carbon dioxide 12 and water. And that's a highly exothermic 13 reaction. Methane oxidation is used in a 14 autothermal reformer to provide the energy 15 required for the reforming step, methane plus 16 water, going to CO and hydrogen. And they limit 17 the amount of oxidation by the amount of oxygen 18 fed to the reactor. And that's why it's called 19 partial oxidation. It doesn't oxidize, it doesn't 20 operate like a methane oxidation step, full 21 oxidation. It's partial oxidation. So that 22 happens inside this reactor.
70 1 the left we have FG, which I believe the patent 2 refers to as feed gas. That's entering box 200. 3 And the feed gas I think from the patent is 4 natural gas plus steam. Is that accurate? 5 A. It's feed gas. 6 Q. Box 200, the '805 patent refers to that as 7 an endothermic reformer. Do you agree with that? 8 A. It's a catalytic oxidizer. 9 Q. And what is the function of box 200? 10 A. To box 200, again, is converting, it's a 11 steam methane reformer. So it's converting 12 methane and water to CO and hydrogen. And it's 13 doing it with an endothermic reaction, which that 14 reaction that I just described, you know, CO -- 15 CH₄ plus H₂O goes to CO and hydrogen. That 16 requires energy, more energy than it generates, so 17 it's endothermic. And the reason that that can 18 happen is because of catalysts. So catalysts 19 reduce the activation energy required for the 20 reaction to go forward. So that's why it's 21 referred to as endothermic, that's why it's 22 referred to as catalytic. So that's a catalytic	72 1 Q. So there's two sections in an autothermal 2 reformer, one that does the oxidation and then 3 there's also a reforming section -- 4 MR. ROBINSON: Objection, form. 5 BY MR. PHILLIPS: 6 Q. -- as well? 7 A. It doesn't have to be two independent 8 chambers, if that's what you're referring to. 9 Those steps occur in a mixture of gas. And so you 10 can actually have a single chamber where you have 11 partial oxidation occurring that provides energy 12 for the other reaction to go forward. 13 Q. In the Figure 3 there's a -- there's 14 this -- a line labeled 202, 202. Do you see that, 15 that goes from the autothermal reformer back to 16 the endothermic reformer? 17 Do you see that? 18 A. I do. 19 Q. What is that stream? 20 A. That's a heat transfer stream. So taking 21 part of the energy that's formed or that's 22 liberated to 201 back to the catalytic reformer

73 1 that requires energy. So this is just a recycle 2 of that heat. 3 Q. Is that a common arrangement for -- to 4 have an endothermic reformer followed by an 5 autothermal reformer? 6 MR. ROBINSON: Objection, form. 7 A. I don't know how you would classify it as 8 common. It's one of the configurations. 9 BY MR. PHILLIPS: 10 Q. As of -- so this patent was filed in 2020. 11 I mean, was it -- at that time was it common to 12 have this arrangement? 13 MR. ROBINSON: Objection, form. 14 BY MR. PHILLIPS: 15 Q. Of an endothermic reformer followed by an 16 autothermal reformer? 17 MR. ROBINSON: Objection, form. 18 A. The organization of how the catalytic 19 reactor is followed by the partial oxidation 20 reactor is something that has been used in other 21 processes. In terms of common, it depends on how 22 you define common, but I would say that it is a	75 1 utilizing waste heat is a best practice. 2 BY MR. PHILLIPS: 3 Q. So as an alternative to this arrangement, 4 you could also just have a steam methane reformer 5 without autothermal reforming; is that correct? 6 MR. ROBINSON: Objection, form. 7 A. Again, you refer to steam methane 8 reformer. These are both steam methane reformers. 9 It's just how they operate. It's just different 10 types of, you know, chemical processes that go 11 into the reformer. So you could have an 12 autothermal reformer, steam methane reformer, you 13 could have a catalytic reformer, endothermic 14 reformer, they're both reformers. Just these are 15 two combined systems that use, again, recycled 16 heat to run the catalytic reformer. The 17 objective -- as a chemical engineer, the objective 18 is to maximize yield. So you're trying to find 19 some configuration that will provide the most for 20 the least. And in this process you're using 21 recycled heat with two reformers to run. Instead 22 of having two, you could have one. And that's
74 1 configuration that's used. And when you talk 2 about sustainability and trying to reduce energy 3 use, that -- this is a configuration that's often 4 used. So in that case, it's common. 5 Heat transfer, again, is a big deal in the 6 chemical process in trying to find ways to use the 7 heat as effectively as possible. Dow Chemical, 8 for example, right now is building a nuclear 9 reactor south of Freeport to generate heat to use 10 in their chemical processes because they need that 11 heat. So, again, recovering that heat is a big 12 deal. And this configuration is designed for 13 that. 14 BY MR. PHILLIPS: 15 Q. So would this fall into the category of a 16 best practice from a chemical engineer that's 17 putting together a process flow for steam methane 18 reforming? 19 MR. ROBINSON: Objection, form. 20 A. I would say that it does follow best 21 practice. I mean, in terms of, again, the best 22 practice related to sustainability, I think	76 1 what you're implying, is to just have one steam 2 methane reformer. And the question that you would 3 have to ask, and your boss would ask you, Is that 4 the most optimal design? And you would have to 5 say, No, I think if we use that waste heat and use 6 a catalytic reformer, we would get more product, 7 and that would be my -- 8 BY MR. PHILLIPS: 9 Q. I'm just trying to understand what the 10 toolbox is. I think as a chemical engineer we all 11 have a toolbox of options, right? So for a steam 12 methane reforming plant there's options -- 13 A. There are options. 14 Q. -- right? You could have an endothermic 15 reformer without an autothermal reformer, right? 16 You could have an autothermal reformer without a 17 reformer before it, I suppose, right? You could 18 have this combination as another option; is that 19 right? 20 A. That is correct. 21 MR. ROBINSON: Objection, form. 22 A. There's the -- this is actually a very

77 1 interesting technology in my process 2 intensification class that I teach that I have 3 developed at the university. There's a third 4 option that is not considered in the '805 patent, 5 and that's chemical looping. And we've actually, 6 in our class we study this, this process. And we 7 compare it, full oxidation, partial oxidation, 8 combination and then chemical looping. And that's 9 another tool in our toolbox as chemical engineers 10 we can use because, again, that chemical looping 11 is a more efficient way. And so we could actually 12 do that. But that's -- that's not included in the 13 '805 patent, but this is -- as a chemical engineer 14 I know it because I have lot of tools in my 15 toolbox. 16 BY MR. PHILLIPS: 17 Q. Just moving down the flow sheet, we're in 18 Figure 3 still, the next box after the autothermal 19 reformer is box 203, which I think the patent 20 refers to as a water-gas shift reactor. Are you 21 familiar with water-gas shift? 22 A. I am.	79 1 direction, away from hydrogen and CO2 back towards 2 CO; is that accurate? 3 A. That is correct. 4 Q. So the water-gas shift reaction has 5 different -- strike that. 6 The water-gas shift reactor can be 7 operated different ways. Is it typically the same 8 catalyst used in a water-gas shift reactor for 9 each of those type of applications? 10 MR. ROBINSON: Objection, form. 11 A. So as you mentioned, and correctly so, 12 it's an equilibrium reaction. So the thing that 13 drives that water-gas shift reaction is the 14 amounts of material. La Chatelier's principle 15 basically says if you have more moles on one side, 16 it wants to go the other way. And so if you want 17 to run a water-gas shift to the hydrogen side, 18 then you adjust the conditions so that it favors 19 that side. If you want to run it to the other 20 side, to the CO side, gas to liquids, as you said, 21 you're making Fischer Tropsch chemicals, then you 22 can push it back the other way. Again, you change
78 1 Q. Can you briefly describe what occurs in a 2 water-gas shift reactor? 3 A. In previous testimony given in this 4 deposition, I have described the shift reaction. 5 The shift reaction, again, is balancing CO with 6 hydrogen. And so you can shift from one side of 7 that reaction, CO, you know, with water to 8 hydrogen with CO2. And the thing is the shift 9 reactor is designed to maximize hydrogen 10 production. And so you're pushing the CO back to 11 hydrogen side. So you operate this reactor under 12 conditions that do that, that force reaction to 13 the hydrogen side. And so a shift reactor is used 14 to increase the yield of hydrogen in this process. 15 Again, steam methane reforming, the main objective 16 is to produce hydrogen. 17 Q. So I'm going to -- I'm going to go off 18 topic because you mentioned that. Water-gas shift 19 reaction can occur in either direction, right, 20 it's an equilibrium reaction, right? So it to my 21 understanding isn't a gas-to-liquids-type process. 22 You're actually going to shift the other	80 1 the conditions of the reactor. If you want to use 2 a catalytic shift reactor, different catalysts are 3 used for different objectives. Again, 4 ConocoPhillips developed several nickel catalysts, 5 iron catalysts, for that principle, for that 6 objective. And, you know, they were making a lot 7 of liquid from gas, you know, gas to liquids as 8 you referred to. The gas-to-liquids process, 9 again, it's an economics issue. ConocoPhillips 10 took a several-billion-dollar write-down by 11 selling their technology that they had developed. 12 When I was at Idaho National Lab, we got a lot of 13 that from Ponca City that then came to Idaho. 14 Their oil circulation loop that they use in their 15 stirrer reactor to make that reaction happen, a 16 Fischer Tropsch reaction. But again, that's -- 17 that shift reactor is just -- it's designed to 18 enhance hydrogen production in this application. 19 BY MR. PHILLIPS: 20 Q. I'm not an expert in this area. I know 21 you are. I understand there's also -- the 22 water-gas shift reaction can be run at different

1 severities. I also understand that they can be 2 run at different temperatures; high temperature, 3 low temperature. You could have two different 4 water-gas shift reactors. Is that all true? 5 A. That's all true. 6 Q. So these are all tools in the toolbox, 7 right, for a chemical engineer who's designing 8 this, a person of skill in the art; is that right? 9 MR. ROBINSON: Objection, form. 10 A. Correct. 11 BY MR. PHILLIPS: 12 Q. So moving on, left to right, where the 13 next box is -- so let me just say, after the 14 water-gas shift reactor there's -- in Figure 3 15 that's labeled SG4. That's a syngas stream, 16 right? I'm assuming in this process in the '805 17 patent that that stream is going to be either no 18 carbon monoxide or significantly reduced carbon 19 monoxide at this point; is that right? 20 MR. ROBINSON: Objection, form. 21 A. Reduced carbon monoxide. 22	81 83 1 like that. 2 Q. In a coal gasification, we talked about 3 this earlier. Is it -- is it a significant -- 4 compared to 75 percent, is it significantly less 5 hydrogen in a coal gasification plant at this 6 point after a water-gas shift? 7 MR. ROBINSON: Objection, form. 8 A. I would say less. I wouldn't say 9 significantly less, but it's certainly less. 10 BY MR. PHILLIPS: 11 Q. So if steam methane reforming if it's 12 75 percent hydrogen, what would you say for coal 13 gasification, what would the hydrogen percentage 14 look like at that point? 15 A. The Texaco gasifier produces about 50 16 percent hydrogen by volume. The Dow gasifier, 17 approximately the same. And again, they -- 18 depending on the application, if they're 19 interested in maximizing hydrogen, then they can 20 have a shift reactor. Afterwards they can have 21 all kinds of technologies after the gasifier to do 22 that. So that's what they've done here, they have
82 1 BY MR. PHILLIPS: 2 Q. So SG4 is going to be primarily CO2 and 3 hydrogen at this point? 4 A. It's minimized the CO. As we said, in a 5 shift reaction, we did that. It's mostly hydrogen 6 with some CO2, some methane, some CO still in 7 there, because it's an equilibrium process. 8 There's still some CO. So that all comes in to 9 204. 10 Q. When you say there's significantly more 11 hydrogen, are we talking about 75 percent 12 hydrogen? I guess I'm talking molar percent. 13 MR. ROBINSON: Objection. 14 BY MR. PHILLIPS: 15 Q. Is it on that order? 16 A. Volume -- 17 (Simultaneous discussion interrupted by 18 reporter.) 19 BY MR. PHILLIPS: 20 Q. I apologize. So 75 percent -- 75 volume 21 percent, you would say? 22 A. Significant, yes, 70, 75, 80, something	84 1 the reformer on one side, but then they have, 2 again, this shift reactor, then they have, you 3 know, different technologies that they use to 4 increase the hydrogen, so that's what they've done 5 here, and that's why 204 has got high hydrogen. 6 Q. So you've gotten to the next box, 204. So 7 there's two -- the next two boxes are 204 and 205. 8 204 the patent describes as pressure swing 9 adsorption, PSA. Box 205, the patent refers to 10 that as the cryogenic CO2 removal; is that 11 correct? 12 A. That is correct. 13 Q. So my question for you is -- so, again, 14 this is -- we're talking about a person of skill 15 in the art. Why would we have box 204 in front of 16 box 205 in this process flow? 17 MR. ROBINSON: Objection, form. 18 A. The reason is because someone has done a 19 process development study, and they looked at this 20 and they said this is the order that maximizes 21 production and minimizes cost. Not shown in these 22 boxes, as you said earlier, and I agreed with you,

85 1 this is a high-level process flow diagram. And 2 inside each of those boxes there's several other 3 things that are going on. One of those other 4 things that are going on are compressors that are 5 running, and compression costs a lot of money. As 6 I mentioned earlier, in a cryogenic system where 7 you have to do compression to separate oxygen and 8 nitrogen, the cost can be as much as 30 percent 9 parasitic power in generating power to make the 10 oxygen for coal oxidation for carbon capture and 11 sequestration. That's an example of that. 12 So in this case, this process, again, has 13 been designed to minimize costs and maximize 14 hydrogen production. So the order that they've 15 listed them there, PSA with cryogenic separation, 16 is based on that. 17 BY MR. PHILLIPS: 18 Q. Would you consider that standard chemical 19 engineering design? 20 A. Yes. 21 MR. ROBINSON: Objection, form. 22	87 1 in 204 is approximately the same. Not the same, 2 but in the same order of magnitude. And so you 3 get the benefit of that, whereas if you had to 4 pump it up further, as in a cryogenic separation, 5 then that would be an additional cost. So this 6 is – this is a benefit of having this PSA unit in 7 that place in the process. 8 BY MR. PHILLIPS: 9 Q. So I'm going to -- I'm going to 10 oversimplify PSA, so correct me if I'm wrong. So 11 my understanding is SG4 is going into this 12 pressure swing adsorption unit, CO2 is going to 13 get absorbed onto whatever material is being used 14 in PSA unit, hydrogen passes through the absorber. 15 And then the pressure swings and so then the CO2 16 is released. Is that -- 17 A. That's correct. 18 Q. -- relatively accurate? 19 MR. ROBINSON: Objection, form. 20 A. Yes, relatively accurate. Simplified, but 21 yes. 22
86 1 BY MR. PHILLIPS: 2 Q. Coming out of box 204, the pressure swing 3 adsorption unit, HG1 is, I believe, the hydrogen 4 product -- 5 A. Yes. 6 Q. -- do you agree with that? 7 A. I do. 8 Q. I know with pressure swing adsorption, and 9 maybe you can describe the process for me, but my 10 understanding is that the hydrogen comes out as a 11 high-pressure stream; is that correct? 12 A. Higher than -- yeah. It's elevated 13 pressure, yeah. Again, "high" is a relative term, 14 so, yeah, elevated pressure. 15 Q. Can you explain that phenomenon of why 16 hydrogen -- is the hydrogen pressure roughly 17 slightly -- roughly the same pressure as SG4? 18 MR. ROBINSON: Objection, form. 19 A. So, again, PSA, pressure swing adsorption, 20 so you're absorbing it with pressure. And so 21 you're pumping the gas up to separate the 22 hydrogen. And in this case SG4 and the pressure	88 1 BY MR. PHILLIPS: 2 Q. So stream RG1, I think the RG -- I think 3 the patent refers to it as residual gas? 4 A. Yes. 5 Q. This is going to be at this point CO2. 6 Perhaps there's still hydrogen in this stream. I 7 think you mentioned earlier there could still be 8 CO. I guess it's possible there's unreacted 9 methane. There's other things that can be in RG1, 10 but it's primarily CO2 at that point; is that 11 correct? 12 MR. ROBINSON: Objection, form. 13 A. That's accurate. 14 BY MR. PHILLIPS: 15 Q. So box 205 -- again, correct me if I'm 16 wrong. RG1 is at a relatively low pressure 17 compared to the hydrogen, HG1; is that correct? 18 A. RG1 is at a lower pressure, correct. 19 Q. So I'm going to ask you this because I'm 20 going to -- I'll mess this up completely, so I'm 21 just going to have you use your own words on this, 22 but cryogenic CO2 removal unit, can you describe

89 1 how that basically operates? 2 A. Yes. So when you compress gases, 3 depending on the gas molecule, the dew point or 4 the point at which it goes from a gas phase to a 5 liquid phase is different. For example, you can 6 think about your Bic lighter. The butane in that 7 Bic lighter at room temperature is a liquid, and 8 that's why it works. If you had a butane lighter, 9 again, more hydrocarbon, it's a heavier hydro -- 10 it also is a liquid. But propane wouldn't work. 11 So you have your barbecue out on your back deck 12 and it maybe it's a propane -- not a charcoal in 13 this case, but propane-fired barbecue. That's a 14 gas. So they pressurize that gas. And so the 15 tank that you get is actually pressurized. So 16 that's liquid propane in there. And then when you 17 open the valve, it depressurizes and it goes 18 across that phase boundary, becomes a liquid. And 19 so that's what happens in a cryogenic separation. 20 They pressurize the gas, and the gas that has a 21 higher dew point, dew point is where the first 22 drop of liquid appears, that comes out first. And	91 1 boiling point gases, including water, but not 2 just -- not just water, but other things that 3 might be in the stream. 4 Q. So there might be a dryer, for example, 5 or -- 6 A. Probably. 7 Q. -- some other type of guard bed to remove 8 those types of chemicals? 9 A. Some type of reactor. It could be a 10 condenser, it could be lots of different things. 11 Q. You had mentioned to me before, and I 12 guess the concept of whether you use PSA first 13 versus cryogenic CO2 first, you describe that as 14 in part due to economics? 15 A. Yes. 16 Q. Is that fair? 17 A. That's what I said. 18 Q. So if you did the cryogenic CO2 removal 19 before the PSA unit, what are the economic 20 downfalls for doing that order of operations? 21 MR. ROBINSON: Objection, form. 22 A. The No. 1 issue related to the economics
90 1 so CO2 has a higher dew point than hydrogen does. 2 And so it's a great separation device. So as you 3 pressurize it, you drop out the CO2, it's a 4 liquid, and then you -- so you can pull it off. 5 And then what's left are the lighter hydrocarbons; 6 hydrogen, CO, that don't pressurize at that 7 pressure or liquefy at that pressure, so that's 8 how the cryogenic separator works. Same thing 9 with nitrogen and oxygen. That's how an ASU 10 works. 11 Q. So again, we were talking about this as a 12 high-level process flow diagram. I think you -- 13 from what you described about how CO2 is removed 14 cryogenically, I'm assuming that water needs to be 15 out of this system before this unit. Is that fair 16 to say? 17 A. Again, the dew point for water is much 18 higher than CO2. And so obviously when you 19 compress that gas, you're going to get anything 20 above CO2 is going to come out as a liquid as 21 well. So if you want too have pure CO2, then you 22 have to find ways to remove all those higher	92 1 of putting the cryogenic separation before the 2 pressure swing adsorption separation is the 3 compression step. In your process design class 4 that you had as a chemical engineer that I've 5 taught, that's something that we talk a lot about, 6 is the cost of compression. And not just in terms 7 of the capital costs of a compressor, but the 8 operating costs of a compressor, the power 9 requirements to run a compressor. And so 10 that's -- that's a significant issue in terms of 11 the economics of this overall process. 12 BY MR. PHILLIPS: 13 Q. If you didn't remove the hydrogen first 14 and you used cryogenic CO2 first before hydrogen 15 removal, does that mean you're also going to be 16 compressing all of that hydrogen in the feed as 17 well? 18 MR. ROBINSON: Objection, form. 19 A. You're compressing the gas, whatever gas 20 it is. 21 BY MR. PHILLIPS: 22 Q. I'm just trying to understand if there's

93 1 an economic benefit to removing -- you said that's 2 a 75 volume percent hydrogen in SG4. Does that 3 make the cryo unit smaller, by taking out all the 4 hydrogen first before doing the cryogenic CO2 5 removal? 6 MR. ROBINSON: Objection, form. 7 A. So the volume of gas that you have to 8 compress certainly has a part of the economics. 9 And a great example of that is oxy combustion, 10 where you remove the nitrogen from air and then 11 you feed pure oxygen either to a gasifier or to a 12 combustor. The volume of the gas is less, and so 13 the equipment size is less, thus the equipment 14 costs are less. So there's a balance between 15 whether or not you have excess operating costs 16 from compression or excess costs -- equipment 17 costs because of the size of the equipment. So 18 certainly that's part of the analysis. 19 BY MR. PHILLIPS: 20 Q. So there's trade-offs that could cause a 21 person of ordinary skill in the art to choose one 22 versus the other; is that right?	95 1 Q. So this is a process where they're 2 intentionally trying to create hydrogen and 3 they're going to separate carbon dioxide, that's 4 the process that they're claiming; is that 5 accurate? 6 A. It is. 7 Q. Step A is providing a feed gas stream that 8 comprises hydrocarbon component and steam, the 9 hydrocarbon component comprising at least methane. 10 Do you see that? 11 A. I do. 12 Q. We're going to reform at least a portion 13 of the feed gas stream in an endothermic reforming 14 step; is that right? 15 A. Correct. 16 Q. And that is, I believe, analogous to 17 box 200 in Figure 3; is that right? 18 A. The catalytic reformer, correct. 19 Q. Step C is reforming a portion of the feed 20 gas stream -- actually -- okay. So this gets 21 complicated, right. So step C actually has an or, 22 right, so I believe the first part of the claim
94 1 MR. ROBINSON: Objection, form. 2 A. That is correct. 3 BY MR. PHILLIPS: 4 Q. Let's -- so we've marched through I guess 5 the relevant parts of Figure 3. Let's take a look 6 if you will -- again, we're still in Exhibit 1001, 7 the '805 patent. If we could take a quick look at 8 claim 1. It's on -- it starts on page 12 of 13, 9 using the numbering at the bottom of the page. 10 Do you see -- are you there? 11 A. I am. 12 Q. So claim 1 starts with a process for 13 preparing hydrogen by reforming hydrocarbons with 14 steam and for separation of carbon dioxide 15 comprising. 16 So do you understand that that part of the 17 claim is referred to as the preamble, in this case 18 it's telling you what the process is about? 19 MR. ROBINSON: Objection, form. 20 BY MR. PHILLIPS: 21 Q. Do you agree with that? 22 A. I agree.	96 1 before the or is the parallel configuration, and 2 we're going to talk about the series 3 configuration, which is the -- after the or; is 4 that correct? 5 A. That is correct. 6 Q. So step C, then, the relevant portion, is 7 reforming the first syngas stream in an 8 autothermal reforming step. 9 So I believe that is -- that follows to 10 box 201 in Figure 3; is that right? 11 A. That is correct. 12 Q. Step D is converting the carbon monoxide 13 present in the third syngas stream to produce 14 hydrogen and carbon dioxide. I believe that 15 step D is the water-gas shift, which is box 203; 16 is that right? 17 A. Correct. 18 Q. Step E is separating hydrogen from the 19 fourth syngas stream by means of pressure swing 20 adsorption. I think we talked about that as being 21 box 204; is that correct? 22 A. That is correct.

97 1 Q. Step F, separating carbon dioxide from the 2 first residual gas stream by cryogenic carbon 3 dioxide separation. 4 Do you see that in step F? 5 A. I do. 6 Q. And I believe we discussed that as being 7 box 205 in Figure 3; is that right? 8 A. We haven't discussed 205, but that's what 9 it is. We got to 204 and that's -- 10 Q. Sorry. So 205 was the cryogenic CO2 11 separation; is that right? 12 A. That's correct. Which is described in 13 letter F. 14 Q. So going -- I just wanted to -- the whole 15 reason why I wanted to march through that was just 16 to -- I'm a picture person. So Figure 3 aligns 17 with claim 1, at least the relevant portion of 18 section C that's talking about the series 19 configuration; is that accurate? 20 A. The first part of the or, yes. 21 Q. The second part of the or? 22 A. The second part of the or, I'm sorry, yes.	99 1 A. I did. 2 Q. I understand from your declaration that it 3 is your opinion that Reinertsen does not 4 anticipate claim 1 or claim 11 of the '805 patent; 5 is that right? 6 A. Correct. 7 Q. And specifically for claim 1 I understand 8 that your opinion is that Reinertsen does not 9 disclose PSA hydrogen separation upstream of 10 cryogenic CO2 separation; is that right? 11 A. That's correct. 12 Q. And for your claim -- and for claim 11, 13 your opinion is that Reinertsen does not disclose 14 a compression step before cryogenic CO2 15 separation; is that right? 16 A. That's correct. 17 Q. And your declaration does not state any 18 other basis for no anticipation by Reinertsen. I 19 just wanted to confirm that that's correct. 20 A. That's what the declaration says. 21 Q. Do you have any other opinions that are 22 not in your declaration?
98 1 Q. I just wanted to make sure, again, because 2 I like -- I like process flow diagrams. I don't 3 know about you. For me a picture is worth a 4 thousand words. But I just wanted to make sure 5 claim 1 in your mind and in mine lines up with 6 Figure 3. Actually, I think we're at a decent 7 breaking point. I need a restroom break. 8 A. Perfect. 9 Q. We're going to move on to Reinertsen after 10 the break, so I think this is a perfect point to 11 take one. 12 MR. PHILLIPS: So off the record. 13 (Recess taken from 11:03 a.m. to 14 11:15 a.m.) 15 BY MR. PHILLIPS: 16 Q. Dr. Smith, we're coming back from the 17 break. I have handed you what has been marked 18 Exhibit 1005. You may recognize this as the 19 Reinertsen prior art reference; is that correct? 20 A. Yes. 21 Q. And you looked at this in preparation for 22 your deposition today?	100 1 A. None. 2 Q. I'm going to direct you to Figure 4 -- 3 it's Exhibit 1005. I'm going to direct you to 4 Figure 4 in Reinertsen and hopefully we can do 5 this quickly. I want to do somewhat the same 6 exercise that we did with respect to the '805 7 patent. 8 So Figure 4 is a high-level process flow 9 diagram. Would you agree with that? 10 A. I would. It's a little bit more detailed 11 than the previous one, but, yes, it's still a very 12 high-level process flow diagram. 13 Q. Why would you say there's a little more 14 detail? 15 A. More boxes, more lines, more numbers. 16 Q. Okay. So, for example, one of the 17 additional boxes is box 5 of the air separation 18 unit. Is that one example? 19 A. That is one example. 20 Q. I noticed there's also box 11, which is a 21 hydrogen compressor; is that correct? 22 A. Correct.

101 1 Q. And box 9, which is a CO2 compressor; is 2 that right? 3 A. That is correct. 4 Q. So those are examples of additional boxes. 5 Box 7, while we're at it, I believe is referred to 6 as a condenser or dryer? 7 A. It's a condenser to remove water, yes. 8 Q. So let's walk through Figure 4. So those 9 are some of the extra boxes were not in the '805 10 patent. So let's start with box 4. I believe the 11 Reinertsen refers to this as a prereformer. Do 12 you agree with that? 13 A. I do. 14 Q. And what's the function of the 15 prereformer? 16 A. It's to improve the quality of the 17 reformed -- the gas that's going to be reformed. 18 The previous patent that we reviewed, '805 patent, 19 talked about methane preferably as the gas that's 20 being reformed. You can use any -- basically any 21 hydrocarbon. And in order to help improve the 22 performance of this steam methane reformer, the	103 1 is that correct? 2 A. That is correct. 3 Q. And I think you talked about this before. 4 This converts carbon monoxide to carbon dioxide 5 and water; is that right? 6 A. It increases the composition of hydrogen 7 in the shift reactor. 8 Q. It also increases CO2 as well? 9 A. Well, it does. I mean, you're shifting 10 from the CO side with water to the hydrogen with 11 CO2. 12 Q. Does this correspond to the water-gas 13 shift box that we saw in the '805 patent, 14 Figure 3? 15 A. It does. 16 Q. So up to this point the boxes are in the 17 same order as we saw in the '805 patent. We had 18 an endothermic reformer, an ATR, followed by a 19 water-gas shift; is that correct? 20 A. That is correct with the addition of box 3 21 and 4. 22 Q. Correct.
102 1 prereformer, preformer, is there to, again, push 2 more of the gas to the methane. So it's trying to 3 improve the quality of gas. 4 Q. So if you were using a higher -- 5 hydrocarbon feed? 6 A. Correct. 7 Q. This acts as -- is it a cracking reaction? 8 A. It can be many different things. Cracking 9 is an example of one of them. 10 Q. Box No. 1, Reinertsen refers to this as a 11 gas-heated reformer. Does that correspond to the 12 endothermic reformer that was described in the 13 '805 patent? 14 A. It does. 15 Q. And box No. 2 Reinertsen refers to as 16 the -- as an ATR, autothermal reformer; is that 17 correct? 18 A. That is correct. 19 Q. And does that correspond to the ATR that 20 we saw in the '805 patent? 21 A. It does. 22 Q. Box No. 6 is the water-gas shift reactor;	104 1 A. This one has, like I said, a little more 2 detail than the previous one. 3 Q. Correct. Box No. 12, the -- with respect 4 to Figure 4, the Reinertsen patent describes this 5 as a palladium membrane unit for hydrogen removal. 6 Do you agree with that? 7 A. I do. 8 Q. How is a palladium membrane different from 9 the PSA separation unit that we discussed earlier? 10 A. So it's a different chemical process. The 11 unit operations, a membrane separation has to do 12 with the size of the molecules that you're trying 13 to separate. The RO unit in your house, if you 14 have a well, operates very similar. You have a 15 membrane that you're pushing water through, and so 16 the bad stuff in your water you don't want to 17 drink is separated out with a reverse osmosis 18 membrane. So a palladium membrane, it does the 19 same thing with hydrogen and CO. Hydrogen is a 20 lot larger molecule and more -- push hydrogen 21 through it and the CO2 stays on the outside. 22 Q. So my understanding is one of the key

105 1 differences -- high-level differences between the 2 PSA unit and the palladium membrane unit is that 3 the hydrogen that's released from the palladium 4 membrane unit is at a relatively low pressure; is 5 that correct? 6 A. Again, "relative" is a relative term. And 7 so a membrane separation system uses pressure to 8 separate the gases, and it uses a membrane or 9 pores, where the smaller molecules can pass 10 through and the larger molecules are prevented 11 from passing through. So the downstream side of a 12 membrane has got a lower pressure. So if that's 13 the reference to relative lower pressure, then I 14 would agree with that. 15 Q. So why do we need box 11, which I think 16 Reinertsen describes as a hydrogen compressor? 17 Why is that needed on this flow sheet? 18 A. In the event that they want to have 19 hydrogen at a higher pressure, they'd use a 20 compressor. 21 Q. And one of the reasons for needing 22 hydrogen at a high pressure is because it's --	107 1 So it's excess volume you don't need. And again, 2 it messes up the purity of the CO2. So it's 3 better to take it out here as a condenser and then 4 compress the CO2. 5 Q. You say it messes up the purity of the 6 CO2. Does it actually have a detrimental impact 7 on the process itself, the cryogenic CO2 process? 8 MR. ROBINSON: Objection, form. 9 A. It's going to condense sooner than CO2. 10 So if the CO2 compressor, what you're after with 11 the cryogenic separation is to have CO2 separate, 12 and so if you have water with the CO2, it's going 13 to mess it up. It's going to cause it to 14 malfunction, cause it to not perform at its 15 optimum design capacity. 16 BY MR. PHILLIPS: 17 Q. So a person of ordinary skill in the art 18 knows that, and knows that they need box 7 in this 19 flow diagram; is that right? 20 A. A person of ordinary skill would 21 understand that, correct. 22 Q. Box 13 Reinertsen describes as the
106 1 that's how hydrogen's going to be stored? Is that 2 one reason? 3 A. Shipped or stored. 4 Q. And that's generally at a higher pressure? 5 A. Correct. 6 Q. Does a PSA unit release hydrogen at the 7 pressure needed for storage? 8 A. Depends on, again, what pressure you 9 wanted. If you're asking is the pressure from 10 this compressor the same as what a PSA provides, 11 the answer is possibly. Not necessarily. 12 Q. After box 12, I think we mentioned this 13 before, box 7 is a dryer condenser, Reinertsen 14 describes that as -- I think we discussed this 15 earlier. The purpose for that is to remove water, 16 which is labeled as stream 72? 17 A. That's correct. 18 Q. Is that correct? And that's because we 19 don't want water in the cryogenic unit because it 20 will -- it will -- it will freeze? 21 A. Well, water has a higher dew point. And 22 so it's going to come out first before CO2 does.	108 1 cryogenic CO2 removal unit. Do you agree with 2 that? 3 A. I do. 4 Q. Is this similar to the cryogenic CO2 5 removal unit that we saw in the '805 patent, 6 Figure 3? 7 A. It's a cryogenic separation unit. And so 8 obviously the implementation may be -- it's a 9 compressor produced by GE, maybe it's not. It's a 10 compressor that's used to pump up the pressure to 11 the CO2 stream to condense it. 12 Q. And then we discussed this a second ago as 13 well, box 9 is a CO2 compressor. What -- why 14 would we need a CO2 compressor in this process 15 flow? 16 A. I would -- in my opinion, the same reason 17 you have box 11 for hydrogen. 18 Q. It's not listed -- it's not shown as a 19 separate box. You describe this as a high-level 20 PFD. But the cryogenic CO2 removal unit, box 13, 21 is that going to require additional compression in 22 order to operate that unit?

109 1 A. Box 13 most likely has a compressor in 2 there to pump it up to cause it to liquefy. 3 Q. So there's a -- there's going to be -- 4 we're going to be -- in this particular flow sheet 5 you're going to end up compressing the hydrogen 6 product in box 11. You're also going to end up 7 compressing the -- the CO₂-rich syngas in the 8 cryogenic CO₂ removal unit, box 13? 9 A. That's correct. 10 Q. Again, taking a high-level view of 11 Figure 4 of Reinertsen, Figure 3 of the '805 12 patent, Figure 4 of Reinertsen, we have the two 13 reforming steps, endothermic and ATR, followed by 14 water-gas shift, followed by hydrogen removal, 15 followed by CO₂ removal. 16 Do you agree with that? 17 A. Yes. 18 Q. And the '805 patent is very similar. You 19 have the two reforming steps, water-gas shift, 20 hydrogen removal -- let me start over. 21 So with the '805 patent we also have the 22 two reforming steps, water-gas shift, hydrogen	111 1 what we've done with box 11. 2 Q. In Reinertsen my understanding is that the 3 CO₂-rich stream coming from the palladium membrane 4 unit is at a higher pressure than the hydrogen 5 stream leaving that unit; is that fair? 6 A. That's fair. 7 Q. So how does a engineer, a person of 8 ordinary skill in the art, know whether they need 9 a compressor or not before the cryogenic CO₂ unit? 10 MR. ROBINSON: Objection, form. 11 A. So let me clarify your question. 12 BY MR. PHILLIPS: 13 Q. Please. 14 A. You're asking if a person skilled in the 15 art understands that they need a compressor for 16 the hydrogen side or a compressor for the CO₂ for 17 cryogenic separation? 18 Q. That's a good question. So let me 19 rephrase this. I think we had already discussed 20 the hydrogen piece. So I was focusing more on the 21 CO₂-rich stream. And I guess let me just boil 22 this right down to where I'm going with this.
110 1 removal, CO₂ removal, in that order. So the order 2 of the steps is the same. I think you will agree 3 with me that the hydrogen removal step is 4 different between the two flow sheets; is that 5 correct? 6 A. That's correct. 7 Q. But it's in the same location in the flow 8 sheet in terms of the process scheme. Would you 9 agree with that? 10 A. I would agree with that. 11 Q. So I'm going to ask what I think is a dumb 12 question, but I'm going ask it anyway. So how 13 does an engineer, a chemical engineer, a person of 14 skill in the art, know that they need a hydrogen 15 compressor for their process? 16 A. So most times when you design a process, 17 you have specifications, requirements that your 18 design is aimed at. And if a design specification 19 requires a certain pressure and the equipment that 20 you use, i.e., in this case the palladium 21 membrane, doesn't provide the required pressure, 22 then you have to add another box. And this is	112 1 My understanding is a -- in the '805 2 patent, a PSA hydrogen separation, the CO₂-rich 3 stream is going to be at a lower pressure than the 4 CO₂-rich stream in Reinertsen. Would you agree 5 with that? 6 A. At a certain place and point in the 7 process, yeah. 8 Q. So is -- when a person of skill in the 9 art -- but -- strike that. 10 The cryogenic CO₂ unit, it needs to 11 operate at a certain pressure in order to make the 12 separation that it's trying to do in order to 13 liquefy the CO₂; is that right? 14 A. Correct. 15 Q. So does a person of skill in the art, how 16 does a chemical engineer know what's needed in 17 order to get from the CO₂-rich stream in order to 18 be able to make that CO₂ separation in the 19 cryogenic unit? 20 MR. ROBINSON: Objection, form. 21 A. It's based on thermodynamics, right? I 22 mean, you understand. You had thermal. And you

113 1 understood what the compression requirements were, 2 what the temperature compression -- you know, 3 pressure/temperature curve look like. So a person 4 skilled in the art would look at the streams and 5 whether that's a stream by hand calculation or a 6 stream in a process simulator likes Aspen that 7 tells you what that stream is going to be, and you 8 can say, Well, I need it to be at this pressure 9 for this PSA unit to work, or this cryogenic unit 10 to work, and so you're going to say, Well, in 11 order to get there I have to have a compressor to 12 bring it up to that pressure. So that's how a 13 person that normally designs a chemical process 14 would do it. 15 BY MR. PHILLIPS: 16 Q. So would you consider that straightforward 17 engineering? 18 MR. ROBINSON: Objection, form. 19 A. Well, you know, straightforward 20 engineering is another relative term that you've 21 used. A person skilled in the art would be able 22 to do that, yeah.	115 1 order for that box 13 to be there, in order for 2 box 7 to be. Why do I need box 7? I would have 3 to have done some analysis. So a person skilled 4 in the art, again, three to five years' experience 5 with PSA, you know, steam methane reforming, a 6 graduate degree, would do some calculations and 7 understand what the conditions were at that point 8 in the process, and then he would pick a piece of 9 equipment to provide what he needed or she needed. 10 BY MR. PHILLIPS: 11 Q. One of the issues in this case, and I know 12 you appreciate this, is the -- is the '805 13 requiring pressure swing adsorption, Reinertsen 14 Figure 4 discloses palladium membrane separation. 15 Does a person of skill in the art know, when you 16 choose pressure swing adsorption, you are not 17 going to need a hydrogen compressor, but you are 18 going to need a compressor to compress the 19 cryogenic CO -- the CO₂-rich stream for cryogenic 20 separation. 21 You agree with that, right? 22 A. I agree.
114 1 BY MR. PHILLIPS: 2 Q. Using tools like Aspen? 3 A. Or by hand. You can do it by hand. I 4 used to do it by hand before they had computers. 5 A lot of plants around here that were designed 6 that way. 7 Q. And we're talking about design. But in 8 terms of just creating the flow diagram, 9 oftentimes engineers start with this. You would 10 be able to use your basic engineering 11 understanding to know pressure needs to be 12 increased for certain units even without designing 13 the compressor itself; is that right? 14 A. So -- 15 MR. ROBINSON: Objection, form. 16 A. -- if I were the one doing the design -- 17 it shows up as a box diagram here, it would be a 18 lot more work than just that box. It's not just 19 putting boxes down in a row, it's not just looking 20 down on a piece of paper. There'd be a lot of 21 hand calculations, a lot of analysis done to 22 understand what has to happen at that point in	116 1 MR. ROBINSON: Objection, form. 2 BY MR. PHILLIPS: 3 Q. And if you used the palladium membrane 4 separation for hydrogen, a person of skill in the 5 art would know you need a hydrogen compressor, 6 because you're going to be -- assuming, again, 7 with your boundary conditions, that we need to 8 pressurize hydrogen for storage or transportation, 9 you would need a compressor, right? 10 A. Depending on -- 11 MR. ROBINSON: Objection, form. 12 A. Depending on the membrane and the pressure 13 drop across the membrane, and what that hydrogen 14 pressure is going to be, and what my stream 15 pressure needs to be in order to ship it or store 16 it, then I -- then I would say, Well, I need to 17 have a compressor there, so somebody skilled in 18 the art would know that. 19 BY MR. PHILLIPS: 20 Q. So in terms of which unit you chose, 21 there's going to be trade-offs, economic 22 trade-offs. Is that fair to say?

117 1 A. That's fair to say. 2 Q. Potentially capital trade-offs? 3 A. Economics include capital and operating. 4 Q. Looking at Reinertsen, the Reinertsen 5 patent discloses a number of process schemes 6 identified in Figure 10, Table 1. 7 Do you see that? 8 A. I do. 9 Q. So if I'm reading this table correctly, 10 and correct me if I'm wrong, there are three 11 specific embodiment examples that utilize 12 cryogenic separation for CO2 removal. 13 Do you agree with that? 14 A. I do. 15 Q. And for -- and so that would be embodiment 16 example 2, embodiment example 4 and embodiment 17 examples 5 through 7. Do you agree? 18 A. I do. 19 Q. And for each of those three embodiments, 20 the hydrogen removal step is palladium membrane in 21 each of those cases. Do you agree with that? 22 A. I do.	119 1 mentioned earlier in my deposition, amine 2 separation was used routinely. You'll notice that 3 in those embodiments 2, 4 and 5 through 7, again, 4 cryogenic separation is used, amine separation is 5 not used. That's an example of how the technology 6 in chemical engineering has evolved over time, and 7 is, you know, related to the focus on climate 8 change and sustainability. And so, again, a PD 9 membrane separation is a very efficient way, and 10 membrane technology has evolved in time. And so 11 this most likely has to do with current status. 12 Somebody skilled in the art would understand that. 13 You or I, when we went to school back in the '80s, 14 probably the technology's different today, and 15 that's what we teach today, is a little bit 16 different. So I suspect that's why a person 17 skilled in the art would have picked this 18 configuration, a PD membrane to separate and then 19 cryogenic separation to separate. 20 Q. Does that decision -- do you think that 21 decision was made in part due to the CapEx and 22 OpEx considerations for cryogenic separation?
118 1 Q. Is it your understanding also that for 2 embodiment examples 2, 4 and 5 through 7, that the 3 palladium membrane -- that this would look like 4 Figure 4 of the Reinertsen patent, the palladium 5 membrane -- the hydrogen removal would be upstream 6 of the cryogenic CO2 removal. 7 Do you agree with that? 8 A. According to figure, whatever we looked 9 at, Figure 4: According to Figure 4, box 12, PD 10 membrane. 11 Q. You described -- so a person of skill in 12 the art, a chemical engineering -- a chemical 13 engineer designing one of these plants has 14 options, in these three embodiments, palladium 15 membrane was -- the hydrogen removal was always 16 before the cryogenic CO2 removal. 17 Do you agree with that? 18 A. That's the way it's written. 19 Q. Do you have a sense for why that is the 20 case? 21 A. Most likely because of the cost and the 22 efficiency. Again, in the early days, as I	120 1 MR. ROBINSON: Objection, form. 2 BY MR. PHILLIPS: 3 Q. It being second behind hydrogen removal. 4 Is that a factor? 5 A. I think that's probably a factor, yeah. 6 Q. Do you consider that the major factor? 7 MR. ROBINSON: Objection, form. 8 A. You know, it depends on where the plant's 9 built. I mean, it depends on -- there's a lot of 10 things that go into plant design. I would -- I 11 would say that for me, whenever I do a process 12 design, economics, which includes CapEx and OpEx, 13 are a major consideration. Not the only 14 consideration, but a major consideration. So 15 depends on the company that's doing the design, 16 depends on who's building the process. I mean, 17 there's a lot of things that go into that 18 decision. 19 BY MR. PHILLIPS: 20 Q. I am going to hand you now what's been 21 marked as Exhibit 1003. I apologize for the size. 22 This is Dr. Klein's declaration that you said you

121 1 reviewed in preparation for today. Again, I tried 2 to make it double-sided to try to -- try to save 3 the trees as best I could. 4 Let's turn to paragraph 238. And that's 5 on page 145, if that helps you. 6 A. Yeah. Let me take this apart here. 7 Q. If you could take a quick read of 238. I 8 don't know if you've seen that paragraph in a 9 while. If you could read that and let me know 10 when you're done. 11 A. Moreover, my opinion would be as a POSA at 12 a critical date, recognizing additional advantages 13 of implementing hydrogen separation, such as by 14 PSA upstream of cryogenic CO2 separation in the 15 manner shown in Darde in the process of Rytter. 16 For example, a POSA at a -- at the critical date 17 would have recognized that separating hydrogen gas 18 upstream reduces the total amount of gas provided 19 for cryogenic CO2 separation, thereby allowing for 20 a physically smaller-sized cryogenic unit and 21 beneficial reductions in capital expenditure costs 22 and operating expense costs associated with	123 1 CapEx and OpEx. 2 Q. And a minute ago you said that was a major 3 consideration. Do you agree with that? 4 A. Yeah, of course I do. 5 MR. ROBINSON: Objection, form. 6 BY MR. PHILLIPS: 7 Q. So in light of that, a POSA reading 8 Reinertsen would not be surprised that Reinertsen 9 only used cryogenic CO2 after hydrogen removal? 10 MR. ROBINSON: Objection, form. 11 BY MR. PHILLIPS: 12 Q. Is that right? 13 A. What I said earlier was that depending on 14 the conditions that the design was put together 15 with, cryogenic separation may be the preferred 16 over amine separation. Prior to a certain point 17 amine separation was the most common used 18 separation process. So I would say a person 19 skilled in the art would have understood that, 20 that the changes in technology, the changes in 21 motivation for using cryogenic versus amine 22 separation. So I think I agree with that
122 1 overall process. 2 Q. So now that you've read that, do you agree 3 with Dr. Klein's testimony regarding the CapEx and 4 OpEx considerations for positioning the cryogenic 5 CO2 separation downstream of hydrogen removal in 6 the steam methane reforming plant? 7 A. Again -- 8 MR. ROBINSON: Objection, form. 9 A. -- he says that a POSA at that date would 10 have recognized separating hydrogen gas upstream 11 reduces the total amount. So, yes, I agree with 12 that statement. In terms of his reference to the 13 two previous patents, Darde and Rytter, I don't 14 agree with that. I think that there are issues 15 that were focused in the Darde patent that we 16 haven't talked about yet here, but they're 17 certainly important. And to compare Darde to 18 Reinertsen, that takes -- that ignores that 19 difference. And so again, that's where I disagree 20 with his statement. But overall, what he says, 21 that somebody skilled in the art would have 22 recognized the impact that size has to do with	124 1 statement, as I've said. What he said is that a 2 person skilled in the art would have recognized 3 the impact that size has on OpEx and CapEx. 4 Q. So you'll acknowledge, though, that 5 Reinertsen, when cryogenic CO2 removal was chosen, 6 that was always downstream of hydrogen removal. 7 Do you agree with that? 8 A. So the PSA -- you're asking if when 9 Reinertsen was issued, that having the PSA 10 upstream of the cryogenic separation was expected? 11 Q. Well, Figure 4 only showed palladium 12 membrane. 13 A. That's correct. 14 Q. So I'm just saying hydrogen removal in 15 general. 16 A. Right. 17 Q. Cryogenic CO2 removal was always 18 downstream of hydrogen removal? 19 A. CO2 separation was downstream. 20 Q. But cryogenic CO2 separation in particular 21 was downstream? 22 A. The way that --

125 1 MR. ROBINSON: Objection, form. 2 A. The way the figure that we reviewed, 3 that's where it was. Again, Reinertsen has 4 several different examples, and in the embodiments 5 that we looked at in that table, it was always 6 cryogenic separation, that's correct. 7 BY MR. PHILLIPS: 8 Q. And that was always downstream of hydrogen 9 removal? 10 A. It was always downstream. 11 Q. Are you aware of any instances in a steam 12 methane reforming plant where cryogenic CO2 13 removal was used upstream of hydrogen removal? 14 MR. ROBINSON: Objection, form. 15 A. Again, it depends on the process in the 16 design. The order -- the order of the process is 17 important to reduce costs and to increase 18 production efficiency and capture efficiency. The 19 order of the processes are very important. And so 20 there are potential cases where it would be, but 21 not -- not common. 22	127 1 A. I have not reviewed this document. 2 Q. Well, let's walk through it, then. 3 A. Okay. 4 Q. We'll take our time. Let's first off -- I 5 guess let's take a second to orient ourselves to 6 the document. And by the way, if you haven't seen 7 this, I want to make sure that you have a chance 8 to look at it all you want, but let's -- let me 9 walk you through it. And hopefully we can avoid 10 some of those questions. 11 You'll notice the title of the document is 12 Technology Handbook, and the author, or at least 13 the company listed on the front, is Air Liquide 14 Engineering and Construction. 15 Do you see that? 16 A. I do. 17 Q. Now, that's the same Air Liquide that's 18 the owner of the '805 patent, the assignee of the 19 '805 patent; is that right? 20 A. That's correct. 21 Q. And Air Liquide is the one that hired you 22 to provide expert testimony in this case; is that
126 1 BY MR. PHILLIPS: 2 Q. And that would be within the skill of a 3 person skilled in the art to make that 4 determination. Do you agree with that? 5 A. I do. 6 MR. ROBINSON: Objection, form. 7 BY MR. PHILLIPS: 8 Q. I'm going to hand you another exhibit -- 9 we'll come back to this, so don't -- actually, you 10 can put Harald Klein's declaration off to the 11 side. 12 A. Okay. 13 Q. I'm going to hand you a document. This 14 is -- if I can get my copy now. This is marked as 15 Exhibit 1018. In was an exhibit that was cited by 16 Dr. Klein in his declaration. You had mentioned 17 that you had reviewed his declaration. I'm not 18 sure if you reviewed all his exhibits. Did you -- 19 have you reviewed this document? 20 A. I have not. 21 Q. Did you review this document originally 22 when you prepared your declaration?	128 1 right? 2 A. That is correct. 3 Q. Let's turn -- we're going to flip around a 4 little bit, but I promise you I'm not trying to 5 fool you. Let's flip to page 106. It's actually 6 the next-to-last page of the document. 7 A. Got it. 8 Q. And I only wanted you to bring -- this 9 page, just to point out that this is -- if you 10 look toward the bottom, that this is dated 11 February 2018, version 2.0. 12 Do you see that? 13 A. I do. 14 Q. So that's -- again, I'm just going to use 15 rough terms. Approximately two years before the 16 filing of the '805 patent. 17 Do you agree with that? 18 A. Yes. 19 Q. So you I want you to -- we're going to go 20 back to page 11 now, back toward the front of this 21 document. This is -- and you can see from 22 page 10, the page right before it, this is the

129 1 table of contents for the document. 2 A. Yes. 3 Q. In the left column, the green section is 4 titled CO2 Capture. 5 Do you see that? 6 A. I do. 7 Q. And first in the list is the Cryocap H2 - 8 Cryogenic CO2 Separation on page 24. 9 Do you see that? 10 A. I do. 11 Q. So let's turn to page 24 and see what that 12 is. So if you could take a second to take a look 13 at this, just general orientation, there's a flow 14 diagram on the right, and then there's a 15 description. But let me know -- read it to 16 yourself. Let me know when you're ready to chat 17 about this. 18 (Witness reviews document.) 19 A. Okay. 20 BY MR. PHILLIPS: 21 Q. All right. So on the right, process flow 22 diagram for this Cryocap process, do you see that?	131 1 Q. So quick question, I guess. What's a cold 2 box? I know a little bit about cold boxes from 3 ethylene plants, but I want to know -- I don't 4 know in this context, what is a cold box? 5 A. Again, it's a heat transfer device. "Cold 6 box," as the term implies, the temperature is 7 cold, cold temperature. So you're going in here 8 to a cold box, like a refrigerator. 9 Q. So I'm assuming there's different ways to 10 do cryogenic CO2 separation, but a cold box is one 11 method for condensing the higher-pressure CO2; is 12 that correct? 13 A. Yeah, a cold box, again -- again, the 14 cryogenic separation, they're taking it down to 15 cryogenic conditions. A cold box could be 16 noncryogenic. It could be just cold. A 17 refrigerator, again, my example, the temperature 18 goes down on air, and the ability for the air to 19 keep moisture goes down. And so a cold box can be 20 used to dry gas. A cold box can be used to 21 separate material. So certainly that's what's 22 happening here. You have a cold box feeding a
130 1 So you see at kind of the upper left portion 2 natural gas goes into a box SMR. Would you agree 3 with me that that's steam methane reformer? 4 A. I do. 5 Q. An arrow going to the next box, which is a 6 schift. Would you agree that's a water-gas schift 7 box? 8 A. In French spelling, yes. 9 Q. In French spelling. Then the effluent 10 from the schift box goes to a PSA unit. Do you 11 agree with that, and a hydrogen product emerges 12 from the top of the box? 13 A. I agree. 14 Q. From the bottom of the box, I think you 15 will see a -- this is going to be the CO2-rich 16 syngas stream at this point, is going to go to a 17 compressor, and then the compressor is going to go 18 to -- I don't know what those two parallel 19 reactors -- that may be a dryer, I don't know. 20 You may know what that is, but it certainly goes 21 to a cold box after that. Do you see that? 22 A. I do.	132 1 compressor with a heat exchanger there, and then 2 the CO2 product. 3 Q. Okay. So I only bring this page to your 4 attention because it shows a cryogenic CO2 unit 5 positioned after a PSA hydrogen removal. Do you 6 agree with that? 7 A. Yes. 8 Q. So, again, everything we've seen so far, 9 at least with Reinertsen and with the '805 patent, 10 and now with this, which is two years before the 11 '805 patent, cryogenic CO2 is always, at least 12 with those examples, after the PSA hydrogen 13 removal -- or after hydrogen removal in general; 14 is that correct? 15 MR. ROBINSON: Objection, form. 16 A. We have -- again, cold box is a not a PSA 17 unit -- I'm sorry, cryogenic unit. Cold box is 18 certainly -- uses temperature, like I mentioned, 19 to separate, but the reason they use the term 20 "cold box" is to differentiate it from, 21 necessarily, a cryogenic unit. Cryogenic has got 22 specific temperature limits. So you've already

133 1 taken the hydrogen out in the PSA unit. So now 2 you've got a rich CO2 gas with some water and some 3 other things in it. So you're coming down here, 4 you're going through a compressor, through a heat 5 exchanger, through these columns, most likely 6 drawing columns, like you said, I would agree with 7 that, and then going up here to a membrane and to 8 a cold box. And so you've got the CO2 product 9 coming out of that CO2-rich stream. So this cold 10 box is most likely a condenser. You're pulling 11 water out just like we did in the Reinertsen 12 patent, the box we pointed out, box 7 I think it 13 was. But that's probably what's happening here. 14 Now, Cryocap hydrogen is what it's saying. And 15 this is a trademarked term, obviously, as it says 16 there. This is their process to remove and make 17 hydrogen. 18 BY MR. PHILLIPS: 19 Q. Correct. And it also says it's a 20 cryogenic CO2 separation process? 21 A. That's what it says. 22 Q. So this is -- I guess where I was going	135 1 BY MR. PHILLIPS: 2 Q. Would you agree with that? 3 A. Yeah, I would agree with that. 4 Q. All right. Let's go back to Reinertsen, 5 the Reinertsen exhibit. This is Exhibit 1005. 6 And if I can draw your attention to paragraph 97. 7 Are you there? 8 A. I am. 9 Q. Okay. So the paragraph says: A number of 10 process schemes are analyzed. These include one 11 comparative example and a number of 12 implementations of embodiments, four of which are 13 summarized in Table 1 in Figure 10. The schemes 14 vary in WGS temperature, use of palladium membrane 15 or PSA for hydrogen separation, use of amine 16 solvents, amine solvents or cryogenic CO2 17 separation, as well as the position of water 18 condensation. 19 Do you see that? 20 A. I do. 21 Q. So, again, based on paragraph 97, you will 22 agree that Reinertsen's embodiments listed in
134 1 with this is obviously there's a little more 2 detail -- sorry. There's obviously a little more 3 detail about the cryogenic CO2 unit. They're 4 using a cold box, but this is a -- for CO2 5 removal, this is a type of cryogenic CO2 removal. 6 Would you agree with that? 7 A. I would agree with that. 8 Q. And it's after hydrogen removal as well? 9 MR. ROBINSON: Objection, form. 10 BY MR. PHILLIPS: 11 Q. Correct? 12 A. That's what it shows. 13 Q. And this was two years before the '805 14 patent was filed, right? 15 A. That's what it shows, yeah. 16 Q. So again, I'm -- we talked about that 17 concept, you know, of an engineer and his toolbox. 18 I mean, this is, again, how to order the process 19 steps. This is within a toolbox of a person of 20 ordinary skill in the art. 21 MR. ROBINSON: Objection, form. 22	136 1 Table 1, Figure 10, is not an exhaustive list of 2 embodiments. Would you agree with that? 3 MR. ROBINSON: Objection, form. 4 A. These include one comparative example and 5 a number of implementations of embodiments. So I 6 would have to agree that it's certainly not 7 exhaustive, but it's a list of potential 8 implementations. 9 BY MR. PHILLIPS: 10 Q. And four of which are summarized in that 11 table. So there's a number -- there's a number of 12 implementations of embodiments, four of which they 13 put in Table 1. You agree with that? 14 A. I do. 15 Q. Let's turn now, same document, 16 Exhibit 1005. If we could turn to paragraph 223. 17 Are you there? 18 A. I am. 19 Q. So this paragraph says: The flowcharts 20 and descriptions thereof herein should not be 21 understood to prescribe a fixed order of 22 performing the method steps described therein;

137 1 rather, the method steps may be performed in any 2 order that is practicable. Although the present 3 invention has been described in connection with 4 specific exemplary embodiments, it should be 5 understood that various changes, substitutions and 6 alterations apparent to those skilled in the art 7 can be made to the disclosed embodiments without 8 departing from the spirit and scope of the 9 invention as set forth in the appended claims. 10 Do you see that? 11 A. I do. 12 Q. So based on this paragraph, 223, you'll 13 agree that Reinertsen expressly states that it 14 would be apparent to a person of ordinary skill in 15 the art to make changes and substitutions to the 16 disclosed embodiments, without departing from the 17 invention. Do you agree with that? 18 A. No. 19 Q. Why don't you agree with that? 20 A. It says: Rather than the method steps -- 21 rather, the method steps may be performed in any 22 order that is practicable.	139 1 arranged, that's how I would read that as well. 2 Q. I'm trying to understand the word 3 "practicable." You kind of hit on that word as 4 well. Does that -- does that mean feasible? 5 A. It's not necessarily just feasible. 6 Feasible is any option. It's any potential. But 7 practicable is something that can be put into 8 practice. Practicable, again, is related to that 9 word practicable, practice. And in practice, you 10 know, they -- the practice of chemical engineering 11 involves, as I've mentioned, several things that 12 we focus on, and we teach in school in order to 13 become trained, and we can call ourselves a 14 chemical engineer. One of the most important 15 parts, as I mentioned earlier in my deposition, 16 the process design has to have -- process safety 17 is paramount in everything that we do. And so we 18 look at a process that involves a flammable gas 19 like hydrogen, extremely flammable, very reactive, 20 and we have to say, Well, you know, what is 21 practicable, that means what is safe, that's 22 included there. Not just the cost. I mean,
138 1 I think that's the key word in that 2 paragraph. One that's skilled in the art would 3 look at a configuration, and based on their 4 understanding of transport, based on their 5 understanding of thermodynamics, based on their 6 understanding of process engineering, safety, 7 there are several things that fall under the word 8 "practicable." And costs and economics certainly 9 are part of that. We've already discussed that. 10 But there are a lot of other things that come into 11 play there, and so obviously if Reinertsen had 12 listed every possible configuration, which, you 13 know, that's -- that's basically the combinations 14 that you could have, and there's several different 15 combinations, but the permutations are also really 16 important. So in statistics, you know, the number 17 of permutations where order is important, not just 18 the combinations that -- where order doesn't 19 matter is important. And so that's how I would 20 read that, to me. Something that's practicable 21 with all those other things taken into account, 22 and then again, the order of how those things are	140 1 obviously if you just worry about cost, you'll do 2 a bunch of stuff and kill a bunch of people. 3 That's certainly not what we want to do. And we 4 go through every effort to conduct process hazard 5 evaluations and safety analysis of designs before 6 we ever issue a set of fabrication drawings, 7 before that's ever -- ever happens, we have gone 8 through months of analysis of a process to make 9 sure that it's not just feasible, but it's 10 practicable. 11 Q. So you'll agree, though, that -- are you 12 saying that the embodiments that are in Table 1, 13 Figure 10, are the only practicable embodiments 14 taught by Reinertsen? 15 A. One moment. Let me get back to my 16 Figure -- Figure 10 here. So there, the 17 comparative example in seven embodiments, and 18 Reinertsen says that this is not -- he implies at 19 least that this is not inclusive. He says that 20 these are examples, and then you read -- we read 21 the spirit is that there may be others that, you 22 know, are not excluded just because he doesn't

141 1 have it listed here, and they should be 2 considered. But then he also says, appropriately, 3 that the examples, if you're going to consider 4 other than these, have to be practicable. They 5 have to make sense. They have to be safe, they 6 have to be cost efficient, they have to, you know, 7 accomplish the purpose. There's a lot of things 8 that is go into play, right, as we said. But 9 these examples that he's listed are embodiments. 10 Those are examples to illustrate the point. 11 Again, as I said earlier, it's not just the 12 combination, but it's the permutation. It's the 13 order. The order is important. So clearly, you 14 can have five different, you know, elements, and 15 if you only have five, then the combination of 16 that five, if you take all five in that set and 17 then you try to -- there's only one set of 18 Combinations, but there's several permutations 19 that you can get from that five units. So that's 20 what he's done here, is he's looked at different 21 combination, but in order, and so those are 22 permutations.	143 1 concerns. 2 BY MR. PHILLIPS: 3 Q. What are some of those concerns? 4 A. Leaks, fugitive emissions, flammability, 5 hydrogen embrittlement. There's a lot of 6 different things that happen when you deal with 7 hydrogen. 8 Q. So that would be a consideration for a 9 person of skill in the art -- 10 A. Yeah. 11 Q. -- in choosing that Figure 4 process 12 scheme -- 13 A. Yes. 14 Q. -- is that you would need to manage those 15 safety issues? 16 A. You would have to certainly analyze them 17 in a has. 18 Q. How do you manage those issues? Is that a 19 matter of material selection? 20 A. Not just, but includes material selection 21 for sure. 22 Q. Special seals on the compressor?
142 1 And I agree with what he said, I mean, I 2 agree with his patent. I think that if you take 3 each of the words and look at it, that's -- he's 4 included that in his -- the spirit of his patent. 5 Q. You had mentioned -- you mentioned this 6 earlier before, safety concerns. 7 A. Yeah. 8 Q. Are there any unique concerns -- strike 9 that. 10 Reinertsen Figure 4 shows palladium 11 membrane separation of hydrogen, correct? 12 A. Correct. 13 Q. And in that scenario a person of skill in 14 the art knows that you need to compress hydrogen 15 in order to get it into storage or transportation. 16 You agree with that, right? 17 A. I do. 18 Q. Are there any unique safety considerations 19 with respect to compressing hydrogen? 20 MR. ROBINSON: Objection, form. 21 A. Yes, of course. I mean, whenever you're 22 dealing with hydrogen, there's always safety	144 1 A. Absolutely. 2 Q. So, again, this contributes to capital 3 costs and operating costs; is that right? 4 A. That is correct. 5 Q. So that would be a consideration -- 6 A. That's correct. 7 Q. -- in choosing that Figure 4 of 8 Reinertsen; is that right? 9 A. That's correct. 10 Q. Let's -- still staying with Reinertsen, 11 let's turn to paragraph 12. Well, actually, 12 before we do that, real quick question. 13 Table 1 in Figure 10 does not disclose -- 14 none of those embodiments show PSA hydrogen 15 followed by cryogenic CO2. Do you agree with 16 that? PSA hydrogen removal followed by cryogenic 17 CO2 removal. Do you agree with that? 18 MR. ROBINSON: Objection, form. 19 A. So the comparative example, again, is 20 amine separation, embody -- example 1 embodiment 21 has got amine separation. And then again, your 22 first one is example 2 -- Embodiment 2 has got

145 1 cryogenic separation with PSA. 2 And back to the illustration on Figure 4, 3 I think it was -- was it Figure 4? Figure 4 here. 4 And so this is membrane separation. So there's -- 5 and then cryogenic or amine. And so the -- 6 BY MR. PHILLIPS: 7 Q. So I just wanted to clarify that Figure 10 8 which shows Table 1 -- 9 A. Right. 10 Q. -- does not show PSA hydrogen 11 separation -- 12 A. That's correct. 13 Q. -- and cryogenic CO2 separation -- 14 A. Together. 15 Q. -- in the same embodiment. You agree with 16 that -- 17 (Simultaneous discussion interrupted by 18 reporter.) 19 MR. PHILLIPS: Do you want me to start 20 over with the question? 21 THE REPORTER: Yeah. 22	147 1 Q. Paragraph 12 says: Preferably, the 2 hydrogen separation process comprises a PSA 3 process. 4 Do you see that? 5 A. I do. 6 Q. And the paragraph right before that, 7 paragraph 11, it says: Preferably, the hydrogen 8 separation process comprises inputting the shifted 9 gas to a hydrogen separator that comprises a 10 palladium membrane. 11 Do you see that? 12 A. I do. 13 Q. So taken together, paragraph 11 and 12, 14 would you agree that Reinertsen teaches that you 15 can either do a palladium membrane for hydrogen 16 separation or a PSA process for hydrogen 17 separation? 18 MR. ROBINSON: Objection, form. 19 A. So let me read 11 and 12 again. 20 Preferably, the hydrogen separation process 21 comprises: Inputting the shifted gas to a 22 hydrogen separator that comprises a palladium
146 1 BY MR. PHILLIPS: 2 Q. So let me see if I can rephrase that. So 3 you'll agree that Figure 10, Table 1 does not show 4 PSA hydrogen separation in the same embodiment as 5 cryogenic CO2 separation. You'd agree with that? 6 A. Yes. 7 Q. But isn't it true that Reinertsen -- the 8 text of Reinertsen actually teaches using PSA 9 hydrogen separation in place of palladium membrane 10 separation. 11 Do you agree with that? 12 MR. ROBINSON: Objection, form. 13 A. Paragraph -- specifically the paragraph in 14 Reinertsen that says that? 15 BY MR. PHILLIPS: 16 Q. We can do that. Let's go to paragraph 12. 17 A. Paragraph 12. Okay. 18 Q. Are you there? 19 A. Yeah. 20 Q. So this is in the Summary of Invention 21 section. 22 A. Yes.	148 1 membrane wherein the hydrogen separator comprises 2 a permeable -- a permeate side of the palladium 3 membrane and the retentate side of the palladium 4 membrane, and the shifted gas is input to the 5 retentate side of the palladium membrane, 6 outputting hydrogen from the permeate side of the 7 palladium membrane, and outputting the 8 hydrogen-depleted shifted gas from the retentate 9 side of the palladium membrane. And again, that 10 retentate side is where the CO2 goes, right? So 11 paragraph 12: Preferably, the hydrogen separation 12 process comprises a PSA process -- PSA process, 13 pressure swing adsorption process. And then: 14 Preferably -- paragraph -- 12 -- 13: The rest gas 15 that is recycled is fed back to the autothermal 16 reforming -- okay. So, yes, I would agree with 17 that. 18 BY MR. PHILLIPS: 19 Q. Let's -- if you can take a look at 20 paragraph 97 -- 21 A. Okay. 22 Q. -- in Reinertsen.

149 1 MR. PHILLIPS: Actually, do you want to go 2 ahead and take a break now? Did you need a 3 restroom break? 4 THE REPORTER: I need a sanity break. 5 MR. PHILLIPS: You're on. Let's take a 6 sanity break, shall we? 7 (Recess taken from 12:14 p.m. to 8 12:52 p.m.) 9 BY MR. PHILLIPS: 10 Q. Dr. Smith, we're coming back after lunch 11 and I just want to remind you you're still under 12 oath. 13 You'll recall we were talking about the 14 Reinertsen reference, Exhibit 1005, when we broke 15 last. I would like to direct you to paragraph 85 16 of Reinertsen. 17 A. Okay. I got it. 18 Q. Okay. So in particular I want to look at 19 the second sentence, which is about four lines 20 down. It says: Embodiments may alternatively use 21 PSA to separate hydrogen from the gas output from 22 WGS reactor.	151 1 reforming process. 2 BY MR. PHILLIPS: 3 Q. But you agree it doesn't say after? 4 A. It does say after. 5 Q. It says from the gas output from the WGS 6 reactor, right? 7 A. Exactly. But again, from the water-gas 8 shift means it's after the water-gas shift. 9 Q. Okay. So can you look at Figure 4 of 10 Reinertsen. 11 A. Yeah. 12 Q. And I think you'll -- you'll agree from 13 your prior testimony that box 6 was the water-gas 14 shift reactor, right? 15 A. Correct. 16 Q. And box 12 is, in this Figure 4 17 embodiment, the palladium membrane hydrogen 18 removal unit; is that right? 19 A. Correct. 20 Q. So wouldn't you agree, though, that the 21 gas output from the WGS reactor would be this 22 stream 61?
150 1 Do you see that? 2 A. Yeah. 3 Q. So that sentence, it's talking about 4 obviously replacing palladium membrane with PSA, 5 but isn't it also telling you exactly where to put 6 it in the process scheme directly after the WGS 7 reactor? 8 MR. ROBINSON: Objection, form. 9 A. Embodiments may alternatively use PSA to 10 separate hydrogen from the gas output from the 11 water-gas shift reactor. The way that I would 12 read that is that it's certainly after the 13 water-gas shift, which completely makes sense, 14 right, you're using the water-gas shift to polish 15 the amount of hydrogen. And so it would have to 16 go afterwards. It couldn't go before. And so 17 after would make sense, but immediately after, 18 downstream, I mean, there's a lot of definitions 19 what "after" means. So that's how I would read 20 it. It would be after, but that makes -- that's 21 just common sense that it would be after the WS -- 22 WGS, because it's -- that's the last step in the	152 1 A. Not necessarily. It could be downstream 2 of the water-gas shift. So gas from that 3 water-gas shift could, again, imply stream 61, 4 which is what you've implied -- you said, but it 5 could also be downstream in any embodiment -- it 6 doesn't have to be there. It's just downstream of 7 it. It's gas coming from the water-gas shift as 8 the last step of that reforming process is going 9 to be downstream of that. And so that's how I 10 would read it. 11 Q. So you don't read that sentence, the gas 12 output from the WGS reactor, to mean the shifted 13 gas from the WGS reactor, you don't read it that 14 way? 15 A. I don't read it to mean immediately 16 from -- I mean from the water-gas shift. So it 17 could be right after, it could be downstream of 18 it. It could be both of those. 19 Q. But it doesn't say downstream of it, it 20 doesn't say after, right? 21 A. But it -- 22 MR. ROBINSON: Objection, form.

153 1 A. It doesn't say immediately after, either. 2 Sorry. It doesn't say immediately after. In 3 chemical processes it's not uncommon to refer to a 4 downstream piece of equipment as receiving feed 5 stream from, and then you identify something 6 coming upstream of it, and it could be, you know, 7 immediately upstream, it could be two or three 8 steps upstream. I mean, that's -- I've seen that 9 before in process descriptions. 10 BY MR. PHILLIPS: 11 Q. But the gas output from a reactor, which 12 is what this sentence says, you're saying that's 13 not the arrow coming out of that reactor in the 14 process flow diagram? 15 A. If I were to just write something, I would 16 say -- if I meant the gas coming from that reactor 17 entering this reactor, I would say coming 18 immediately from this reactor into the reactor. I 19 wouldn't say from, from -- or from this reactor. 20 Because that -- it could be -- as I've said now a 21 couple times, that it's downstream, it could be 22 immediately in front, it could be two steps in	155 1 the PSA unit? 2 MR. ROBINSON: Objection, form. 3 BY MR. PHILLIPS: 4 Q. Is that what that -- 5 A. Again, what I -- what I just said was that 6 there are a series of steps that come after the 7 water-gas shift reactor, and those can be 8 organized according to various permutations in 9 order to accomplish the objective of producing 10 hydrogen. 11 Q. Let's turn to paragraph 56 -- 12 A. Okay. 13 Q. -- of Reinertsen. 14 A. I'm there. 15 Q. In the third sentence of paragraph 56, it 16 says: PSA processes may also result in CO2 being 17 released at low pressure; e.g., atmospheric 18 pressure; and so there is a subsequent need for 19 compression and cooling. 20 Do you see that? 21 A. I do. 22 Q. So my first question to you, honest, I'm
154 1 front. It's downstream of it. It's coming from 2 that reactor. Because this is a product that 3 we're focused on. We have this gas coming from 4 this water-gas shift reactor which includes the 5 CO2, which includes the hydrogen, includes some 6 CO, includes some hydrogen, includes some water, 7 some methane possibly. And so that's the gas 8 coming from that shift reactor. And it's going to 9 go either to an amine system, it's going to go to 10 a cryogenic separator, it's going to go to a PSA, 11 it's going to go to a membrane. Those are all 12 separation steps that are downstream of this 13 water-gas shift reactor. And each one of those 14 steps have a purpose. And the overall objective 15 of the plant is to make hydrogen. And so the 16 combination of a series of those steps or the 17 orientation of a series of those steps is an 18 important part of the technology. That's what I 19 think -- that's how I would read paragraph 85, 20 second -- the second sentence. 21 Q. Well, I mean, are you saying that it's a 22 possibility to put cryogenic CO2 removal before	156 1 confused, in your declaration you said that 2 Reinertsen did not address the need for 3 compression of the CO2-rich syngas stream when PSA 4 hydrogen separation is chosen. Doesn't this 5 sentence state unequivocally that that CO2-rich 6 stream needs compression? 7 MR. ROBINSON: Objection, form. 8 A. Let's go to my declaration and refer to 9 the part that you're quoting in my opinion. There 10 are three clauses. 11 BY MR. PHILLIPS: 12 Q. Where would you like to go? 13 A. I'm asking you. You're quoting me. 14 Q. Well, I mean, I thought you had said that 15 previously, right, with respect to claim 11. I 16 will take you there. So starting with 17 paragraph 41. 18 A. 41, yeah. Dr. Klein claims that 19 Reinertsen's mention of pressure necessarily 20 discloses a compression step. Specifically, 21 Dr. Klein points to Reinertsen's declaration that 22 embodiments preferably use cryogenic separation to

157 1 separate CO₂; that is to say the gas stream is 2 cooled to a temperature and a -- at a pressure 3 where CO₂ is liquefied. For each of multiple 4 reasons Dr. Klein does not establish disclosure of 5 a compression step. 6 That's what I said. I said I -- this is 7 more regarding Dr. Klein's declaration, not this 8 patent. Now, in my -- in part B on that same page 9 right above paragraph 41, it says claim 11, 10 Reinertsen does not disclose cryogenic CO₂ 11 separation -- 12 THE REPORTER: Slowly, please. 13 A. -- subjecting the first residual gas 14 stream to a compression step. 15 So it does not disclose cryogenic CO₂ 16 separation subjecting the first residual gas 17 stream to a compression step. It doesn't say 18 specifically that you don't need compression. It 19 says that -- Reinertsen doesn't disclose cryogenic 20 CO₂ separation subjecting the first residual gas 21 stream. That's -- that is referring to an order. 22 The first residual gas -- RS -- RG1 or RG2, in the	159 1 second sentence in that paragraph says: In some 2 implementations of PSA processes by a PSA reactor, 3 the PSA reactor is a large and costly part of the 4 hydrogen plant. PSA processes may also result 5 in -- may also result in CO₂ being released at low 6 pressure -- which we've talked about before, the 7 hydrogen coming off of a PSA unit is a higher 8 pressure and the CO₂ is a lower pressure -- e.g., 9 atmospheric pressure. So there is a subsequent 10 need for compression and cooling. That's just 11 talking about that PSA process. It's not 12 necessarily saying anything about cryogenic CO₂ 13 separation. And what I think you're saying, and 14 I'm -- I apologize if I'm not understanding what 15 you're saying, but what you're saying is that 16 implies cryogenic CO₂ separation; is that correct? 17 Or have I misunderstood you? 18 BY MR. PHILLIPS: 19 Q. No, I think that's where I'm getting with 20 that. You know, the sentence we read before about 21 the PSA separating hydrogen from the gas output of 22 the W GS reactor, I asked if that meant the PSA
158 1 embodiments or in the figures, back to Figure -- 2 Figure 4. This doesn't show it. Anyway, 3 stream 61, for example, is on a -- it's a resid 4 gas, right. And so that's what I'm talking about 5 here. It's not necessarily a compression step, 6 which is what you're referring to in that 7 paragraph -- that statement. 8 Q. But going back to paragraph 56 in 9 Reinertsen -- 10 A. Yeah. 11 Q. -- and this is a different sentence than 12 what Dr. Klein cited in his declaration. This 13 sentence says: PSA processes may also result in 14 CO₂ being released at low pressure, e.g., 15 atmospheric pressure, and so there is a subsequent 16 need for compression and cooling. 17 Why would you need compression and cooling 18 after the PSA unit unless it's going to a 19 cryogenic CO₂ removal unit? 20 MR. ROBINSON: Objection, form. 21 A. Back up and just -- again, we were talking 22 about paragraph 56, the sentence starts -- the	160 1 was directly after the WGS reactor. You said not 2 necessarily. That's fine. 3 But this section seems to corroborate my 4 point. So the CO₂-rich syngas from the PSA unit 5 needs subsequent compression and cooling also 6 supports the fact that this is happening, the PSA 7 is happening before a CO₂ cryogenic removal unit. 8 MR. ROBINSON: Objection, form. 9 BY MR. PHILLIPS: 10 Q. Wouldn't you agree with that? 11 A. And I do not agree with that. Again, what 12 I -- the way I read this, and it goes back to my 13 original statement, that just because it says that 14 the PSA unit is making gas from the water-gas 15 shift reactor, it could be after the water-gas 16 shift reactor, downstream someplace. I mean, 17 because I've seen that in process descriptions. 18 And then this statement, again, is talking 19 about -- again, starting in the beginning of 56, 20 hydrogen may be separated from hydrogen-containing 21 gas mixers by use of pressure swing adsorption -- 22 THE REPORTER: Slow down, please.

161 1 A. -- PSA. In some implementations of PSA 2 process by a PSA reactor, the PSA reactor is a 3 large and costly part of the hydrogen plant. 4 That's the overall plant. PSA processes may also 5 result -- and so again, that may also -- "may" is 6 a general term. PSA processes -- so pressure 7 swing adsorption processes may also result in CO2 8 being released at low pressure. And that's just 9 as part of a stand-alone PSA unit. The CO2 coming 10 off is at a lower pressure than the hydrogen. 11 We've all agreed on that. E.g., atmospheric 12 pressure. So there is a subsequent need for 13 compression and cooling. Agree completely. 14 Again, it's talking about a stand-alone PSA unit. 15 It's not talking about this process, it's not 16 talking -- he's talking in general terms here. 17 And so, and a PSA unit has to have -- because it 18 has CO2 coming out at a lower pressure, i.e. -- or 19 e.g., atmospheric pressure, a compression and 20 cooling step. Completely agree with that. But 21 again, it doesn't -- this stand-alone paragraph 22 right there, 56, does not put in order that the	163 1 CO2 syngas to be fed to a cryogenic CO2 unit, 2 right? 3 MR. ROBINSON: Objection, form. 4 A. Agreed. 5 BY MR. PHILLIPS: 6 Q. By the way, the last sentence of 7 paragraph 56: Still, it could be feasible to use 8 PSA for some hydrogen production plants. 9 What does the word "feasible" mean to a 10 person of ordinary skill in the art? 11 A. Yeah. We've talked at length about what a 12 person that's skilled in the art would use to 13 decide whether something is useful and feasible or 14 useful and -- was it "practicable," I think that 15 was the word we spent a lot of time talking about. 16 Feasible in this case is similar to 17 practicable. Feasible in the sense of economics, 18 feasible in the sense of safety, feasible in the 19 sense of efficiency. All those parts that, you 20 know, you use to develop a plant design. 21 Q. I want to take a look at -- I don't think 22 I've given you this yet. Dr. Klein's deposition
162 1 PSA unit is right after the water-gas shift, 2 followed by a cryogenic COT -- cryogenic CO2 3 separation. It doesn't say that. It's talking 4 about PSA as a stand-alone process, which 5 everything it says in here I agree with. Just the 6 way you've interpreted it I don't agree with. And 7 the way that Dr. Klein, again, that was my 8 contention here, that claim 11, Reinertsen does 9 not disclose cryogenic CO2 separation subjecting 10 the first residual gas stream -- that first 11 residual gas stream puts it in order, puts in a 12 position in the process to a compression step. 13 That's what I've said. I haven't disagreed that 14 we don't need a compression. We do need a 15 compression step. In the PSA unit we have 16 atmospheric CO2 coming out. If you're going to 17 use it, you're going to compress it to push it 18 down the line, you're going to use it to separate 19 it cryogenically. You're going to use -- there's 20 lots of reasons to use a compressor after a PSA 21 unit. 22 Q. But one of those reasons would be for the	164 1 transcript, did you review that in preparation for 2 your deposition today? 3 A. I did. 4 Q. That's not it. Here we go. Here you go. 5 Handing you what's been marked as Exhibit 2023. 6 And I'd like to direct you to page 124. 7 MR. PHILLIPS: Sorry, there you go. 8 A. I'm sorry, page 124. This just goes to 9 page 55. 10 BY MR. PHILLIPS: 11 Q. Oh, no, that's -- okay. So you're in the 12 index. 13 A. Yeah. 14 Q. Sorry. If you get in front of the index. 15 A. Oh, I see. 124. Okay. 16 Q. Yeah. 17 A. I'm there. 18 Q. So page 124, this is addressing -- there's 19 a discussion of pressure swing adsorption and 20 palladium membrane. So I guess we're talking 21 about the trade-offs that we discussed earlier. 22 Starting at line 22, Dr. Klein says: For

165 1 instance, what's quite obvious is when you want to 2 do the membrane separation, you keep the CO₂ at 3 high pressure, but you lose the hydrogen pressure. 4 And therefore you would have to compress the 5 hydrogen. And a person skilled in the art knows 6 that hydrogen compression is much more 7 complicated, both CapEx and OpEx wise, as compared 8 to CO₂ compression, because hydrogen is the 9 molecule with the lower molecular weight. That's 10 a physical law. 11 Do you agree with Dr. Klein -- 12 A. I do. 13 Q. -- on that? So correct me if I'm wrong, 14 he's saying one consideration will be he'd rather 15 compress the CO₂ than compress the hydrogen. 16 A. I think what he said is it's more 17 complicated to compress hydrogen than it is to 18 compress CO₂, and I agree with that. 19 Q. And so that would be something that a 20 person of ordinary skill in the art would weigh, 21 that trade-off? 22 A. Sure.	167 1 embrittlement? 2 A. Hydrogen embrittlement, yeah. 3 Q. That's an issue with compressing hydrogen; 4 is that right? 5 A. That's correct. 6 Q. Does that exist with CO₂ compression? 7 A. No. 8 Q. Hydrogen molecules are smaller than CO₂ 9 molecules as well; is that right? 10 A. That is correct. 11 Q. So they have a higher diffusivity. Is 12 that fair to say? 13 MR. ROBINSON: Objection, form. 14 A. So the diffusivity for most gases is 15 about .8 centimeters per second, and for hydrogen 16 it's about .8. So .2, .8, those are the relative 17 diffusivities for hydrogen and most other gases. 18 Hydrogen diffuses way faster than other gases, so 19 flammability issues are associated with that, 20 ignition issues are associated with that. There 21 are a lot of safety issues associated with 22 hydrogen because of its smallness, the size of its
166 1 Q. And that would affect CapEx and OpEx? 2 A. It definitely would affect CapEx and OpEx. 3 Anything that's more complicated is usually more 4 expensive. 5 Q. It also affects -- you talked about -- 6 with the trade-offs you talked about safety 7 implications, and I think before the break we 8 talked about the issues with compressing hydrogen, 9 there's particular issues. 10 Are there issues with compressing CO₂? 11 A. I mean, the cost is certainly an issue, 12 the compression required to bring CO₂ to the point 13 where it will liquefy. That's an issue. In terms 14 of process safety, anything that's at high 15 pressure is basically, you know, a safety concern 16 because it's -- in the event that you have a leak 17 or in the event you have -- Elon Musk refers to an 18 unplanned expansion or whatever, explosion, 19 decompression, whatever. There are safety issues 20 associated with every compression step, including 21 CO₂. 22 Q. I think you had mentioned hydrogen	168 1 molecule. You know, a molecular weight of two 2 compared to 44. CO₂ and hydrogen. Those are all 3 things that you take into account in terms of 4 physical properties, in terms of, you know, 5 diffusion is just one of them. Thermal 6 connectivity, you know, those things are all -- 7 viscosity of the gas and how it flows in a 8 mixture. Those are all part of it, yeah. 9 BY MR. PHILLIPS: 10 Q. So you mentioned flammability and 11 ignition. I guess the ultimate culprit there is 12 the fact it's more likely to leak during the 13 compression. Is that what leads to the ignition 14 and the flammability issues? 15 A. Well, the flammability and ignition issues 16 are specific to hydrogen. It has nothing to do 17 with whether it leaks or whether it, you know, can 18 be contained or not. It's because the molecule 19 itself is extremely reactive, and that's because 20 it's got one electron in the outer shell, and it 21 wants to find another electron, so it wants to 22 react. Until just recently we didn't believe

169 1 there were any free hydrogen deposits available. 2 And so we had to make hydrogen. Now we know that 3 there are some deep ground hydrogen reserves that 4 we can mine, but hydrogen itself is extremely 5 reactive. And so it's not found generally in the 6 free state in nature. It reacts. And so you get 7 a lot of hydrates, you get other types of products 8 that form from that reaction. But hydrogen 9 itself, because it's so reactive, if it leaks and 10 it gets exposed to another compound that it wants 11 to react with, chlorine, for example, HCL is a 12 huge issue, you know, in the chemical industry, 13 and hydrogen and chlorine reaction is extremely 14 fast. So that's an example of hydrogen. Hydrogen 15 flammability is related to the reactivity of the 16 molecule itself. The flammability, again, related 17 to the diffusivity coupled with the reactivity of 18 the molecule. Those are all specific to hydrogen 19 and then, you know, the leaking part is -- you 20 know, that's another issue. 21 Q. It's a related issue, though, isn't it, 22 because you're more likely to have the free	171 1 measure hydrogen, but it's not a trivial thing. A 2 gas chromatograph, for example, doesn't measure 3 hydrogen. It's a symmetric molecule. So it 4 doesn't come out in a GC trace. But they have 5 other techniques that they use, FID, that can be 6 used to detect hydrogen. 7 So, yes, one way to mitigate the safety 8 issues is by sensing and then having, you know, 9 the appropriate equipment to combat it, whether 10 it's dilution, using nitrogen, a nitrogen purge, 11 for example, nitrogen blankets, you know, over a 12 hydrogen line can minimize the ability for 13 hydrogen to react with oxygen in a hydrogen flame. 14 Q. And that's capital cost? 15 A. That's capital cost. Any equipment you 16 have to add, absolutely. Any additional work that 17 has to be done to protect a process, that's 18 capital cost. And operating cost. It also 19 affects operating cost. 20 Q. And these are unique to hydrogen 21 compression versus CO2 compression? 22 MR. ROBINSON: Objection, form.
170 1 hydrogen if there's a leak? Wouldn't you agree 2 with that? 3 MR. ROBINSON: Objection, form. 4 A. Hydrogen is more prone to leaks just 5 because it's -- again, it's a small molecule and 6 it's hard to contain. But my point is that 7 reactivity is -- is an inherent physical property 8 of hydrogen itself. 9 BY MR. PHILLIPS: 10 Q. CO2 doesn't have that type of hazard, does 11 it? 12 A. No, it doesn't. 13 Q. So how does one manage the -- in a 14 hydrogen compression process, how do you manage 15 those leaks? Is it a matter of a more 16 sophisticated sealing system? Is that one way? 17 A. That's one way. 18 Q. I guess are there ways to manage leak 19 detection? 20 A. So hydrogen as a molecule, because it's a 21 light molecule, is hard -- it's hard to detect. I 22 mean, they have hydrogen meters, and you can	172 1 A. Anything, again, where you have hydrogen 2 leaks or you have potential for hydrogen leaks 3 will affect the safety equipment that's required. 4 And so if you don't require it for, you know, CO2 5 compression, then that's going to possibly not be 6 on the, you know, balance sheet. But that doesn't 7 mean that CO2 compression isn't expensive, doesn't 8 mean that the energy costs required to compress 9 hydrogen or compress carbon dioxide are, you know, 10 significantly different. I mean, compression is a 11 PV work process. And so if you've got more volume 12 you've got to compress, so PV, pressure volume, 13 there's more work associated with it. 14 With hydrogen, the density is much lower 15 because molecular weight is lower. With carbon 16 dioxide the density is higher, but again, volume 17 is the key, not the mass. 18 BY MR. PHILLIPS: 19 Q. But hydrogen will occupy more volume? 20 A. Hydrogen, again, is -- the density is 21 lower because the molecular weight is lower. So 22 PV equals NRT. So if you do that calculation, the

173 1 molecular mass is over on the right-hand side on 2 the bottom. So lower, that means more volume for 3 the same pressure. 4 Q. Does hydrogen compression generate more 5 heat than CO2 compression? 6 A. It does. It has a higher heat capacity. 7 Q. So does that require multiple -- multiple 8 stages with intercoolers, is that how you manage 9 that? 10 A. Generally, yes. In the process design the 11 compressor, for a CO2 compressor, you've got to 12 have more intercooling because of the heat 13 generated during the compression step. 14 Q. Everything I said about hydrogen 15 compression versus CO2 completion, that's within 16 the skill of a person of skill in the art. Would 17 you agree with that? 18 A. I would agree -- 19 MR. ROBINSON: Objection, form. 20 A. I would agree with that. 21 BY MR. PHILLIPS: 22 Q. And so these are all -- I mean, you	175 1 interpreted lots of different ways. I don't 2 think -- I guess the way I would say that, it 3 doesn't necessarily discourage it, but it doesn't 4 emphasize it. It focuses -- again, in Table 1, 5 Figure 10, if you look at embodiment 1 through 7, 6 they're all PD separation, PD membrane separation. 7 And so it's got PSA listed and the embodiment -- 8 or the comparative example uses PSA. So I don't 9 think it necessarily comes right out and says it's 10 not preferable, but it doesn't emphasize it for 11 sure. 12 Q. In fact, we did actually read a section 13 that says preferably PSA can be used for hydrogen 14 separation, right? 15 A. Yeah, it does say that. 16 Q. Are you familiar with -- let me get this 17 right. Are you familiar with Reinertsen New 18 Energy AS? 19 A. Where is this at? 20 Q. Sorry, this is -- so, again, the 21 Exhibit 1005, the Reinertsen reference, the 22 assignee for this patent is Reinertsen New Energy
174 1 understand this case, right? The issue is -- with 2 Reinertsen, which teaches palladium membrane 3 hydrogen separation, but also says alternatively 4 you could use PSA hydrogen separation. It changes 5 the compression requirement. Would you agree with 6 that? 7 MR. ROBINSON: Objection, form. 8 A. I would agree. 9 BY MR. PHILLIPS: 10 Q. So all of these considerations that we 11 just talked about, these all come into play with a 12 person of skill in the art in weighing the 13 trade-offs of what you would choose or what a 14 person of skill in the art would choose. Do you 15 agree with that? 16 MR. ROBINSON: Objection, form. 17 A. Yes. 18 BY MR. PHILLIPS: 19 Q. Do you feel that the Reinertsen reference 20 discourages the use of PSA hydrogen separation? 21 A. That's an interesting question. 22 "Discourages," again, is a word that can be	176 1 AS. 2 A. Okay. 3 Q. Are you familiar with that company? 4 A. I'm not. In Trondheim, Norway. 5 Q. Would it surprise you to know that they 6 provide -- that they're a provider of palladium 7 membrane hydrogen separation technology? 8 A. I guess it would neither surprise nor 9 shock me that they do. I mean -- 10 Q. Why wouldn't it shock you? 11 A. No, I said it would not shock me. It 12 wouldn't shock me or surprise me. If they're a 13 new energy company, they're -- interest in 14 company, you know, they would have energy 15 technology, and palladium membrane is a separation 16 technique that doesn't surprise me. I think the 17 idea that potentially there's some conflict of 18 interest there, I wouldn't agree with that. I 19 think that if they -- if they provide a product, 20 you know, that they feel from an engineering 21 perspective is the best product for what they're 22 doing, I mean, that's a business decision. That's

177 1 something that they would have to make the 2 decision on, not me. I would just say that 3 membrane separation is something that's being used 4 more and more in the chemical process industry 5 because of the relative low cost of operation 6 compared to compression and cryogenic separation 7 or PSA or any of those other techniques. So it 8 doesn't surprise me at all. It doesn't shock me, 9 even. 10 Q. In his deposition Dr. Klein referred to 11 palladium membrane hydrogen separation as having a 12 low technology readiness level, TRL, which he -- I 13 think he clarified was a European term of art. Do 14 you recall that testimony? 15 A. I do. 16 Q. What does that mean to you, if something 17 has a low TRL? 18 A. Yeah. So let me -- let me give you my 19 opinion in terms of TRL. TRL is not a European 20 concept. It's something that's used in science. 21 The NSF uses TRL, DOE uses TRL. We quantify 22 process technology in terms of its readiness. A	179 1 so the TRL is in that 5 to 7 range where it's -- 2 it's not just a concept now, it's actually in 3 pilot testing, and has been used. And so 4 palladium membranes would fall in that. I would 5 agree with that statement, but I wouldn't -- I 6 wouldn't say it's low. To me low is 2 to 3, 7 something that I would do in the university. 8 Q. When you say something you would do in the 9 university, what -- 10 A. Research. 11 Q. Research. Bench scale research? 12 A. Again, the NSF generally funds low TRL 13 projects. NSF is really focused on basic 14 sciences. DOE generally funds more practical type 15 of technologies. And so those TRLs are generally 16 5, 7, in that range. RPE, for example, in terms 17 of energy technology, those are TRLs of 5 to 7. 18 They haven't been commercialized yet, but they're 19 in the pilot testing. And so benchtop testing to 20 me is actually a step above what I would consider 21 low. Low is basic science. If you are interested 22 in understanding how a molecule reacts under
178 1 TRL of 2 to 4 is still in the research phase. 2 That's in the universities. TRLs of 5 to 6, this 3 is something that's in commercial testing, but not 4 commercial implementation. And TRL 7 to 9 and 10 5 you get into commercial applications, and so there 6 are technologies that are commercially used, 7 they're common in the chemical industry. They 8 have TRLs of 9 and 10. Coal combustion, for 9 example, has got a TRL of 10. Coal gasification 10 TRL of maybe 7 or 8, because there are still 11 issues associated with coal gasification that 12 haven't been resolved. That's why we don't see a 13 lot of coal gas fires. Sorry. The PSA is a 14 common technology that's been used for many, many 15 years. TRL of 9, 10. Cryogenic separation, 9, 16 10. When he says that a palladium membrane has a 17 TRL -- a low TRL, again, low is a relative term. 18 So what I would say, a palladium membrane is 19 probably in the 5 to 8, in that range. And that 20 depends on the company, it depends on, you know, 21 the application. But certainly membrane 22 separation in general is an evolving field. And	180 1 certain conditions, that's basic science. And 2 you're understanding how a cell reacts to certain 3 viruses, you know, that's a certain -- that's a 4 low TRL. To me that's what I mean when I say 5 university research. As opposed to industrial 6 research, research at Dow Chemical, for example, 7 generally a more practical is higher TRL. 8 Q. If something is commercial, commercially 9 available, commercially used, commercially 10 implemented in a plant, does that -- is that 11 TRL 10? 12 A. It can be -- again, 8 to 10 is usually a 13 commercial application. 14 Q. Are you aware of any applications for 15 palladium membrane separation in a steam reforming 16 plant? 17 MR. ROBINSON: Objection, form. 18 A. Am I familiar with a specific process or a 19 specific company that uses palladium membranes? 20 BY MR. PHILLIPS: 21 Q. Let me rephrase it. That's a -- that's a 22 good clarification.

181 1 Are you aware of any commercial 2 applications of palladium membrane units in 3 operation or under construction with regards to 4 steam methane reforming plants? 5 A. I am not. 6 MR. ROBINSON: Objection, form. 7 A. I am not. 8 BY MR. PHILLIPS: 9 Q. Let's take a look at Exhibit 1018 again. 10 This is the Air Liquide Technology Handbook. Let 11 me know when you have it. 12 A. Okay. 13 Q. I want to direct you to page 38. 14 A. Okay. 15 Q. By the way, before I ask my question, on 16 the issue of TRL, is there a place that a person 17 of ordinary skill in the art can go to find a 18 listing of TRLs? 19 A. Yes. 20 Q. Where is that? 21 A. The Internet. 22 Q. Is TRL an objective rating --	183 1 minute ago to page 38 of Exhibit 1018. Are you 2 there? 3 A. I am. 4 Q. So this is, again, the Air Liquide 5 Technology Handbook dated 2018. This page is 6 directed to pressure swing adsorption, PSA, 7 hydrogen purification. 8 Do you see that? 9 A. I do. 10 Q. What I wanted to ask you is sort of in the 11 middle of the page, towards the bottom there's a 12 section for references. 13 Do you see that? 14 A. I do. 15 Q. And there's greater than 70, and in 16 parentheses, in operation or under construction. 17 Do you see that? 18 A. I do. 19 Q. Now, let's look at page 42. This is the 20 page for hydrogen separation membranes. 21 Do you see that? 22 A. I do.
182 1 A. Yes. 2 Q. -- for a technology? 3 A. It is. 4 Q. Who assigns that? 5 A. DOE. 6 Q. The Department of Energy? 7 A. The Department of Energy uses that as part 8 of their proposal evaluation. NSF does the same 9 thing. Both of those funding agencies use it. 10 It's commonly discussed in the FOAs, call for 11 proposals. They talk about this level of 12 technology. ARPA-E is another example of a 13 funding agency that uses TRL in terms of what 14 they're going to fund, the type of research 15 they're funding. 16 Q. And Europe has a similar -- 17 A. Yeah. 18 Q. -- source to Department of Energy? 19 A. It's science. It's used generally across 20 the world in terms of discussing technology and 21 science. 22 Q. Let's look at -- so I directed you a	184 1 Q. I don't see any references for palladium 2 membranes that are in operation or under 3 construction. Do you see any? 4 A. No. Nothing listed. 5 Q. Does that surprise you? 6 A. Again, I would say -- it doesn't surprise 7 me in the sense that I haven't really had a chance 8 to study this, but this book -- or this manual was 9 published in 2017, is that what we said? 10 Q. 2018. 11 A. 2018. Okay. 2018. You know, 2018 is 12 eight years ago, and membrane technology has 13 evolved considerably over the last ten years. And 14 so it doesn't surprise me that they don't have a 15 list of lots of applications where membranes have 16 been applied. Doesn't mean they're not there. 17 I'm not familiar with them. I've already answered 18 that question. Membrane separation has become 19 more and more of a focus, with our focus on 20 sustainability and finding ways to reduce our 21 impact on the environment. And so there's a lot 22 of technologies that have developed over the last

185 1 ten years with that refocusing on climate change. 2 And so, again, I think this is consistent with 3 what I've seen in other areas as well. 4 Q. But you'd agree with me, then, that PSA 5 for hydrogen separation, a person of ordinary 6 skill in the art would be able to use that process 7 to remove hydrogen in a steam reforming plant 8 without undue experimentation? 9 MR. ROBINSON: Objection, form. 10 BY MR. PHILLIPS: 11 Q. Would you agree with that? 12 MR. ROBINSON: Objection, form. 13 A. As I had mentioned earlier, the TRL for 14 membrane is probably 5 to 7 in that range, so it's 15 evolving. PSA 8 to 10, you know, is more 16 commercial. So it's out there. And that's 17 consistent with what you've pointed out here. 18 70 percent implementations of PSA, no listed, at 19 least in 2017 implementations of PB membrane. 20 None of that surprises me. And a person skilled 21 in the art as of 2020 with three to five years' 22 experience would be very familiar -- or at least	187 1 Q. Is that correct? 2 A. Yes. 3 Q. And because of that, a person of ordinary 4 skill in the art would not be motivated to try PSA 5 hydrogen separation; is that right? 6 MR. ROBINSON: Objection, form. 7 A. So what I said -- what I meant to say, if 8 I didn't completely clearly define what I meant -- 9 what I meant, the Darde-Rytter combination in 10 comparison to Reinertsen. Darde has got a 11 different focus. That technology is focused on 12 producing condensates. And in places where I've 13 worked in the Middle East where water is a 14 premium, condensates have been valuable. And they 15 have a lot of refineries and a lot of hydrocarbon 16 plants in the Middle East; Iraq, Oman, Saudi 17 Arabia. 18 And so they very seldom have steam flares 19 in the Middle East. So they don't use water for 20 flaring, whereas in most of the plants here in the 21 US, down on the coast, not too far from here, 22 Texas, Louisiana, they use steam flares. And
186 1 much more familiar with PSA technology than 2 membrane separation technology. 3 BY MR. PHILLIPS: 4 Q. Let's take a look at your declaration, 5 Exhibit 2021. I'm going to direct you to 6 paragraphs 19 through 21. And just to orient you, 7 we're in the section -- Section 4 of your 8 declaration under Legal Considerations, Section B, 9 Obviousness. 10 Do you see that? 11 A. I do. 12 Q. First question, did you write this 13 section? 14 A. I wrote parts of it. This was done in 15 collaboration with my attorney. 16 Q. So I'm not going to fault any of the 17 recitation of the law here. However, I do note 18 later in your deposition -- in your declaration 19 that you claim that the Reinertsen-Darde and 20 Rytter-Darde Combinations are inferior, in part 21 because of purity and capture metrics. 22 A. Okay.	188 1 that's the reason. And so, again, Darde, that 2 focus is on -- and again, they're using steam 3 methane reforming, but with a different focus. So 4 when you combine those two to try to imply 5 something about Reinertsen, I think that that's 6 the whole thing with obviousness. I don't think a 7 person skilled in the art would have put those two 8 together and then would have been able to make a 9 determination for the Reinertsen claims. That's 10 what I was trying to say, if that makes any sense. 11 BY MR. PHILLIPS: 12 Q. But you'd agree with me, though, that 13 Reinertsen expressly teaches, as an alternative to 14 palladium membrane separation, using PSA hydrogen 15 separation. You'd agree with that, right? 16 MR. ROBINSON: Objection, form. 17 A. So Reinertsen certainly focuses on PD 18 membrane. We've already established that -- 19 BY MR. PHILLIPS: 20 Q. Right. 21 A. -- in Table 1, Figure 10. He does show 22 PSA in the example embodiment that he lists in

189 1 that. So I'm not necessarily -- I don't 2 necessarily think that he teaches that we should 3 use PSA. I think that he says it's an option, and 4 there it is. To me, again, obviousness is if 5 something is either potential, if something is -- 6 you can combine them in different orders, if you 7 can -- and so that, again, is obviousness. 8 The stuff that Reinertsen teaches, again, 9 are based on a collection of embodiments that he 10 uses to do PSA -- or to -- sorry, to do steam 11 reforming. But I don't necessarily believe that 12 he's trying to or she's trying to or they're 13 trying to teach one or another over another to 14 select it. Here's what we're claiming, and this 15 is the combination and this is the order of that 16 combination. And so that's what I believe has 17 happened here. 18 Q. But Reinertsen does, in fact, disclose 19 using PSA as an alternative? 20 A. He does. I think it's a he. I'm not 21 sure. Is it a he? I can never tell. 22 Q. Don't know.	191 1 BY MR. PHILLIPS: 2 Q. And I think you agreed with me earlier in 3 your declaration that the only issue between -- 4 that keeps Reinertsen from anticipating the '805 5 patent claim 1 is the order of PSA hydrogen and 6 cryogenic CO₂; is that right? 7 A. That is correct. 8 Q. And I know you were fighting me over that 9 portion of Reinertsen -- 10 MR. ROBINSON: Objection, form. 11 MR. PHILLIPS: Can I finish? 12 MR. ROBINSON: That wasn't a question. 13 MR. PHILLIPS: I haven't finished. 14 MR. ROBINSON: That wasn't a question. 15 BY MR. PHILLIPS: 16 Q. Earlier we were discussing the passage in 17 Reinertsen that stated that the PSA unit should be 18 after the output of the water-gas shift reactor. 19 Do you recall that testimony? 20 A. I do. 21 Q. I asked you if that meant that should be 22 the block right after water-gas shift, and you
190 1 A. It's just -- yeah. It's just whatever. 2 Reinertsen teaches that, yeah. 3 Q. We compared Figure 4 of Reinertsen and the 4 '805 patent claims and Figure 3 of the '805 5 patent, right? 6 A. We did. 7 Q. And I thought we had agreed that in terms 8 of the process blocks; reforming, water-gas shift, 9 hydrogen removal, CO₂ removal; that that order was 10 the same between the '805 patent and Reinertsen. 11 MR. ROBINSON: Objection, form. 12 A. We did. Described the way you've just 13 described it. 14 BY MR. PHILLIPS: 15 Q. Right, of course. 16 A. Yeah. 17 Q. And Reinertsen teaches that hydrogen 18 removal can be -- that PSA hydrogen removal is an 19 option, correct? 20 MR. ROBINSON: Objection, form. 21 A. That's correct. 22	192 1 disagreed with that? 2 A. I did. 3 Q. But a reading of that could also be that 4 it is right after the water-gas shift. Do you 5 agree with that? 6 MR. ROBINSON: Objection, form. 7 A. I do. 8 BY MR. PHILLIPS: 9 Q. And a POSA would believe that as well? 10 MR. ROBINSON: Objection, form. 11 A. Again, if I consider myself as a POSA, 12 which I do, then I would say that I would think it 13 was after the water-gas shift. Not immediately 14 after. It could be immediately after, but it 15 doesn't have to be. And I would look at different 16 configurations and I would consider different 17 configurations based on that, and then I would 18 pick the configuration that made the most sense 19 from all the criteria that we've discussed today; 20 process safety, cost, you know, production yield, 21 quality, all of the things, CapEx, you know, OpEx. 22

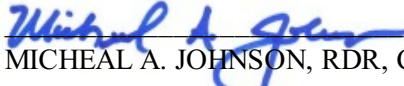
193 1 BY MR. PHILLIPS: 2 Q. And your conclusion would be that PSA 3 hydrogen should be before cryogenic CO2 removal? 4 MR. ROBINSON: Objection, form, asked and 5 answered. 6 A. As I've said earlier, the reason that I -- 7 I would pick one or another would be dependent on 8 the application of the process. The Darde 9 example, that's -- again, that application is 10 different from the Reinertsen application. If you 11 have a process that's interested in using a fuel 12 gas -- or a fuel cell, the hydrogen production for 13 a fuel cell is different than making electric 14 power from a -- hydrogen from a gasifier. Those 15 applications are important. And so that's what 16 Reinertsen has done. They've got a focus, the 17 Rytter's got a focus, Darde's got a focus. And so 18 a person skilled in the art would look at what his 19 or her objective is, and then they would make a 20 decision based on that. So it's impossible to 21 say -- you could say it, I guess, and it would be 22 not very sound to make the statement, that it is	195 1 So best practices are related to that. 2 Q. So in a plant that's steam reforming 3 natural gas feed, you're going to have a higher 4 volume of hydrogen -- 5 A. Most likely. 6 Q. -- after the water-gas shift? 7 A. After the water-gas shift, that's most 8 likely true. 9 Q. So a POSA would be led to remove the 10 hydrogen first before CO2 removal; is that right? 11 MR. ROBINSON: Objection, form. 12 A. That is most likely correct. Now, I would 13 add to that that a POSA, you know, would use best 14 practices to establish initial design, but then 15 those designs would be evaluated. And there would 16 be options that you would look at in different 17 designs. And then based on process modeling, 18 based on experience in the plant and the company, 19 if you're working for Dow Chemical, you -- there's 20 a certain procedure that you go through, and there 21 are scientists that you consult. So those things 22 are all involved before you make the decision to
194 1 always this way or it's always that way. It's 2 preferred this way or preferred that way. It's 3 dependent on the application. 4 BY MR. PHILLIPS: 5 Q. We talked about best practices, though, at 6 the beginning of this deposition, though, right? 7 A. Best practices, yes. 8 Q. I mean, do you think it would be a best 9 practice -- do you think a POSA would believe that 10 it's a best practice to put cryogenic CO2 removal 11 before a PSA unit in a steam reforming plant? 12 A. I don't think the -- what I said earlier 13 today in the best practices is that in terms of 14 separation science, one of the best practices is 15 that you remove the component with the highest 16 volume percent in the mixture first, before you 17 start trying to separate the ones that have small 18 concentrations. And so if hydrogen has got the 19 most composition, most volume, then you remove 20 hydrogen first. If CO2 has got the most volume, 21 then you remove CO2. Again, it depends on the 22 mixture of the gas, it depends on the application.	196 1 what you're going to do. But best practices are 2 kind of a starting point that gets you in the 3 right area. 4 BY MR. PHILLIPS: 5 Q. When I was an engineer at Exxon, we had -- 6 I was in the process group. We had a gate system 7 at Exxon for getting projects through to a funding 8 decision. Early on you're looking at flow 9 diagrams, feed stock availability, product needs. 10 Is that where best practices comes into play in 11 terms of kind of initially choosing what you think 12 the flow sheet might look like? 13 A. In my experience, yes. 14 Q. And what you're saying, though, is once 15 you get into detail sign, once this thing ends up 16 at KBR or Fluor Daniel to design this thing, 17 things may shift at that point? 18 A. It may shift at that point, may shift even 19 before it leaves Exxon. It may shift when it gets 20 into engineering at Exxon before they go to an 21 EPC, outside agency. It may also shift after the 22 process hazard evaluation, when you analyze the

197 1 safety of a piece of -- of a process that's all 2 combined now as a system, and you go through each 3 of those nodes in the process, and then you say, 4 Well, this step is out of order, it should be over 5 here. So you would actually modify the design 6 based on the result of the HAZOP. 7 Q. I'm going to switch gears a little bit. I 8 think one of the bases for your opinions on no 9 obviousness was that the '805 patent said that 10 hydrogen purity using a PSA unit was 99.9 percent? 11 A. High purity, yeah. 12 Q. But in Reinertsen's table, it showed PSA 13 hydrogen at 99 percent? 14 A. Yeah. 15 Q. And my question for you is, if you're a 16 person of skill in the art, what do you think the 17 purity of hydrogen is on a PSA unit? 18 MR. ROBINSON: Objection, form. 19 BY MR. PHILLIPS: 20 Q. Do you believe Reinertsen? 21 A. 99 percent? I would say that I do believe 22 it. And I say that in the sense that it's	199 1 And I direct you over to the left. In the middle 2 of that red section there's product. And it says: 3 Hydrogen up to 99.9999 percent purity. That's six 4 nines, right? 5 A. I can read it. That's what it says. 6 Q. Wouldn't a POSA know that that's really 7 the answer? 8 A. Here's what -- 9 MR. ROBINSON: Objection, form. 10 A. Here's what I think a POSA would know. 11 That's what they claim, that's what they're 12 selling. I don't know if I would get what they 13 claim. Now, what they show on a trade manual like 14 this, as opposed to a guarantee, I would look at 15 the guarantee, because that's what they're 16 standing behind. And Exxon would do the same 17 thing. 18 BY MR. PHILLIPS: 19 Q. What about Reinertsen, when it's trying to 20 promote palladium membranes in its patent? 21 MR. ROBINSON: Objection, form. 22
198 1 possible. I think that depending on the actual 2 PSA that's used, you could get, you know, 3 99 percent. Others, you know, maybe you get 4 99.9 percent. It's a pressure-dependent process. 5 It's an absorption process. So there are things 6 that come into play when you're using 7 thermodynamics, when you're using materials. So a 8 PSA can have a range of purities. And so 99, 99.9 9 is not unreasonable to expect. But Reinertsen's 10 made that statement and so, yes, I guess I would 11 say yes. 12 Q. I think one of your positions -- your 13 opinions was that you wouldn't change Reinertsen 14 because it's a lower -- 99 is less than 99.9. Do 15 you really agree with that? 16 A. I do. I believe that. 17 Q. Let's look at Exhibit 1018 again. This is 18 the Air Liquide Technology Handbook. And I want 19 to direct you to page 38. 20 A. Yeah. I'm there. 21 Q. This is the -- we looked at this earlier. 22 This is the pressure swing adsorption, PSA, page.	200 1 BY MR. PHILLIPS: 2 Q. Would you take that with a grain of salt 3 as well when they're trying to compare 99.9 versus 4 99? 5 A. I would say -- first of all, Reinertsen 6 is -- as I said earlier, I don't believe 7 Reinertsen is promoting palladium. I think 8 they've certainly used the embodiments with 9 palladium, but I would say that the data that 10 Reinertsen has included, the data that Rytter 11 includes in their tables from their process 12 simulation, I would use those as examples of what 13 is possible, but not necessarily what I would use 14 for my design. When I -- if I were to design 15 something, I would maybe take the literature, 16 including the patent literature, and then when I 17 did any process simulation, I would compare what 18 I'm seeing to what's in the literature to see if 19 what I'm seeing is agreeable with that. And then 20 if I have a vendor like Air Liquide that's going 21 to provide a PSA to me that says it as six nines, 22 I would say, Okay, what are you going to

201 1 guarantee. And if they say four nines, then I 2 would take the four nines. 3 Q. I guess where I'm going with this, though, 4 is in your declaration you affirmatively stated 5 you would -- a POSA would never replace the 6 palladium membrane unit because it's a lower 7 hydrogen purity. And my question to you is 8 simply, wouldn't a POSA know that 99 is a little 9 low for PSA hydrogen purity, such that that 10 wouldn't be determinative of whether you would use 11 that alternative? 12 MR. ROBINSON: Objection, form. 13 A. There are more than the cost effects that 14 are involved here in this discussion. Palladium, 15 as I mentioned to you before, is an evolving 16 technology, membrane technology, it's evolving. 17 Membrane separation has become more desirable 18 because of sustainability issues, because of 19 climate change issues. And so, again, I would 20 look at PSA as a technology that's proven, as a 21 technology that's been in practice for a long 22 time, a high TRL, and then I would look at	203 1 BY MR. ROBINSON: 2 Q. But PSA hydrogen purity is not really 3 lower, is it? 4 MR. ROBINSON: Objection, form. 5 A. 99 versus 99.9 versus 99.9999, that's 6 pretty high. 7 BY MR. ROBINSON: 8 Q. That's right. 9 (Discussion off the record.) 10 BY MR. ROBINSON: 11 Q. You've already testified that PSA is high 12 TRL, that's the proven way commercially to 13 separate hydrogen from syngas, correct? 14 A. Correct. 15 Q. You've characterized the palladium 16 membrane as a potential new option in light of 17 sustainability and other factors today, right? 18 A. I would say -- not say potential. I would 19 say is. And I think that the technology has 20 evolved to the point where you're seeing more and 21 more use of membrane separation. And so it's not 22 potential, it's actually used. And it's not -- it
202 1 membrane and say, Well, you know, I have to make a 2 decision and if I'm going to accept PSA or if I'm 3 going to accept, you know, membrane technology for 4 separation, the 99.9999 will certainly be a 5 consideration. It won't be a deciding factor for 6 me. 7 BY MR. PHILLIPS: 8 Q. That's fair. But in your declaration you 9 said it was a deciding factor in the other 10 direction. 11 A. Right. 12 Q. That you wouldn't do PSA -- 13 MR. ROBINSON: Objection. 14 BY MR. ROBINSON: 15 Q. -- because it's too low. Isn't that 16 right? 17 MR. ROBINSON: Objection, form. 18 A. I just said that the comparison of one 19 versus the other, just with that alone, that's 20 what I would -- I would not take the lower one for 21 that reason. 22	204 1 doesn't have the same level of commercial 2 application right now, because it hasn't been 3 around long enough to. But it will be. I can 4 guarantee that. I would put my salary on that. 5 We'll see more and more membrane separation as we 6 go forward. Because all the research, all the 7 work has been focused on that. And PSA is kind of 8 like a -- it's a standby. It's an excellent 9 technology, but the horse and buggy was really 10 good too for a while. 11 Q. But in 2020, at the time that this -- the 12 '805 patent was filed, palladium membrane was the 13 exception, PSA hydrogen removal was the rule, 14 right? 15 A. I agree. 16 Q. So when Reinertsen says you can use PSA 17 hydrogen as an alternative, a person of ordinary 18 skill in the art would know how to apply that in 19 the Reinertsen process. Would you agree with 20 that? 21 A. I would. 22 MR. PHILLIPS: Let's go off the record and

205 1 let me -- let me take a minute and see if I have 2 anymore questions, and then we're probably going 3 to be done here. 4 (Recess taken from 2:02 p.m. to 2:06 p.m.) 5 MR. PHILLIPS: I have no more questions, 6 Dr. Smith, and I'll pass the witness. 7 MR. ROBINSON: Just a couple questions. 8 EXAMINATION 9 BY MR. ROBINSON: 10 Q. Dr. Smith, would you please refer back to 11 Exhibit 1018, specifically page 38. Do you see on 12 the left-hand column under the heading Economics 13 where it lists an H2 recovery rate for pressure 14 swing adsorption hydrogen purification? 15 A. I do. 16 Q. And what's the recovery rate there? 17 A. 60 to 90 percent. 18 Q. Would you please refer to page 42 of that 19 same exhibit that addresses hydrogen separation 20 membranes? 21 A. Got it. 22 Q. And under the economics heading for that	207 1 please. 2 MR. PHILLIPS: Which one is that? 3 MR. ROBINSON: Sorry, 1005. Apologies. 4 The Reinertsen reference. 5 A. Here it is. Got it. 6 BY MR. ROBINSON: 7 Q. Okay. And Figure 2. 8 A. Yeah. 9 Q. So this is the Reinertsen comparative 10 example figure, correct? 11 A. Correct. 12 Q. So block 10 is PSA hydrogen separation? 13 A. Correct. 14 Q. Okay. And block 11 is hydrogen 15 compression, correct? 16 A. Correct. 17 Q. And block 9 is CO2 compression? 18 A. Correct. 19 Q. In liquefying CO2 gas, is there cooling 20 involved in that, typically? 21 A. There is. 22 MR. ROBINSON: Pass the witness back.
206 1 page, what does it list for the hydrogen recovery 2 rate? 3 A. 98 percent. 4 Q. Is that commercially more than 63 to 5 90 percent? 6 A. As written, yes. 7 Q. And under capacity on that left-hand 8 column, do you see where it says, Largest system 9 referenced by Air Liquide is 124-membrane 10 cartridges? 11 A. Yes. 12 Q. Does that indicate to you an existing 13 system referenced? 14 A. Say that again. 15 Q. Does that suggest to you that there is an 16 existing system as of the publication of this with 17 124-membrane cartridges? 18 A. It does. 19 MR. PHILLIPS: Objection, form. 20 A. It does, yeah. 21 BY MR. ROBINSON: 22 Q. I'd ask you to refer to Exhibit 2005,	208 1 FURTHER EXAMINATION 2 BY MR. PHILLIPS: 3 Q. Dr. Smith, looking at -- staying on 4 Exhibit 1005 and staying on Figure 2, we said 5 block 150 was pressure swing adsorption; is that 6 right? 7 A. Yes. 8 Q. What's block 8? 9 A. Block 8 -- we're back in Figure 10. So 10 block 8 is -- I'd have to review the patent. I 11 don't recall now block 8. 12 Q. I believe looking at Figure 10, Table 1 -- 13 A. I was looking at that, yeah. 14 Q. I think Figure 2 relates to the 15 comparative example, but I'll let you confirm 16 that. 17 A. I agree with that. I believe that's what 18 it refers to, comparative example. 19 Q. So you'll agree that Figure 2 does not 20 show cryogenic CO2 separation; is that right? 21 A. It says no -- there's not a check by the 22 cryogenic, but that is certainly a CO2 compression

209 1 step. Block 9 is the CO2 compression. 2 Q. Is -- 3 A. But they don't have that listed in the 4 metrics on the left of Table 1. They don't say, 5 you know, CO2 compression. They don't -- they 6 also don't have -- I mean, they have cryogenic 7 separation, but, again, CO2 compression is not 8 cryogenic separation. 9 Q. They do have a check mark next to amine 10 separation. 11 A. They do. And that, again, is this block 7 12 I believe is the amine separation. 6 is the shift 13 reactor and then the shift reactor is 7 and I 14 think amine is 8. And then, again, CO2 separation 15 and then hydrogen purification separation there. 16 Q. So I'll direct you to -- this is 17 paragraph 103. 18 A. Okay. 19 Q. And specifically the second column. It's 20 bolded. I was just going to take your eye to the 21 seventh line, where you see the 8 that's bolded. 22 A. Eight, separate CO2 from shifted gas,	211 1 here, then out of that stripper to a PSA unit 2 No. 10, and then over to a compressor No. 11. I'm 3 sure that's what that is. Pressure swing 4 adsorption, yeah, in that same paragraph. Strips 5 hydrogen from the gas, 82. Already depleted CO2. 6 Yeah. Okay. 7 Q. So I just wanted to confirm that Figure 2 8 does not relate to cryogenic CO2 removal. Do you 9 agree with that? 10 A. There's a PSA unit at No. 10 and that's -- 11 that is a pressure swing -- it's a pressure swing 12 absorber, and so it's not cryogenic, it's PSA. 13 9 is a CO2 compressor, not a cryogenic separator. 14 There's no cryo in that. 15 Q. But block 8 is -- block 8 is a CO2 removal 16 step? 17 A. It's an amine process. 18 Q. Right. 19 A. That's right. It's a strip -- 20 Q. Block 10 is a hydrogen removal process 21 which is -- 22 A. PSA, yup --
210 1 yeah. 2 Q. And it's an amine-type separation process, 3 8. 4 A. Amine-type, yes. 5 Q. So you'll -- 6 A. That's the amine separator, then. Okay. 7 Q. So you'll agree that Figure 2 does not 8 relate to cryogenic CO2 separation; is that right? 9 A. Hang on for just a second. Let me -- 10 there's the shift reactor. Condenser is 7. So 11 that's a condenser. 7 is the condenser. And then 12 so that's removing the water. So 72 would be 13 water. Yeah. And then 8 is the amine separator. 14 Okay. And then coming off amine, 81 is the CO2 15 line. Yeah, that's CO2 coming out of the amine 16 separator. And again, these boxes are high-level 17 boxes. And so inside that box there's a -- 18 there's an absorption tower that's pulling the CO2 19 out with amine, and then it's, again, separating 20 and deabsorbing or stripping that CO2 out, so 21 that's CO2 coming out, going up to 9, which is the 22 compressor, and then down, hydrogen is coming down	212 1 (Simultaneous discussion interrupted by 2 reporter.) 3 BY MR. PHILLIPS: 4 Q. Let me -- let's clean this up. I just 5 wanted to confirm. Block 8 in Figure 2 is a CO2 6 removal step that is the amine absorber process, 7 correct? 8 A. Correct. 9 Q. Block 10 is a hydrogen removal step that 10 is pressure swing adsorption, correct? 11 A. Correct. 12 Q. So I think the testimony that you had 13 earlier still stands, that of all the embodiments 14 that Reinertsen shows, when they use cryogenic CO2 15 separation, it's always after the hydrogen removal 16 step? 17 MR. ROBINSON: Objection, form. 18 BY MR. PHILLIPS: 19 Q. Is that correct? 20 A. In this figure, Figure 2, there's no 21 cryogenic separation used. There's PSA to remove 22 the hydrogen, as you pointed out, followed by a

213 1 hydrogen compressor, block 11. There's an amine 2 scrubber that separates the CO2 from the stream, 3 that then de -- or strips out the CO2 that goes to 4 a compressor, CO2 compressor, block 9, that then 5 becomes stream 91. That's that process. That's 6 what shows here. And in Table 1, Figure 10, the 7 comparative example, which is the first column, 8 it's consistent with what it says here. So 9 there's no cryogenic separation there. And the 10 only cryogenic separation in all of the 11 embodiments it looks at are example 2, example 4 12 and example 5 through 7. That's what's in 13 Table 1, Figure 10. 14 Q. And in terms of the order of steps, when 15 cryogenic CO2 removal is used, it's always 16 downstream of the hydrogen removal. Would you 17 agree with that? 18 MR. ROBINSON: Objection, form. 19 A. I believe that's correct. 20 MR. PHILLIPS: I have no further 21 questions. 22 MR. ROBINSON: Let's call it a day.	215 REPORTER'S CERTIFICATION I, Micheal A. Johnson, Registered Diplomate Reporter and Notary Public within and for the State of Texas do hereby certify: That JOSEPH D. SMITH, Ph.D., the witness whose deposition is hereinbefore set forth, was duly sworn by me before the commencement of such deposition and that such deposition was taken before me and is a true record of the testimony given by such witness. I further certify that the deposition of JOSEPH D. SMITH, Ph.D. occurred at the offices of Norton Rose Fulbright, 98 San Jacinto Boulevard, Suite 1100 on Tuesday, July 7, 2026, commencing at 6:04 a.m. to 2:18 p.m. I further certify the inspection, reading and signing of said deposition was not waived on the record by agreement of all parties. I further certify that I am not related to any of the parties to this action by blood or marriage, I am not employed by or an attorney to
214 1 MR. PHILLIPS: Let's call it a day. 2 (Deposition concluded at 2:18 p.m.) 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	216 1 any of the parties to this action, and that I am 2 in no way interested, financially or otherwise, in 3 the outcome of this matter. IN WITNESS WHEREOF, I have hereunto set my hand this 9th day of July, 2026.  MICHEAL A. JOHNSON, RDR, CRR My commission expires: 8/8/2028 NOTARY PUBLIC IN AND FOR THE STATE OF TEXAS 10 11 12 13 14 15 16 17 18 19 20 21 22

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