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Transcript of Dr. J. Matt Quinlan

Date: April 19, 2024
Case: Robert Bosch, LLC, et al. -v- Westport Fuel Systems Canada, Inc. (PTAB)

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WORLDWIDE COURT REPORTING & LITIGATION TECHNOLOGY

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ROBERT BOSCH LLC and MERCEDES-BENZ USA, LLC,

Petitioners,

v.

WESTPORT FUEL SYSTEMS CANADA, INC.,

Patent Owner.

IPR2023-00292

U.S. Patent No. 6,298,829 B1

ORAL AND VIDEOTAPED DEPOSITION OF

DR. J. MATT QUINLAN

APRIL 19, 2024

ORAL AND VIDEOTAPED DEPOSITION of DR. J. MATT QUINLAN, produced as a witness at the instance of Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on the 19th day of April, 2024, from 10:04 a.m. to 3:43 p.m. before Karen G. Kolohe, CSR in and for the State of Texas, recorded by machine shorthand, via Zoom Videoconference pursuant to 37 C.F.R. § 42.53(d)(1) and the provisions stated on the record or attached hereto.

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THE VIDEOGRAPHER: Here begins media number one in the videotaped taped deposition of Dr. J. Matt Quinlan in the matter of Robert Bosch, LLC and Mercedes-Benz USA, LLC v. Westport Fuel Systems Canada, Inc. in the United States Patent and Trademark Office Before the Patent Trial and Appeal Board, U.S. Patent No. 6.298.829 B1. 10:04:11 10:04:12 10:04:17 10:04:23 10:04:29 10:04:32 10:04:32

Today's date is April 19th, 2024. The time on the video monitor is 10:04, Central. The remote videographer today is Maddie Reif representing Planet Depos. All parties of this video deposition are attending remotely. Would counsel voice identify themselves and state whom they represent? 10:04:46 10:04:51 10:04:55 10:04:59 10:05:00 10:05:03

MR. PHILBIN: Phillip Philbin at Winstead on behalf of Westport. 10:05:06 10:05:09

MS. JONES: Miranda Jones of Winstead on behalf of Westport. 10:05:12 10:05:15

MR. HERMAN: Patrick Herman from Orrick, Herrington and Sutcliffe here on behalf of petitioners. 10:05:20 10:05:23

MR. ROTZ: Nicholas Rotz from Hogan Lovells here on behalf of petitioners. 10:05:26 10:05:30

THE VIDEOGRAPHER: Thank you, counsels. 10:05:34

The court reporter today is Karen Kolohe representing Planet Depos. The witness will now be sworn. 10:05:35 10:05:39 10:05:42

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(Witness sworn) 10:05:42

MR. PHILBIN: Per the parties' agreement, this deposition is being taken for purposes of both IPR 203-00292 and IPR 2023-00293. Any testimony provided in this deposition can be used in both or either IPR proceeding. Is that correct, counsel? 10:06:00 10:06:01 10:06:05 10:06:13 10:06:19

MR. HERMAN: Yes, that's right. 10:06:20

MR. PHILBIN: And I believe we established before we went on the record that Mr. Rotz from Hogan Lovells has not made an appearance in this -- either IPR but we do not object to him attending the deposition. 10:06:24 10:06:25 10:06:28 10:06:33

DR. J. MATT QUINLAN, 10:06:33

being first duly sworn, testified as follows: 10:06:33

EXAMINATION 10:06:38

BY MR. PHILBIN: 10:06:38

Q. Good morning, Dr. Quinlan. How are you? 10:06:38

A. I'm well. You? 10:06:41

Q. Just fine. Thank you for asking. You're appearing for this deposition from a remote location today, correct? 10:06:42 10:06:45 10:06:47

A. Correct. 10:06:48

Q. Where are you located today? 10:06:48

A. Monument, Colorado. 10:06:51

Q. Who else is in the room with you? 10:06:53

A. No one. 10:06:56

Q. If anyone else comes in the room with you at any time, will you agree to let me know immediately? 10:06:57 10:07:02

A. I will. 10:07:04

Q. Do you have any method that allows you to communicate with your lawyers or your legal team while we're on the record today? 10:07:05 10:07:09 10:07:12

A. No. 10:07:13

Q. Are there any apps open on your screen other than this deposition app? 10:07:13 10:07:19

A. I have my e-mail open so that I can receive e-mails if there's any more exhibits that I need to receive. 10:07:22 10:07:25 10:07:27

Q. Got it. So your lawyers could e-mail you and you could read the subject line of the e-mail while you're on the record today, correct? 10:07:28 10:07:32 10:07:36

A. I don't think I would be able to see it without us agreeing to go to that window because I'm instructed to do so. 10:07:37 10:07:40 10:07:44

Q. You'll agree that if you look at any materials other than the materials that are part of this deposition, you'll agree to let me know? 10:07:46 10:07:50 10:07:52

A. I will. 10:07:54

Q. Do you have any written notes or documents with you today? 10:07:57 10:08:00

A. I had a clean set of documents provided to me by 10:08:00

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Orrick in addition to the electronic documents in a folder on my desktop that you provided and that clean set from Orrick as well. 10:08:04 10:08:07 10:08:10

Q. What's in the clean set of documents that you have from your legal team? 10:08:14 10:08:17

A. So, it's the exhibits from the declaration along with the declarations and the patents. 10:08:18 10:08:24

Q. Anything else? 10:08:28

A. No. 10:08:28

Q. What's in the electronic files you have access to? 10:08:29 10:08:34

A. The exhibits that you sent to me and then a folder containing the same information that's printed out here just so that I would have everything that I used in my creating of the document. 10:08:34 10:08:40 10:08:42 10:08:47

Q. Will you agree not to communicate with anyone through any form of communication other than the Zoom application while we're on the record today? 10:08:52 10:08:55 10:09:00

A. I do. 10:09:02

Q. Will you agree not to communicate with your counsel about the subject matter of your testimony until I've completed my questions? 10:09:06 10:09:12 10:09:14

A. I do. 10:09:16

Q. You understand we asked for this deposition to be in person and your side refused? 10:09:16 10:09:23

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A. I was not involved in that. 10:09:26
Q. Please tell me what you did to prepare for this deposition. 10:09:28
A. I met with my legal team and prepared by reviewing my declaration and the prior art that I relied on. 10:09:33
Q. Who all's on your legal team? 10:09:41
A. Specifically, I met with Bosch, Patrick, and Nicholas along with in-house counsel for Bosch. 10:09:46
Q. Who was the in-house counsel? 10:09:48
A. It's Yurgan (phonetic) and Joaquin. 10:09:50
Q. Do you know their last names? 10:10:01
A. I do not. 10:10:08
Q. How long did you meet with your legal team in preparation for your deposition today? 10:10:11
A. I believe it was five hours. 10:10:18
Q. Yesterday? 10:10:20
A. We met over three days for shorter meetings. 10:10:21
Q. Did you meet in person? 10:10:26
A. We did not. 10:10:27
Q. Other than your declarations, what documents did you review in preparation for the deposition today? 10:10:30
A. I reviewed the prior art that I used in creating of the declaration as well. 10:10:34
Q. Anything else? 10:10:40
10:10:41
10:10:42
10:10:50
10:10:52
10:10:58
10:11:00

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A. No. 10:11:04
Q. Did you carefully review each of your declarations in preparation for the deposition today? 10:11:05 10:11:09
A. I did. 10:11:11
MR. HERMAN: Objection, form. 10:11:14
Q. (BY MR. PHILBIN) You would agree that you carefully performed the analysis reflected in both your declarations, correct? 10:11:17 10:11:18 10:11:21
A. I would say I carefully did my research on the material at hand and formed my opinions. 10:11:24 10:11:32
Q. You checked your opinions for accuracy, correct? 10:11:35
A. I believe I -- I believe so. I believe that everything I presented is true. 10:11:40 10:11:47
Q. Okay. And you checked your declarations for any mistakes, correct? 10:11:49 10:11:53
A. Yes. 10:11:54
Q. And as you sit here today, you're confident in all of the statements that you made in each of your declarations, correct? 10:11:58 10:12:03 10:12:05
A. I'm sure that things could sometimes be worded more eloquently, but I believe that -- that what I have said stands. 10:12:05 10:12:10 10:12:16
Q. And it's your expert opinion that the math you did in your declarations is correct, right? 10:12:19 10:12:23
A. I'm not aware of much math that I did for my 10:12:27

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declaration but we surely can discuss that. 10:12:30

Q. And are you as confident in the math that you did in your declarations as you are in the rest of your opinions in the declarations? 10:12:33 10:12:37 10:12:40

MR. HERMAN: Objection, form. 10:12:41

A. Again, I'm not sure what math we're talking about because I don't remember doing much math for the declarations, so I would surely like to see what you're talking about before I say that I'm confident or not confident. 10:12:44 10:12:46 10:12:50 10:12:56 10:13:01

Q. (BY MR. PHILBIN) So as you sit here today, you're not sure whether you're confident in the math that's in your declarations? 10:13:04 10:13:06 10:13:08

MR. HERMAN: Objection, form. 10:13:12

A. Uh -- 10:13:13

Q. (BY MR. PHILBIN) Make sure I got your testimony right. 10:13:13 10:13:17

MR. HERMAN: Same objection. 10:13:18

A. Like I said, I don't know specifically what you're talking about, but I feel like my declaration is accurate. 10:13:20 10:13:22 10:13:26

Q. (BY MR. PHILBIN) Okay. I skipped over a couple of preliminary matters. If at any time today I ask you a question you don't understand, will you agree to let me know? 10:13:27 10:13:32 10:13:34 10:13:37

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A. Yes. 10:13:37
Q. If at any time I ask you -- I'm sorry. If at any time today, you need to take a break for any reason, 10:13:38 10:13:41
will you agree to let me know? 10:13:43
A. Yes. 10:13:45
Q. And will you agree not to ask for a break when there's a question pending unless you need to discuss 10:13:45 10:13:51
the question with your lawyers? 10:13:53
A. Yes. 10:13:54
Q. Are you on any medication or have any medical condition that would prevent you from telling the truth 10:13:57 10:14:00
today? 10:14:02
A. No. 10:14:03
Q. And the reason it occurred to me to go through those preliminary matters is, will you also agree to try 10:14:06 10:14:08
and have one of us talking at a time so the court reporter can take down one speaker at a time as opposed 10:14:13 10:14:17
to us talking over each other? 10:14:20
A. Yes. 10:14:21
Q. Thank you. 10:14:21
You agree that your opinions related to the Klugl reference are important, correct? 10:14:28 10:14:31
MR. HERMAN: Objection, form. 10:14:32
A. I think Klugl is very pertinent to this case, yes. 10:14:34 10:14:39

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Q. (BY MR. PHILBIN) In fact, the Klugl reference is one of the foundations of each of your opinions in both IPRs, correct? 10:14:40 10:14:46 10:14:50

A. I believe that is correct. 10:14:51

Q. So, all of your opinions in both IPRs rest on the foundation of Klugl and other references, correct? 10:14:56 10:15:02

MR. HERMAN: Objection, form. 10:15:04

A. All of my opinions based on -- is based on the whole intrinsic evidence in the case and extrinsic evidence where needed. 10:15:06 10:15:13 10:15:19

Q. (BY MR. PHILBIN) Is Klugl intrinsic or extrinsic evidence in this case? 10:15:21 10:15:24

MR. HERMAN: Objection, form. 10:15:25

A. I would consider it intrinsic evidence. 10:15:27

Q. (BY MR. PHILBIN) What other prior art references would you consider intrinsic evidence in this case? 10:15:32 10:15:34

MR. HERMAN: Objection, form. 10:15:38

A. I believe all of the -- the documents listed in my declaration, I would consider intrinsic. 10:15:38 10:15:45

Q. (BY MR. PHILBIN) In preparation for your -- strike that. 10:15:50 10:16:06

In preparing both of your declarations and for this deposition, you reviewed the Klugl reference, correct? 10:16:06 10:16:09 10:16:13

A. Correct. 10:16:14

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Q. And you read the entire Klugl reference, correct? 10:16:14
A. I have read the Klugl reference thoroughly. 10:16:18
Q. How many times have you read the entire Klugl reference? 10:16:24 10:16:26
A. I wouldn't have any idea. 10:16:26
Q. More or less than ten? 10:16:29
A. I -- again, I don't know, cover to cover, if I read it ten times, but I have looked at it thoroughly. 10:16:31 10:16:37
Q. Okay. Did you review the German Klugl reference or the English translation of the Klugl reference? 10:16:41 10:16:49
A. The English translation. 10:16:55
Q. Do you read German? 10:16:56
A. I do not. 10:16:58
Q. Do you speak German? 10:16:58
A. I do not. 10:17:00
Q. Did you speak with the person that translated the Klugl reference from German to English? 10:17:00 10:17:04
A. I did not. 10:17:05
Q. Your expert opinions in this case rely on the English translation of the Klugl from German to English, correct? 10:17:06 10:17:10 10:17:14
A. Yes. 10:17:14
Q. Do you believe the Klugl reference is accurately translated? 10:17:17 10:17:22
MR. HERMAN: Objection, form. 10:17:23

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A. I'm sure that there is always alternate translations that could be done, but the translation seemed consistent and, you know, we could surely discuss word choice issues, but I think that the -- taken on a whole, it seemed -- it seemed like it would be an accurate translation from what I could see. 10:17:24 10:17:33 10:17:36 10:17:45 10:17:49 10:17:54

Q. (BY MR. PHILBIN) Your opinions rely on the accuracy of the translated Klugl reference, correct? 10:17:57 10:17:59

MR. HERMAN: Objection, form. 10:18:02

A. My opinions -- my opinions depend on the entirety of the material in this case. 10:18:03 10:18:08

Q. (BY MR. PHILBIN) Including Klugl, correct? 10:18:13

A. Including Klugl but lots of other things as well. 10:18:15

Q. Did you review the Wirbeleit reference prior to signing your declarations and in preparation for this deposition today? 10:18:19 10:18:28 10:18:31

A. I did. 10:18:31

Q. Did you review the Hayes reference prior to signing your declarations and in preparation for today's deposition? 10:18:32 10:18:37 10:18:40

A. I did. 10:18:41

Q. Did you review the Newcomb (phonetic) reference prior to signing your declarations and in preparation for today's deposition? 10:18:43 10:18:45 10:18:47

A. I did. 10:18:48

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Q. Did you fully understand what was in the Klugl reference before signing your declarations? 10:18:48 10:18:54

A. I believe so. 10:18:56

Q. Did you notice any errors in the Klugl reference before signing your declaration? 10:18:57 10:19:02

MR. HERMAN: Objection, form. 10:19:04

A. Not that I recall. 10:19:05

Q. (BY MR. PHILBIN) Did you notice any errors in the Wirbeleit reference before signing your declaration? 10:19:09 10:19:16

MR. HERMAN: Objection, form. 10:19:19

A. Not that I recall. 10:19:20

Q. (BY MR. PHILBIN) Did you notice any errors in the Hayes declaration before signing your declaration? 10:19:24 10:19:25

A. Not that I recall. 10:19:31

Q. Did you notice any errors in the Newcomb reference before signing your declarations? 10:19:32 10:19:38

MR. HERMAN: Objection, form. 10:19:39

A. Not that I recall. 10:19:39

Q. (BY MR. PHILBIN) Have you discussed your deposition today with anyone other than your legal team? 10:19:40 10:19:43

A. No, I did not. 10:19:47

Q. Do you have a printed copy of your declaration for IPR 2023-292 in front of you? 10:19:48 10:19:56

A. Yes, I do. 10:20:01

(Exhibit No. 1 marked) 10:20:01

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Q. (BY MR. PHILBIN) Okay. I've marked the electronic version of that declaration as Quinlan Exhibit No. 1. Would you prefer to look at the electronic version or your paper version? 10:20:01 10:20:04 10:20:08 10:20:10

A. I think both is helpful. 10:20:13

Q. Okay. Well, I'll have my assistant, Nikki, put the declarations when I'm referring to them on the screen, but on the off chance that she doesn't give you the page that you're looking for, you've got printed copies of both declarations where you can look at any page you want to in front of you, correct? 10:20:18 10:20:18 10:20:27 10:20:30 10:20:32 10:20:34

A. Correct. 10:20:36

Q. Okay. And you also have a copy of your declarations from IPR 2023-293 in front of you, correct? 10:20:36 10:20:39

A. The 138 Patent declaration? Is that what you said? 10:20:50 10:20:57

Q. Yes, sir. 10:20:58

A. Yeah. Yes, I do. 10:20:59

Q. I'm going to mark the declaration from IPR 2023-293 as Quinlan Exhibit No. 2. 10:21:02 10:21:08

(Exhibit No. 2 marked) 10:21:11

Q. (BY MR. PHILBIN) And, again, you have a printed copy that you can look at. We also have an electronic copy available for the Zoom deposition. 10:21:12 10:21:13 10:21:15

Does your printed copy include anything that is 10:21:19

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not included in the original signed version of your declaration? 10:21:21 10:21:26

A. I don't believe so. 10:21:27

Q. Are there any notes, markings, highlights, post-it notes, et cetera, on any of your declarations that you have in front seat of you? 10:21:31 10:21:35 10:21:39

A. No. This is the first time I've opened the binder. 10:21:40 10:21:42

Q. So the binder you've got is the binder you received from your legal team? 10:21:42 10:21:46

A. It is. 10:21:48

Q. So you don't know whether there's notes or anything else in there. You just know the two declarations are in there, right? 10:21:48 10:21:52 10:21:54

A. I know they're -- they were sending me clean copies. 10:21:55 10:21:59

Q. Is there any portion of Klugl that you would say is more important than other portions? 10:22:01 10:22:19

MR. HERMAN: Objection, form. 10:22:22

A. No. I think that being in the prior art, that we can take the entire document as being very important. 10:22:23 10:22:31

Q. (BY MR. PHILBIN) What does stroke translation mean to you in the context of the Klugl reference? 10:22:39 10:22:42

A. So -- so, how Klugl uses stroke translation is the relationship between the motion of one piece on one 10:22:44 10:23:14

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side of the hydraulic link versus the motion on the other side of the hydraulic link and the -- essentially, whether that is the same or different. 10:23:23 10:23:28 10:23:34

Q. You would agree with me, the word "translation" only appears twice in the translated version of the Klugl reference, right? 10:23:37 10:23:52 10:23:53

MR. HERMAN: Objection, form. 10:23:53

A. I would have to go through and count. 10:23:54

Q. (BY MR. PHILBIN) You haven't looked for all the appearances of the word "translation" in Klugl prior to now? 10:24:00 10:24:01 10:24:05

A. I have not specifically searched that out and counted the number of times. 10:24:05 10:24:11

Q. Okay. What does stroke translation mean to you in the context of the Klugl reference? 10:24:12 10:24:14

A. Stroke transmission? 10:24:16

Q. Yes, sir. 10:24:20

A. Can I open up the electronic copy on my computer here? 10:24:26 10:24:29

Q. Sure. If you don't mind telling me what you're looking at on your screen while you're doing it, that's just fine. 10:24:30 10:24:35 10:24:38

A. Let's see. From -- from your -- through Bosch, you guys sent me the two declarations. 10:24:40 10:24:50

Q. Perhaps you misunderstand. I didn't send 10:24:52

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anything through Bosch to you. 10:24:55
A. Okay. 10:24:57
Q. You may have received something from your legal team and he may have anticipated what he thought I was going to ask about, but let me assure you, I did not instruct him to send you anything. 10:24:57 10:25:00 10:25:03 10:25:06
MR. HERMAN: Just to clarify the record, your partner did, in fact, direct an e-mail to our attention instructing us to provide the witness with a package of materials -- 10:25:07 10:25:10 10:25:13 10:25:18
MR. PHILBIN: Okay. 10:25:18
MR. HERMAN: -- which we did do. 10:25:18
MR. PHILBIN: Okay. 10:25:19
Q. (BY MR. PHILBIN) So you've got that package electronically and in paper, right? 10:25:20 10:25:23
A. Yes, I do. 10:25:25
Q. Do you have the Klugl reference up in front of you? 10:25:26 10:25:27
A. I do not have the Klugl reference up in front of me. I was going to -- let's see. 10:25:27 10:25:31
Q. What are you looking at now? 10:25:37
A. I'm just getting to it right now. 10:25:38
(Brief pause) 10:26:11
A. So it looks like your Exhibit 4 that you sent is the Klugl reference. Is that correct? 10:26:11 10:26:17

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Q. (BY MR. PHILBIN) Yes, sir. 10:26:19
A. Okay. 10:26:20
(Exhibit No. 4 marked) 10:26:21
Q. (BY MR. PHILBIN) We'll go ahead and mark the Klugl reference as Exhibit 4, and I believe in both IPRs, it was also identified as Exhibit 1006 which is the English translation that you or your legal team did and you relied upon. Is that correct? 10:26:21 10:26:23 10:26:25 10:26:29 10:26:34
MR. HERMAN: Objection, form. 10:26:37
A. I would have to check that it's the same, but it looks like it's Petitioner Exhibit 00- -- marked as Exhibit 006, so I believe that's -- I believe that's correct. 10:26:40 10:26:43 10:26:48 10:26:54
Q. (BY MR. PHILBIN) Okay. In the Klugl reference you have in front of you, you can electronically search, correct? 10:26:55 10:26:59 10:27:02
A. I can. 10:27:03
Q. Let's go back to stroke translation. Will you search for "translation" and let me know how many hits you get? 10:27:04 10:27:10 10:27:14
A. So, I believe the question that was standing was about stroke transmission. 10:27:14 10:27:17
Q. Well, that's right, and I said, let's go back to translation while you you've got it open and you can electronically search. So will you electronically 10:27:20 10:27:23 10:27:25

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search for "stroke translation" and let me know how many times that appears in the Klugl reference that you relied upon? 10:27:28 10:27:30 10:27:32

A. It appears that stroke translation shows up two times. 10:27:33 10:27:47

Q. In reference to Figure 1 and Figure 2, correct -- Figure 1 and Figure 3, correct? 10:27:47 10:27:50

A. Figure 1 and Figure 3. 10:27:52

Q. And Klugl doesn't provide a definition of stroke translation, correct? 10:27:54 10:28:01

MR. HERMAN: Objection, form. 10:28:02

A. It's not mentioned elsewhere but I think that a POSITA would have an understanding from reading the text and looking at the figures of what this means. 10:28:02 10:28:12 10:28:16

Q. (BY MR. PHILBIN) Okay. What does stroke transmission -- I'm changing from translation to transmission -- what does stroke transmission mean to you in the context of the Klugl reference? 10:28:21 10:28:24 10:28:27 10:28:30

A. So, I don't specifically find that term in the document. 10:28:38 10:28:40

Q. Okay. So you don't have an understanding of what stroke transmission means in the context of Klugl reference? 10:28:48 10:28:52 10:28:54

MR. HERMAN: Objection, form. 10:28:54

A. Again, I don't -- it's not listed in the 10:28:56

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document, so I -- in that context, I don't think I have an opinion on what it means. 10:28:58 10:29:05

Q. (BY MR. PHILBIN) Okay. What does transmission mean to you in the context of the Klugl reference? 10:29:07 10:29:09

MR. HERMAN: Objection, form. 10:29:15

A. Again, I haven't specifically looked at what that term means in light of this patent and so that would take time on my behalf to come up with what I think. 10:29:16 10:29:19 10:29:24

Q. (BY MR. PHILBIN) So would you look at column seven, line 18 of Klugl? Do you see that? 10:29:27 10:29:38

A. Column seven, line 18. Okay. I see stroke transmission there. It didn't come up when I searched it, though. 10:29:41 10:29:57 10:30:00

Q. So, now you see on column seven, line 18, the word "stroke transmission," correct? 10:30:01 10:30:04

A. Okay. 10:30:05

Q. And it's still your testimony that you don't know what stroke transmission means in the context of Klugl, correct? 10:30:05 10:30:08 10:30:10

MR. HERMAN: Objection, form. 10:30:13

A. Let me look at the document here and see what we're speaking about. 10:30:15 10:30:18

(Brief pause) 10:30:40

A. So, in this context, what we're speaking about is the -- the relative motion of the different members that 10:31:38 10:31:52

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are touching the two membranes on the opposite sides of the hydraulic link and the Klugl is discussing advantages that can potentially be had by having the areas on the different sides of the hydraulic transmission link being different so that you end up with a different stroke on one side versus the other. 10:31:56 10:32:00 10:32:10 10:32:15 10:32:19 10:32:25

Q. (BY MR. PHILBIN) So are stroke translation and stroke transmission the same thing in the context of Klugl based on your understanding? 10:32:28 10:32:35 10:32:37

MR. HERMAN: Objection, form. 10:32:48

A. So, when -- you know, what is clear is that.... 10:32:52

Q. (BY MR. PHILBIN) I'm just asking, are they the same thing? 10:33:08 10:33:09

A. Sorry. I'm looking at one thing here on the page on mine. Let's see. About 14, there -- Klugl speaks of achieving a stroke ratio between the deflections of the piezoelectric actuator and the deflection of the dry piston. So, again, here we're talking about whether or not those two members change distance equally, or unequally, okay? And in this case, that is given by the stroke ratio. 10:33:11 10:33:13 10:33:24 10:33:30 10:33:33 10:33:36 10:33:45 10:33:53

And when referring to Figure 1 and Figure 3, those are two different embodiments where one has a stroke ratio essentially of one and another where the stroke ratio is not equal to one to try to take 10:33:56 10:34:01 10:34:04 10:34:09

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advantage of that for particular cases. 10:34:13

MR. PHILBIN: Objection, nonresponsive. 10:34:19

Move to strike. 10:34:21

Q. (BY MR. PHILBIN) My question, sir, is -- 10:34:21

MR. HERMAN: For purposes of the record, 10:34:22

that is not relief that you can seek in a deposition. 10:34:24

If you want to move to strike, you have to move the 10:34:26

board, so that's an improper -- improper colloquy. Ask 10:34:28

your questions. If you want relief, seek permission to 10:34:33

get that relief from the board. 10:34:35

MR. PHILBIN: Are you finished? 10:34:37

MR. HERMAN: Yes, I am. 10:34:38

Q. (BY MR. PHILBIN) My question, sir, is: In the 10:34:39

context of Klugl, is it your opinion, stroke translation 10:34:42

and stroke transmission mean the same thing? 10:34:47

MR. HERMAN: Objection, form. 10:34:48

A. Again, I think that the key is here, that stroke 10:34:49

translation has to do with -- from looking at the 10:35:02

embodiments in Figure 1 and Figure 3, we see that it's 10:35:05

clear that we're talking about the stroke ratio. And by 10:35:08

stroke transmission, I think we can potentially mean two 10:35:15

different things. 10:35:17

MR. PHILBIN: Objection, nonresponsive. 10:35:20

Q. (BY MR. PHILBIN) Do stroke translation and 10:35:22

stroke transmission mean different things in the context 10:35:24

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of Klugl, in your opinion? 10:35:28

MR. HERMAN: Objection, form. 10:35:30

A. Again, I think that depends on the light in which we're taking stroke transmission in the Klugl reference. 10:35:31 10:35:39

Q. (BY MR. PHILBIN) In your opinion, are the terms stroke translation and stroke transmission interchangeable in the context of the Klugl reference? 10:35:46 10:35:49 10:35:50

MR. HERMAN: Objection, form. 10:35:53

A. Again, I think that we would have to look at every appearance of that and see if that was consistent with the rest of the document. 10:35:56 10:35:59 10:36:05

Q. (BY MR. PHILBIN) Okay. You've searched translation and it appeared twice. Go ahead and take your time and search for stroke transmission. 10:36:07 10:36:11 10:36:13

A. Well, so when I searched stroke transmission, it didn't find this case, so.... 10:36:21 10:36:21

Q. Well, I've established that it's in there once, correct? 10:36:24 10:36:26

A. Yeah. Is it in there again? 10:36:27

Q. Not that I know of, but I want you to confirm it. 10:36:30

A. So, I'm not finding it via search. That doesn't mean that it doesn't exist anywhere in there that I can't find with the search. We don't know if the PDF is that good. 10:36:34 10:36:39 10:36:43 10:36:50

Q. And you didn't use the word "stroke transmission" 10:36:50

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in either of your declarations, correct? 10:36:52
MR. HERMAN: Objection, form. 10:36:53
A. I'm not aware whether I did or not. 10:36:54
Q. (BY MR. PHILBIN) Okay. What's the difference 10:36:58
between stroke -- strike that. 10:37:03
Do stroke translation and stroke ratio mean the 10:37:04
same thing to you in the context of the Klugl reference? 10:37:09
MR. HERMAN: Objection, form. 10:37:11
A. Do they mean exactly the same thing? I can't 10:37:15
tell you, but what I can tell you is they may refer to 10:37:17
the same structure and function. For example, looking 10:37:20
at Figure 1, we essentially see that there is a 10:37:28
basically one-to-one ratio between how much each side of 10:37:35
the hydraulic link moves whereas in Figure 3, the areas 10:37:41
have been chosen specifically to make that much 10:37:48
different than one, and thus, have a very different than 10:37:53
one stroke area -- stroke ratio. Excuse me. 10:37:57
MR. PHILBIN: Objection, nonresponsive. 10:38:04
Q. (BY MR. PHILBIN) What does the term, stroke 10:38:05
ratio mean to you in the context of -- 10:38:07
(Simultaneously speaking) 10:38:07
MR. HERMAN: You're not permitted to object 10:38:09
to the witness's testimony. If you don't want the 10:38:11
testimony, don't ask the questions, but his testimony 10:38:13
stands and there's no reason to object and strike from 10:38:15

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the record. 10:38:18
MR. PHILBIN: I will continue to object to 10:38:18
his nonresponsive answers and I will not let him 10:38:19
interject whatever he wants to say if it's not 10:38:22
responsive to my questions. And I will continue to 10:38:25
object and each of my objections, you can assume carry 10:38:27
with it a motion to strike. 10:38:30
(Simultaneously speaking) 10:38:34
MR. HERMAN: I object to that procedure. 10:38:35
You're only permitted to file a motion to strike after 10:38:36
you get the board's permission. There's no standing 10:38:40
right to file a motion to strike. As far as I 10:38:42
understand, there has been no permission granted in this 10:38:45
case. 10:38:48
MR. PHILBIN: Thank you. Your objection is 10:38:48
noted. Are you finished? 10:38:49
Q. (BY MR. PHILBIN) Sir, do you have an 10:38:53
understanding of what stroke ratio means in the context 10:38:54
of the Klugl reference? 10:38:58
MR. HERMAN: Objection, form. 10:38:59
A. I surely have not taken the time to create a 10:39:01
formal definition of that, but I think that we have a 10:39:06
good understanding of the -- the devices, the different 10:39:11
embodiments that Klugl teaches and how the area ratio 10:39:18
from one side of the hydraulic link to the other can be 10:39:24

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changed for different situations that you want to use inside of a fuel injector. 10:39:28 10:39:33

Q. (BY MR. PHILBIN) Let's try it this way, sir. 10:39:35

Can you identify for the board, every difference between the term, stroke translation and stroke transmission as those terms are used in the Klugl reference? 10:39:37 10:39:42 10:39:46 10:39:49

MR. HERMAN: Objection, form. 10:39:49

A. Can I -- please re- -- please repeat the question so I can make sure -- 10:39:51 10:39:59

Q. (BY MR. PHILBIN) Please identify every difference in the term, stroke translation and stroke transmission, in your opinion, in the context of the Klugl reference. 10:40:00 10:40:03 10:40:08 10:40:10

A. I -- 10:40:12

MR. HERMAN: Objection, form. 10:40:12

A. I surely don't think I can -- you know, these are words that show up a few times as we've just established, so I don't think that I can clearly see where exactly they're the same and where exactly they're different. 10:40:13 10:40:20 10:40:24 10:40:28 10:40:31

Q. (BY MR. PHILBIN) So is it your testimony that despite relying on the Klugl reference in every one of your opinions in this case, you don't know whether there's any difference between the term, stroke 10:40:37 10:40:40 10:40:43 10:40:46

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translation, stroke transmission, and stroke ratio as those terms are used in the Klugl reference? 10:40:49 10:40:52

MR. HERMAN: Objection, form. 10:40:54

A. Again, we can talk about what each word means in a specific light, but I think what that -- taking Klugl as a whole, what we see is that there are different ways of -- for example, treating that stroke ratio and whether or not that's one or non one, and the specific words as they got translated from German aren't necessarily, you know, the whole thing. We're taking the whole document, the embodiments that they teach, and using that to see what a POSITA would understand. 10:40:58 10:41:01 10:41:04 10:41:09 10:41:17 10:41:20 10:41:25 10:41:29 10:41:36

Q. (BY MR. PHILBIN) In your opinion, in the context of the Klugl reference, are the terms, stroke translation, stroke transmission, and stroke ratio interchangeable? 10:41:40 10:41:42 10:41:43 10:41:52

MR. HERMAN: Objection, form. 10:41:52

A. I can't tell you whether they're interchangeable without, you know, looking at the whole document and seeing if I start flip-flopping them in any order, if they mean the same thing or not, but I can tell you that it is clear what, for example, stroke ratio means in light of the teachings of Klugl. 10:41:52 10:41:55 10:41:58 10:42:02 10:42:07 10:42:13

Q. (BY MR. PHILBIN) In your declaration, did you use stroke translation and stroke ratio to mean the same 10:42:15 10:42:18

thing? 10:42:21

MR. HERMAN: Objection, form. 10:42:23

A. We use them -- I use them at least as parallels with each other. We're referring to the same thing there. 10:42:24 10:42:33 10:42:36

Q. (BY MR. PHILBIN) So when you -- if you look at paragraph 222 in your declaration, I believe you state, "Klugl contrasts with this embodiment shown in Figure 3 which does provide a change in stroke translation by applying a stroke ratio such that the movement of the piston exceeds that of the actuator." 10:42:39 10:42:42 10:42:45 10:42:49 10:42:54 10:42:56

Are you saying in that sentence, stroke translation and stroke transmission mean the same thing? 10:42:57 10:42:59

MR. HERMAN: Objection, form. 10:43:01

A. So, this is paragraph 222. Is that correct? 10:43:04

Q. (BY MR. PHILBIN) Yes, sir. Your words. 10:43:06

(Brief pause) 10:43:39

Q. (BY MR. PHILBIN) Can you see paragraph 222 up on the screen? 10:43:47 10:43:49

A. Yes, I can. 10:43:50

Q. Can you see in paragraph 222, you put stroke translation and stroke ratio in quotes? 10:43:51 10:43:55

A. I do. I'm looking at a Klugl document right now. 10:43:57

Q. So, yes or no, does stroke translation and stroke ratio mean the same thing to you or different things? 10:44:18 10:44:21

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A. So, I'm looking at the context at which I stated that, so, one second, please. 10:44:22 10:44:26

Q. Sure. Take your time. 10:44:28

(Brief pause) 10:45:13

A. So your question is whether they mean the same exact thing? 10:45:13 10:45:18

Q. (BY MR. PHILBIN) Yes, sir. Yes, sir. 10:45:20

A. So, again, I don't know if they mean the same exact thing, but they're referring to the same function and that's why we have said -- I have said that we're saying that stroke translation is the same as maybe applying a stroke ratio. So, you know, can you say those things are the same? I'm not sure, but it surely is talking about the same function whether or not the one side of the hydraulic link and the other side of the hydraulic link are traveling the same displacement. 10:45:22 10:45:28 10:45:33 10:45:38 10:45:42 10:45:47 10:45:50 10:45:55 10:45:58

Q. When you signed your declaration, specifically paragraph 222, did you intend stroke translation to be interchangeable with stroke ratio? 10:46:03 10:46:06 10:46:10

MR. HERMAN: Objection, form. 10:46:12

A. Again, whether it's interchangeable, I would have to see everywhere whether you could interchange those and it meant the same thing, but they are surely very related functions if nothing else. 10:46:14 10:46:20 10:46:23 10:46:28

Q. (BY MR. PHILBIN) Will you not answer my 10:46:32

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question? 10:46:35
MR. HERMAN: Objection, form. 10:46:35
A. I believe I did. 10:46:37
Q. (BY MR. PHILBIN) So we can change paragraph 222 to say, Klugl contrasts this with the embodiment shown in Figure 3, which does provide a change in stroke translation by applying a stroke translation? 10:46:39 10:46:42 10:46:46 10:46:48
MR. HERMAN: Objection, form. 10:46:51
Q. (BY MR. PHILBIN) Yes or no? Can we put stroke ratio to mean stroke translation in your paragraph 222 to mean the same thing? 10:46:55 10:47:00 10:47:03
MR. HERMAN: Objection, form. 10:47:05
A. So, whether the specific words could be interchanged, I would have to look at everywhere in the declaration since that's what you asked about and see whether we could switch them everywhere -- 10:47:05 10:47:09 10:47:11 10:47:13
Q. (BY MR. PHILBIN) No. I just asked about paragraph 222, sir. 10:47:15 10:47:17
A. Okay. So we're talking about just paragraph 222. 10:47:19
Q. Yes, sir. 10:47:22
(Simultaneously speaking) 10:47:23
A. -- nonsensical to replace one with the other, but that doesn't mean that they don't mean that they are obviously related phrases. 10:47:23 10:47:30 10:47:32
Q. (BY MR. PHILBIN) So can we agree that it's your 10:47:35

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opinion that they're related but different? 10:47:36
MR. HERMAN: Objection, form. 10:47:39
A. Again, I can't tell you whether, semantically, if you can replace one with another in a sentence, but they surely are related in the way that they function in the injector. How Klugl was using the term or in the translation, the term was used to refer to the specific function of the hydraulic link. 10:47:42 10:47:46 10:47:50 10:47:59 10:48:01 10:48:06
Q. (BY MR. PHILBIN) In your opinion, outside of the Klugl reference, do stroke translation and stroke ratio mean the same thing? 10:48:11 10:48:12 10:48:14
A. It would have to depend -- 10:48:15
MR. HERMAN: Objection, form. 10:48:18
A. -- depend on the context that we're talking about. 10:48:18 10:48:21
Q. (BY MR. PHILBIN) Okay. So, categorically, you you can't say that stroke translation and stroke ratio mean the same thing, correct? 10:48:21 10:48:22 10:48:25
MR. HERMAN: Objection, form. 10:48:27
A. I -- I think it depends on the context. We'd have to talk about specific context. 10:48:27 10:48:31
Q. (BY MR. PHILBIN) And you would agree that outside the context of Klugl, stroke translation and stroke transmission don't mean the same thing, correct? 10:48:36 10:48:37 10:48:41
MR. HERMAN: Objection, form. 10:48:44

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A. Again, I -- I would have to know the specific context that we're talking about. 10:48:45 10:48:49

Q. (BY MR. PHILBIN) What does amplification mean in the context of the Klugl reference? 10:48:54 10:48:57

MR. HERMAN: Objection, form. 10:48:59

A. I haven't studied that one specific word in terms of this -- in terms of that, so I can't offer a formal opinion on what that one word means. 10:49:04 10:49:08 10:49:12

Q. (BY MR. PHILBIN) Okay. What does amplification mean to you? 10:49:13 10:49:16

A. Again, I haven't taken the time to do a formal analysis on what amplification means. 10:49:16 10:49:22

Q. Would you agree that amplification means something larger? 10:49:28 10:49:31

MR. HERMAN: Objection, form. 10:49:31

A. Again, I think it depends on the complex -- on the context, but, you know, a amplifier that amplifies things can be turned to have a gain less than one or more than one. 10:49:37 10:49:41 10:49:50 10:49:54

Q. (BY MR. PHILBIN) I'm glad you mentioned music. If I amplify the volume of music, I'm increasing it, correct? 10:49:58 10:50:00 10:50:03

A. I didn't mention music. 10:50:04

Q. Okay. In the context of music, if I amplify the volume of music, I'm increasing the volume, correct? 10:50:07 10:50:10

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MR. HERMAN: Objection, form. 10:50:13

A. When you run a piece of music through an amplifier, the gain could be set greater than one or less than one. 10:50:14 10:50:17 10:50:22

MR. PHILBIN: It wasn't my question, sir. 10:50:27

Objection, nonresponsive. 10:50:28

Q. (BY MR. PHILBIN) Can you listen to and answer my question -- 10:50:28 10:50:30

MR. HERMAN: Objection, form. Also highly argumentive. 10:50:30 10:50:32

Q. (BY MR. PHILBIN) Can you answer my question, sir? 10:50:41 10:50:42

A. Could you repeat your question? 10:50:42

Q. If I tell you I'm amplifying the volume of music, I'm increasing the volume, correct? 10:50:45 10:50:50

MR. HERMAN: Objection, form. Also outside the scope of direct. 10:50:51 10:50:56

A. I would say it depends on how we're using it in that sentence. If that music is coming from a source as represented as a voltage and I'm sending it through an an amplifier, creating a voltage, that then is going to go to speakers that I'm listening to, I am -- the amplification is the gain between the voltage on one side of the amplifier and the voltage on the other side of the amplifier, and that could be less than one or it 10:50:58 10:51:04 10:51:10 10:51:14 10:51:18 10:51:23 10:51:26 10:51:30

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could be greater than one. 10:51:33
MR. PHILBIN: Objection, nonresponsive. 10:51:35
Q. (BY MR. PHILBIN) Do you have an opinion as to what stroke amplification means in the context of the Klugl reference? 10:51:36 10:51:38 10:51:43
MR. HERMAN: Objection, form. 10:51:44
MR. PHILBIN: What's your objection? 10:51:47
MR. HERMAN: To the form of your question. You used -- 10:51:48 10:51:50
MR. PHILBIN: Okay. 10:51:51
(Simultaneously speaking) 10:51:52
MR. HERMAN: -- so I objected to the form of your question. 10:51:52 10:51:54
MR. PHILBIN: Oh, so your objection is that stroke amplification is not in the Klugl reference? 10:51:55 10:51:59
MR. HERMAN: So, if you would like to point the witness to a particular portion of the reference, you're welcome to do so, but -- and I am also entitled to make objections to form, which I did. 10:52:02 10:52:03 10:52:05 10:52:07
MR. PHILBIN: And your objection is -- what's your form objection? That's my question. 10:52:10 10:52:11
MR. HERMAN: You are not being clear regarding which specific passage in the reference you're referring to. If you refer to this column and line, I will not make an objection to form. But if you don't 10:52:13 10:52:15 10:52:18 10:52:21

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use the word (distorted audio) make an objection to form. 10:52:21 10:52:25

MR. PHILBIN: Got it. 10:52:25

Q. (BY MR. PHILBIN) Do you have an opinion as to what stroke amplification means in the context of the Klugl reference? 10:52:27 10:52:28 10:52:31

MR. HERMAN: Objection, form. 10:52:31

A. I haven't studied that word in detail and been asked to offer an opinion on what that single word means, so I cannot do that at this time. 10:52:33 10:52:38 10:52:41

Q. (BY MR. PHILBIN) Okay. Do stroke amplification and stroke translation mean the same thing in the context of Klugl reference? 10:52:44 10:52:46 10:52:49

MR. HERMAN: Objection, form. 10:52:50

A. Again, I think we're talking about -- the function is clear, what we're talking about is the displacement on one side of the hydraulic link versus the displacement on the other side of the link. What the semantics are, what word is what, I have not analyzed in detail. 10:52:55 10:52:57 10:53:03 10:53:06 10:53:09 10:53:14

Q. (BY MR. PHILBIN) How are stroke amplification and stroke translation related in terms of the Klugl reference? 10:53:23 10:53:38 10:53:43

A. Can you repeat the question? 10:53:43

Q. How are stroke amplification and stroke 10:53:48

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translation related in terms of the Klugl reference? 10:53:52

A. Is stroke amplification in Klugl? 10:53:54

Q. Perhaps your lawyer didn't tell you this, but I get to ask the questions and you get to answer them. And I would assume you've read Klugl as you testified, as many times you've testified, and understood it thoroughly before you signed your declarations. 10:54:08 10:54:10 10:54:13 10:54:17 10:54:20

So my question is: Are stroke amplification and stroke -- I'm sorry -- stroke amplification and stroke translation the same, in your opinion, in the Klugl reference as you relied upon it in your opinions and declarations in this case? 10:54:22 10:54:25 10:54:28 10:54:32 10:54:35

MR. HERMAN: Objection, form. 10:54:37

A. So, I don't remember off the top of my head, amplification being -- stroke amplification being mentioned. And as I do a quick search, I don't think I see it. So you can -- you know, you can either point me to a specific place in the document -- beyond that, I can't really form an opinion whether those two things mean the same thing or not. 10:54:41 10:54:46 10:54:47 10:54:52 10:54:56 10:55:02 10:55:04

Q. (BY MR. PHILBIN) In your opinion, in Figure 1 of Klugl, is there a stroke amplification change? I'm sorry. In your opinion, in Figure 1, does stroke amplification occur? 10:55:10 10:55:11 10:55:17 10:55:21

A. In Figure 1, let's see. I'm going back to my 10:55:27

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declaration. 10:55:36

(Brief pause) 10:56:01

A. So, Figure 1, is Klugl -- so I'm looking at page 31 on my document, the figure associated with paragraph 121. And so there's a -- a colored version of Figure 1 to highlight the different pieces and, specifically, I'm looking at the right side of that where the hydraulic link has been made larger so that I can see it more clearly. 10:56:01 10:56:05 10:56:10 10:56:19 10:56:22 10:56:26 10:56:31

And what we can see is that between the mention of what Figure 1 is in the Klugl's and the way that this device would work is that one side of the hydraulic link and the other side of the hydraulic link would change -- their displacement would be essentially the same. 10:56:33 10:56:42 10:56:48 10:56:53 10:56:58

MR. PHILBIN: Objection, nonresponsive. 10:57:04

Q. (BY MR. PHILBIN) My question was about stroke amplification. Does stroke amplification occur in Figure 1 of Klugl? 10:57:05 10:57:08 10:57:10

A. So, again, I haven't done any definition of, you know, any deep dive in thinking about the specific term, stroke amplification, so I can't offer an opinion about that, but I do understand how the -- the injector -- the components shown in Figure 1 of Klugl function. 10:57:12 10:57:18 10:57:22 10:57:27 10:57:33

Q. Do you have an understanding of what the word amplification means in the context of Klugl? 10:57:38 10:57:40

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MR. HERMAN: Objection, form. 10:57:44

A. Seeing as how I don't see it in the document, I would not be able to form an opinion about it in that light. 10:57:46 10:57:50 10:57:52

Q. (BY MR. PHILBIN) Do you have an opinion as to what without amplification means in the context of Klugl? 10:57:54 10:57:57 10:57:59

MR. HERMAN: Objection, form. 10:58:00

A. Seeing as how I haven't had time to think about what amplification means in that light, I would say that I can't form an opinion on that. 10:58:00 10:58:05 10:58:10

Q. (BY MR. PHILBIN) Do you have an opinion as to whether without stroke translation means without amplification? 10:58:11 10:58:14 10:58:16

A. Again, I haven't done any formal definitions based on stroke amplification, so I would have to -- you know, have time to take a deep dive and form an opinion on that. 10:58:19 10:58:23 10:58:31 10:58:33

Q. Does without amplification mean exactly equal to? 10:58:39

MR. HERMAN: Objection, form. 10:58:43

A. So you're -- you said without amplification is -- say that again. 10:58:46 10:58:51

Q. (BY MR. PHILBIN) Does without amplification mean exactly equal to? 10:58:52 10:58:56

A. Again, I haven't formed an opinion exactly of 10:59:00

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what amplification means in terms of this, and so I don't think I would be able to offer an opinion on that. 10:59:07 10:59:11

MR. PHILBIN: We've been going about an hour. Why don't we take a five-minute break. 10:59:14 10:59:15

THE WITNESS: Okay. 10:59:22

THE VIDEOGRAPHER: All right. We are going offer the record at 10:59. 10:59:22 10:59:23

(Off the record at 10:59 a.m.) 10:59:26

(Back on the record at 11:10 a.m.) 11:10:14

THE VIDEOGRAPHER: We are back on the record at 11:10. 11:10:15 11:10:16

Q. (BY MR. PHILBIN) Dr. Quinlan, are you ready to proceed? 11:10:18 11:10:19

A. I am. 11:10:22

Q. Great. Would you look at Exhibit 1, your declaration, specifically page 53, 54 and 55, and more specific than that, starting at paragraph 225? 11:10:22 11:10:24 11:10:31

A. Okay. 11:10:37

Q. Are you with me? 11:10:38

A. Yes, I am. 11:10:40

Q. Perfect. Did you prepare paragraph 225, 226, 227? 11:10:41 11:10:47

A. I don't recall if I wrote every word of the text, but it surely -- the technical information included in there and the opinions are mine. 11:10:53 11:10:56 11:11:01

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Q. Did you do the math at the top of page 54 of Exhibit No. 1? 11:11:02 11:11:05

A. By doing the math, you're talking about the demonstration figure and the changes in the stroke length or -- what, exactly, math are we talking about here? 11:11:16 11:11:22 11:11:30 11:11:36

Q. Okay. Did you prepare the figures at the top of page 54 in Exhibit No. 1? 11:11:37 11:11:39

A. Again, I don't know if I specifically prepared the figure. It was prepared with my supervision, though. 11:11:42 11:11:47 11:11:50

Q. What are the figures at the top of page 54 of Exhibit No. 1 intended to show? 11:11:50 11:11:54

A. I was trying to show that if you -- if we take the kind of reddish or pink colored part that we -- as the hydraulic link and the purple and green as the members that are touching them, looking at how changing the area between those two pistons or those two members on each side of the hydraulic link can either keep it so that the translation of each of those members are the same distance or that you can change it to some non-unity value. 11:11:58 11:12:02 11:12:11 11:12:17 11:12:21 11:12:28 11:12:30 11:12:34 11:12:40

Q. Okay. Do you agree that you used math to calculate how far the pink section moved in the bottom right diagram on page 54 of Exhibit No. 1? 11:12:41 11:12:46 11:12:52

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MR. HERMAN: Objection, form. 11:12:57

A. I mean, we put numbers to it as a demonstration to it. I don't know if that's doing the math. 11:12:59 11:13:09

Q. (BY MR. PHILBIN) Wouldn't you calculate the area of the circle on the high side of the diagram and the area of the circle on the low side of the diagram to calculate the volume of pink material that moved from high to low on page 54 of Exhibit No. 1? 11:13:11 11:13:13 11:13:17 11:13:21 11:13:23

MR. HERMAN: Objection, form. 11:13:28

A. I don't think that either of those are circles. 11:13:29

Q. (BY MR. PHILBIN) You don't? 11:13:35

A. This is a -- 11:13:36

(Simultaneously speaking) 11:13:38

Q. (BY MR. PHILBIN) Is it intended to be a 2D or a 3D demonstration? 11:13:40 11:13:43

A. If it was a circle, right, wouldn't there be center lines -- yeah. This is, I believe, just a 2D demonstration of the idea of an area change. 11:13:48 11:13:54 11:14:02

Q. Can you calculate volume in a 2D diagram? 11:14:04

A. If we take it to the unit depth, surely, yes. 11:14:09

Q. Is there a square fuel injector? 11:14:15

A. Does it specifically have to be inside of a fuel injector? 11:14:19 11:14:25

Q. Is that what you intended it to be? 11:14:25

A. No. It's just a demonstration of how an area 11:14:28

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change could change the translation from one side of the hydraulic link to another. This -- 11:14:34 11:14:40

Q. Is the -- oh, I'm sorry. Go ahead. 11:14:41

A. This isn't a real device, clearly. 11:14:43

Q. Are the diagrams at the top of page 54 in Exhibit No. 1 intended to represent a cylindrical space? 11:14:46 11:14:52

A. No. 11:14:56

Q. So in paragraph 226 when you said, "and located in the cylindrical space," what were you referring to? 11:15:00 11:15:01

A. Again, here, the cylindrical space may be the volume inside the hydraulic link. It's not the specific cartoon volume in the figure above. 11:15:15 11:15:22 11:15:29

Q. So paragraph 226 starts with, "as shown in the top figures." And the top figures are the only figures located above paragraph 226 on page 54, correct? 11:15:35 11:15:38 11:15:42

A. So, again, these are meant to be demonstrative, not actual devices. 11:15:48 11:15:52

Q. You would agree the cylinder has a circular top, correct? 11:15:55 11:15:58

A. Again, this isn't meant to be a cylindrical demonstration. It's just showing how, for example, the -- you know, if the 2D width of this thing is two as shown in the bottom figures on the top and one on the bottom, then their ratio, you know, keeping this same amount of pink in the drawing would translate a further 11:16:00 11:16:13 11:16:15 11:16:20 11:16:23 11:16:31

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distance as we push the purple piece down from left to right. 11:16:38 11:16:44

Q. On page 54, would you identify the cylinder of larger diameter? 11:16:44 11:16:49

A. So, again, it's the -- these aren't cylinders in the drawings. They're 2D but in the hydraulic link, right, they may be cylindrical. So we're -- I'm demonstrating the difference from one side to the other. It's not that -- 11:16:52 11:17:00 11:17:05 11:17:10 11:17:14

Q. On -- go ahead. 11:17:14

A. Feel free. 11:17:22

Q. On page 54, would you identify the cylinder of smaller diameter? 11:17:22 11:17:25

A. Again, I haven't shown any where in the figure that these are cylindrical exactly, right? This is a two-dimensional demonstration. 11:17:27 11:17:33 11:17:40

Q. Could you show me where in paragraphs 225, 226 or 227 that you say this is a two-dimensional demonstration and not intended to be a cylinder? 11:17:41 11:17:45 11:17:49

A. If this was a cylinder, I would have drawn it with a center line and I would have put diameter marks on the twos and ones respectively on the top and the bottom. 11:17:51 11:17:57 11:18:01 11:18:05

Q. Did you write paragraph 227 that starts on page 54 of Exhibit No. 1? 11:18:05 11:18:08

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A. Again, I can't tell you whether I wrote that specific paragraph or whether it was with help with my legal team, but the technical details and the opinions offered within it are mine. 11:18:12 11:18:14 11:18:17 11:18:20

Q. So let's look at the first paragraph of paragraph -- I'm sorry. Strike that. Let's look at the first sentence of paragraph 227 on page 54 of Exhibit No. 1. Tell me if I read this incorrectly. 11:18:22 11:18:24 11:18:27 11:18:32

"But the actuator in the bottom set of figures expands, a hydraulic fluid is pushed from a cylinder of larger diameter into a cylinder of smaller diameter." Did I read that correctly? 11:18:36 11:18:39 11:18:45 11:18:50

A. You missed the word "when" but otherwise, I think so. 11:18:51 11:18:56

Q. Okay. Did you write that sentence? 11:18:56

A. Again, I can't tell you if I wrote that specific sentence but it was prepared under my direction if nothing else. 11:18:58 11:19:01 11:19:05

Q. Okay. What -- identify what the bottom set of figures are that you refer to in paragraph 227 in Exhibit No. 1. 11:19:08 11:19:11 11:19:15

A. So, the bottom two figures between paragraphs 225 and 226. 11:19:16 11:19:22

Q. And identify the cylinder of larger diameter in in the bottom set of figures that you just identified. 11:19:23 11:19:27

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A. So, again, while the actual hydraulic link is probably cylindrical and three dimensional, the demonstrative is two dimensional to show an easier representation of that. 11:19:30 11:19:40 11:19:44 11:19:50

Q. Can you identify the cylinder of smaller diameter in the bottom set of figures as referenced by you in paragraph 227 of Exhibit No. 1? 11:19:53 11:19:56 11:19:59

A. Again, the actual hydraulic link would be cylindrical, but the demonstrative figure, I have drawn in two dimensions to make it clear. 11:20:04 11:20:08 11:20:13

Q. What does flexible mean to you, sir? 11:20:14

A. I haven't come up with a formal definition for flexible, but it's how much something bends, perhaps. 11:20:17 11:20:23

Q. What's your understanding what flexible means in the context of the Klugl reference? 11:20:30 11:20:35

MR. HERMAN: Objection, form. 11:20:37

A. Again, I haven't been asked to offer a formal opinion of what flexible means in light of this, but if you want to talk about a specific -- excuse me -- part of the document, I'd be happy to. 11:20:40 11:20:45 11:20:51 11:20:57

Q. (BY MR. PHILBIN) What is a membrane? 11:21:00

A. Usually, it's a thin sheet of material but I haven't formed a formal opinion on it. 11:21:02 11:21:11

Q. What is a flexible membrane? 11:21:13

A. Again, I haven't offered a formal opinion what a 11:21:15

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flexible membrane is. 11:21:19

Q. What is a diaphragm in the context of fuel injectors? 11:21:21 11:21:25

MR. HERMAN: Objection, form. 11:21:27

A. Again, this -- I haven't come up with a formal definition of what a diaphragm is. 11:21:27 11:21:32

Q. (BY MR. PHILBIN) In the context of fuel injectors, what's the difference between a membrane and a diaphragm? 11:21:36 11:21:38 11:21:40

MR. HERMAN: Objection, form. 11:21:41

A. Again, I haven't offered a formal opinion on either one so I would have to do the careful analysis to see. 11:21:42 11:21:46 11:21:50

Q. (BY MR. PHILBIN) In October of 1999, what material were membranes made from in fuel injectors? 11:21:51 11:21:54

MR. HERMAN: Objection, form. 11:22:06

A. I -- I could imagine that you use -- could use many different materials for -- for that. 11:22:06 11:22:09

Q. (BY MR. PHILBIN) Can you name three? 11:22:12

A. I cannot. If you want to talk about specifics.... 11:22:14 11:22:22

Q. In October of 1999, what material were diaphragms made from in fuel injectors? 11:22:23 11:22:30

MR. HERMAN: Objection, form. Outside the scope of direct. 11:22:31 11:22:34

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A. Again, I don't have any specifics that I would know from that, but if you want to talk about specifics, I'd be happy to. 11:22:35 11:22:43 11:22:46

Q. (BY MR. PHILBIN) Would you agree that a material that is flexible can deform? 11:22:47 11:22:50

MR. HERMAN: Objection, form. 11:22:54

A. Again, I haven't offered formal opinions on what flexible means and whether it can deform or not. 11:22:56 11:23:01

Q. (BY MR. PHILBIN) Would you agree that a material that is flexible can deflect? 11:23:11 11:23:13

MR. HERMAN: Objection, form. 11:23:16

A. Again, I think we'd have to see it in context to see what we're talking about. 11:23:19 11:23:25

Q. (BY MR. PHILBIN) Are you aware of any commercial fuel injectors that use a flexible membrane? 11:23:27 11:23:29

A. Not that I'm aware of. 11:23:32

Q. In October of 1999, were you aware of any commercial fuel injectors that used a flexible membrane? 11:23:35 11:23:39

A. Not that I'm aware of. 11:23:43

Q. Have you ever seen or worked with a flexible membrane? 11:23:48 11:23:51

MR. HERMAN: Objection, form. 11:23:52

A. I -- again, maybe -- you know, semantics on what a membrane is, but I believe I have seen and worked with a membrane. 11:23:54 11:24:04 11:24:07

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Q. (BY MR. PHILBIN) Do you understand how the embodiments depicted in Klugl Figure 1 and Figure 3 work? 11:24:09 11:24:21 11:24:25

(Brief pause) 11:25:17

A. Grab my glasses real quick. 11:25:17

(Brief pause) 11:25:46

A. I believe so. 11:25:52

Q. (BY MR. PHILBIN) Have you formed an opinion -- strike that. 11:25:54 11:25:58

Do you understand how the embodiment shown in Figure 2 of Klugl works? 11:25:58 11:26:01

A. I believe so. 11:26:02

Q. So, just to summarize, you have analyzed and formed an opinion as to how the embodiments shown in Figure 1, 2, and 3 operate in Klugl, correct? 11:26:56 11:27:01 11:27:06

MR. HERMAN: Objection, form. 11:27:10

A. Whether I formed a formal opinion about it, I'm not sure about that, but I believe that I understand how those injectors work. 11:27:12 11:27:16 11:27:18

Q. (BY MR. PHILBIN) Okay. Let's take item number one in Figure 1, 2, and 3. Do you see that? Item number one, I believe, is the actuator. Are you with me? 11:27:24 11:27:27 11:27:40 11:27:44

A. Yes. 11:27:45

Q. Is the actuator, item number one, the same in 11:27:45

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Figures 1, 2, and 3? 11:27:50

MR. HERMAN: Objection, form. 11:27:52

A. I think that from what I recall, that -- that -- I would have to go back and look at the translation of it rather than this German copy. 11:28:01 11:28:15 11:28:20

Q. (BY MR. PHILBIN) Do you not have the translation there in front of you? 11:28:30 11:28:33

A. I do. In the description of Figure 1 and Figure 3 from the translation, it seems like it specifically calls out a piezo actuator, but I don't see a specific actuator referenced to Figure 2 in the Klugl translation. 11:28:35 11:29:36 11:29:39 11:29:46 11:29:50

Q. Okay. So in your opinion, is the actuator item number one the same in Figure 1 and Figure 3? 11:29:53 11:29:56

MR. HERMAN: Objection, form. 11:30:02

A. Whether it's the same actuator, I can't tell you, but they both list it as a piezo actuator -- piezoelectric actuator. 11:30:02 11:30:05 11:30:11

Q. (BY MR. PHILBIN) Okay. Did you do any analysis of the claims in Klugl? 11:30:15 11:30:16

A. I reviewed them. I don't know if I did a deep analysis of it. 11:30:24 11:30:30

Q. Did you analyze, for instance, claim one to determine which of the figures or embodiments depicted in the figures that claim one covers? 11:30:30 11:30:39 11:30:44

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MR. HERMAN: Objection, form. Outside the scope of direct. 11:30:48 11:30:49

A. I did not. I took the document as a whole as, you know, the teachings of Klugl. 11:30:49 11:30:53

Q. (BY MR. PHILBIN) So I'm clear, you don't have an opinion as to which embodiment any of the individual claims in Klugl refer to, correct? 11:30:59 11:31:01 11:31:03

A. I have not done a thorough analysis of which claims refer to which figures. 11:31:05 11:31:11

Q. Did you analyze whether or not the item numbers listed in the figures are described in the specification of the Klugl patent? 11:31:14 11:31:17 11:31:21

A. Repeat that again, please. 11:31:25

Q. Did you do an analysis of whether the item numbers shown in the figures of Klugl are described in the specification of Klugl? 11:31:26 11:31:31 11:31:36

A. I cannot go point by point checking every leader on every figure and that they correspond to the specification. 11:31:38 11:31:43 11:31:47

Q. So if I just look at Figures 1 and 3 of Klugl, we've covered item number one, and you can't tell me if those are the same, correct? 11:31:49 11:31:55 11:31:57

MR. HERMAN: Objection, form. 11:31:59

A. Again, I don't know if they are the same actuator. They're both labeled as a piezoelectric 11:32:05 11:32:07

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actuator. 11:32:16
Q. (BY MR. PHILBIN) Does Klugl describe them as 11:32:16
being different? 11:32:17
(Brief pause) 11:33:17
A. Looking at it quickly, I don't see any place 11:33:50
where -- that Klugl says that they are different 11:33:54
actuators. 11:34:00
Q. (BY MR. PHILBIN) So you took a couple minutes 11:34:03
and you looked at a couple of documents there on your 11:34:04
desk. What documents did you look at? 11:34:06
A. I was glancing through the Klugl translation 11:34:09
here, and so I -- you know, at glance, I actually don't 11:34:13
see that. If you want me to sit down and read the 11:34:20
entire document and specifically look for that, I think 11:34:23
that would take an awful lot of time to do that right 11:34:27
now. 11:34:31
Q. As you sit here today, you don't have an opinion 11:34:32
whether item number one, the actuator, is the same 11:34:35
between Figure 1 and Figure 3 of Klugl. Is that 11:34:38
correct? 11:34:43
MR. HERMAN: Objection, form. 11:34:43
A. Again, I don't know if they're the same exact 11:34:44
actuator. Klugl does specify that they're both 11:34:48
piezoelectric actuators. 11:34:52
Q. (BY MR. PHILBIN) How much force would a 11:34:54

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piezoelectric actuator generate in 1999? 11:34:56
A. I wouldn't know a number. 11:35:00
Q. Would you look at Figure 3 of Klugl for me, please, sir? Do you see that? 11:35:06
A. Yes, I do. 11:35:09
Q. Do you understand how Figure 3 works? 11:35:19
A. I believe so. 11:35:19
Q. Do you understand how the actuator depicted in Figure 1 of Klugl works? 11:35:22
A. How the specific actuator -- I mean, I know it's an actuator. I don't know how that specific actuator works. 11:35:36
Q. Well, let me ask it a different way. 11:35:39
Do you understand how the fuel injector depicted in Figure 1 of Klugl works? 11:35:40
A. I believe so. 11:35:46
Q. Okay. Let's look at Figure 3. Would you agree that during actuation, item number one generates a force? 11:35:48
A. So, again, I don't know about the specifics of the actuator, but presumably, when we energize this actuator, it -- the intent appears to be that it longitudinally grows in length, and with that, provides a force if that's opposed by something. 11:35:48
Q. What's the function of item 29 in Figure 3 of 11:35:51
11:35:54
11:35:56
11:35:58
11:36:09
11:36:15
11:36:15
11:36:27
11:36:35
11:36:39
11:36:43
11:37:03

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Klugl? 11:37:09

(Brief pause) 11:38:25

A. So, they're calling east 29 a dye. It appears to be a disc of -- of material that transmits kind of the in-the-load path from the actuator to the upper member -- upper membrane. I believe that's 28. 11:39:35 11:39:41 11:39:50 11:39:59

Q. (BY MR. PHILBIN) Do you understand Figure 3 to depict a fuel injector that opens the valve at the bottom of Figure 3? 11:40:07 11:40:09 11:40:13

A. So, by opening the valve at Figure 3, we're talking about the -- the ball, number four, against the housing, 12, there? That appears what this injector is meant to do or what this device is meant to do -- 11:40:14 11:40:25 11:40:33 11:40:40

Q. Okay. Do you understand that -- go ahead. Finish. 11:40:44 11:40:45

A. Just to open and close that -- that seeding between those two. Yeah. 11:40:45 11:40:49

Q. Okay. And you understand the difference between pieces that move and pieces that are stationary? 11:40:51 11:40:53

A. Yeah. I think I know which ones are moving and which ones are stationary in this case. 11:41:02 11:41:06

Q. Okay. And in Figure 3, would you identify all the moving pieces that move during actuation? 11:41:09 11:41:11

MR. HERMAN: Objection, form. Outside the scope of direct. 11:41:16 11:41:18

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A. So you want me to go through and list every single leader number that is a moving piece versus not? 11:41:20 11:41:24

Q. (BY MR. PHILBIN) Yes, sir. 11:41:30

A. Okay. Well, parts of 1 move. 29, 38, 8. The orifice of 10. The -- 7 will be moving. It's easy to -- it's hard to see exactly whichever one is going through this quickly as membrane 38 or 6, whichever one is a membrane. 17, 3, 15, 4, 32, parts of 33. 11:41:37 11:41:52 11:42:07 11:42:11 11:42:16

It'd be easy to have missed a number, but that central stack there is all -- it's all moving. 11:42:28 11:42:34

Q. Okay. For Figure 1, would you identify the moving pieces, please? 11:42:39 11:42:41

MR. HERMAN: Objection, form. 11:42:45

A. So, again, 1, 8 -- let's see -- 7; the orifice in 10; 5 is pointing to that disc. Membrane 6, 17, 3, 32, 4, 33, parts of 15 -- let's see -- 11 and 14. 11:42:48 11:43:00 11:43:17

Q. (BY MR. PHILBIN) Anything else? 11:43:31

A. It'd be easy to have missed one little thing or -- little thing there. 18, the O ring, grooves. 11:43:33 11:43:40

Q. What about item two in Figure 1? Does it move? 11:43:50

MR. HERMAN: Objection, form. 11:43:56

A. Figure -- Figure 1, item two? 11:43:59

Q. (BY MR. PHILBIN) Yes, sir. 11:44:04

A. Yes. That moves. 11:44:05

Q. All right. In Figure 3, is item four, the 11:44:06

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closing element, attached to item 32? 11:44:16

A. In this embodiment, it's hard to tell, but I would anticipate that in this embodiment, it's not. 11:44:21 11:44:30

Q. What is the function of item 33, the valve spring in Figure 3 of the Klugl reference? 11:44:35 11:44:39

A. It provides -- in which figure? Just make sure we're talking about -- 11:44:42 11:44:49

Q. Figure 3. 11:44:49

A. Figure 3. Spring 33 provides an upward force onto component four. 11:44:50 11:44:56

Q. Would it be fair to say component is depicted as a loose ball that valve spring 33 holds in place? 11:44:59 11:45:02

MR. HERMAN: Objection, form. 11:45:08

Q. (BY MR. PHILBIN) In Figure 3 of Klugl. 11:45:14

A. So, referring to the specifications, they call it a closing element. In this specific embodiment, is that what it appears, maybe, to be a ball? Sure. 11:45:26 11:45:30 11:45:38

Q. Is the only thing in Figure 3 of Klugl that prevents item four, the closing element, from rolling away valve spring 33? 11:45:43 11:45:50 11:45:53

MR. HERMAN: Objection, form. 11:45:56

A. This is not a complete drawing of a real device, so I purely cannot tell you whether, you know, when I don't remove portions of 12, the housing, whether that ball can go anywhere or not. 11:46:02 11:46:10 11:46:14 11:46:20

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Q. (BY MR. PHILBIN) Do you have an opinion if we took valve spring 33 away, what would happen to item four in Figure 3 of Klugl? 11:46:24 11:46:25 11:46:28

MR. HERMAN: Objection, form. 11:46:30

A. Again, without knowing what the housing is and what the pressures and flows are on the other side, no. No, I can't. 11:46:32 11:46:35 11:46:40

Q. (BY MR. PHILBIN) Turning to Figure 1 of Klugl, is item four attached in any way to item 32? 11:46:41 11:46:47

MR. HERMAN: Objection, form. 11:46:53

A. Specifically, I mean, I -- I can't tell you if they're attached. It doesn't give details on that, so I don't have an opinion. 11:46:56 11:47:00 11:47:06

Q. (BY MR. PHILBIN) What is item 24 in Figure 3 of Klugl? 11:47:21 11:47:24

A. I'm going to the electronic version of the translation. So, I don't know see number 24 specifically listed on there. If you'd like to point me to -- to it, I'd be happy to discuss it. 11:48:33 11:48:35 11:49:02 11:49:07

Q. I didn't find it either. Do you have an opinion as to what's depicted in item 24 on Figure 3 of the Klugl reference? 11:49:09 11:49:11 11:49:15

A. So, I can't tell you the specific of what that device or what that piece is. Presumably, the authors didn't think it was very important if they didn't 11:49:16 11:49:38 11:49:47

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mention it, strangely, right? 11:49:48

Q. Do you have an opinion as to what material the item depicted as number 24 in Figure 3 of Klugl would be made out of? 11:49:51 11:49:54 11:49:58

MR. HERMAN: Objection, form. 11:49:59

A. So, again, I don't think that it seems like Klugl put much weight into it if they didn't mention it. And whether it's material or void is not particularly clear, right? It could easily be a void since it's not cross-hatched. 11:50:20 11:50:32 11:50:36 11:50:44 11:50:50

Q. (BY MR. PHILBIN) What's your understanding of item 24, the place where item 24 points in Figure 3 of Klugl? Is that a void? 11:50:53 11:50:53 11:51:01

A. Again, I couldn't tell you whether that's a void or a component. We would have to, you know, does it -- it surely, you know, depends. 11:51:02 11:51:07 11:51:21

(Brief pause) 11:52:49

A. So, again, the way it's probably drawn without the cross-hatching, I think one would assume that it's a void. 11:52:49 11:52:52 11:52:56

Q. (BY MR. PHILBIN) Did you assume that? 11:53:02

A. I'm going to the electronic version of the translation again. The search is not working to find what I was looking for here. 11:54:14 11:54:17 11:54:38

(Brief pause) 11:54:47

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A. So, looking through the specifications quickly here, I don't see, necessarily, you know, the mention of what that device does and what it could do. Surely, in this embodiment, it appears to be a void, but also, this isn't a scale drawing, so, I mean, that could just be a chamfer on the -- on the housing -- the screwed in housing, their 16, so it's pretty hard to tell what exactly it is. 11:57:26 11:57:28 11:57:35 11:57:40 11:57:47 11:57:52 11:57:54 11:58:00

THE COURT REPORTER: And I'm sorry to interrupt. This is the court reporter. I didn't catch the word before "on the housing."

THE WITNESS: 16.

THE COURT REPORTER: You said that it could just be a jamfer (sic) on the housing?

THE WITNESS: Chamfer. Yeah.

THE COURT REPORTER: Thank you. 11:58:27

Q. (BY MR. PHILBIN) That's the analysis you used of Figure 3 of Klugl in forming your opinions in this case, correct? 11:58:27 11:58:30 11:58:34

MR. HERMAN: Objection, form. 11:58:35

A. So, you know, I think I took it to be likely a void rather than a component, but, for example, the outer diameter of that, so as that component meets with the diaphragm number 6, you know, as drawn, it doesn't look like it would really support the diaphragm 11:58:35 11:58:41 11:58:47 11:58:54 11:59:00

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particularly well, and so, you know, this isn't likely scaled particularly well, in my understanding that these aren't scaled drawings. They're demonstrative. And so I -- you know, I took it as, you know, likely a void, but I can't tell just from this one embodiment. 11:59:03 11:59:06 11:59:11 11:59:16 11:59:20

Q. (BY MR. PHILBIN) Do you have an opinion as to what material would be contained in the void in Figure 3 of Klugl reference? 11:59:26 11:59:29 11:59:32

A. No. I mean, it doesn't teach us that, whether it's a material or a void and so, you know, I don't have a formal opinion on what -- what is there. 11:59:34 11:59:40 11:59:47

Q. Would you look at column eight, specifically line 46 of the Klugl reference, please, sir? And specifically, I'm directing you to the word, first flexible membrane (6). 11:59:51 11:59:56 12:00:12 12:00:15

A. Okay. I see that. 12:00:18

Q. You just mentioned diaphragm 6 in reference to Figure 3 of Klugl. Is that the same thing as a first flexible membrane 6? 12:00:20 12:00:24 12:00:28

A. No. I was probably just using that in a loose sense. 12:00:34 12:00:40

Q. Would you agree that the item depicted as number 6 in Figure 3 of Klugl is a first flexible membrane? 12:00:40 12:00:45

MR. HERMAN: Objection, form. 12:00:47

A. So, there are places where it's -- you know, I 12:00:53

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can see first membrane 6, glancing at it. I think there's places where it's referred to first membrane 6, (unintelligible) 6. Again, what we call it and what a person of ordinary skill in the art maybe understands it to be, is probably semantics. 12:00:55 12:01:04 12:01:09 12:01:10 12:01:12

Q. (BY MR. PHILBIN) In -- strike that. 12:01:16

In Figure 3 of the Klugl reference, is the item identified as number 6 flexible? 12:01:22 12:01:26

A. So, in -- so, for example, in column seven of the translation, line 26 -- or 27, the deflection is transmitted directly via the first and third membranes. 26 in the transmission medium, it talks about deflection there, but is that -- is that really deflection or is that translation? 12:01:33 12:02:08 12:02:21 12:02:29 12:02:36 12:02:41

You know, it's hard to tell just from that one phrase, which, you know, whether it's saying it's flexible or whether it's just the whole thing moving up and down. But it's probably -- yeah. It's the -- it has to deflect in this case, right? That's what it's saying. 12:02:42 12:02:44 12:02:47 12:02:51 12:03:01 12:03:07

Q. In your opinion, is item number 6 in Figure 3 of the Klugl reference flexible? 12:03:12 12:03:14

A. Yes. In this case, I believe that 6 relies on some bending to perform and function. 12:03:30 12:03:38

Q. In Figure No. 1, is the item identified as number 12:03:43

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6 flexible, in your opinion? 12:03:48

MR. HERMAN: Objection, form. 12:03:51

A. So, I think in Figure 1, you know, whether or not that substantially changes, you know, essentially bends in some way, is more of a typical design engineer process that you would go through in selecting, say, the material that you use in 6, the thickness of that member, and how that functions in this case. 12:04:00 12:04:07 12:04:14 12:04:22 12:04:26 12:04:30

Q. (BY MR. PHILBIN) My question, sir, is: In Figure 1 of Klugl, is item number 6 flexible, in your opinion? 12:04:33 12:04:37 12:04:41

MR. HERMAN: Objection, form. 12:04:41

A. So, the idea is that it's during its operation that it's transmitting the -- you know, the distance that the actuator moves on the bottom end of the actuator and that the distance that the -- the component number three travel are the same. 12:04:45 12:04:53 12:04:59 12:05:03 12:05:10

Q. (BY MR. PHILBIN) Will you answer my question, sir? 12:05:16 12:05:18

A. Please restate your -- your question. 12:05:19

Q. In Figure No. 1 of Klugl, is item number 6 flexible, in your opinion? 12:05:22 12:05:27

MR. HERMAN: Objection, form. 12:05:29

A. Again, the intent of it is that during actuation, that it transmits the distance that the actuator -- the 12:05:33 12:05:36

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bottom of the actuator travels is the same as the distance that component number three travels axially. 12:05:40 12:05:44

Q. (BY MR. PHILBIN) Can you answer my question, sir? 12:05:49 12:05:51

A. I think I am. 12:05:51

Q. So is it flexible or not? 12:05:52

MR. HERMAN: Objection, form. 12:05:56

A. You know, during actuation, the point is, is that those two displacements are the same, right? That's what Klugl teaches. 12:05:57 12:06:03 12:06:06

Q. (BY MR. PHILBIN) Sir, that's not my question. 12:06:08

A. Okay. 12:06:13

Q. My question is: In Figure No. 1 of the Klugl reference, is item number 6 flexible or not? 12:06:13 12:06:16

MR. HERMAN: Objection, form. 12:06:22

A. And I believe I already answered that the details of what 6 is made out of, how thick it is, how it behaves with reference to its loads are normal design engineering choices that would be made during, you know, the changing of this embodiment into a real injector. 12:06:22 12:06:26 12:06:33 12:06:38 12:06:43

Q. (BY MR. PHILBIN) Was that a yes or a no? 12:06:48

A. So, I'm saying that the engineer would go through a process where they pick, say, the thickness so that the -- that the behavior of that piece is what they would like. 12:06:51 12:06:54 12:06:58 12:07:01

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Q. You would agree with me that multiple times in the Klugl reference, item number 6 is defined as a flexible membrane or flexible element, correct? 12:07:06 12:07:12 12:07:15

MR. HERMAN: Objection, form. 12:07:18

Q. (BY MR. PHILBIN) Specifically, if you look at column seven, line 69, column eight, line 46, column seven, line 45 -- 12:07:27 12:07:29 12:07:33

A. Let's take the first one of those. Which line would you like me to look at? 12:07:38 12:07:41

Q. Sir, it's throughout column seven, eight, and nine -- 12:07:43 12:07:47

A. Okay. Well, you just gave me a specific reference. Can you give me the first one, please? 12:07:47 12:07:49

Q. Yeah. Sure. Column eight, line 46. First flexible membrane 6. Do you see that? 12:07:49 12:07:57

A. Okay. I see where -- 12:07:58

Q. So my question -- my question, sir: In your opinion, is item 6 in Figure 1 of Klugl flexible or not? 12:08:00 12:08:01

MR. HERMAN: Objection, form. 12:08:08

A. The device that Klugl teaches in Figure 1 is intended to have the same stroke, length from the bottom of the actuator as the same distance that component number three would change -- would move axially. Does that mean that it's flexible or not? And when it's not operating, whether that's considered flexible or not? 12:08:15 12:08:24 12:08:27 12:08:32 12:08:34 12:08:39

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Then we have to talk about a specific time and when we're looking at this thing, it's -- 12:08:41 12:08:47

Q. (BY MR. PHILBIN) So -- so it's your opinion that Figure 3 of Klugl discloses a flexible item number 6 and you can't determine whether item number 6 in Figure 1 is flexible or not. Is that correct? 12:08:52 12:08:55 12:08:59 12:09:04

MR. HERMAN: Objection, form. 12:09:05

A. So, figure -- in Figure No. 1, the flexibility of 6 would be dependent on how the design was used, right? I mean, there -- there's two different functions here. One is during actuation and one is in the hydraulic link's ability to make up for things like wear and thermal expansion. 12:09:07 12:09:15 12:09:21 12:09:26 12:09:32 12:09:39

Q. (BY MR. PHILBIN) Is that your complete opinion on flexibility of item number 6 in Figures 1 and 3? 12:09:41 12:09:42

MR. HERMAN: Objection, form. 12:09:46

A. I -- I haven't formed a complete opinion on how 6 specifically is flexible or is not flexible. 12:09:46 12:09:52

Q. (BY MR. PHILBIN) Okay. I'd like to mark as Exhibit No. 6, a color diagram that is an excerpt of Figure 3 of the Klugl reference. 12:09:56 12:09:57 12:10:04

MR. PHILBIN: Ms. Becraft, can you put that on the screen, please? 12:10:07 12:10:09

(Exhibit No. 6 marked) 12:10:09

Q. (BY MR. PHILBIN) Can you see Exhibit 6, sir? 12:10:13

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And I'll represent to you that the top number on Exhibit 6 is 38 there and the number to the side of number 10 is cut off, just as it appears on the screen now, and the bottom number visible on Exhibit 6 is 42 just as it is on the screen now. So I think you can see the entirety of Exhibit 6 on the screen right now. 12:10:25 12:10:27 12:10:29 12:10:33 12:10:38 12:10:40

A. Okay. Can I see the whole page just for one second? Just scroll top to bottom. Okay. So it's not marked as an exhibit or anything yet. Is that correct? 12:10:42 12:10:44 12:10:55

Q. It's Exhibit No. 6. 12:10:56

A. Okay. 12:10:58

Q. Do all the the green pieces in Exhibit No. 6 move? 12:11:05 12:11:07

MR. HERMAN: Objection, form. 12:11:08

A. So, I'm making sure that I got that this is a colored portion of Figure 3 from Klugl. 12:11:15 12:11:19

Q. (BY MR. PHILBIN) You are correct. 12:11:24

A. Okay. 12:11:25

Q. You recall, you presented color versions of figures out of Klugl in your declaration -- 12:11:32 12:11:34

A. I have no exception to adding color to the figures. All right. What is your question? 12:11:36 12:11:39

Q. Do you agree that items depicted in green on Exhibit No. 6 move? 12:11:58 12:12:00

MR. HERMAN: Objection, form. 12:12:05

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A. During actuation of the injector, it appears all of the -- all of the components labeled in green would move. 12:12:08 12:12:11 12:12:16

Q. (BY MR. PHILBIN) In Exhibit 6, the transmission medium is shaded blue in the correct areas. Do you agree? 12:12:17 12:12:21 12:12:25

MR. HERMAN: Objection, form. 12:12:26

A. So, the specifications refers to figure -- or to item number 25 as the -- the -- essentially, the lines, okay? So not the transmission medium itself, it seems like. 12:13:15 12:13:22 12:13:35 12:13:41

Q. (BY MR. PHILBIN) So you're saying the pipes that contain the transmission medium are what are around what I've shaded in blue in Exhibit 6? Is that correct? 12:13:44 12:13:46 12:13:51

A. Yeah. And I'm just trying to make sure I understand the lines in the middle of 25 and the coloring on both sides of them. 12:13:54 12:13:55 12:14:01

Q. But you've got the Klugl reference that's not colored if you need to look at it. 12:14:02 12:14:04

A. Yep. And that's what I just did. 12:14:05

Q. Okay. So if we take item 25 to mean the pipes, that the transmission medium is contained in, using your definition, does item 25 move during actuation of the fuel injector depicted in Figure 3 in Exhibit 6 of Klugl? 12:14:08 12:14:15 12:14:18 12:14:24 12:14:27

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A. The component in which the lines are presumably drilled through in this specific embodiment do not move. 12:14:28 12:14:41

Q. Would you agree that the yellow section depicted in Exhibit 6 does not move? 12:14:51 12:14:53

MR. HERMAN: Objection, form. 12:14:58

A. Clearly, the outer piece of -- of the component labeled and shown in yellow, component number -- component number two in this -- or embodiment number -- shown in Figure 3 does not move during actuation. 12:14:59 12:15:05 12:15:12 12:15:17

Q. (BY MR. PHILBIN) Identify all parts shown in yellow on Exhibit 6 you believe move during actuation. 12:15:21 12:15:23

A. So, the upper membrane, I believe that's 26; third membrane, parts of it must move. 12:15:40 12:15:55

Q. Anything else? 12:16:07

A. And the intent is that the middle membrane does not move during actuation substantially, and so that's the only one in yellow I see. 12:16:08 12:16:13 12:16:19

Q. Would you agree that flexible membrane is depicted in purple in Exhibit 6? 12:16:24 12:16:26

MR. HERMAN: Objection, form. 12:16:30

A. The -- what's labeled as the first flexible membrane number 6 does move, yes. 12:16:32 12:16:38

Q. (BY MR. PHILBIN) Do you agree that's what's shaded in purple? 12:16:45 12:16:46

A. Yes. At least some of it does move, right? 12:16:47

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Q. Do you agree the yellow shading is the transmission module? 12:16:57 12:17:00

MR. HERMAN: Objection, form. 12:17:04

Q. (BY MR. PHILBIN) In Exhibit 6. 12:17:05

A. So, I don't think I formed a formal opinion of what I would call the exact transmission link for -- for Figure 3, which is what this is drawn from. 12:17:16 12:17:19 12:17:27

Q. You used the word "transmission link" and I used the word "transmission module" so let me try this again. 12:17:31 12:17:34

A. Sorry. 12:17:37

Q. Is the transmission module in Exhibit 6 shaded in yellow? 12:17:38 12:17:41

A. Again, I don't think I formed a formal opinion on what the transmission module is in Figure 3 of Klugl, which this exhibit is drawn from. 12:17:41 12:17:44 12:17:49

Q. Have you formed an opinion as to what constitutes the transmission module in Figure 1 of Klugl? 12:17:51 12:17:56

(Brief pause) 12:18:41

A. So, turning to the figure contained in my declaration for the 829 Patent, paragraph 211 -- finding that -- just about there. We have -- I have colored the piezoelectric actuator 1 in dark purple and the -- what I'm considering the transmission module from Klugl as the light purple there in the center. 12:19:43 12:19:48 12:20:13 12:20:21 12:20:23 12:20:28

Q. (BY MR. PHILBIN) So you have an opinion as to 12:20:32

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what the transmission module is for Figure 1 but not for Figure 3, correct, sir? 12:20:34 12:20:37

A. That is correct. 12:20:39

Q. Looking back at Exhibit No. 6, do you agree that the red shading indicates a screw? 12:20:40 12:20:46

MR. HERMAN: Objection, form. 12:20:53

A. The component labeled -- colored in red appears to be screwed into the housing. 12:20:53 12:20:58

Q. (BY MR. PHILBIN) Do you agree that that red shaded screw in Exhibit 6 holds the transmission module 2 in place even when it's actuated? 12:21:01 12:21:03 12:21:09

MR. HERMAN: Objection, form. 12:21:13

A. It keeps component number 2 from traveling down. 12:21:16

Q. (BY MR. PHILBIN) Is there anything that keeps component number 2 in Exhibit 6 from traveling up? 12:21:27 12:21:28

A. Well, you know, component number 13 not shown in Exhibit 6. 12:21:36 12:21:42

(Brief pause) 12:21:42

A. Yes. 12:22:33

Q. (BY MR. PHILBIN) Okay. Let's look at Exhibit No. 6. You agree that the actuator is the green component shown at the top of Exhibit 6, correct? 12:22:33 12:22:35 12:22:37

MR. HERMAN: Objection, form. 12:22:41

A. It's the component labeled number one on the figure from which this is drawn that is colored green 12:22:44 12:22:48

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among other parts that are colored green. 12:22:54

Q. (BY MR. PHILBIN) And you agree that the part of at the bottom of Exhibit 6 colored green is item 3 which is defined as the drive piston? 12:22:57 12:23:00 12:23:04

A. I believe that's correct. 12:23:11

Q. And you agree that the drive piston moves downward during actuation, correct? 12:23:14 12:23:19

A. When we energize actuator number 1 and it gets longer, it seems like component number 3 is traveling -- is pushed in the downward direction. 12:23:25 12:23:30 12:23:35

Q. Okay. So as shown in Exhibit No. 6 -- and I'm going to go through what moves and what doesn't, and you tell me what I got wrong. 12:23:37 12:23:40 12:23:44

The green pieces at the top of Exhibit No. 6 move in a downward direction during actuation. The yellow piece in Exhibit No. 6 does not move downward during actuation and the green piece at the bottom of the Exhibit 6 does move downward during actuation. 12:23:45 12:23:49 12:23:53 12:23:58 12:24:01

Did I get that correct? 12:24:05

MR. HERMAN: Objection, form. 12:24:07

A. The upper membrane 26 must also move and the lower membrane number 6 must also move and there must be, you know, fluid that moves. 12:24:08 12:24:17 12:24:25

Q. (BY MR. PHILBIN) Does the entire lower membrane 6 move downward? 12:24:37 12:24:39

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MR. HERMAN: Objection, form. 12:24:40

A. Again, without seeing how this -- the detailed implementation of this is, it's hard to tell what, exactly, happens there. Again, the -- the region 24 that we discussed maybe is unclear on this figure and how it interacts with the lower flexible membrane 6. 12:24:43 12:24:51 12:24:54 12:25:00 12:25:05

Q. (BY MR. PHILBIN) Do you agree or disagree that the sides of flexible membrane 6 are restricted from moving downward by the part shown in red in Exhibit 6 which is an excerpt of Figure 3 of Klugl? 12:25:11 12:25:12 12:25:18 12:25:23

MR. HERMAN: Objection, form. 12:25:27

A. Again, without seeing the detailed design, whether that membrane is attached to two or whether it's held in place by the red component number 16, is not necessarily clear in this figure. 12:25:30 12:25:33 12:25:38 12:25:45

Q. (BY MR. PHILBIN) And you can't determine that by reading Klugl, correct? 12:25:47 12:25:49

A. I mean, I can't tell how that membrane is specifically restrained, no, but that would be a normal engineering design operation that the designer would go through and decide how that specifically was done. 12:25:51 12:25:55 12:26:00 12:26:03

Q. What causes the green piece at the bottom of Exhibit No. 6 which I think is item number 3, to move downward other than the flexing of membrane 6? 12:26:06 12:26:11 12:26:15

A. For Figure No. 3 which Exhibit 6 is pulled from, 12:26:22

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the flexibility of 6 is what pushes on piston number 3. 12:26:28

Q. And flexible membrane 6 has to be flexible enough to bend far enough to fully open the valve, correct? 12:26:39 12:26:41

MR. HERMAN: Objection, form. 12:26:45

A. So, depending on how we use this device and what it is in, I don't know how much we have to move piston 3 for it to be fully open, but that deflection in this case for Figure No. 3 will control how much component 4 will lift off of component 12. 12:26:50 12:26:55 12:27:01 12:27:10 12:27:18

Q. (BY MR. PHILBIN) You agree that Klugl defines item two as the transmission module, correct? It's column two, line 11. 12:27:27 12:27:29 12:27:49

A. Yep. I see that one. I agree that's what it says in column two there. 12:27:51 12:28:00

Q. So does the transmission model -- module, item number two, move in the embodiment shown in Figure 1 of Klugl? 12:28:02 12:28:04 12:28:09

A. In Figure No. 1, the transmission module number two in Figure No. 1 does move during actuation. 12:28:11 12:28:38

Q. So you would agree with me that what Klugl defines as the transmission module number two, the difference between Figure 1 and Figure 3 is transmission module two moves in Figure 1 and it does not in Figure 3. Is that correct? 12:28:45 12:28:47 12:28:51 12:28:54 12:29:00

MR. HERMAN: Objection, form. 12:29:01

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A. The transmission -- the displacement is -- could you please ask the question again? 12:29:03 12:29:18

Q. (BY MR. PHILBIN) Sure. Referring to item number two as Klugl defines it as the transmission module, that transmission module moves during actuation in the embodiment shown in Figure 1 and does not move in the embodiment shown in Figure 3. 12:29:20 12:29:22 12:29:27 12:29:30 12:29:33

A. Among other parts, whether they move or not between those two figures and those two specific embodiments, yes. Component two does move in one and not the other. I think that's it. 12:29:38 12:29:45 12:29:47 12:29:53

Q. Do you have an understanding as to the difference between mechanical force and hydraulic force? 12:29:58 12:30:01

A. I mean, I understand you can -- you can have forces that are different from different actuation standpoints or different -- arrive from different, you know, applications of -- you know, of force. 12:30:05 12:30:08 12:30:12 12:30:19

Q. Is there a hydraulic force depicted in Exhibit No. 6? 12:30:27 12:30:34

MR. HERMAN: Objection, form. 12:30:34

Q. (BY MR. PHILBIN) During actuation? 12:30:35

MR. HERMAN: Same objection. 12:30:37

A. I mean, whether -- you know, we haven't done that free body diagram of each component and shown all of the forces acting on it. We are relying on most mechanical 12:30:43 12:30:46 12:30:50

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and hydraulic forces in this specific embodiment. 12:30:56

Q. (BY MR. PHILBIN) Where are the mechanical forces in Exhibit No. 6 that cause the actuation? 12:31:02 12:31:04

MR. HERMAN: Objection, form. 12:31:11

A. So, I would say that the mechanical forces originate with the actuator number 1, component number 1, and that its displacement causes -- is resisted by the stack of components here and it -- you know, in turn, creates a force to try to displace the parts. 12:31:14 12:31:18 12:31:22 12:31:26 12:31:32

Q. (BY MR. PHILBIN) Do you agree that the two flexible membranes are moved by hydraulic force? 12:31:41 12:31:43

MR. HERMAN: Objection, form. 12:31:46

A. So, again, I would say -- I would have to, you know, imagine that component pulled out of that stack and draw a free body diagram of that and -- and label the mechanical and hydraulic forces that may be on it. 12:31:52 12:31:57 12:31:59 12:32:05

Q. (BY MR. PHILBIN) So you don't have an opinion as of today whether or not the membranes are moved by hydraulic force. Is that correct? 12:32:10 12:32:12 12:32:16

MR. HERMAN: Objection, form. 12:32:17

A. I think they're -- again, I would have to pull that out and look at the forces applied to it. There may be hydraulic forces, but there's also mechanical forces, so it's -- I wouldn't say it's moved just by hydraulic forces. 12:32:22 12:32:25 12:32:28 12:32:32 12:32:35

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MR. PHILBIN: I promised lunch at 12:30 and it's 12:30. Why don't we take a short lunch break? You want 30, 45 minutes? What works for you? 12:32:38 12:32:40 12:32:42

THE WITNESS: I guess 30 is fine for me, but I'm -- either way. 12:32:48 12:32:50

MR. PHILBIN: Great. Let's take 30 minutes. Thanks. 12:32:51 12:32:52

THE VIDEOGRAPHER: All right. We are going off the record at 12:32. 12:32:54 12:32:55

(Off the record at 12:32 p.m.) 12:33:05

(Back on the record at 1:04 p.m.) 13:04:56

THE VIDEOGRAPHER: We are back on the record at 13:04. 13:04:57 13:04:58

Q. (BY MR. PHILBIN) Dr. Quinlan, did you get some lunch? 13:05:02 13:05:04

A. I did. 13:05:04

Q. Are you ready to proceed? 13:05:04

A. I am. 13:05:05

Q. Do you know Dr. Christopher Atkinson? 13:05:05

A. Not that I'm aware of. 13:05:10

Q. Have you ever heard of Dr. Christopher Atkinson? 13:05:13

A. Not that I'm aware of. 13:05:22

Q. Do you have any reason to question the qualifications of Dr. Christopher Atkinson to offer opinions in this case? 13:05:23 13:05:24 13:05:29

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MR. HERMAN: Objection, form. Outside the scope of direct. 13:05:29 13:05:32

A. I would have to see who he is to determine that. 13:05:32

Q. (BY MR. PHILBIN) As you sit here today, you have no reason to dispute his qualifications, correct? 13:05:36 13:05:42

A. As I stand right now -- excuse me -- as I sit here today, I do not. 13:05:45 13:05:56

Q. Do you have the Wirbeleit reference in the materials before you? 13:05:57 13:06:03

A. It's one of the documents that was included electronically -- nine of two -- okay. I do. 13:06:19 13:06:22

Q. You have United States Patent No. 5479902 to Wirbeleit, et al. in front of you? 13:06:31 13:06:36

A. Yes. The one that was electronically provided to you as well as -- from you as well as a hardcopy here. 13:06:38 13:06:40

Q. And you relied upon that Wirbeleit reference in forming some of your opinions in this case, correct? 13:06:46 13:06:49

A. I did. 13:06:51

Q. And you reviewed it and understood it, correct? 13:06:52

A. Correct. 13:06:54

Q. Agree or disagree that the Wirbeleit reference alone discloses the claimed passive hydraulic link? 13:06:55 13:06:59

A. So, in this reference, number 22 is referred to as the hydraulic transmission element, and so it teaches us at least how to use that element in this case. 13:07:05 13:07:26 13:07:34

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MR. PHILBIN: Objection, nonresponsive. 13:07:40

Q. (BY MR. PHILBIN) Agree or disagree, the Wirbeleit reference alone discloses the claimed passive hydraulic link? 13:07:41 13:07:43 13:07:47

MR. HERMAN: Objection, form. 13:07:50

A. Again, I think that it discloses the hydraulic transmission element number 22 and how that would be used. 13:07:51 13:07:54 13:07:59

Q. (BY MR. PHILBIN) Identify, in your opinion, where in the Wirbeleit reference, the passive hydraulic link is disclosed. 13:08:04 13:08:05 13:08:09

A. So, again, the number 22, the pass- -- the hydraulic transmission element is taught in Wirbeleit. 13:08:17 13:08:25

Q. Anywhere else? 13:08:40

A. Well -- and so, specifically, we -- when we are looking at that, we're including the other prior art in determining what that is, the passive hydraulic link. 13:08:41 13:08:47 13:08:56

Q. Do you agree or disagree with the statement, "Wirbeleit does not depict the specifics of its hydraulic transmission element"? 13:09:07 13:09:09 13:09:15

A. The -- there is not much description of the pass- -- of the hydraulic transmission element in that reference. But what a POSITA would then go look for, other pieces of art that would point them to how to implement that device. 13:09:22 13:09:25 13:09:31 13:09:43 13:09:50

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MR. PHILBIN: Objection, nonresponsive. 13:09:51

Q. (BY MR. PHILBIN) Do you agree or disagree with that statement? 13:09:52 13:09:54

A. As I said, there is not much about that -- about 22, the hydraulic transmission element within this document and I believe that a POSITA would go and look and see what the options were for doing that at the time. 13:09:54 13:10:03 13:10:06 13:10:12 13:10:16

Q. In fact, you made the very statement in paragraph 293 that "Wirbeleit does not depict the specifics of its hydraulic transmission element," didn't you, sir? 13:10:16 13:10:19 13:10:22

A. Paragraph 293? 13:10:30

Q. Yes, sir. 13:10:32

A. Can you ask the question again, please? 13:10:36

Q. We can move on. It's your statement. You've already signed it. 13:10:38 13:10:40

The hydraulic transmission element wasn't part of the invention to which Wirbeleit was directed, was it? 13:10:42 13:10:45

MR. HERMAN: Objection, form. 13:10:49

A. Please ask the question again. 13:10:50

Q. (BY MR. PHILBIN) The hydraulic transmission element wasn't part of the invention to which Wirbeleit was directed. Agree or disagree? 13:10:51 13:10:55 13:11:00

MR. HERMAN: Objection, form. 13:11:02

A. So, it surely taught that in this embodiment and 13:11:07

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the specifications, how a -- how a hydraulic transmission element might be used. 13:11:16 13:11:23

MR. PHILBIN: Objection, nonresponsive. 13:11:30

Q. (BY MR. PHILBIN) Can you answer my question? 13:11:32

MR. HERMAN: Objection, form. Also asked and answered. 13:11:33 13:11:35

MR. PHILBIN: I didn't ask anything about an embodiment. 13:11:36 13:11:39

MR. HERMAN: Just to be clear, counsel, you're not entitled to the answer that you want. You're entitled to the answer that you get. 13:11:39 13:11:41 13:11:43

MR. PHILBIN: I'm entitled to an answer to my question. 13:11:45 13:11:47

(Simultaneously speaking) 13:11:47

MR. HERMAN: -- are highly argumentive -- 13:11:47

MR. PHILBIN: Please don't -- please don't coach your witness on the record. That's improper. You had a lunch break. Please don't coach your record -- coach your witness on the record. I object to that. If you've got an objection, make it. 13:11:48 13:11:50 13:11:54 13:11:57 13:12:00

A. Ask the question again, please. 13:12:06

Q. (BY MR. PHILBIN) Yes or no, sir, the hydraulic transmission element was part of the invention to which Wirbeleit was directed or not? 13:12:07 13:12:09 13:12:13

MR. HERMAN: Objection, form. 13:12:17

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A. So, being that this is a piece of prior art, I took the entire patent and the teachings from the entire patent and from that, we can see how this hydraulic transmission element might be used in an injector and that's what we -- what I used in forming my opinion on how we could want to combine this reference with other references. 13:12:18 13:12:26 13:12:30 13:12:33 13:12:36 13:12:40 13:12:50

Q. (BY MR. PHILBIN) What type of fluid was used in Wirbeleit's passive hydraulic link? 13:12:50 13:12:53

A. So, in what Wirbeleit calls the hydraulic transmission element, it's -- it doesn't, I don't think -- so, reading from column two, the paragraph starting at line 60, specifically -- so, I'm starting from 63 -- "a hydraulic transmission element 22 which is not shown in detail. Instead of the magnetostrictive actuator, a piezo actuator may be utilized." And then it says, "also as a transmission element one with elastomer or with mechanical force can be utilized." 13:13:02 13:13:10 13:13:17 13:13:42 13:13:53 13:13:57 13:14:03 13:14:10 13:14:10

So it appears they're disclosing three possible ways of doing it with a hydraulic means and some kind of elastic means or by other mechanical means. 13:14:16 13:14:20 13:14:25

Q. What type of fluid was used for Wirbeleit's passive hydraulic link? 13:14:31 13:14:35

A. Again, the hydraulic transmission element looks like it's listed as being able to use a fluid, an 13:14:37 13:14:42

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elastomer, or a -- other mechanical means. 13:14:49

Q. Is that your complete answer to my question? Can you answer my question, sir? 13:14:55 13:15:12

A. You asked if I had a complete answer. I'm checking if I have a complete answer or not. 13:15:13 13:15:18

Q. The question's what type of fluid? You haven't answered yet. Can you identify a single type of fluid? 13:15:18 13:15:21

MR. HERMAN: Objection, form. 13:15:24

A. It doesn't go into the specifics so it would be likely that a POSITA would already have knowledge on how to apply that or would go seek out other references from the art to see how to specifically do that. 13:15:29 13:15:35 13:15:39 13:15:43

Q. (BY MR. PHILBIN) Are you finished? 13:15:46

A. Yes. 13:15:48

Q. What does hydraulic transmission mean to you? 13:15:49

MR. HERMAN: Objection, form. 13:15:53

A. I would have to be talking about a specific thing -- device or something to see what hydraulic transmission meant. 13:15:58 13:16:00 13:16:05

Q. (BY MR. PHILBIN) Is the hydraulic transmission element in Wirbeleit enclosed in a cylindrical space? 13:16:06 13:16:08

A. Again, it looks like from the embodiment, I would guess that that's the intent, but no specifics are necessarily given on that. Leading a POSITA to seek further references or understanding that they already 13:16:37 13:16:41 13:16:45 13:16:52

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have from working in this field. 13:16:54

Q. Does item number 22 in Wirbeleit move up and down or not? 13:16:58

MR. HERMAN: Objection, form. 13:17:08

A. So, the details of item 22 are not given. It's not necessarily just one thing. It's a function in this case. 13:17:13

Q. (BY MR. PHILBIN) Does item 22 in Klugl function like the item we looked at in Exhibit 6 in Klugl, Figure 3, that doesn't move? 13:17:29

MR. HERMAN: Objection, form. 13:17:41

A. So, 22 in -- in Wirbeleit comparing that to item number 2 in Figure 3 of Klugl, they -- 13:17:54

Q. (BY MR. PHILBIN) Yes, sir. 13:18:05

A. -- do not perform the same function. 13:18:16

Q. Can you answer my question? 13:18:18

A. I believe I did. 13:18:19

Q. Okay. That's your full answer. Is that right? 13:18:23

A. Yeah. In that specific case for Figure 3, they're different. I think for Figure 1, we can have a different discussion. 13:18:24

Q. Did you understand all the parts of Wirbeleit when you read it? 13:18:32

A. I believe so. 13:18:34

Q. Okay. 13:18:39

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MR. PHILBIN: Can we pull up the first exhibit which we'll mark as Exhibit 7? 13:18:40 13:18:42

(Exhibit No. 7 marked) 13:18:44

Q. (BY MR. PHILBIN) Do you see that on your screen, sir? 13:18:55 13:18:56

A. Okay. Has this been supplied to me? 13:18:56

Q. No, sir. You can compare it to the lone figure in the Wirbeleit reference that you relied upon and opined upon. Do you see that? It's on the second page. 13:18:59 13:19:11 13:19:15

A. Yeah. I have that one. 13:19:20

Q. And do you see that I've added blue coloring to Exhibit 7? Do you agree or disagree that the chambers colored blue in Exhibit No. 7 are in fluid connection with each other? 13:19:22 13:19:29 13:19:40 13:19:43

MR. HERMAN: Objection, form. 13:19:44

A. Well, I am seeing this document for the first time so I'd have to form a careful analysis of it, but at first glance, I surely would think not all of those blue chambers are connected with each other. 13:19:50 13:19:54 13:20:02 13:20:05

Q. (BY MR. PHILBIN) Which blue chambers do you believe are not in fluid connection with each other in Exhibit 7? 13:20:07 13:20:09 13:20:13

A. Well, so, in this case, Wirbeleit teaches that line 12 is the fuel admission passage, so this is presumably at high pressure, containing the fuel that's 13:20:14 13:20:23 13:20:33

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going to be injected into the engine, whereas, I believe item 6, the spring chamber, there's no reference on how that is connected to the fuel. But, presumably, a POSITA at the time would assume that that is an event/drain rather than something that's kept at hot pressure. 13:20:36 13:20:52 13:21:01 13:21:07 13:21:12 13:21:16

Q. Do you agree that the top right of Exhibit No. 7 where that blue pipe comes out, that that's fuel leaving the fuel injector? 13:21:19 13:21:23 13:21:27

MR. HERMAN: Objection, form. 13:21:30

A. In this specific embodiment, again, without the details of 22 given, it's hard to tell whether it would be going in or out. 13:21:34 13:21:49 13:21:53

Q. (BY MR. PHILBIN) So you don't have an opinion one way or another if the right side of Exhibit 7 is fuel exiting? 13:21:55 13:21:57 13:22:02

MR. HERMAN: Objection, form. 13:22:05

A. Again, it would depend on the detailed implementations of component number 22, but, yeah. 13:22:09 13:22:13

Q. (BY MR. PHILBIN) Where are all the places that fuel can get into the fuel injector in Exhibit No. 7? 13:22:20 13:22:24

A. So, in this specific embodiment, we don't have listed what component 22 does, whether it brings in fluid, whether it doesn't, whether it's connected, so I can't tell from there. Beyond that, there are two lines 13:22:33 13:22:41 13:22:46 13:22:51

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that are -- one, number 12, that is specifically supplying fuel to the injector and the unnumbered line on the right that we don't know its function yet. 13:22:54 13:23:00 13:23:03

Q. So you would agree with me that line 12 is fluid -- or fuel in, correct? -- in Wirbeleit, as shown in Exhibit 7? 13:23:07 13:23:11 13:23:15

A. So, in -- in column two, line 38, it talks about the common supply three, so, presumably, this is a high pressure supply of fuel and that it gets into the injector by way of a fuel admission passage 12. 13:23:16 13:23:43 13:23:48 13:23:53

Q. In your opinion, what is the purpose of the vent shown on the right side of Exhibit No. 7? 13:23:59 13:24:02

A. So, I don't know that it's only a vent. That line, you know, depends on the implementation of number 22. 13:24:04 13:24:09 13:24:17

Q. In your opinion, does fluid get in item number 6 as shown in Exhibit 7? 13:24:19 13:24:23

A. Is there fluid in there? 13:24:24

Q. Yes, sir. 13:24:26

A. In this implementation, I surely would think there would be. Is there a way where you could seal piston number 10 against the body in such a way to isolate that high pressure fuel so it doesn't leak up that direction and that 6 could have air in it or something? I imagine there might be a case for that, 13:24:27 13:24:38 13:24:43 13:24:50 13:24:52 13:24:56

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but it's not totally clear. 13:25:03

MR. PHILBIN: All right. Let's look at the next demonstrative I've prepared. 13:25:18 13:25:15

Ms. Becraft, would you put that on the screen? I'll mark it as Exhibit 8. 13:25:18 13:25:20

(Exhibit No. 8 marked) 13:25:23

Q. (BY MR. PHILBIN) Again, I will tell you that this is an excerpt of the exact same diagram from the Wirbeleit reference that you relied upon in forming your opinions in this case. 13:25:24 13:25:25 13:25:29 13:25:32

Do you agree or disagree that the parts colored in green in Exhibit No. 8 are physically connected? 13:25:35 13:25:37

A. And have you supplied this document to me? 13:25:53

Q. No, sir. You've got the Wirbeleit reference in front of you and the only thing you don't have from Exhibit No. 8 is the green coloration. 13:25:57 13:25:58 13:26:01

A. Okay. Great. I'm just making it clear. And your question is whether these are physically connected or not? 13:26:04 13:26:10 13:26:14

Q. Yes, sir. 13:26:15

A. So, column two of Wirbeleit talks about the compensation piston with the needle tip, you know, potentially saying that they are the same component or not, and from this specific embodiment, you can't tell whether things are attached or not. 13:27:19 13:27:22 13:27:29 13:27:33 13:27:41

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Q. So you didn't determine whether the items shown in green in Exhibit 8 were physically attached or not in formulating your opinions in this case, correct? 13:27:47 13:27:49 13:27:52

MR. HERMAN: Objection, form. 13:27:54

A. Again, I think that I haven't decided whether they're physically connected or not. I think in this case, it makes the most sense for them to be physically connected to each other how they're shown, but there surely are other ways that you could form a similar injector that is taut here where maybe there are multiple pieces. 13:28:05 13:28:06 13:28:09 13:28:12 13:28:16 13:28:20 13:28:24

Q. (BY MR. PHILBIN) Sir, you understand the purpose of this deposition is, I get to ask you questions about your opinions, correct? 13:28:25 13:28:29 13:28:31

A. And I just gave you my opinion. 13:28:33

Q. I don't want new opinions after this deposition if I've asked you a question about it because you're seeking to take someone's patents away from them. Do you understand that, sir? 13:28:35 13:28:40 13:28:43 13:28:47

MR. HERMAN: Objection, form. Also argumentive. 13:28:47 13:28:48

A. Ask your specific question again, please. 13:28:53

Q. (BY MR. PHILBIN) Do you understand? 13:28:55

MR. HERMAN: Same objections. 13:28:57

A. I understand the purpose of this deposition. 13:29:02

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Q. (BY MR. PHILBIN) Okay. Did you use the Wirbeleit section shown in Exhibit 8 in forming opinions about combinations in this case? 13:29:04 13:29:13 13:29:18

MR. HERMAN: Objection, form. 13:29:21

Q. (BY MR. PHILBIN) Yes or no? 13:29:38

A. I'm.... 13:29:40

Q. You don't know? 13:29:40

A. I didn't say that, did I? 13:29:42

Q. Sir, this is a timed deposition. 13:29:46

MR. HERMAN: Please give the witness the time he needs to answer his question. 13:29:49 13:29:51

Q. (BY MR. PHILBIN) How much time do you need, sir? 13:29:54

A. Well, we'll know when we know. So, again, I took the idea, for example, if we're looking at -- if we're looking at, for example, page 66 on the document declaration for the 829 Patent, would give the motivations to combine here. 13:29:57 13:30:06 13:30:15 13:30:22 13:30:27

And specifically, the lack of detail in 22 from Wirbeleit leads us to say, well, we need more detail on that, and that leads us to the motivation -- one of the motivations to combine with, say, Klugl, and so we are looking for how to move the components that you show in green with something like this hydraulic transmission element that's not given any detail in 22. So, surely, you know, the -- the green elements that you've shown 13:30:29 13:30:40 13:30:44 13:30:49 13:30:55 13:31:02 13:31:07 13:31:12

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here are related to the motivation to combine, I believe. 13:31:16 13:31:22

MR. PHILBIN: Objection, nonresponsive. 13:31:22

Q. (BY MR. PHILBIN) Will you turn to page 57 of Exhibit No. 1, please, sir? 13:31:23 13:31:25

A. Okay. 13:31:36

Q. What's shown in the diagram on the bottom half of page 57 of Exhibit No. 1? 13:31:36 13:31:39

A. This is a demonstrative combination, one way that we can combine the injector given in Wirbeleit with the teachings of Klugl. 13:31:43 13:31:50 13:31:55

MR. PHILBIN: Okay. Ms. Becraft, will you pull up Exhibit No. 9? 13:32:01 13:32:03

(Exhibit No. 9 marked) 13:32:05

Q. (BY MR. PHILBIN) Do you agree that the green section of Exhibit No. 9 is the section of Wirbeleit that you took to make your figure on page 57 of Exhibit No. 1? 13:32:06 13:32:12 13:32:16 13:32:23

MR. HERMAN: Objection, form. 13:32:23

A. I believe that looks correct. 13:32:47

Q. (BY MR. PHILBIN) And you decided to take out the yellow section 21 as shown on Exhibit No. 9 and replace it with the yellow section of Klugl at the bottom of Exhibit No. 9, correct? 13:32:49 13:32:52 13:32:56 13:33:00

MR. HERMAN: Objection, form. 13:33:04

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A. So, component number 21 is, for example, in Wirbeleit, column two, line 61 or so, a magnetostrictive actuator 21 and Klugl lists the actuator number 1 as being a piezoelectric or magnetostrictive actuator, so we're showing just, you know, an embodiment where you could imagine that 21 and 1 are the same or not. They could be taken from the teachings of -- of Wirbeleit or Klugl, and 22 is given a more specific embodiment taken from Klugl and seeing how that fits into there. 13:33:08 13:33:15 13:33:21 13:33:28 13:33:34 13:33:42 13:33:45 13:33:51 13:33:57

MR. PHILBIN: Objection, nonresponsive. 13:34:02

Q. (BY MR. PHILBIN) The diagram outlined in green in Exhibit No. 9 is from Wirbeleit, correct? It's right there on the screen, sir. 13:34:04 13:34:06 13:34:17

A. So, it's not -- 13:34:21

Q. We just went through this. 13:34:22

A. It's not on the screen. If we're talking about the figure on the bottom of page 57, it's not on the screen, so I was pulling it up. 13:34:24 13:34:26 13:34:29

Q. Exhibit No. 9 is on the screen in front of you. I'm asking about the green portion. 13:34:31 13:34:33

A. And you were asking if that's what became the figure on page 57. I was confirming that that is the case. 13:34:35 13:34:38 13:34:41

Q. Okay. Now, can you answer my question? 13:34:43

A. Ask your question again, please. 13:34:45

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Q. Okay. I'm going to call what you've shown on page 57 your Frankenvalve where you've taken part of this and part of that and combined it. So, your Frankenvalve shown on page 57, you took the green part of Wirbeleit and replaced the yellow box in the top of Exhibit No. 9 with the yellow portion at the bottom of Exhibit No. 9, correct? 13:34:47 13:34:50 13:34:52 13:34:56 13:34:59 13:35:04 13:35:08

MR. HERMAN: Objection, form. Also argumentive. 13:35:09 13:35:12

A. That appears to be what they're -- where each is taken from. I have to look at all the details of everything to make sure it's where it came from, but, yes. 13:35:12 13:35:14 13:35:19 13:35:22

Q. (BY MR. PHILBIN) Okay. Thank you. Do you agree that you made a number of modifications to the disclosures in Klugl and Wirbeleit to come up with your Frankenvalve shown on page 57 of Exhibit No. 1? 13:35:23 13:35:30 13:35:32 13:35:35

MR. HERMAN: Objection, form. 13:35:42

A. The embodiment on page 57 is shown as a demonstrative of how you could implement the hydraulic transmission element number 22 in combining these two teachings. 13:35:43 13:35:51 13:35:57 13:36:03

Q. (BY MR. PHILBIN) Are they modifications or not? 13:36:09

MR. HERMAN: Objection, form. 13:36:11

A. So, I mean, there's a shoulder in one versus 13:36:12

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another and that change may be, you know, inconsequential or it may be important, but it's all more normal design matters of how you would specifically design an injector. At the time, you know, you would go through the process of seeing how you would combine these. It's not meant to be a scaled drawing of the actual injector. It's a demonstration of how these things function together and reasonably expect the -- the injector to work. 13:36:20 13:36:26 13:36:33 13:36:36 13:36:38 13:36:40 13:36:47 13:36:50 13:36:54

Q. (BY MR. PHILBIN) Is the diagram shown on page 57 of Exhibit No. 1 your best effort to combine Klugl and Wirbeleit? 13:37:02 13:37:04 13:37:08

A. Is it my best effort? 13:37:08

MR. HERMAN: Objection, form. 13:37:10

A. It's a demonstration of how they could be defined. I did not go through the detailed design process of designing the injector, combining those two teachings. 13:37:11 13:37:16 13:37:18 13:37:23

Q. (BY MR. PHILBIN) Would the fuel injector shown on page 57 work? 13:37:25 13:37:27

MR. HERMAN: Objection, form. 13:37:28

A. So, from, you know, for instance, the details in the representation shown on page 57 of my declaration, the details of, say, the actuator are not given and how the actuator is installed and pre-stressed, but that was 13:37:53 13:38:26 13:38:31 13:38:35

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not the intent of this demonstration, is to show all of the details, for example. What it is, is to show how one could use the teachings of Klugl inside of the injector given by Wirbeleit. 13:38:41 13:38:46 13:38:50 13:38:54

Q. (BY MR. PHILBIN) Would you testify under oath that the fuel injector you depicted on page 57 of Exhibit No. 1 would work? 13:39:00 13:39:03 13:39:05

MR. HERMAN: Objection, form. 13:39:08

A. Again, I don't think that the -- necessarily, all of the details are in that drawing. What I'm showing is how the specific parts of Klugl could be used in an injector like Wirbeleit. 13:39:10 13:39:17 13:39:20 13:39:29

Q. (BY MR. PHILBIN) Are you finished? Is there some part of the question, "would it work," you don't understand? 13:39:33 13:39:36 13:39:39

MR. HERMAN: Objection, form. Also argumentive. 13:39:41 13:39:44

A. This isn't a complete injector, perhaps, right? This is a demonstration of how one could use the teachings of Klugl. 13:39:47 13:39:50 13:39:54

MR. PHILBIN: Objection, nonresponsive. 13:39:57

Pull up the next exhibit please, Ms. Becraft. 13:40:06 13:40:09

(Exhibit No. 10 marked) 13:40:25

Q. (BY MR. PHILBIN) Okay. Let's mark that as 13:40:26

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Exhibit No. 10. This is an exhibit I prepared and colored from your diagram that you can't testify it works on page 57 of Exhibit No. 1. 13:40:27 13:40:30 13:40:36

MR. HERMAN: Objection, form. Also argumentive. 13:40:42 13:40:45

Q. (BY MR. PHILBIN) Do you agree with me, sir, that Exhibit 10 is an excerpt of your diagram on page 57 of Exhibit No. 1? I've just added color. 13:40:48 13:40:50 13:40:53

A. It appears to be. 13:40:58

Q. Okay. Where do the red structures shown on Exhibit 10 come from? 13:41:00 13:41:13

A. Again, so, for example, the -- the springs that are shown as diagonal pieces of the left and right of the larger spring -- 13:41:14 13:41:18 13:41:23

Q. Sir, I'm asking about the red. We're going to be be here all night if you continue to answer things I don't ask. 13:41:24 13:41:29 13:41:31

MR. HERMAN: Please wait for the witness to complete his answer before interjecting as a courtesy. 13:41:31 13:41:32

Q. (BY MR. PHILBIN) Can you answer the question about where did the red parts of Exhibit No. 10 come from, sir? 13:41:39 13:41:40 13:41:42

MR. HERMAN: Objection, form. That was the question that the witness was asking before you interrupted him. 13:41:43 13:41:47 13:41:49

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A. So, the diagonal springs here, they need to be compressed against something to preload the -- the actuator so that it can generate the correct amount of force. And they have to resist against something, so a POSITA would know that there has to be a shoulder there for them to press against, and so that's the modification that you see there. 13:41:50 13:41:56 13:42:02 13:42:06 13:42:07 13:42:09 13:42:13

Q. (BY MR. PHILBIN) The question was, where? Can you answer that question? 13:42:15 13:42:17

MR. HERMAN: Objection, form. 13:42:20

A. It's a -- just a standard engineering change that you would know you would have to make to use this. You have to have something for the springs to push against, so in this case, adding a shoulder, as an example, is one way of doing that. 13:42:21 13:42:33 13:42:37 13:42:38 13:42:42

Q. (BY MR. PHILBIN) So the red part did not come from Wirbeleit; it did not come from Klugl; it came from you, correct? 13:42:46 13:42:48 13:42:50

MR. HERMAN: Objection, form. 13:42:51

A. If you want to say that, you know -- let's look at Klugl's -- or -- yeah, Klugl's Figure No. 1. If we look at component 30, I believe, is it -- component number 30 is listed as the ring shape peripheral first stop 30. So, in my opinion, it could easily be considered as coming directly from Klugl and could be 13:42:54 13:42:59 13:43:06 13:43:29 13:43:34 13:43:38

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considered -- you know, could be made green in your figure to represent that -- or excuse me -- yellow to represent that it came from Klugl. So, it surely shows there has to be a stop there for this spring to react against. 13:43:42 13:43:45 13:43:52 13:44:00 13:44:03

So it's within the teachings of Klugl and again, the normal day-to-day engineering that a POSITA would have to go through to implement this combination. 13:44:03 13:44:05 13:44:08

Q. So you can't even admit you added the red parts of Exhibit 10, can you? 13:44:16 13:44:19

MR. HERMAN: Objection, form. 13:44:20

A. It.... 13:44:23

Q. (BY MR. PHILBIN) Just yes or no. Did you add them? 13:44:31 13:44:33

MR. HERMAN: Objection, form. 13:44:34

A. I mean, they're literally structure 30 from -- from -- from Klugl, so, you know, I don't think -- I think in your figure, they should be colored yellow. 13:44:34 13:44:38 13:44:45

Q. (BY MR. PHILBIN) Okay. Look at the part colored purple or dark pink in Exhibit 10. Did you add that? 13:44:48 13:44:50

MR. HERMAN: Objection, form. 13:44:53

A. So, I mean, if we look at -- I mean, I don't think that's necessarily the component, is it? I mean, this is taking the piston top that is shown in green and the membrane that is at the bottom of the yellow pieces. 13:45:34 13:45:57 13:45:59 13:46:05

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They're touching each other and around them could or could not be something. Again, this is meant to be a demonstration of how these components could work together, and so whether that's a specific component or not, you know, or if that's just a small gap, it would be a design choice as the -- someone was going through the process of figuring out how to combine these two things. Again, this isn't a designed injector. This is a representation of how these components could work together. 13:46:12 13:46:16 13:46:19 13:46:23 13:46:28 13:46:31 13:46:37 13:46:40 13:46:43 13:46:45

MR. PHILBIN: Objection, nonresponsive. 13:46:47

Q. (BY MR. PHILBIN) In the diagram you show on page 57 of Exhibit No. 1, did you intend the piston head to span from one side of the cylinder to the other? 13:46:49 13:46:51 13:46:55

MR. HERMAN: Objection, form. 13:46:58

A. I did not do the detailed design of this, but, you know, that would be a normal design process, deciding how large that piston is and how the contact with the membrane above it, number 6 from Klugl looked, and that would be well within a normal design procedure. 13:47:01 13:47:07 13:47:10 13:47:13 13:47:18

Q. (BY MR. PHILBIN) Do you agree or disagree that the spaces on the side of the piston head you show in Exhibit 57 (sic) are proportionately much smaller than those shown in the Klugl reference? 13:47:24 13:47:26 13:47:30 13:47:35

MR. HERMAN: Objection, form. 13:47:38

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A. The proportions are surely different between the two figures but, again, those don't represent real things. Neither of them are scaled drawings. That would come through the detailed design process of how you pick (noise interference). 13:47:42 13:47:45 13:47:48 13:47:50 13:47:54

Q. In coming up with the figure on exhibit -- on Exhibit 1, page 57, how did you determine what components to add or subtract? 13:47:59 13:48:00 13:48:04

A. I included the components that I bought from Klugl that would combine to make a realistic actuator and hydraulic transmission unit as listed from the Wirbeleit document to try to give more details of how that implementation would be possible. 13:48:06 13:48:19 13:48:22 13:48:26 13:48:30

Q. In the figure shown on page 57 of Exhibit No. 1, is membrane 6 flexible? 13:48:32 13:48:44

MR. HERMAN: Objection, form. 13:48:48

A. Again, we have to talk about when it's flexible, right? 13:48:48 13:48:52

Q. (BY MR. PHILBIN) So let me -- 13:48:53

A. The intent is that it doesn't -- that it transmits the linear distance that the actuator at the bottom travels and transmits that as a linear change in position of the -- of the piston, approximately. 13:48:55 13:48:57 13:49:01 13:49:05

Q. Let me get this straight. It's your opinion that when Klugl refers to a flexible membrane, that it's 13:49:09 13:49:12

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sometimes flexible and sometimes not flexible. Is that correct? 13:49:16 13:49:20

MR. HERMAN: Objection, form. 13:49:20

A. Uh -- 13:49:23

Q. (BY MR. PHILBIN) Just yes or no. Do I have it right? 13:49:25 13:49:27

A. It totally depends on the speed at which we're talking about things moving and the orifice size number 10 that you pick, the transmission fluid that you use within the device. These are normal design considerations that you would go through in designing that interface. 13:49:27 13:49:30 13:49:34 13:49:38 13:49:42 13:49:47

Q. What speed does the Klugl embodiment operate at? 13:49:49

MR. HERMAN: Objection, form. 13:49:54

A. Which speed are we talking about? 13:49:55

Q. (BY MR. PHILBIN) You just said it depends on the speed, and I'd like for you to show me in Klugl where it references the speed. 13:49:57 13:49:59 13:50:02

A. In Klugl, you're specifically speaking? 13:50:03

Q. Well, is that what your opinion's based on? Klugl's a six-page reference. Can you show me where it references speed? 13:50:22 13:50:55 13:50:57

MR. HERMAN: Objection, form. 13:50:58

MR. PHILBIN: I left out the figures. You're correct. 13:51:09 13:51:11

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A. So, I would point you to my declaration for the 829 Patent. On page 33, paragraph 28, there's a discussion on -- that Klugl explains that during actuation, only an insignificant amount of hydraulic fluid flows out of chamber 5, so this is speaking to, essentially, how the orifice that is 10 that is in the central part of your lower yellow portion and the fluid contained below that between flexible membrane 6 and that orifice interact with each other. 13:51:41 13:51:47 13:51:56 13:52:01 13:52:04 13:52:11 13:52:17 13:52:21 13:52:26

So, during actuation, if there's no flow through there, we have to maintain the volume of fluid in there. So there's not going to be much flexing going on there whereas -- it continues, "during idle periods, hydraulic fluid can move from chamber 5 through throttle 6, an orifice, to chamber 7 (inaudible) to automatic adjust (inaudible) difference is and the gradual wear (inaudible) -- 13:52:28 13:52:31 13:52:35 13:52:40 13:52:45 13:52:49 13:52:49 13:53:22

THE COURT REPORTER: I'm sorry. I'm sorry. This is the court reporter. I didn't -- I apologize to interrupt but when the witness is reading from a document and he's turned to the side, I'm not able to hear clearly. Thank you. 13:53:22 13:53:22 13:53:22 13:53:22 13:53:22

THE WITNESS: All right. 13:53:25

MR. PHILBIN: Objection, nonresponsive. 13:53:25

A. So, I haven't finished my answer yet. 13:53:27

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Q. (BY MR. PHILBIN) If you want to waste more time, go ahead. 13:53:29 13:53:31

MR. HERMAN: Objection, form. 13:53:32

Q. (BY MR. PHILBIN) The question was speed disclosed in Klugl, and you haven't even cited anything in Klugl yet, but go ahead. 13:53:33 13:53:35 13:53:37

MR. HERMAN: Objection, form. 13:53:41

A. So, I am looking at Klugl. Again, if you look at page 32, paragraph 28, this is about Klugl and it's talking about the relative motion of the diaphragm with respect to how this orifice 10 is designed in the detailed design so that during actuation when this is moving, that that volume is maintained below there whereas it spends most of its time not being actuated and so in this longer period of time, that there is some ability for flow to go through that and the volume within there to change and adjust to small changes in the position of these components. 13:53:46 13:53:50 13:53:54 13:54:01 13:54:06 13:54:09 13:54:14 13:54:19 13:54:23 13:54:28 13:54:31

MR. PHILBIN: Objection, nonresponsive. 13:54:36

Ms. Becraft, would you pull up Exhibit 11, please? 13:54:43 13:54:47

(Exhibit No. 11 marked) 13:54:47

Q. (BY MR. PHILBIN) Dr. Quinlan, do you agree that the spaces shown in blue in Exhibit 11 contain fluid? 13:54:51 13:54:53

MR. HERMAN: Objection, form. 13:54:58

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A. I would say that I know from Wirbeleit that the line on the left coming down and supplying high pressure to the needle nozzle tip region must have fluid in it. That's the fluid that's going to be injected when the actuator is actuated and the fuel injector is commanded to inject fuel. 13:54:59 13:55:13 13:55:18 13:55:26 13:55:29 13:55:31

The details of which, you know, above piston 10 in spring chamber and the line shown on the right and the area around the actuator, no details are given necessarily from Wirbeleit how that would work, and whether or not that needs to have fluid or whether that could be air or something else. 13:55:35 13:55:38 13:55:45 13:55:51 13:55:56 13:55:59

MR. PHILBIN: Objection, nonresponsive. 13:56:02

Q. (BY MR. PHILBIN) Do you see Exhibit No. 11 on the screen? 13:56:05 13:56:07

A. I do. 13:56:09

Q. Can you identify any areas in blue that do not contain fluid? 13:56:10 13:56:12

A. Again, in that spring chamber line on the right, I don't know. 13:56:14 13:56:19

Q. So, other than the spring chamber that leads to the line on the right, you agree every other blue portion in Exhibit 11 contains fluid. Is that correct? 13:56:20 13:56:22 13:56:24

A. No. I don't know that the region above the piston 10 and the area around actuator 1 -- what that 13:56:26 13:56:29

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material is. I haven't done the details on that. 13:56:36

Q. In your combination as shown on page 57 of Exhibit 1 and highlighted on Exhibit 11, the space around the actuator is in fluid connection with other chambers or is not? 13:56:43 13:56:46 13:56:51 13:56:55

MR. HERMAN: Objection, form. 13:56:56

A. In this embodiment, it does not appear to be, but that doesn't -- again, this isn't a detailed design. I haven't gone through the process of designing it and deciding where would be needed to connected to what in terms of what, this -- you know, say if it was a, you know, relatively low pressure vent region or a low pressure supply region, what I do know is it's not connected to the -- I mean, in this drawing, it's not connected to that, but that doesn't mean when you actually implement the design details, that it would or wouldn't be. 13:57:02 13:57:06 13:57:10 13:57:13 13:57:18 13:57:22 13:57:31 13:57:33 13:57:36 13:57:38 13:57:41

MR. PHILBIN: Objection, nonresponsive. 13:57:42

Would you turn to Exhibit No. 12, please, Ms. Becraft? 13:57:44 13:57:47

(Exhibit No. 12 marked) 13:57:58

Q. (BY MR. PHILBIN) Exhibit 12 is a shaded version of your combination valve shown on page 57 of your declaration, correct? 13:57:59 13:58:00 13:58:09

MR. HERMAN: Objection, form. 13:58:13

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A. That's what it appears like. 13:58:20

Q. (BY MR. PHILBIN) Okay. The guiding sleeves on either side of the transmission module in Exhibit 12 are shaded in green, correct? 13:58:22 13:58:23 13:58:27

A. From what we called the transmission module, it's that -- the -- again, the -- you know, we've called all of those pieces as one unit, the transmission module that we took from Klugl. 13:58:30 13:58:36 13:58:49 13:58:54

Q. Can you answer my question, sir? 13:58:58

A. So, I'm saying that your question is ill posed because what I'm referring to is the transmission module from -- from Klugl. If we look at page 31 of my declaration, the light purple color, that's the transmission module and you only have the sleeve highlighted from that component number 11. 13:58:59 13:59:03 13:59:06 13:59:10 13:59:16 13:59:18

Q. Do you agree that the guiding sleeves, whether they're part of the transmission module or in addition to the transmission module, move downward in your combination shown on page 57 of Exhibit 1 during actuation? 13:59:29 13:59:46 13:59:49 13:59:55 13:59:58

A. I believe they would move with the -- with the actuator. 13:59:59 14:00:23

Q. Does your combination on page 57 of Exhibit 1 have disc springs? 14:00:30 14:00:36

A. Yes, it does. 14:00:38

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Q. Are those disc springs crushed during actuation? 14:00:50
A. They may be partly loaded already to pretension, 14:00:53
the actuator, but they may be additionally, you know, 14:01:06
displaced as the actuator is actuated. 14:01:12
Q. And in your combination, when -- during 14:01:14
actuation, the central spring is depressed, correct? 14:01:18
A. I believe that's spring 15 in the center there. 14:01:23
Yes, it is compressed. 14:01:27
Q. What provides the closing forces in the diagram 14:01:29
you've shown on page 57 of Exhibit No. 1? 14:01:36
A. Okay. So, when the actuator 1 is -- you know, 14:01:41
the voltage or the amperage, whatever type of actuator 14:01:48
it is is decreased, it shrinks in its axial length, and 14:01:53
there is force from -- in this case -- let's see -- 14:02:01
forces definitely from spring 15. We have forces from 14:02:13
the disc springs and potentially, depending on how 14:02:17
things are implemented, hydraulic force on the actual 14:02:22
piston 10. 14:02:27
Q. Would the high pressure of the fuel also be an 14:02:30
imposing force in your diagram on page 57 of Exhibit 1? 14:02:33
A. As I just said, it depends on the implementation 14:02:39
on how you do it, whether that force is balanced with 14:02:42
something else or not, and so it could be, but it's not 14:02:45
necessarily. 14:02:51
Q. Are the disc springs on each side of the diagram 14:02:55

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shown on page 57 of Exhibit 1 redundant of the spring surrounding the piston? 14:02:58 14:03:05

MR. HERMAN: Objection, form. 14:03:06

A. They -- they may provide some of the opposing force but the main reason that they are there is to preload the piezo actuator so that the force can be higher. So I would say fundamentally, they serve a different purpose. 14:03:08 14:03:12 14:03:14 14:03:19 14:03:23

Q. (BY MR. PHILBIN) Is the diagram that you've shown on page 57 on Exhibit 1 an outwardly opening fuel injector valve? 14:03:29 14:03:31 14:03:36

A. It is. 14:03:39

Q. Does Klugl disclose an inwardly open -- opening fuel injector valve? 14:03:39 14:03:42

A. Klugl? 14:03:44

MR. HERMAN: Objection, form. 14:03:47

A. I mean, Klugl discloses a valve and says that it has many ways that it can be used. The specific implementation that's shown, the ceiling -- right term for it -- for example, they call for a servo valve sometimes; they call for a closing element sometimes. In this, you know, embodiment that they're showing, it's opening as the motion goes down. Whether that's outside of something, again, I don't think in Klugl, they show the rest of the housing. 14:03:58 14:04:04 14:04:13 14:04:37 14:04:42 14:04:44 14:04:47 14:04:54 14:04:57

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MR. PHILBIN: Objection, nonresponsive. 14:05:03

Q. (BY MR. PHILBIN) In your opinion, does Klugl disclose an inwardly opening fuel injector valve? 14:05:04 14:05:05

MR. HERMAN: Objection, form. 14:05:11

A. I think what Klugl discloses is a valve and that -- whether that closing element 4 is in or out would depend on the implementation of it. Specifically, the embodiment shows it as opening when it goes down. 14:05:12 14:05:17 14:05:27 14:05:29

MR. PHILBIN: Objection, nonresponsive. 14:05:37

Q. (BY MR. PHILBIN) In the diagram you've shown on page 57 of Exhibit 1, the modifications you made to Wirbeleit make the electric control modules adjustment limited by the adjustments of the transmission module, correct? 14:05:37 14:05:41 14:05:46 14:05:51 14:05:56

MR. HERMAN: Objection, form. 14:05:56

A. I don't think so because if you sensed with the sensing coil if you could do that accurately enough to know that you weren't quite closed, you know, and that you were trying to adjust that with the actuator and you could change the actuator's resting voltage from 70 to 90 so that its extended length when it's at the non-injecting period is the same, it seems like it could still adjust for that change in position. The -- you know, the.... 14:06:25 14:06:29 14:06:31 14:06:35 14:06:39 14:06:45 14:06:50 14:06:56 14:07:05

Q. (BY MR. PHILBIN) Are you finished? 14:07:22

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A. You know, I don't think I've considered that in detail, actually, whether, you know, how the electronic control would be necessarily useful in that state. I would have to think about that more, I think, to form an opinion about it. 14:07:37 14:07:40 14:07:46 14:07:53 14:07:55

Q. Will you turn to page 93 of Exhibit No. 1, please, sir? 14:07:56 14:08:02

A. Okay. 14:08:12

Q. On page 93 of Exhibit No. 1, there's a demonstrative you created to show your proposed combination of Klugl with Hayes, correct? 14:08:13 14:08:16 14:08:18

A. Correct. 14:08:20

Q. Did you make this demonstrative? 14:08:24

MR. HERMAN: Objection, form. 14:08:27

A. I don't remember who made it but the technical details are -- are surely mine. 14:08:28 14:08:34

Q. (BY MR. PHILBIN) Do you believe the combinations shown on page 93 of Exhibit No. 1 reflects a good fuel injector design? 14:08:37 14:08:39 14:08:45

MR. HERMAN: Objection, form. 14:08:45

A. Good or bad, I think that it's a combination that shows that you could combine these two references and make a fuel injector that could function. 14:08:49 14:08:53 14:08:58

Q. (BY MR. PHILBIN) Can you testify under oath that the fuel injector shown on page 93 would work? 14:09:01 14:09:04

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(Simultaneously speaking) 14:09:06
MR. HERMAN: Objection, form. 14:09:06
Q. (BY MR. PHILBIN) Sorry. I didn't hear you. I heard some lawyers talking in the background. 14:09:15 14:09:17
A. Why don't you re-ask your question and we'll get it right. 14:09:19 14:09:22
Q. Have you ever built a fuel injector shown on page 93 of Exhibit No. 1? 14:09:24 14:09:27
A. No, I have not. 14:09:27
Q. Would the fuel injector on page 93 of Exhibit No. 1 work? 14:09:27 14:09:37
A. I think that the combination would give a POSITA the reassurance that there's a reasonable expectation that this injector would work. 14:09:38 14:09:44 14:09:49
Q. In coming up with your combination of Hayes and Klugl, did you rely upon patent owner's understanding of the claims being applied? 14:10:03 14:10:06 14:10:13
A. The claims in Hayes, are we talking about? 14:10:17
Q. No. I believe the claims in these certain patents that you want to invalidate. 14:10:25 14:10:29
MR. HERMAN: Objection, form. 14:10:31
A. Please ask your question again, then, so I make sure I understand it. 14:10:31 14:10:34
Q. (BY MR. PHILBIN) To come to the opinion that Hayes and Klugl disclose the limitations of the asserted 14:10:36 14:10:48

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claims in the 829 Patent to render it obvious, you had to rely upon the patent owner's understanding of the claims being applied, correct? 14:10:52 14:10:56 14:11:01

A. The -- this combination is showing that there is an obvious solution in the prior art and specifically, what we had -- what I have to deal with here is that the patent owner's understanding of some of the terms and the understanding that I took of the terms are different. 14:11:10 14:11:28 14:11:39 14:11:46 14:11:51 14:11:52

And so what I'm proposing here is if the understanding from the patent owners is proved to be what the -- the understanding is, then this is an embodiment that encompasses that situation. 14:11:52 14:11:56 14:12:02 14:12:10

Q. How did you obtain the patent owner's understanding of the claims? 14:12:14 14:12:18

A. Again, this is through the understanding of the -- so, it's taking all of Klugl and Hayes into account to read those in terms of how they compare to the claims in the asserted patents and -- and seeing whether each one of the components and functions inside of the -- of the claim is covered by something that is clearly in the prior art. 14:12:20 14:12:32 14:13:27 14:13:32 14:13:47 14:13:51 14:13:57

Q. Does Klugl expressly disclose an interior chamber? 14:14:02 14:14:06

MR. HERMAN: Objection, form. 14:14:15

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A. I would have to look through the entire Klugl document, but as I'm, you know, sitting here, I don't think that it does. 14:14:15 14:14:22 14:14:25

Q. (BY MR. PHILBIN) Does Klugl expressly disclose a nozzle? 14:14:28 14:14:31

MR. HERMAN: Objection, form. 14:14:32

A. Klugl definitely says that -- that its device could be used to -- as a servo valve, for example, to drive a piston that could drive a nozzle needle on column four, line 16, 17. 14:14:36 14:14:56 14:15:01 14:15:07

MR. PHILBIN: Objection, nonresponsive. 14:15:14

Q. (BY MR. PHILBIN) Does Klugl expressly disclose a nozzle orifice? 14:15:15 14:15:18

MR. HERMAN: Objection, form. 14:15:19

A. I -- again, I think that Klugl is talking about injector valves, not necessarily each one of the components of an injector (unintelligible). 14:15:36 14:15:42 14:15:46

Q. (BY MR. PHILBIN) Is that your best answer to my question? 14:15:54 14:15:57

MR. HERMAN: Objection, form. Also argumentive. 14:15:58 14:16:00

A. It's the answer I've got. 14:16:00

Q. (BY MR. PHILBIN) Does Klugl expressly disclose a fuel inlet? 14:16:01 14:16:07

MR. HERMAN: Objection, form. 14:16:09

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A. So, it mentions that fuel is delivered by the injector, but beyond that, it doesn't talk about specifics of that, you know, specific line. 14:16:28 14:16:31 14:16:34

Q. (BY MR. PHILBIN) Klugl does not mention the combustion chamber, does it? 14:16:42 14:16:43

MR. HERMAN: Objection, form. 14:16:57

A. It talks about, you know, the injection into an internal combustion engine, but not specifics of that. 14:16:58 14:17:02

MR. PHILBIN: We've been going a little over an hour. Let's take a ten-minute break. 14:17:08 14:17:09

THE VIDEOGRAPHER: All right. We are going off the record at 14:17. 14:17:12 14:17:13

(Off the record at 2:17 p.m.) 14:17:16

(Back on the record at 2:31 p.m.) 14:31:46

THE VIDEOGRAPHER: We are back on the record at 14:31. 14:31:47 14:31:48

(Brief pause) 14:31:48

THE VIDEOGRAPHER: Did taking counsel drop from the call? I'm going to take us back off. We're going off the record at 14:32. 14:31:48 14:32:14 14:32:14

(Off the record at 2:32 p.m.) 14:32:16

(Back on the record at 2:33 p.m.) 14:33:27

THE VIDEOGRAPHER: We are back on the record at 14:33. 14:33:28 14:33:30

Q. (BY MR. PHILBIN) Dr. Quinlan, are you ready to 14:33:34

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proceed? 14:33:35
A. I am. 14:33:37
Q. In 1999, are you aware of any reasons not to use a flexible membrane in a high pressure fuel injector? 14:33:38
A. I'm sure there's reasons to and to not use flexible membranes in an injector. 14:33:44
Q. What are the reasons in 1999 to not use a flexible membrane in a high pressure fuel injector? 14:33:59
MR. HERMAN: Objection, form. 14:34:02
A. There could be material compatibility between the fluid and the -- what the membrane's made of, as an example. 14:34:07
Q. (BY MR. PHILBIN) Anything else? 14:34:10
A. I think we could be here a long time. Do you have a specific membrane you'd like to talk about or.... 14:34:16
Q. You didn't design any fuel injectors with a flexible membrane in 1999, did you, sir? 14:34:21
A. I did not. 14:34:29
Q. Let's look at the Klugl reference yet again. Do the -- does the actuation in Figure 1 and Figure 3 take place at the same speed? 14:34:30
A. I think that would come down to the specific application where you planned on using each one of those valves. 14:34:31
Q. Is there a disclosure in Klugl that says Figure 1 14:34:36
14:34:48
14:34:51
14:34:51
14:34:52
14:35:01
14:35:04
14:35:23
14:35:25
14:35:27
14:35:31

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and Figure 3 actuate at different speeds? 14:35:34
MR. HERMAN: Objection, form. 14:35:37
A. Without going through it in detail, not that I'm aware of. 14:35:42
14:35:46
Q. (BY MR. PHILBIN) Is the same hydraulic fluid used in Klugl Figure 1 embodiment and Klugl Figure 3 embodiment? 14:35:46
14:35:50
14:35:51
A. Again, I think that would depend on the application that you're using. 14:35:51
14:35:53
Q. Does Klugl have any disclosure of a different hydraulic fluid being used for Figure 1 versus Figure 3? 14:35:57
14:36:00
A. At a glance, I don't believe so. I mean.... 14:36:31
Q. In Klugl Figure 3, is the membrane sometimes flexible and sometimes not flexible? 14:36:37
14:36:40
MR. HERMAN: Objection, form. 14:36:44
A. Is it any -- it's -- in Figure 3 of Klugl, its actuation depends on that membrane, that lower membrane 6 in being flexible since component 11 does not move in this case -- excuse me -- not component 11; component 2. 14:36:46
14:36:59
14:37:03
14:37:17
Q. (BY MR. PHILBIN) So my question, sir, was: Is the membrane in Figure 3 sometimes flexible and sometimes not flexible? 14:37:28
14:37:30
14:37:33
MR. HERMAN: Objection, form. 14:37:34
A. If you mean that it's in a flexed state, sometimes yes and sometimes no. I would agree with 14:37:39
14:37:41

that. 14:37:44

Q. (BY MR. PHILBIN) Is there any point in time during actuation or afterwards that membrane 6 becomes not flexible? 14:37:45 14:37:48 14:37:52

MR. HERMAN: Objection, form. 14:37:54

Q. (BY MR. PHILBIN) In Figure 3 of Klugl. 14:37:59

A. In Figure 3 of Klugl, whether it's in the -- you know, whether it's perfectly flat and it started off to be perfectly flat or whether it's curved and that was its original shape, again, those details are design details that would have been worked out during the design process. 14:38:03 14:38:07 14:38:11 14:38:14 14:38:17 14:38:23

Q. So is it your testimony that the design details determine whether flexible membrane 6 is flexible or not? 14:38:26 14:38:29 14:38:35

MR. HERMAN: Objection, form. 14:38:35

A. In Figure 3, whether it's in a flexed position or not at its resting state, I think would be up to the designer at the time and well within their ability to decide what would be a -- a good configuration to use there. 14:38:39 14:38:43 14:38:49 14:38:52 14:38:57

Q. (BY MR. PHILBIN) Sir, I notice you keep changing my question from flexible to flexed. 14:38:58 14:39:00

A. Well, so ask your question again so I make sure I'm accurately answering it. 14:39:04 14:39:09

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Q. I'm not asking about a flexed state. I'm asking, is membrane 6 sometimes flexible and sometimes inflexible in Figure 3 of Klugl? 14:39:11 14:39:15 14:39:20

A. So, in Figure 3 of Klugl, the membrane 6 relies on its flexibility to perform its job, right? To actuate piston number 3. So does it have the property of being flexible? It must have some property of being flexible for this case, for Figure 3. 14:39:24 14:39:35 14:39:41 14:39:47 14:39:52

Q. Is that your complete answer to my question? 14:40:01

A. Well, I don't know how something has a state of being flexible at one time and not being flexible at another time. It could be in a flexed state or not at two different times. 14:40:03 14:40:08 14:40:12 14:40:16

Q. So you would agree that a membrane is either capable of being flexible or not capable of being flexible, correct? 14:40:17 14:40:21 14:40:24

MR. HERMAN: Objection, form. 14:40:25

A. It would be relative to the forces applied to it and the material that it's made out of, so within this embodiment in Figure 3 shown, the operation requires it to be flexible. 14:40:28 14:40:32 14:40:36 14:40:43

Q. (BY MR. PHILBIN) Does Klugl disclose anything about the forces being applied to a membrane being different between Figure 1 and Figure 3? 14:40:45 14:40:47 14:40:51

A. Forces being applied to make a difference between 14:40:53

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1 and -- so just a general membrane or a specific membrane? You know, 6, 26, 20- -- what is the other one -- 8? 14:41:08 14:41:11 14:41:15

Q. Sir, any membrane. 14:41:25

A. For any membrane. I think you'll have to repeat your question. I don't think I quite understand -- so you're saying -- you just ask your question again. Sorry. 14:41:27 14:41:45 14:41:48 14:41:51

Q. You responded that -- in response to my question about a membrane is either capable of being flexible or not being capable of being flexible, you said it would be relative to one, the forces applied to it and two, the material it's made out of. So let's focus on one first. The forces -- 14:41:51 14:41:56 14:41:59 14:42:02 14:42:05 14:42:09

(Simultaneously speaking) 14:42:10

Q. (BY MR. PHILBIN) Don't cut me off. My question is related to your answer number one. The forces applied to the membrane in Klugl, is there any disclosure in Klugl of how much those forces are? 14:42:12 14:42:14 14:42:18 14:42:22

MR. HERMAN: Objection, form. 14:42:26

A. As I'm sitting here right now, I don't think that it mentions forces that -- the -- like, amount of force that the actuator is generating, for example. 14:42:31 14:42:33 14:42:38

Q. (BY MR. PHILBIN) So as to your second reason, the material it's made out of, is there any disclosure 14:42:43 14:42:45

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in Klugl as to what any of the membranes are made out of? 14:42:47 14:42:50

MR. HERMAN: Objection, form. 14:42:50

A. As I sit here, I don't remember any specific materials listed but, again, this would be a normal design process that you would go through as selecting the material, the thickness, the areas of the pistons (noise interference) membrane, the forces that the actuator is capable of generating, and you would take those all into account. That's normal engineering practices. 14:42:54 14:42:57 14:43:01 14:43:05 14:43:11 14:43:12 14:43:15 14:43:20

Q. (BY MR. PHILBIN) With regard to the upper membrane in Klugl, is it sometimes flexible and sometimes not capable of being flexible? 14:43:35 14:43:37 14:43:39

MR. HERMAN: Objection, form. 14:43:44

A. The upper membrane in Figure 3? 14:43:48

Q. (BY MR. PHILBIN) We can start there. 14:43:51

A. Again, this -- for the embodiment shown in Figure 3, the actuation relies on the flexibility of membrane 26. 14:44:09 14:44:15 14:44:22

Q. So, in your opinion, is membrane 26 flexible all the time or just part of the time? 14:44:34 14:44:35

MR. HERMAN: Objection, form. 14:44:40

A. In Figure 3, the membrane 26 must have the ability to flex. Period. 14:44:45 14:44:50

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Q. (BY MR. PHILBIN) In forming your opinions related to Figure 1 of Klugl, did you assume that membrane 6 was flexible or inflexible? 14:44:57 14:44:58 14:45:01

A. Again, that depends on the forces that are applied due to membrane 6 in regards to how it functions. 14:45:13 14:45:15 14:45:20

Q. And you agree there's no disclosure of forces applied to membrane 6 in Klugl expressly, correct? 14:45:25 14:45:26

MR. HERMAN: Objection, form. 14:45:34

A. No. But there is a discussion on how the fluid flow through throttle 10 is different between the short actuation period of the injector and the long dwell time between injections. 14:45:35 14:45:38 14:45:45 14:45:48

Q. (BY MR. PHILBIN) Is the fluid that flows through throttle 10 different in Figure 1 and Figure 3 in Klugl? 14:46:28 14:46:29

A. It would depend on the application where you're using the valve. It could be the same; it could be a different fluid. 14:46:35 14:46:39 14:46:41

Q. And there's no disclosure in Klugl that shows that the fluid that flows through throttle 10 is different between the embodiment in Figure 1 and Figure 3, correct? 14:46:42 14:46:45 14:46:47 14:46:49

A. Not that I remember right offhand, but, again, that would be a design choice depending on the application; picking the viscosity; the other fluid 14:46:50 14:46:54 14:46:56

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dynamic properties of the fluid so that the components function how you want them to function. 14:47:03 14:47:05

Q. And as of 1999, you had not made a single design choice related to designing a fuel injector, correct? 14:47:07 14:47:11

MR. HERMAN: Objection, form. 14:47:15

A. As of 1999, I was not working on diesel fuel injectors, no. 14:47:17 14:47:21

Q. (BY MR. PHILBIN) Is it important to your opinions whether membrane 6 is flexible in Figure 1? 14:47:22 14:47:25

MR. HERMAN: Objection, form. 14:47:29

A. Again, it's -- we have to look at -- it's during actuation or during the long period of dwell time between actuations. 14:47:37 14:47:41 14:47:43

Q. (BY MR. PHILBIN) So does that mean it's important? 14:47:44 14:47:45

MR. HERMAN: Objection, form. 14:47:48

A. The membrane 6 in Figure 1, when you actuate the valve, the intent, as I see it from the author, is that the -- that membrane acts relatively rigidly so that the amount of displacement of the bottom of actuator 1 is the same displacement as the piston 3. 14:47:54 14:48:00 14:48:04 14:48:15 14:48:21

Q. (BY MR. PHILBIN) So your opinion is that flexible membrane 6 is different in Figure 1 than Figure 3, correct? 14:48:26 14:48:28 14:48:31

A. It would depend on the application that you were 14:48:33

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using them in and the intent. 14:48:35
Q. Is a balloon a flexible membrane? 14:48:44
MR. HERMAN: Objection, form. 14:48:49
A. Again, I haven't done a detailed analysis of what I would call a flexible membrane, so I couldn't form a formal opinion on that. 14:48:50 14:48:53 14:48:59
Q. (BY MR. PHILBIN) Is an inner tube that you sit on in a swimming pool a flexible membrane? 14:49:00 14:49:04
A. Same answer. 14:49:07
Q. You opine that transmission fluid is held in place by membrane 6, correct? 14:49:08 14:49:12
A. Can you point me to a specific line? 14:49:16
Q. I will in a second on that. 14:49:35
Would a balloon hold fluid in place during actuation? 14:49:37 14:49:41
MR. HERMAN: Objection, form. 14:49:41
A. I haven't considered that hypothetical. 14:49:41
Q. (BY MR. PHILBIN) So if you look at paragraph 220 on page 52 of Exhibit 1, you state, "as the fluid in chamber 5 is held in place by a membrane 6." Do you see that? 14:49:59 14:50:00 14:50:06 14:50:08
A. Which paragraph? Sorry. I just got to the page. 14:50:09
Q. Paragraph 220, paragraph -- page 52. 14:50:11
A. Okay. 14:50:15
Q. And it's your opinion that a transmission fluid 14:50:35

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is held in place by flexible membrane 6, correct? 14:50:42

A. So, the fluid is held in chamber 5 -- is in 14:50:46

chamber 5 by membrane 6, yes, on the lower half. 14:50:54

Q. So would a balloon hold fluid in place during 14:51:00

actuation? 14:51:06

MR. HERMAN: Objection, form. 14:51:07

A. So you're saying if I stuck a balloon in the 14:51:11

injector somewhere? 14:51:13

Q. (BY MR. PHILBIN) Yeah. Right where item 6 is, 14:51:15

the flexible membrane. Would the balloon hold that 14:51:17

fluid in place during actuation? 14:51:20

MR. HERMAN: Objection, form. 14:51:22

A. I don't know how that membrane would be a 14:51:25

balloon, so -- but if you're speaking about whether it 14:51:28

was a piece of very, very thin rubber, then, you know, 14:51:34

that would be a design choice and you would get 14:51:39

something with that compared to picking, you know, 14:51:41

stainless steel membrane, right? 14:51:46

Q. (BY MR. PHILBIN) Sir, can you answer my 14:51:50

question? If you used a balloon for membrane 6 in 14:51:51

Figure 1, would the balloon hold the fluid in place 14:51:55

during actuation? 14:51:58

A. I mean, I don't think your question's well posed. 14:52:01

I don't know how to put a balloon in there. I know how 14:52:03

to maybe put a sheet of rubber in there. 14:52:06

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Q. Okay. Then a sheet of rubber. Will it hold the fluid in place during actuation in Figure 1 of Klugl? 14:52:08 14:52:13

A. It could. It would depend on the pressures, the thicknesses. It could not, though, too. 14:52:16 14:52:19

Q. Will an incompressible fluid change volume under pressure against a flexible membrane? 14:52:22 14:52:25

A. An incompressible fluid would not change its volume due to reactions of forces -- force applied to it if it's, you know, constrained. 14:52:34 14:52:40 14:52:46

Q. Let me make sure I understand your opinion on Figure 1. What is the area underneath flexible membrane 6 on the left and the right of item number 3? 14:52:54 14:52:57 14:53:02

A. So, the contact between the piston and the membrane? 14:53:15 14:53:19

Q. If you look at Figure 1, do you see item number 6? 14:53:22 14:53:25

A. Yep. 14:53:25

Q. Okay. The left-hand side of item number 6 is restricted on the top and on the bottom. Do you agree with that? 14:53:26 14:53:31 14:53:34

A. So, like at leader 34? 14:53:35

Q. Yes, sir. 14:53:42

A. Okay. 14:53:43

Q. Do you agree it's restricted on the top and on the bottom? 14:53:44 14:53:46

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A. It's held between piece 45 and piece 11, it looks like, at item 34. 14:53:46 14:53:52

Q. Okay. And in the middle, the flexible membrane is prevented from going downward by item number 3, correct? 14:53:54 14:53:57 14:54:01

A. Well, item 3 also moved down. 14:54:06

Q. Wasn't my question, sir. 14:54:08

A. Okay. 14:54:08

Q. Do you agree that item number 3 is in contact with a portion of the bottom of flexible membrane 6? 14:54:16 14:54:20

A. Yes. 14:54:23

Q. Okay. Now, do you see the areas that I'll just say in Figure 3 were labeled number 24, but in Figure 1, have no label. Do you see that? On the left and on the right? 14:54:23 14:54:27 14:54:32 14:54:38

A. The area labeled as 24, the part that we couldn't figure out what it was? So you're saying the volume or what appears to be maybe a volume, an annular part around 3 -- 14:54:43 14:54:47 14:54:55 14:54:59

(Simultaneously speaking) 14:55:02

A. -- part 11? 14:55:04

MR. PHILBIN: Ms. Becraft, will you pull up Exhibit 13? 14:55:08 14:55:10

(Exhibit No. 13 marked) 14:55:12

MR. PHILBIN: Go to the top and bottom. 14:55:21

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It's showing all of Exhibit 13. Exhibit 13 is one page. 14:55:24
Q. (BY MR. PHILBIN) Do you see all that, sir? 14:55:25
A. Okay. 14:55:26
Q. What's the yellow portion of Exhibit 13? 14:55:27
A. I would generally consider it -- from the looks of it, it looks like it would be an open area. 14:55:30 14:55:35
Q. Okay. An open area is where a flexible membrane can flex, correct? 14:55:40 14:55:43
MR. HERMAN: Objection, form. 14:55:45
A. It depends on the forces that are reacting against it. 14:55:53 14:55:55
Q. (BY MR. PHILBIN) Okay. Let me give you an example. If I've got a plate that's solid on the top and a plate that's got a hole in it on the bottom and I've got a balloon in the middle and I press those two plates together, where's the balloon going to go? 14:55:56 14:55:57 14:56:02 14:56:05 14:56:07
A. It's going to get spread out and push through the hole in this hypothetical. 14:56:10 14:56:13
Q. Why would it get pushed through the hole? 14:56:16
A. The -- you're trying to balance the tension in the balloon with the pressure inside of the balloon as you push those plates together. 14:56:19 14:56:24 14:56:27
Q. And in my example on Exhibit 13, the yellow area on the left and right next to 10 and 5 numbers is the area in which a flexible membrane can flex much like the 14:56:30 14:56:34 14:56:40

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hole in the plate, correct? 14:56:44
MR. HERMAN: Objection, form. 14:56:46
A. So -- but I don't know how large in diameter 14:56:48
piston 3 is versus the diameter inside of 11 which is 14:56:55
the unsupported edge of the membrane, so I don't know 14:57:02
how big that gap is. 14:57:07
Q. (BY MR. PHILBIN) That wasn't my question, sir. 14:57:09
MR. PHILBIN: Objection, nonresponsive. 14:57:11
A. Okay. 14:57:12
Q. (BY MR. PHILBIN) My question is: The flexible 14:57:12
membrane 6 can flex into the yellow area of Exhibit 13, 14:57:14
correct? 14:57:18
MR. HERMAN: Objection, form. Also asked 14:57:18
and answered. 14:57:19
A. I don't know how much the flex into that yellow 14:57:24
area is without doing the detailed design of the contact 14:57:26
between membrane 6; what the material of membrane 6 is; 14:57:30
what the thickness of the material 6 is; what the size 14:57:35
of the volume of the yellow is; the diameter of piston 14:57:38
11; the inside diameter on piston 13. I can't that 14:57:43
analysis yet. 14:57:49
Q. (BY MR. PHILBIN) You would agree that if 14:57:50
flexible membrane 6 were going to flex anywhere, it 14:57:51
would flex in the yellow area of Exhibit 13, correct? 14:57:54
MR. HERMAN: Objection, form. 14:57:57

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A. So, if the -- this is -- it depends on how 6 is supported at 34 and the thickness of the material and the applied loads in it. Take it to the other extreme, if the pressure above membrane 6 is very high compared to the forces resisting it at piston 3, just like a balloon, it's going to try to minimize its surface tension effect, balancing the pressure, and it's going to become -- it could become an arched shape instead of bulging into that yellow area if it's, you know, essentially held at -- at 34 so that it doesn't have bending at that interface. 14:58:06 14:58:14 14:58:19 14:58:23 14:58:28 14:58:32 14:58:36 14:58:40 14:58:44 14:58:46 14:58:53

So, without picking the design details of what 6 really means, what its -- its conditions are, its thickness, its material, the loading on it, I can't tell you what that shape is yet. Again, that would be something that we did during the design process. Analyze that contact. That's -- that's normal stuff. 14:58:56 14:58:59 14:59:07 14:59:09 14:59:21 14:59:25

Q. (BY MR. PHILBIN) In 1999, what were the disadvantages in using a diaphragm in a fuel injector? 14:59:51 14:59:53

A. Again, I haven't determined what exactly -- I think that was a diaphragm that would be used inside of an injector, particularly, because I haven't necessarily had to deal with that in this case yet, and I think the disadvantages and advantages could both be a large number of things. 14:59:57 15:00:06 15:00:08 15:00:12 15:00:19 15:00:23

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Q. In 1999, what were the disadvantages of using a flexible membrane in a fuel injector? 15:00:24 15:00:31

A. Same answer. I haven't determined what that flexible membrane means in terms of its definition; what it would be made out of, all of these conditions that would be design choices as I went along. 15:00:32 15:00:36 15:00:42 15:00:46

Q. In 1999, would complicated mechanical balancing be a disadvantage of using a flexible membrane in a fuel injector? 15:00:49 15:00:52 15:00:57

MR. HERMAN: Objection, form. 15:00:57

A. Without context of what this complicated mechanical -- what did you call it? A complicated mechanical coupling? 15:00:58 15:01:07 15:01:10

Q. (BY MR. PHILBIN) Balancing. 15:01:12

A. Balancing. What that specifically was, I can't tell you if that would be an issue. 15:01:14 15:01:16

Q. Would risk of rupture of the membrane be a disadvantage in using a flexible membrane in a fuel injector in 1999? 15:01:19 15:01:26 15:01:27

A. If you're trying to build a prototype -- or a production type injector, you would surely go through the design process to minimize the chance of rupturing this membrane, but it's always a possibility. 15:01:29 15:01:37 15:01:39 15:01:43

Q. So is that a disadvantage? 15:01:48

A. Well, likely, the injector wouldn't work if you 15:01:50

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ruptured that. 15:01:55

Q. In 1999, was low efficiency of membranes a 15:01:59
disadvantage of using a flexible membrane in a fuel 15:02:02
injector? 15:02:07

A. Again, I would have to look at the specifics by 15:02:07
(noise interference) absorbs energy as -- as it flexes, 15:02:13
that could be an advantage or disadvantage. 15:02:17

THE COURT REPORTER: I'm sorry. This is the court reporter. I hate to interrupt but -- it hasn't happened too many times, but there's some pages shuffling that I'm able to hear when the witness is answering that sometimes interferes with his answer.

MR. PHILBIN: Oh, I'm sorry.

THE COURT REPORTER: Like that just now.

(Simultaneously speaking)

THE COURT REPORTER: Yeah. Sorry. 15:02:51

Q. (BY MR. PHILBIN) Did you rely upon United States 15:02:51
Patent number 6, 295, 969 to Kato in formulating your 15:02:54
opinions in this case? 15:03:01

A. I don't believe so. 15:03:02

Q. Would you look at paragraph 152 of your 15:03:21
declaration, Exhibit 1, please? Do you see paragraph 15:03:24
152 on page 37? 15:03:37

A. I do. 15:03:38

Q. Do you see you cite to Exhibit 1008? 15:03:38

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A. Yes, I do. 15:03:41
Q. What is Exhibit 1008? 15:03:41
A. Kato. I thought you said takato (phonetic). 15:03:45
Sorry. 15:03:58
Q. That's where I read the patent number. 15:03:58
A. Okay. 15:04:00
Q. So let's go back. Did you rely upon United 15:04:01
States Patent No. 6, 295, 969 to Kato in formulating 15:04:04
your opinions in this case? 15:04:07
A. I did use that document. 15:04:11
Q. And did you use Kato as prior art? 15:04:12
A. I did. 15:04:18
Q. In your opinion, is Kato prior art? 15:04:18
A. Let me see. So, I think I misspoke. I maybe 15:04:20
used it as a reference to demonstrate something here. 15:04:49
It may not be prior art as it is -- looks like it has a 15:04:53
filing date of November 15th, 1999. 15:04:59
MR. PHILBIN: Objection, nonresponsive. 15:05:08
Q. (BY MR. PHILBIN) In your opinion, is Kato prior 15:05:09
art? 15:05:10
MR. HERMAN: Objection, form. Also asked 15:05:11
and answered. 15:05:13
A. So, I think that this would be up to lawyers to 15:05:17
decide specifically whether it was prior art or not, but 15:05:19
it appears to me that it may not be. 15:05:23

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Q. (BY MR. PHILBIN) Is it your opinion that Klugl's hydraulic fluid in chamber 5 will not flow up because of throttle 10? 15:05:54 15:05:56 15:06:00

MR. HERMAN: Objection, form. 15:06:03

Q. (BY MR. PHILBIN) I'm sorry. What did you say? 15:06:11

A. I believe he said he had an objection. 15:06:19

Q. Oh, got it. 15:06:21

A. So, we'd have to talk about which figure we're talking about and during actuation or not during actuation. 15:06:22 15:06:29 15:06:33

Q. Does throttle 10 perform differently between Figure 1 and Figure 3 in Klugl? 15:06:34 15:06:36

A. I believe it performs a similar function. 15:07:05

Q. Is it the same function between the embodiment disclosed in Figure 1 and Figure 3? 15:07:06 15:07:10

MR. HERMAN: Objection, form. 15:07:12

A. So, whether everything behaves exactly the same or not, I think it performs a similar function. 15:07:17 15:07:20

Q. (BY MR. PHILBIN) Does Klugl disclose any distinction between the throttle 10 between Figure 1 and Figure 3? 15:07:24 15:07:26 15:07:29

A. Not that I see offhand. If you think there is, you can let me know where you think that is and we can discuss it. 15:08:38 15:08:41 15:08:43

Q. What does it mean for the throttle to be 15:08:44

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dimensioned in relation to the transmission medium? 15:08:46

A. So, I'm pretty sure that that's from a 15:08:51

specification. Can you point me to a line? So it looks 15:08:54

like column four, line 18. 15:09:05

Q. I'm looking at column four, line 11, but -- 15:09:10

A. Okay. Yeah. 15:09:12

Q. Do you know what that means? 15:09:14

A. So, again, this comes back to the idea that 15:09:22

during injection or during actuation of this valve, that 15:09:28

throttle 10 prevents fluid flow from above -- let's 15:09:34

see -- from -- I believe it's region five to region 15:09:42

seven, and -- whereas during the dwell time between 15:09:49

actuations, there is significant time for significant 15:09:55

flow to take place. 15:09:59

And if you change -- to specifically answer your 15:10:05

question, if you change fluid from something that's -- 15:10:08

has very low viscosity to something that has very high 15:10:12

viscosity, you may have to change the size of that hole 15:10:17

so that those proportions are right; the lack of flow 15:10:19

during the short period of time and a significant enough 15:10:23

flow over a long period of time for the injector to 15:10:27

behave how it's disclosed here. 15:10:32

Q. The dimensioning is such that the throttle 15:10:37

prevents fluid from flowing upward out of the chamber 15:10:43

that is just above flexible membrane 6, correct? 15:10:51

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A. Yeah. I think that's labeled 5, the pressure chamber. 15:10:55 15:10:58

Q. So if we've got pressure from above on chamber 5 and the fluid cannot go upward, then the only place for the fluid to go is downward against the item 3 or into the open areas on each side of item 3, correct? 15:11:00 15:11:07 15:11:10 15:11:17

MR. HERMAN: Objection, form. 15:11:22

A. Again, it depends on the thickness of the membrane, the material of the membrane, the forces acting on it, and the interface with the membrane with piston 3 in this case, right? We have to know the details of how those things interact to understand what happens to the fluid. 3 is moving down. 15:11:28 15:11:29 15:11:32 15:11:37 15:11:40 15:11:43

If the -- you know, hydraulic forces pushing on the membrane are high and that thing acts very stiff because of it, then when it pushes on 3, 3 will just move rather than maybe changing the shape of 3 -- of membrane 6. 15:11:48 15:11:51 15:11:58 15:12:00 15:12:05

Q. (BY MR. PHILBIN) Klugl discloses that no fluid flows upward through throttle 10, correct? 15:12:09 15:12:12

A. During actuation that flow is limited, yes. 15:12:17

Q. Correct. But Klugl does not disclose that the fluid does not flow any place in a downward direction, does it? 15:12:23 15:12:25 15:12:29

MR. HERMAN: Objection, form. 15:12:31

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A. Where would it go downwards? 15:12:36

Q. (BY MR. PHILBIN) In the open areas that I showed on -- in yellow in Exhibit 13 that you said was a gap or a void. 15:12:38 15:12:40 15:12:43

A. So, again, whether the membrane moved into those areas or not would depend on the thickness of the membrane, the material of the membrane, and the pressure that's developed within that chamber 6 -- excuse me -- 5. 15:12:46 15:12:51 15:12:55 15:12:56 15:13:00

Q. And the only reason that the membrane would not flex into the open air in the yellow of Exhibit 13 is if the flexible membrane 6 were not flexible, correct? 15:13:03 15:13:05 15:13:10

MR. HERMAN: Objection, form. 15:13:13

A. It could flex under different loads, but maybe at the time that you're actuating it -- again, if the pressure is very high, that thing is held very firmly because of the support of the high pressure behind it, and depending on the design of the interface with piston 3, it may flex or it may not flex very much at all or any. 15:13:19 15:13:22 15:13:26 15:13:31 15:13:34 15:13:39 15:13:45

Q. (BY MR. PHILBIN) In your demonstrative on page 54 of Exhibit No. 1, you purport to show that hydraulic fluid is contained in cylinders, correct? 15:13:51 15:13:53 15:13:58

A. I would say the demonstrative shows a two-dimensional representation of that, not in 15:14:06 15:14:09

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cylinders. 15:14:12

Q. Did you -- strike that. 15:14:21

What are the sides of your demonstrative on page 54 of Exhibit No. 1 made of? 15:14:22 15:14:27

A. Again, this isn't a device. This is to demonstrate the difference in the changing of an area and how the fluid could react to that. 15:14:28 15:14:31 15:14:40

Q. And your diagrams on page 54 assume an inflexible membrane at the bottom of the cylinder of larger diameter as reflected in paragraph 227, correct? 15:14:43 15:14:47 15:14:51

MR. HERMAN: Objection, form. 15:14:54

A. This is a much more general figure than that. There's no diaphragms in here. There's nothing. It's purely looking at the area change between the upper purple part and the green part at the bottom and showing how you could get different, essentially, extensions through a hydraulic process. 15:14:58 15:14:59 15:15:03 15:15:08 15:15:12 15:15:18

Q. (BY MR. PHILBIN) Does the word "diaphragm" have a special meaning in the automotive arts? 15:15:20 15:15:23

A. I haven't specifically studied that word. 15:15:26

Q. If the Klugl reference used the word diaphragm instead of membrane, would it change any of your opinions? 15:15:30 15:15:34 15:15:36

A. I haven't, again, worried about what the formal definition of a membrane versus a diaphragm is and, you 15:15:38 15:15:43

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know -- so, in my opinion, I think that if you replaced all those words one place and another, I think a person of the ordinary skill in the art would understand that it could mean a different material or it could mean the same material, and they would be able to figure that out. 15:15:49 15:15:57 15:16:01 15:16:04 15:16:06 15:16:11

Q. Does diaphragm have a different meaning to you than membrane? 15:16:12 15:16:15

A. To me personally? I haven't formed a formal opinion. 15:16:17 15:16:22

Q. When you say a "formal opinion," are you saying a paid opinion? 15:16:23 15:16:29

A. I'm saying, like, have I sat down and gone through the careful analysis of those two words and define what they mean to me, whether paid or not, I don't think has any pertinence on it. I haven't taken the time to fully examine those two words and compared them. 15:16:31 15:16:31 15:16:36 15:16:39 15:16:41 15:16:46

Q. Are the statements made in your declarations one and two formal opinions as you used that term today? 15:16:48 15:16:51

A. I think they're -- I have presented formal opinions in that document, yes, and they're -- I have thought through the process. I have thought about what these things mean and done my due diligence to understand the different components and present them in 15:16:54 15:17:01 15:17:05 15:17:09 15:17:13

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a fair and meaningful way. 15:17:18

Q. In Klugl Figure 1, does chamber 5 change dimension over time? 15:17:25 15:17:30

A. It could depending on where in thermal expansion, but not necessarily. 15:17:44 15:17:49

Q. Is the fuel injector in Figure 1 of Klugl designed to accommodate the change in dimension in chamber 5 over time? 15:17:53 15:17:56 15:18:00

A. I would say yes. 15:18:06

Q. The membrane 6 in Figure 1 of Klugl designed to flex inwardly and outwardly over time, correct? 15:18:07 15:18:10

MR. HERMAN: Objection, form. 15:18:13

A. Whether it's inward or outward, I can't -- I can't tell you. It's -- the idea is that when you go through the design process, that you ensure that, say, a membrane 6 stays in contact with member 3, the piston-like component. 15:18:17 15:18:19 15:18:23 15:18:29 15:18:36

Q. (BY MR. PHILBIN) Would it also stay in contact with chamber 5? 15:18:42 15:18:43

A. Well, it's -- forms the wall, the containing part of volume 5. 15:18:44 15:18:56

Q. So no matter what the distance is between item 3 and item 5, flexible membrane 6 is designed to remain in contact with both those items, correct? 15:19:00 15:19:04 15:19:08

A. Well, so, I think it's not a clear question 15:19:12

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because the distance between piece 3 and a volume 5, I don't think are well defined. If you mean the upper wall of 5 -- or what do you mean exactly? 15:19:16 15:19:25 15:19:29

Q. Lower wall of 5 where it touches 6. 15:19:35

A. So that's just the upper surface of the membrane? 15:19:37

Q. No. The upper surface of the membrane would touch the lower surface of 5 and the bottom surface of the membrane would touch item 3, and no matter how much that distance varied over time, that membrane would continue to fill that gap, correct? 15:19:43 15:19:46 15:19:49 15:19:52 15:19:55

A. Again, I don't know the -- necessarily the details of the contact between 3 and 6, but there -- you know, the intent is that we keep it in contact whether that's the -- you know, so, at one point, maybe so, but across the whole surface of 3, I don't know. I don't know what the shape of 3 is on top. It's a design choice. 15:20:01 15:20:04 15:20:13 15:20:16 15:20:21 15:20:24 15:20:30

Q. Are you finished? 15:20:30

A. Yes. 15:20:35

Q. As membrane 6 flexes over time, would you expect it to lose rigidity? 15:20:35 15:20:38

MR. HERMAN: Objection, form. 15:20:42

A. Seeing as how I haven't done the design process to go through and decide what 6 is made out of and what its material is, I don't know. 15:20:44 15:20:47 15:20:50

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Q. (BY MR. PHILBIN) Is membrane 6 prone to leaks over time? 15:20:52 15:20:55

MR. HERMAN: Objection, form. 15:20:55

A. Same answer. 15:20:59

Q. (BY MR. PHILBIN) Is it your opinion that Klugl's transmission module 2 is a piston? 15:21:00 15:21:15

A. I don't think that I would necessarily require it to be a piston. Maybe it's shaped like a piston, but its main function is to transit loads from the actuator 1 downwards in the stack and maybe to hold membrane 8 in location. And as long as the component (noise interference) requirements, I don't particularly care what shape it is at this point. 15:21:43 15:21:44 15:21:47 15:21:50 15:21:56 15:22:01 15:22:04

Q. Is Klugl's glide -- guide sleeve 11 a hydraulic cylinder? 15:22:10 15:22:14

A. Again, I don't know I would define hydraulic cylinder as anything specific. Is it likely cylindrical shaped and have pistons on it that can slide in a bore? Sure. That is one representation that is possible of that device. 15:22:19 15:22:26 15:22:31 15:22:36 15:22:39

Q. Does the transmission medium in Klugl form any layer between guide sleeve 11 in transmission module 2? 15:22:43 15:22:48

MR. HERMAN: Objection, form. 15:22:55

A. Again, I think that comes down to the details of what you do, say, in chamber 9 and the ceiling location 15:22:57 15:23:07

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between 2 and 11 and 2 in the membrane, and the membrane in 45. I can imagine that there are cases where that would or would not be, you know, have the same fluid in it as the transmission fluid. 15:23:14 15:23:18 15:23:25 15:23:30

Q. (BY MR. PHILBIN) I guess I'm not asking for your imagination. I'm asking: Does the transmission medium in Klugl form any layer between guide sleeve 11 and transmission module 2? 15:23:40 15:23:42 15:23:45 15:23:50

MR. HERMAN: Objection, form. 15:23:53

A. Well, so what Klugl teaches is a way of doing this. The details of actually doing that aren't in Klugl. That would be through -- again, through the design process. So, I can imagine a design where that is and I can imagine that there is a design where that is not. 15:23:54 15:23:59 15:24:04 15:24:06 15:24:11 15:24:14

Q. (BY MR. PHILBIN) And your imagination is based on 2024, not your experience in 1999, correct? 15:24:22 15:24:24

MR. HERMAN: Objection, form. 15:24:27

A. I'm trying to put myself as a person of ordinary skill at the time of filing of this, and think about what design options I would have of how to fit part two and part 11 in there and clamp membrane 8 in there. Those are all normal day-to-day design operations that a diesel fuel designer would do regardless -- 15:24:30 15:24:36 15:24:40 15:24:44 15:24:50 15:24:55

MR. PHILBIN: Objection, nonresponsive. 15:25:02

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Q. (BY MR. PHILBIN) How many cycles would you expect a fuel injector to be able to perform over its lifetime? 15:25:03 15:25:05 15:25:09

A. Depends on whether it's a prototype or a production or -- and whether it's on a train or an automotive -- automobile. There's -- probably could be a lot of difference. 15:25:11 15:25:16 15:25:21 15:25:28

Q. How many cycles would you expect a fuel injector for commercial use in an automobile to be able to perform over its lifetime? 15:25:30 15:25:33 15:25:37

A. Again, I think it would depend on whether it's a prototype or production. 15:25:39 15:25:43

Q. I believe I answered that question. It's production. 15:25:46 15:25:48

A. Production? 15:25:48

Q. In commercial -- 15:25:49

(Simultaneously speaking) 15:25:51

A. So, in a commercial automobile, production, you know, millions of cycles or tens of millions of cycles. 15:25:51 15:25:55

Q. (BY MR. PHILBIN) How would you design a membrane to last tens of millions of cycles? 15:26:01 15:26:05

A. Again, it depends on how much the membrane has to -- a membrane or a diaphragm or whatever you want to call it has to move, the loads that are going through it, the thickness that you pick, the material you pick, 15:26:07 15:26:14 15:26:17 15:26:21

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so I would go through that operation. I would think about what kind of materials I have available to me, what kind of loads there are. If I take, for example, membrane 6, it looks like just about as simple a membrane as you could come up with, right? It's flat and there's nothing very exciting to it. 15:26:25 15:26:29 15:26:33 15:26:37 15:26:42 15:26:45

The amount of adjustment that it's going to take into account might be on the order of microns, so I can't imagine that the design of that membrane would be the most difficult membrane design taking place in 1999. 15:26:49 15:26:55 15:26:57 15:27:04

Q. Would you look at Klugl column seven, line 60- -- the last line. 15:27:29 15:27:37

A. The last line before the claims? 15:27:41

Q. No. Claims -- last line of the column, "a first flexible element 6." Do you see that? 15:27:43 15:27:47

A. Klugl, column seven? 15:27:50

Q. Yes, sir. Last line, line 69. 15:27:58

A. Limited by a first flexible element 6. Okay. Yes. 15:28:02 15:28:05

Q. Which embodiment in Figure 1, 2, or 3 does column seven, line 69, first flexible element 6 refer to? 15:28:06 15:28:12

MR. HERMAN: Objection, form. Also outside the scope of direct. 15:28:17 15:28:19

A. It does not specify which embodiment that word -- that it's speaking about, it seems like. 15:28:35 15:28:40

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Q. (BY MR. PHILBIN) Look at column 28, line 25. You see the first flexible element 6? 15:28:44 15:28:46

A. Yes. 15:28:48

Q. Does that apply to Figure 1, Figure 2, Figure 3 or some combination thereof? 15:28:52 15:28:55

MR. HERMAN: Objection, form. 15:28:57

A. It does not seem to differentiate at first look between which figure it's referring to. 15:29:28 15:29:33

Q. (BY MR. PHILBIN) If you look at column eight, line 47, a first flexible membrane 6, does that apply to Figure 1, Figure 2 or some combination thereof? 15:29:40 15:29:42 15:29:45

A. I don't see that it refers to a specific embodiment. 15:30:11 15:30:17

Q. Would you look at column nine, line eight, a first flexible membrane 6? Does that apply -- column nine, line eight, a first flexible membrane 6. Does that apply to Figure 1, Figure 2, or Figure 3, or some combination thereof? 15:30:19 15:30:24 15:30:29 15:30:31 15:30:36

MR. HERMAN: Objection, form. 15:30:37

A. Again, it doesn't seem to and probably shouldn't apply to a specific embodiment. 15:30:47 15:30:51

Q. (BY MR. PHILBIN) Why do you mean that? 15:30:57

A. The embodiments are just ways of doing it. The claims are what they are. 15:30:59 15:31:02

Q. Look at column nine, lines 31 and 32, first 15:31:06

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flexible element 6. Does that apply to Figures 1, 2, 3 and the embodiments disclosed therein or some combination thereof? 15:31:10 15:31:16 15:31:20

A. Again, this is just referring to a method by which this is used, not a specific embodiment. 15:31:41 15:31:43

Q. So in all your analysis of Klugl, you haven't determined if the embodiment shown in Figures 1, 2 or 3 apply to any one of the claims, correct? 15:31:50 15:31:55 15:32:00

MR. HERMAN: Objection, form. 15:32:04

A. So, this being prior art, I'm dating the whole document as what a POSITA would be able to understand at the time. They could take this document, read the whole document, learn from the whole document and take that as a complete set, so anything that's in the specification, whether or not it's for -- relates to a specific claim within this patent is still something they could learn from reading this -- this document. 15:32:05 15:32:14 15:32:16 15:32:19 15:32:23 15:32:29 15:32:36 15:32:39

MR. PHILBIN: Objection, nonresponsive. 15:32:43

Q. (BY MR. PHILBIN) Sir, I didn't ask you why you didn't do the analysis. I simply asked you, did you or did you not figure out which claim applies to which embodiment shown in which figure? Is the answer you didn't do it? I take it, you just gave me the reason why not. 15:32:44 15:32:46 15:32:50 15:32:53 15:32:56 15:33:02

MR. HERMAN: Objection, form. Also highly 15:33:02

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argumentive. 15:33:04

A. So that wasn't my intent in the analysis. My intent of the analysis was to go through the document and understand what a POSITA would -- understood at the time. 15:33:04 15:33:09 15:33:11 15:33:16

MR. PHILBIN: Objection, nonresponsive. 15:33:16

Q. (BY MR. PHILBIN) I didn't ask about your intent. I asked, did you perform the analysis or not? 15:33:19 15:33:19

MR. HERMAN: Objection, form. Also asked and answered. 15:33:24 15:33:25

A. This -- I did an analysis of the entire document and took that all into account. So whether I compared this to that and matched everything up, I was taking the document as a whole and seeing what I could learn about this time period. 15:33:33 15:33:39 15:33:45 15:33:47 15:33:51

MR. PHILBIN: All right. Let's take a 10-minute break. 15:33:53 15:33:55

THE VIDEOGRAPHER: All right. We are going off the record at 15:33. 15:33:55 15:33:57

(Off the record at 3:33 p.m.) 15:34:00

(Back on the record at 3:43 p.m.) 15:43:13

THE VIDEOGRAPHER: We are back on the record at 15:43. 15:43:13 15:43:14

MR. PHILBIN: Pass the witness. 15:43:17

THE WITNESS: Say again? 15:43:22

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MR. HERMAN: He passed the witness. And I don't have any further questions. So with that, I think we're done. 15:43:22 15:43:26 15:43:29

THE VIDEOGRAPHER: All right. Should I read us off the video record, then? 15:43:38 15:43:38

(Simultaneously speaking) 15:43:38

THE COURT REPORTER: Yes. Before we go off the record, Mr. Herman, will you be requesting a copy of today's transcript? 15:43:38 15:43:38 15:43:42

THE VIDEOGRAPHER: If it's okay, I would take us off the video before we do orders if that's okay. 15:43:42 15:43:43 15:43:43

MR. HERMAN: Let's do that. 15:43:43

THE VIDEOGRAPHER: Okay. We are going off -- sorry. This marks the end of the video deposition of Dr. J. Matt Quinlan. We are going off the record at 15:43. 15:43:43 15:43:51 15:43:54 15:43:56

(Deposition concluded at 3:43 p.m.)

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CHANGES AND SIGNATURE

WITNESS NAME: DR. J. MATT QUINLAN DATE: 04/19/2024

PAGE/LINE	CORRECTION	REASON FOR CHANGE

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I, DR. J. MATT QUINLAN, have read the foregoing deposition and hereby affix my signature that same is true and correct, except as noted above.

_____
DR. J. MATT QUINLAN

THE STATE OF _____)
COUNTY OF _____)

Before me, _____, on this day personally appeared DR. J. MATT QUINLAN known to me (or proved to me under oath of through _____) (description of identity card or other document) to be the person whose name is subscribed to the foregoing instrument and acknowledged to me that they executed the same for the purposes and consideration therein expressed.

Given under my hand and seal of office this _____ day of _____, _____.

_____
NOTARY PUBLIC IN AND FOR
THE STATE OF _____

My Commission Expires: _____

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COURT REPORTER CERTIFICATE

I, Karen Kolohe, Certified Reporter within and for the State of Texas do hereby certify:

That Dr. J. Matt Quinlan, 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 adverse party, Petitioners, was represented by counsel at the Deposition.

I further certify that the deposition of Dr. J. Matt Quinlan, occurred via Zoom Videoconference on Friday, April 19th, 2024 commencing at 10:04 a.m. to 3:43 p.m.

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 any of the parties to this action, and that I am in no way interested, financially or otherwise, in the outcome Of this matter.

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IN WITNESS WHEREOF, I have hereunto set my hand this 21st day of April, 2024.



_____

Karen G. Kolohe, TEXAS CSR NO. 8776

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ROBERT BOSCH LLC, and
MERCEDES-BENZ USA LLC,
Petitioners,
v.
WESTPORT FUEL SYSTEMS CANADA INC.,
Patent Owner.

U.S. Patent No. 6,298,829
Case No. IPR2023-00292

DECLARATION OF DR. J. MATT QUINLAN





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I, Dr. J. Matt Quinlan, declare as follows:

I. INTRODUCTION

1. I have been retained by Robert Bosch Corp. ("Robert Bosch") as an independent expert consultant in this proceeding before the United States Patent and Trademark Office ("PTO"). I am not an employee of Bosch or any affiliate or subsidiary of Robert Bosch or any of the other petitioners or real parties-in-interest in this petition.

2. I have been asked to consider whether certain references teach or suggest the features recited in certain claims of U.S. Patent No. 6,298,829 B1 to Welch et al., which I refer to herein as the '829 patent.

3. My opinions and the bases for my opinions are set forth below.

4. I am being compensated at my ordinary and customary rate of $400 per hour for my work, plus reimbursement for any reasonable expenses. My compensation is based solely on the amount of time that I devote to activity related to this case and is in no way contingent on the nature of my findings, the presentation of my findings in testimony, or the outcome of this or any other proceeding. I have no other financial interest in this proceeding.

II. EDUCATION BACKGROUND, PROFESSIONAL EXPERIENCE, AND OTHER QUALIFICATIONS

5. My curriculum vitae ("CV") is attached hereto as Attachment A and provides an accurate identification of my background and experience.

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6. I am currently an assistant professor in the Mechanical and Aerospace Engineering department at the University of Colorado, Colorado Springs ("UCCS"). I am also the Director of UCCS's Combustion and Acoustics Lab.

7. I received a B.S. in mechanical engineering from Colorado State University in 2001.

8. From 2001 to 2006, I worked as a fuel systems engineer at Sturman Industries. My responsibilities included the development, testing, design, analysis, and customer interface/installation of diesel fuel injectors.

9. Starting in 2006, I returned to Colorado State University to continue my studies. I received a M.S. in mechanical engineering in 2009.

10. Starting in 2009, I attended the Georgia Institute of Technology. While there, I served as a Graduate Research Assistant and Research Engineer, focusing on combustion instability in liquid propellant rocket engines and the remote measurement of rocket engine chamber pressure dynamics.

11. I received a Ph.D. in aerospace engineering from the Georgia Institute of Technology in 2015.

12. From 2005 to the present, I also worked as a consultant engineer for my own consulting firm, known as Quinlan Engineering and Design, LLC. I engage in engineering design, development, and analysis in fuel systems.

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13. I joined the faculty at UCSS in 2018 as a visiting assistant professor and permanently in 2019 as an assistant professor.

14. I am the named inventor on a number of patents relating to automotive technology, including fuel injectors. These patents include, for example, U.S. Patent No. 7,681,592 (entitled "Three-way poppet valves with floating seat"), U.S. Patent No. 8,282,020 (entitled "Three-way valves and fuel injectors using the same"), and U.S. Patent No. 8,366,018 (entitled "Oil Intensified common rail injectors").

15. I have also co-authored papers relating to fuel injectors, including "Evaluation of a 3-Way Direct Needle Control Unit Injector on Hydraulic Test Bench and V8 Engine," SAE Technical Paper 2004-01-0024 (2004).

16. A complete list of my patents and publications is included as part of my attached CV.

III. ASSIGNMENT AND MATERIALS CONSIDERED

17. I have been asked to provide analysis and explain the subject matter of the '829 patent, including the state of the art when the '829 patent application was filed. I have also been asked to consider, analyze, and explain certain prior art to the '829 patent, including how that art relates to the challenged claims of the '829 patent and to provide my opinions regarding whether that art invalidates the claimed subject matter.

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18. The opinions expressed in this declaration are not exhaustive of opinions I may offer in the future regarding the unpatentability of the claims of the ’829 patent. Therefore, the fact that I do not address a particular point should not be understood to indicate an agreement on my part that any claim complies with the requirements of any applicable patent or other rule.

19. I reserve the right to amend and supplement this declaration in light of additional evidence, arguments, or testimony presented during this IPR or related proceedings on the ’829 patent.

20. In forming the opinions set forth in this declaration, I have considered and relied upon my education, knowledge of the relevant field, knowledge of scientific and engineering principles, and my experience. I have also reviewed and considered the ’829 patent (Exhibit 1001), its prosecution history (Exhibit 1002), and the following additional materials:

Exhibit	Description
1004	U.S. Patent No. 5,479,902 to Wirbeleit et al. (“Wirbeleit”)
1005	DE 197 08 304 A1 to Klügl (“Klügl”)
1006	Certified translation of Klügl and associated translator’s declaration
1007	U.S. Patent No. 5,735,240 B1 to Ito et al. (“Ito”)
1008	U.S. Patent No. 6,295,969 B1 to Kato et al. (“Kato”)
1009	U.S. Patent No. 5,697,554 B1 to Auwaerter et al. (“Auwaerter”)
1010	U.S. Patent No. 4,725,002 to Trachte (“Trachte”)

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1011	U.S. Patent No. 3,598,506 to O'Neill ("O'Neill")
1012	U.S. Patent No. 4,684,067 to Cotter et al. ("Cotter")
1013	EP 0 107 894 A2 to Beck et al. ("Beck")
1014	U.S. Patent No. 4,284,263 to Newcomb ("Newcomb")
1015	GB 2 318 390 A to Roessler et al. ("Roessler")
1022	Plaintiff Westport Fuel Systems Canada Inc.'s Disclosure of Asserted Claims and Infringement Contentions from *Westport Fuel Systems Canada Inc. v. Ford Motor Company,* Case No. 2:21-cv-00453 (E.D. Tex.)
1023	U.S. Patent No. 6,148,842 to Kappel et al. ("Kappel")
1024	U.S. Patent No. 5,779,149 to Hayes, Jr. ("Hayes")

IV. UNDERSTANDING OF THE LAW

21. I am not an attorney but have been instructed in and applied the law as described in this section.

22. I understand that the first step in comparing an asserted claim to the prior art is for the claim to be properly construed. I address how a person of ordinary skill in the art ("POSITA") would have understood the claims in Section VIII below.

23. I have been further instructed and understand that a patent claim is unpatentable and invalid as obvious if the subject matter of the claim as a whole would have been obvious to a POSITA of the claimed subject matter as of the time of the invention at issue. I understand that when assessing the obviousness of claimed subject matter, the following factors are evaluated: (1) the scope and content

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of the prior art; (2) the difference or differences between each claim of the patent and the prior art; and (3) the level of ordinary skill in the art at the time the patent was filed.

24. I understand that claimed subject matter may be obvious in view of more than one item of prior art. I understand, however, that it is not enough to show simply that all the limitations of the claimed subject matter are spread throughout the prior art. Instead, for claimed subject matter to be obvious over multiple references, there must be some reason or motivation for a POSITA to combine the prior art references to arrive at the claimed subject matter.

25. I have been informed that, in seeking to determine whether an invention that is a combination of known elements would have been obvious to a POSITA at the time of the invention, one must consider the references in their entirety to ascertain whether the disclosures in those references render the combination obvious to such a person.

26. I have been informed and understand that, while not required, the prior art references themselves may provide a teaching, suggestion, motivation, or reason to combine, but other times the motivation linking two or more prior art references may be supplied by common sense or the background knowledge of a POSITA at the time of the invention.

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27. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. I have been informed that, if a technique has been used to improve one device, and a POSITA would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.

28. I further understand that an obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references also may be supplied by the direction of the marketplace. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

29. I have been informed that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. Thus, where all of the elements of a claim are used in substantially the same manner, in devices in the same field of endeavor, the claim is likely obvious.

30. Additionally, I understand that a patent is likely to be invalid for obviousness if a POSITA can implement a predictable variation or if there existed

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at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims. Therefore, when a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one.

31. I further understand that combining embodiments related to each other in a single prior art reference would not ordinarily require a leap of inventiveness.

32. I also understand that a POSITA must have had a reasonable expectation of success when combining references for claimed subject matter to be obvious.

33. I have been informed and I understand that factors referred to as "objective indicia of non-obviousness" or "secondary considerations" are also to be considered when assessing obviousness when such evidence is available. I understand that these factors can include: (1) commercial success; (2) long-felt but unresolved needs; (3) copying of the invention by others in the field; (4) initial expressions of disbelief by experts in the field; (5) failure of others to solve the problem the claimed subject matter solved; and (6) unexpected results.

34. I also understand that evidence of objective indicia of non-obviousness must be commensurate in scope with the claimed subject matter. I further understand that there must be a relationship, sometimes referred to as a "nexus," between any such secondary indicia and the claimed invention.

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35. Finally, I have been informed that one cannot use hindsight to determine that an invention was obvious.

36. I provide my opinions in this declaration based on the guidelines set forth above.

V. LEVEL OF SKILL IN THE ART

37. I have been informed and understand that the level of ordinary skill in the relevant art at the time of the invention is relevant to inquiries such as the meaning of claim terms, the meaning of disclosures found in the prior art, and the reasons a POSITA may have for combining references.

38. I have been informed and understand that factors that may be considered in determining the level of ordinary skill include: (1) the education of the inventor; (2) the type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology; and (6) education level of active workers in the relevant field. I have been further informed and understand that a POSITA is also a person of ordinary creativity.

39. A POSITA in the technology field of the '829 patent would, in my opinion, have had a degree in mechanical engineering or a similar discipline, along with 2 years of professional experience working with the design and development

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of fuel injection systems for internal combustion engines or an equivalent level of skill, knowledge, and experience.

40. In my opinion, this POSITA would have been aware of and generally knowledgeable about how fuel injectors and the valves used within are structured and operate, and how they are used to deliver fuel to an engine's combustion chambers.

41. In my opinion, a POSITA would have had the same basic level of skill and background knowledge regardless of whether the '829 patent is entitled to an October 1999 or March 2000 filing date.

42. In view of my educational background (e.g., a M.S. in mechanical engineering and Ph.D. in aerospace engineering) and work experience in the fuel injector field, I am a person of more than the ordinary level of skill in the art of the '829 patent. In forming my opinion, I have drawn on my academic background and professional experiences. My opinions herein, however, were formed taking into account the perspective of an ordinarily skilled artisan.

VI. THE '829 PATENT'S EFFECTIVE FILING DATE

43. I understand that the application leading to the '829 patent was filed on March 9, 2000.

44. Based on my review of the '829 patent, I note that it also references an October 15, 1999 provisional application filing on its face.

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45. For purposes of this declaration, I have been instructed to use October 15, 1999 as the effective filing date of the ’829 patent. My opinions in this declaration were formed from the perspective of a POSITA as of October 15, 1999, including both the knowledge of a POSITA at that time as well as how a POSITA would have understood the prior art. Nevertheless, the opinions I express in this declaration would be the same regardless of whether the ’829 patent has an October 15, 1999 or a later March 9, 2000 effective filing date.

VII. THE ’829 PATENT

A. Overview

46. The ’829 patent relates to “high pressure fuel injection valves or injectors for internal combustion engines” that are “directly controllable by” a “piezoelectric or magnetostrictive” activator. (Ex. 1001, 1:12-16.)

47. According to the patent, the injector also includes a “passive hydraulic link.” (*Id.*, 1:17.)

48. The patent begins by discussing prior art fuel injectors.

49. Here, the patent explains that as of its filing, it was known to be beneficial to engage in “[d]irect injection.” Direct injection entails injection directly into the “combustion chamber of an internal combustion engine[.]” (*Id.*, 1:21-29.) The patent explains that this type of injection—in contrast to indirect injection into

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the manifold and outside of the combustion chamber—is "desirable" because it improves engine performance and reduces emissions. (*Id.*)

50. The patent also explains that "prior direct fuel injection systems" that were "hydraulically actuated," employ "solenoid actuators," or "use piezoelectric or magnetostrictive actuation" were all known and available. (*E.g.*, *id.*, 1:56-57, 2:24-27, 2:62-65.)

51. The patent goes on, however, to identify certain purported problems with these known systems.

52. For instance, hydraulically actuated systems require "additional hydraulic hardware" which adds "increased bulkiness" and subjects the system to a "delayed response" and reduced "controllability of movement of the injection valve." (*Id.*, 2:1-23.)

53. Solenoid actuators are "not suitable for" use with "high-pressure fuels." (*Id.*, 2:45-48.)

54. Further, known piezoelectric and magnetostrictive actuators were purportedly only used to "operate a control valve, which in turn controls the flow of a hydraulic fluid to operate an injection valve" resulting in delayed injector operation and increased complication. (*Id.*, 3:39-50.)

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55. After discussing these known fuel injectors, the ’829 patent proposes a “directly actuated” injector that does not include “an intermediate active hydraulic operator generating any actuating forces.” (*Id.*, 3:45-48.)

56. The ’829 patent explains that its injector does include a “passive hydraulic link.” (*Id.*, 4:20, 7:10-20.)

57. The patent explains however, that in contrast to “[c]onventional active hydraulic operators,” the passive “hydraulic link” employed by its injector “merely transmits the actuating forces” or serves as a “load path” “but is not employed to generate an actuating force for actuating the valve.” (*Id.*)

58. The patent also notes that the “passive hydraulic link” provides a “further advantage” in that it “may be employed to correct for differential thermal expansion, wear and dimensional variability within permitted manufacturing and assembly tolerances.” (*Id.*, 7:43-46.)

59. The link does this by “auto-adjusting itself in response to these effects by allowing movement of hydraulic fluid between opposite sides of [a] hydraulic piston” to “re-zero[] itself to ensure that a desired valve needle lift is maintained.” (*Id.*, 7:46-51.)

60. The below annotated versions of Figures 1 and 2 of the ’829 patent provide an example of a “directly actuated fuel injection valve 100.” (*Id.*, 8:39-41.)

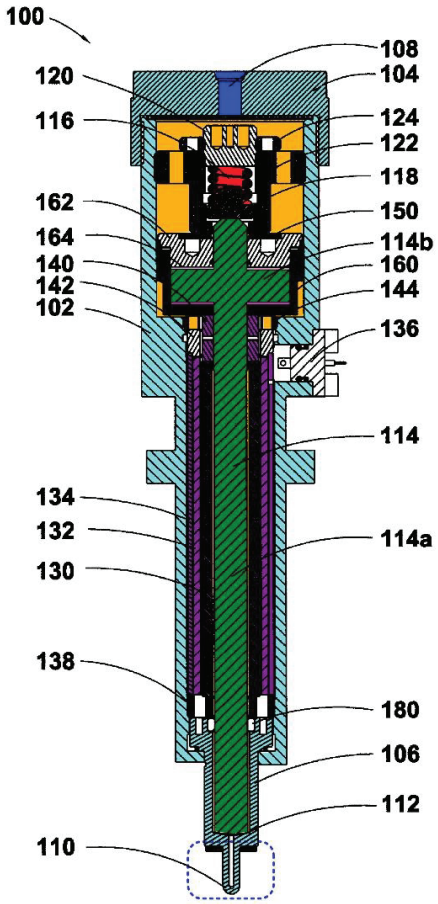


Figure 1

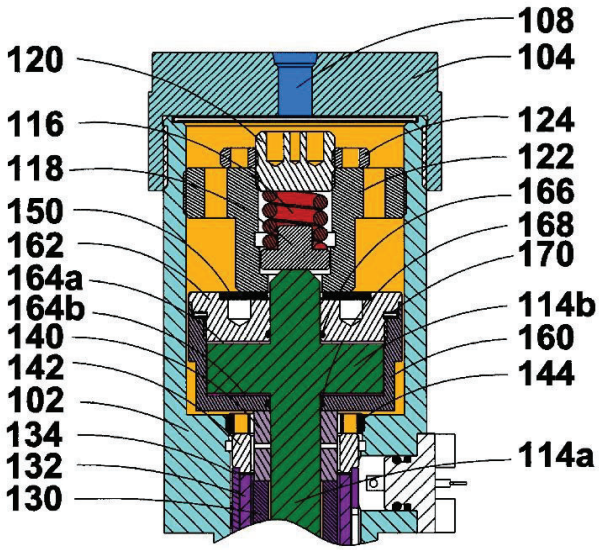


Figure 2

(*Id.*, Figs. 1-2 (annotated).)

61. The elements of this injector have been annotated as follows:

62. **Teal:** A "valve housing 102," "cap 104," and "tip 106" that "provide a fluidly sealed valve body." (*Id.*, 8:41-43.)

63. **Blue:** An "inlet port 108" (blue) allows fuel to enter the hollow injector interior (partially annotated orange). (*Id.*, 8:45-46.)

64. **Orange:** interior space within the injector that receives fuel from the inlet port. (*Id.*)

65. **Dashed blue outline:** A "valve tip 106" with a "nozzle orifice 110" "through which fuel exits" the injector. (*Id.*, 8:46-48.)

66. **Green:** A "valve needle 114" within the injector. (*Id.*, 8:59-60.) One end of the needle is located at the nozzle "seat 112," adjacent to the nozzle orifice. (*Id.*, 8:52-62.)

67. **Red:** A "needle spring 116" that is located at the end of the needle opposite the nozzle and "biases valve needle 114 in the closed position." (*Id.*, 9:16-19.)

68. **Purple:** A "magnetostrictive actuator" including a member 130, coil 132, and flux tube 134 located within the housing. (*Id.*, 9:45-49.)

69. **Pink:** "[H]ydraulic fluid 164b" of "a hydraulic link assembly." (*Id.*, 10:62-64; 12:46-51.)

70. The patent also explains how the injector operates. More particularly, to open the injector and inject fuel, current is applied to the actuator causing it to "expand" and "provide[] an opening force in opposition to the closing force of the spring assembly." (*Id.*, 9:51-10:8.)

71. "The opening force generated by the actuator assembly is transmitted to valve needle 114 through" "hydraulic fluid 164b" of "a hydraulic link assembly." (*Id.*, 10:62-64; 12:46-51.)

72. The patent also explains that the injector can auto adjust because the space containing fluid 164b is connected to another space containing fluid 164a (**light pink**) via a "narrow clearance gap between" the needle's "piston 114b and hydraulic cylinder 160." (*Id.*, 12:57-60.)

73. During actuation, fluid "does not have time to flow" through this gap and the fluid 164b instead "acts as a solid and transfers the movement of magnetostrictive member 130 to valve needle 114." (*Id.*, 12:57-66.)

74. When the injector is at "rest," however, "fluid" 164b and 164a can "redistribute itself by flowing through the clearance gap" so as to "re-zero" the piston. (*Id.*, 11:41-49.)

B. Prosecution History of the '829 Patent

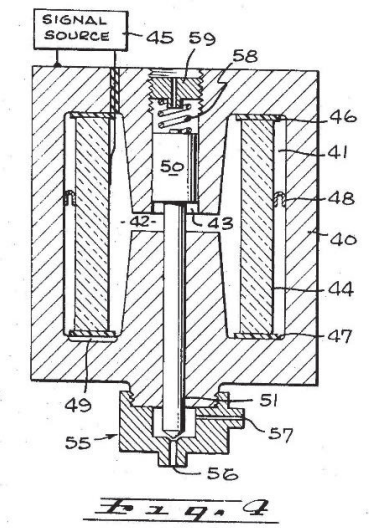
75. As noted above, I have reviewed the '829 patent's prosecution history.

76. Originally filed claims 1-20 were rejected in a March 2001 office action as anticipated by or obvious over O'Neill (Ex. 1011). (*See* Ex. 1002, p. 119-121.)

77. Claims 21-30, which either required a particular "magnetostrictive member" structure or were directed to a method, were allowed. (*See id.*, pp. 79-83 121.)

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78. In rejecting claims 1-20, the Examiner pointed to Fig. 4 of O'Neill as pertinent, which I have reproduced below for reference:



(Ex. 1011, Fig. 4.)

79. The Examiner explained that chambers 42 and 43 shown in this figure correspond to the "hydraulic link assembly" required by the pending claims. (*Id.*, p. 120.)

80. I have reviewed the O'Neill reference. In O'Neill, to open the injector, "electroexpansive material 44" expands as a result of the application of an electrical signal. This then results in fluid being pushed out of chamber 41 and the transmission of the expansive force of material 44 through the fluid stored "chamber 41," to "passage 42," to "piston cylinder 43," and finally to a "piston 50" for purposes of opening a "valve 55" to which the piston is attached. (Ex. 1011, 4:10-49.)

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81. The applicant responded to the Examiner's rejection in June 2001 by noting that "O'Neill … rel[ies] on the dynamic flow of a hydraulic fluid to actuate/open the valve." (Ex. 1002, p. 129.)

82. According to the applicant, in O'Neill, the "electroexpansive material 44 is activated to displace fluid from chamber 41 through passage 42 in piston cylinder 43 to lift piston 50 and open the valve." (*Id.*, p. 130.)

83. Because of this, the applicant characterized O'Neill's device as employing fluid flow and displacement, and not the "'passive' hydraulic link" required by the claims. (*Id.*, p. 129.) Similarly, the applicant argued that because O'Neill's "actuating fluid is displaced and flows dynamically," it "behaves as a liquid" and not "substantially as a solid while said actuator assembly is activated" as required. (*Id.*, p. 130.)

84. The claims were allowed immediately after this response. (*See id.*, p. 138.).

C. The '829 Patent's Claims

85. For reference, claims 1-3, 6, 11-12, 14-15, and 18-20 of the '829 patent are reproduced below:

> **1.** An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:
>
> (a) a valve housing comprising:

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a fuel inlet port;

an interior chamber fluidly connected to said fuel inlet port;

a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber;

(b) a valve needle disposed within said valve housing wherein said valve needle is movable between a closed position at which a sealing end of said valve needle contacts a valve seat to fluidly seal said interior chamber from said nozzle orifice, and an open position at which said sealing end of said valve needle is spaced apart from said valve seat whereby said interior chamber is fluidly connected with said nozzle orifice, wherein valve needle lift equals the distance traveled by said sealing end away from said valve seat;

(c) a needle spring associated with said valve needle, wherein said needle spring applies a closing force to said valve needle for biasing said valve needle in said closed position;

(d) an actuator assembly associated with said valve needle, wherein said actuator assembly may be activated to apply an opening force to said valve

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needle stronger than said closing force, for moving said valve needle to said open position; and

(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is activated and wherein said thickness of said hydraulic link is adjustable while said actuator is not activated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve needle lift upon activation of said actuator assembly.

2. The injection valve of claim **1** wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by differential thermal expansion.

3. The injection valve of claim **2** wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by wear to components of said injection valve.

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6. The injection valve of claim **1** wherein said actuator assembly comprises a magnetostrictive member or a piezoelectric stack.

11. The injection valve of claim **6** wherein when said actuator assembly is controllable to control said desired lift to between 10 and 100 percent of maximum lift.

12. The injection valve of claim **11** wherein said lift is controllable by controlling the electric current directed or voltage applied to said respective magnetostrictive or piezoelectric actuator assembly.

14. The injection valve of claim **6** wherein said valve needle is controllable to move between said open and closed positions in less than about 200 microseconds.

15. The injection valve of claim **6** further comprising a compression spring member for applying a compressive force to said magnetostrictive or piezoelectric member.

18. The injection valve of claim **1** wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 MPa).

19. The injection valve of claim **1** wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body.

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20. The injection valve of claim **1** wherein said valve housing, said valve needle, and said actuator assembly, are selected from materials with similar thermal expansion coefficients to reduce changes in the dimensional relationship between said components caused by changes in temperature.

VIII. CLAIM CONSTRUCTION

86. I am not a legal expert or an attorney and offer no opinions on the law. I understand that claim construction is a matter of law. I have been informed by counsel of the legal standards that apply to claim construction in an *inter partes* review, however, and I have applied them in forming my opinions. I understand that during an *inter partes* review, the same claim construction standard used in federal district court is applied when addressing the meaning of claim terms.

87. I have been informed that the words of a claim are generally given the ordinary and customary meaning that the term or phrase would have to a POSITA at the time of the invention in view of the surrounding claim language, the specification and the file history (collectively, the "intrinsic evidence" or "intrinsic record").

88. I also understand that courts may consider extrinsic evidence, such as expert and inventor testimony, dictionaries, and learned treatises (collectively, the "extrinsic evidence" or the "extrinsic record"), but that such extrinsic evidence should be given less weight than the intrinsic evidence.

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89. In my opinion, the terms of the '829 patent's claims do not require further construction and can be afforded their plain and ordinary meaning.

90. I understand that Patent Owner has alleged that the claims cover a nozzle/needle injection valve that is controlled indirectly through an intermediate pilot valve. A pilot actuated nozzle injector valve is one where the pilot valve armature acted upon by the actuator does not itself open a fluid pathway into the combustion chamber but instead only opens the pilot valve that in turn triggers other components to open the injection pathway. (See, e.g., Ex. 1022, pp. 10-11 (pointing to a "nozzle" opened by a "nozzle needle" when addressing one claim limitation, and a separate "valve needle" that opens a pilot valve when addressing another different limitation).)

91. I disagree that the claims can be properly interpreted to extend to this type of an indirectly actuated injector.

92. First, it is contrary to the claim language itself.

93. Claim 1 provides that the "valve needle"—and not some other structure—"seal[s] said interior chamber from said nozzle orifice." (Ex. 1001, claim 1.) The claim similarly provides that the "valve needle" moves to an "open position" where its "sealing end" is "spaced apart from said valve seat whereby said interior chamber is fluidly connected with said nozzle orifice." (*Id.*)

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94. Thus, the valve needle must be structured to itself seal and open the fluid path from the "interior chamber" to "nozzle orifice" and subsequently the "combustion chamber." It does not operate to simply open an intermediate valve that does not open to the combustion chamber.

95. In my opinion, the specification confirms that the '829 patent's claims require a directly actuated injector.

96. In particular, the specification repeatedly and consistently characterizes the "invention" as "an injection valve that is directly controllable." (*Id.*, 1:12-17.)

97. The specification also explains that the discussed injector meets a "need for an injector that is directly actuated." (*Id.*, 3:45-48.)

98. Further, the patent explains that it provides "advantages" and "benefits" because it is a "directly actuated injector." (*Id.*, 8:18-19; 16:18-20.)

99. Moreover, the patent contrasts its directly actuated valve with prior art valves that are indirectly actuated. (*See, e.g., id.*, 3:33-45.)

100. The '829 patent is even entitled "Directly Actuated Injection Valve." (*Id.*, Cover.)

IX. UNPATENTABILITY ANALYSIS

101. For the reasons I explain in greater detail below, it is my opinion that as of the effective filing date of the '829 patent, a POSITA would have considered

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claims 1-3, 6, 11-12, 14-15, and 18-20 of the '829 patent to be unpatentable as obvious over the prior art discussed in this declaration.

A. Overview of the Prior Art

102. The following paragraphs provide an overview of the main prior art references I discuss throughout this declaration.

1. Wirbeleit

103. Wirbeleit indicates on its face that it issued January 2, 1996. (Ex. 1004, Cover.) In view of this date of issuance, which predates the '829 patent's filing by more than a year, I understand that Wirbeleit is prior art to the '829 patent under at least 35 U.S.C. § 102(b).

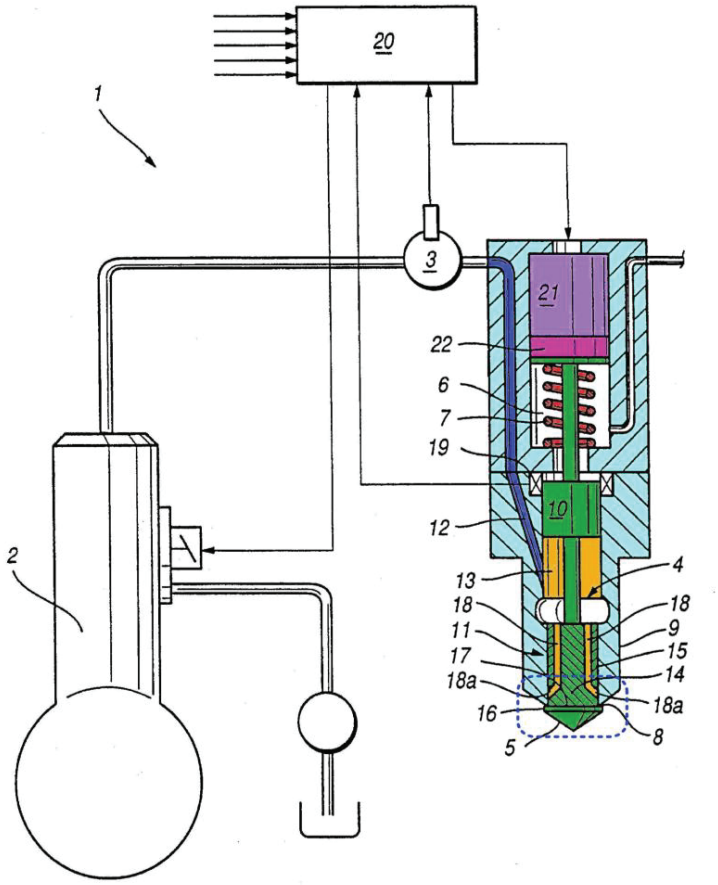
104. Wirbeleit is not cited on the face of the '829 patent. It also was not discussed or mentioned during the '829 patent's prosecution history.

105. Wirbeleit relates to a "fuel injection system for a Diesel engine." (*Id.*, 1:45-46.)

106. Wirbeleit's injector has a "control needle" with fuel injection orifices that can be "exposed to a degree controllable … depending on engine operating parameters." (*Id.*, 1:52-57.) This allows for different, controllable amounts of fuel injection. (*See id.*)

107. Wirbeleit's injector is shown in the below annotated figure:

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(*Id.*, Fig.) The below paragraphs provide additional details regarding the depicted injector's components.

108. **Teal**: The injector's outer "body 9." (*Id.*, 2:31-35.)

109. **Green**: A "control needle 5" and "piston 10." (*Id.*, 2:35-39)

110. **Blue**: A "fuel admission passage 12" (*Id.*)

111. **Orange**: A "pressure chamber 13," grooves 18, and orifices 18a inside the injector through which fuel from the admission passage passes on its way out of the end of injector (**circled blue**) into the combustion chamber. (*Id.*)

112. **Red**: A "spring 7" that forces the tip of a "control needle 5" (green) onto a "valve seat 8" to close the injector. (*Id.*)

113. **Purple**: A "piezo" or "magnetostrictive actuator 21." (*Id.*, 2:60-65.)

114. **Pink**: A "hydraulic transmission element 22" through which the force exerted by the actuator is passed to the control piston/needle for purposes of opening the injector. (*Id.*)

115. Again, Wirbeleit explains that the desired needle lift off the valve seat and the corresponding amount by which the needle's orifices are exposed "is maintained by voltage control of the actuator 21." (*Id.*, 3:1-7.)

2. Klügl

116. Klügl indicates on its face that it published September 10, 1998. (*See* Ex. 1006, Cover.) In view of this date of publication, which predates the '829 patent's filing by more than a year, I understand that Klügl is prior art to the '829 patent under at least 35 U.S.C. § 102(b).

117. Klügl is not cited on the face of the '829 patent. It also was not discussed or mentioned during the '829 patent's prosecution history.

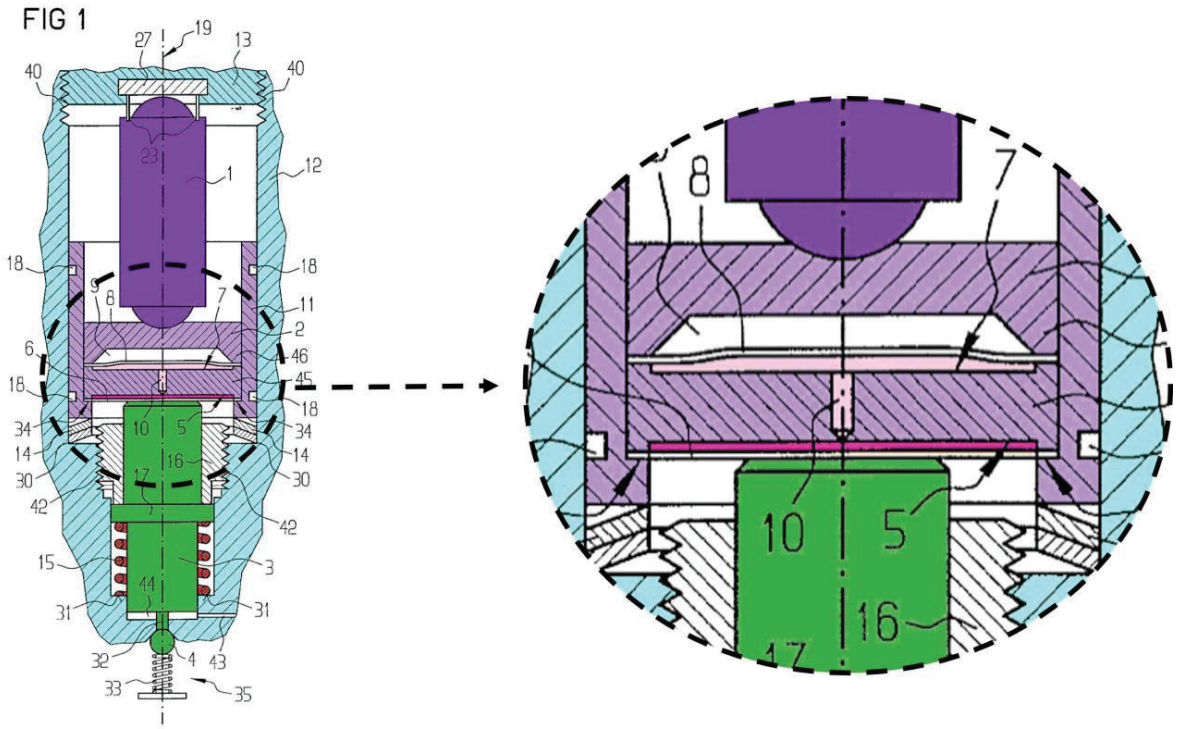
118. Klügl published in German. Throughout this declaration I will refer to and cite to a certified translation (Ex. 1006) of Klügl.

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119. Klügl related to a "power transmission device" to "transmit the movement of a piezoelectric actuator" for valve opening and closing in a fuel injector. (*Id.*, 1:7-12.)

120. Klügl explains that a chamber of hydraulic fluid within this device not only transfers this opening force, but also allows the injector to adjust for the effects of "thermal expansion differences and gradual wear." (*Id.*, 3:63-4:31.)

121. Klügl's injector is shown in the below annotated figure. The central portion of the figure has been excerpted and expanded to the right to better show the chamber of hydraulic fluid:



(*Id.*, Fig. 1.)

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122. The various injector components shown in this figure are discussed in more detail below:

123. **Teal:** The injector includes an outer "housing 12" and "upper stop 13" that surround its components. (*Id.*, 1:47-51.)

124. **Green:** A "drive piston 3"—along with connected "drive needle 32," "ball 4," and "shoulder ring 17" are located within the injector. (*Id.,* 2:35-39, 50-57.)

125. **Red:** A "spring 15" forces the "drive piston 3" (green) upwards, allowing "spring 33" to force the "drive needle 32" and "ball 4" (both also green) upwards to close the injector. (*Id.,* 2:35-39, 50-57.)

126. **Dark purple:** A "piezoelectric actuator 1" to which a signal can be applied causing it to expand for purposes of opening the injector. (*Id.*, 1:47-51.)

127. **Light purple**: A "transmission module 2" that is pressed downward towards the piston 3 by the expanding actuator. (*Id.*, 3:23-33.)

128. **Dark pink:** Force is transmitted from the actuator to the piston through incompressible hydraulic fluid "located in [a] pressure chamber 5." (*Id.*, 3:26-29.) Klügl explains that during actuation "only an insignificant amount" of hydraulic fluid flows out of chamber 5. (*Id.*, 4:11-22.) But, during idle periods, hydraulic fluid can move from chamber 5 through "throttle 10" (an orifice) to chamber 7 (**light pink**) to "automatic[ally] adjust[]" for "thermal expansion differences and gradual

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wear" and keep the "drive piston 3" in contact with "transmission module 2." (*Id.*, 3:50-4:33.) The hydraulic fluid is completely captured and contained within the transmission module. (*See id.*; Fig. 1.) There is no external fluid source. (*See id.*)

129. When the injector is actuated, the piston's ball 4 is moved off its seat causing the pressure in a "pressure chamber" to drop, an "injection needle" to open, and fuel to be injected. (*Id.*, 3:30-38.)

3. Newcomb

130. Newcomb indicates on its face that it issued August 18, 1981. (*See* Ex. 1014, Cover.) In view of this date of issuance, which predates the '829 patent's filing by more than a year, I understand that Newcomb is prior art to the '829 patent under at least 35 U.S.C. § 102(b).

131. Newcomb is not cited on the face of the '829 patent. It also was not discussed or mentioned during the '829 patent's prosecution history.

132. Newcomb relates to a "control valve such as a … fuel injection valve for controlling flow of a medium." (*Id.*, 1:5-7.)

133. Newcomb explains that the materials used to make such a valve should be chosen such that the materials' coefficients of thermal expansion are selected so as to "enable[] the effects of thermal expansion to be reduced…." (*Id.*, 1:45-49.)

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4. Hayes

134. Hayes indicates on its face that it issued July 14, 1998. (*See* Ex. 1024, Cover.) In view of this date of issuance, which predates the '829 patent's filing by more than a year, I understand that Hayes is prior art to the '829 patent under at least 35 U.S.C. § 102(b).

135. While Hayes is listed on the face of the '829 patent, it was not discussed or mentioned by the examiner during the '829 patent's prosecution history.

136. Hayes relates to an indirectly actuated fuel injector. (*Id.*, 1:7-9.) This is an injector where the nozzle needle valve is indirectly controlled by a pilot valve.

137. Hayes explains that such an injector includes an intermediate "control valve 1" sealed by a ball-shaped "component 12." (*Id.*, 2:7-15, 30-33.)

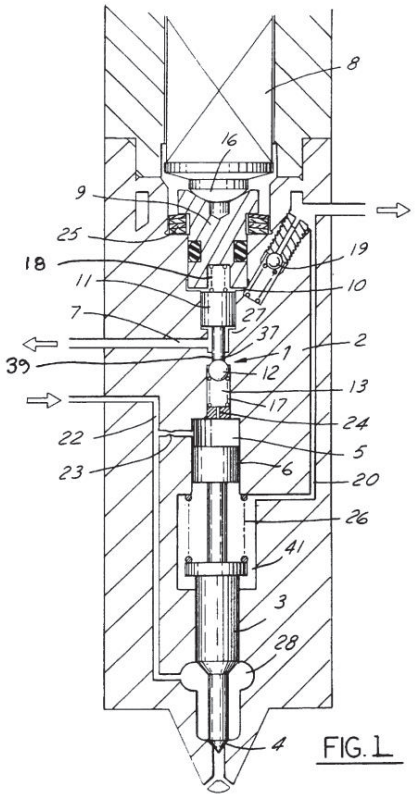
138. Activating the actuator of the injector opens this control valve. (*Id.*, 3:24-45.)

139. Hayes also explains how this in turn opens a valve into the combustion chamber.

140. In particular, opening the intermediate control valve lowers the pressure in a "chamber 5," which causes a separate "valve needle 3" to lift and open a passage into combustion chamber. (*Id.*, 3:53-63.) Fuel supplied by a "feeding line 22, which feeds the fuel at high pressure," is then injected through the passage opened by the needle. (*Id.*, 2:45-48, 3:53-63.)

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141. Figure 1 of Hayes shows these various components:



(*Id.*, Fig. 1.)

B. Ground 1: Claims 1-3, 6, 11-12, 14-15, and 18-19 Are Obvious Over Wirbeleit and Klügl

142. In my opinion, a POSITA would have considered Wirbeleit and Klügl to be within the scope of the prior art and highly relevant to the patentability of the '829 patent's claims.

143. In my opinion, moreover, when viewed and considered in light of the knowledge possessed by a POSITA, Wirbeleit and Klügl together disclose all the

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limitations of and render claims 1-3, 6, 11-12, 14-15, and 18-19 of the '829 patent obvious.

144. In addition, not only would a POSITA have been motived to combine and collectively consider the teachings of these references to arrive at the subject matter claimed by the '829 patent, but they would have had a reasonable expectation of success when doing so.

1. Claim-By-Claim Analysis

a. Claim 1

[1-p] "An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:"

145. In my opinion, to the extent the preamble is limiting, Wirbeleit teaches the claimed ***"injection valve."***

146. Wirbeleit explains that it relates to a "fuel injection system for a Diesel engine…." (Ex. 1004, 1:7-8.)

147. Wirbeleit's fuel injection system includes "valve-controlled injectors [for] the injection of fuel under the control of an electronic control unit." (*Id.*, 1:8-12.)

148. Wirbeleit also explains that its injector valve is meant for use with "direct-injection Diesel engines." (*Id.*, 1:30-37.)

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149. As of the filing of the ’829 patent, a POSITA would have understood that a “direct-injection” engine is one in which fuel is injected directly into an engine’s combustion chamber, and not indirectly into the engine manifold.

150. Showing this, numerous prior art references explain that this is what “direct” injection entails.

151. For instance, a “direct cylinder injection system” was known to be one in which “the fuel injector is mounted in the cylinder block and sprays … into the cylinder bore” (*See* Ex. 1007, 2:7-10.)

152. Similarly, in contrast to an “indirect injection” system that injects fuel into the manifold, a “direct injection system[]” “inject[s] fuel directly into the combustion chamber.” (Ex. 1008, 1:16-24.)

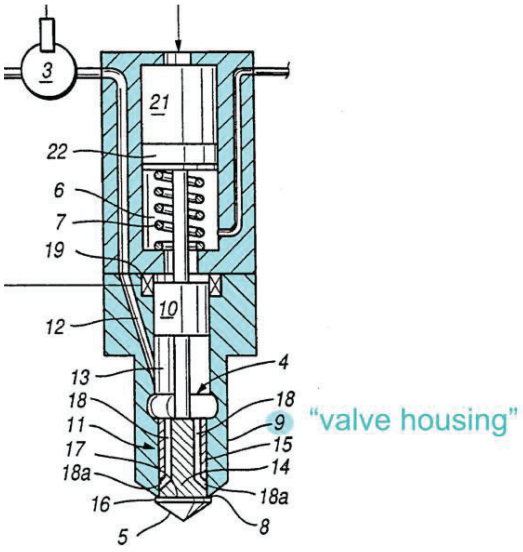
[1(a)] “(a) a valve housing comprising:”

153. In my opinion, Wirbeleit includes the claimed ***“valve housing.”***

154. Wirbeleit explains that its “injector” includes an “injector body 9” that surrounds and contains the other injector components. (Ex. 1004, 2:31-35.)

155. Body 9 of Wirbeleit’s injector has been highlighted in teal in the figure below. Note that this figure (which is Wirbeleit’s only figure) has been cropped throughout this declaration to better focus on the depicted injector:

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(*Id.*, Fig. (annotated).)

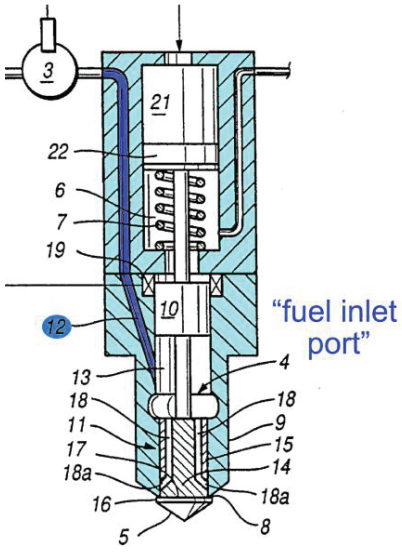
[1(a)-1] "a fuel inlet port;"

156. In my opinion, Wirbeleit includes the claimed ***"fuel inlet port."***

157. Wirbeleit's "fuel inject[or]" includes "a fuel injection conduit structure with a common supply conduit 3 for all injectors." (Ex. 1004, 2:27-30.)

158. A "fuel admission passage 12" in "communication with the common supply conduit 3" allows fuel to enter the injector. (*Id.*, 2:35-40.)

159. Wirbeleit's fuel admission passage 12 is highlighted below in blue:



(*Id.*, Fig. (annotated).)

[1(a)-2] "an interior chamber fluidly connected to said fuel inlet port;"

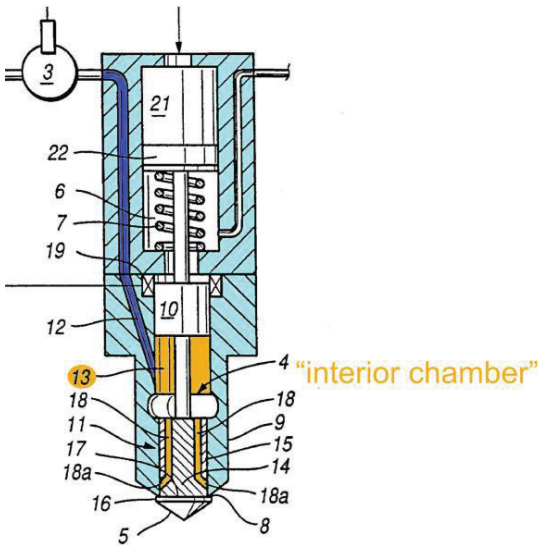
160. In my opinion, Wirbeleit includes the claimed ***"interior chamber."***

161. Wirbeleit explains that its injector includes a "slot orifice 4" within its injector body that contains "an injector orifice control needle 5." (Ex. 1004, 2:31-32.)

162. Wirbeleit also explains its needle "delimit[s] a pressure chamber 13 which is in communication with the common supply conduit 3 by way of [the] fuel admission passage 12." (*Id.*, 2:35-40.) This pressure chamber 13 is connected to grooves 18 and orifices 18a within the needle through which fuel can flow to exit the injector. (*See* i*d.*)

163. In my opinion, these spaces within Wirbeleit's injector—including the chamber 13, grooves 18, and orifices 18a—are the claimed "interior chamber." Further, fuel flows from the admission passage 12 to these spaces as required.

164. The spaces are highlighted below in orange:



(*Id.*, Fig. (annotated).)

[1(a)-3] "a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber;"

165. In my opinion, Wirbeleit includes the claimed ***"nozzle"*** and ***"nozzle orifice."***

166. In particular, Wirbeleit explains that one end of its injector includes "slot-shaped orifices," which Wirbeleit also referred to as "slot-injection orifices," in the form of "opening[s] 18a." (Ex. 1004, 1:52-58, 2:1-2, 2:45-55.)

167. Wirbeleit explains that these orifices "form fuel injection passages" into the combustion chamber when positioned outside of the injector housing. (*Id.*)

168. Because it is where injection occurs, in my opinion this end of Wirbeleit's injector is the claimed ***"nozzle."***

169. Wirbeleit's injector also includes a central "slot orifice 4" (or central interior space) within its "injector body 9." (*Id.*, 2:31-34.)

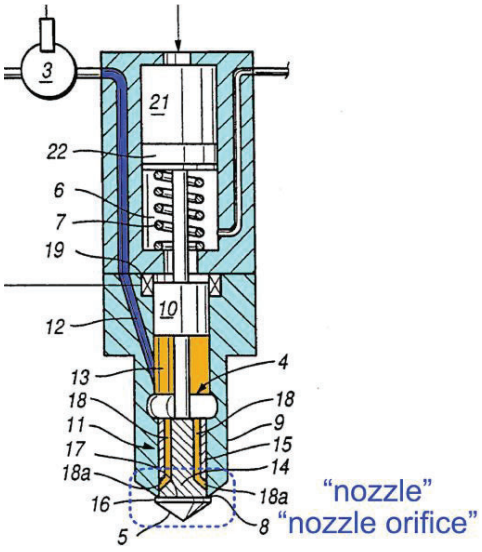
170. Wirbeleit's needle is located within this space. The "slot orifice 4" includes a hole or opening at the injector's nozzle end that can be "open[ed]" by "outwardly" moving an "injector orifice control needle 5" off its seat. (*Id.*)

171. This opening between Wirbeleit's injector body and control needle is, in my opinion, the claimed ***"nozzle orifice"*** that ***"provid[es] a fluid passage"*** as claimed.

172. Moving the control needle through the opening creates "fuel injector passages" originating at the supply conduit 3, proceeding through the injector's housing via the fuel admission passage 12, into the pressure chamber 13, through a series of "grooves 18," and finally out the opening via the "oblong opening[s] 18" for injection into the combustion chamber. (*Id.*, 2:38-40, 45-50, 55.) Again, these passages only allow for fuel injection when Wirbeleit's needle is moved off its seat to open the nozzle end of its injector. (*See id.*)

173. Wirbeleit's nozzle is the lower teal part, and its nozzle orifice is circled in blue below:

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(*Id.*, Fig. (annotated).)

[1(b)] "(b) a valve needle disposed within said valve housing wherein said valve needle is movable between a closed position at which a sealing end of said valve needle contacts a valve seat to fluidly seal said interior chamber from said nozzle orifice, and an open position at which said sealing end of said valve needle is spaced apart from said valve seat whereby said interior chamber is fluidly connected with said nozzle orifice, wherein valve needle lift equals the distance traveled by said sealing end away from said valve seat;"

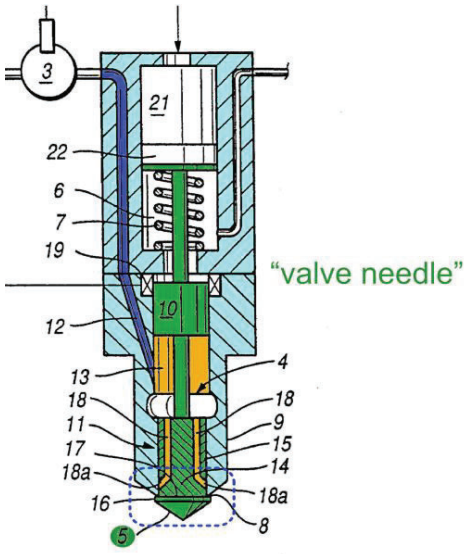
174. In my opinion, Wirbeleit also includes the claimed ***"valve needle."***

175. Wirbeleit's injector includes "an injector orifice control needle 5" within its "injector body 9." (Ex. 1004, 2:31-32; *see also* Abstract, 1:48-49.)

176. Wirbeleit's needle 5 includes a "piston-like needle tip 11" with a "collar 16 which is disposed outside the injector body 9…." (*Id.*, 2:35-37, 40-45.) The "rear side 17" of the "collar 16" "forms the valve seating surface." (*Id.*, 2:43-45.) To close the injector, the rear side 17 of collar 16 is "forced onto the valve seat 8 on the injector body 9." (*Id.*, 2:31-35; *see also* Abstract, 1:48-52.)

177. Because it includes an end (tip 11 with collar 16 and rear side 17) that cooperates with a valve seating surface to seal the injector, Wirbeleit includes the claimed ***"valve needle"*** with a ***"sealing end"*** that ***"contacts a valve seat."***

178. Wirbeleit's needle 5 and pressure compensation piston 10, which are generally shaped as a slender, elongated, pointed rod, are highlighted green below:



(*Id.*, Fig. (annotated).)

179. Wirbeleit's needle is also, in my opinion, ***"movable between a closed position"*** and ***"open position"*** as claimed.

180. In this regard, Wirbeleit explains that its "control needle 5" is both "movable outwardly for opening the orifice" to facilitate fuel injection, and can be "forced onto the valve seat 8 on the injector body 9" to close the valve and stop injection. (Ex. 1004, 2:31-35.) Similarly, according to Wirbeleit, its needle moves between a position where the needle's "slot-shaped orifices" are "fully covered when

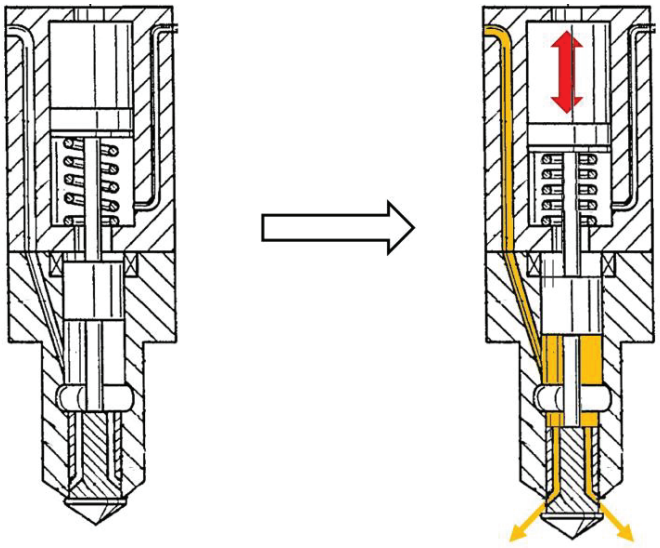
the control needle is seated" to another position where the orifices are "exposed" *(Id.,* Abstract; 1:52-58 (likewise explaining that the needle's "slot-shaped orifices … are fully covered when the control needle is seated but which are exposed" by moving the needle); 3:5-11 (again explaining that the needle moves from one position where "[a]n appropriate injector slot orifice cross-section 18a … is maintained" and a "rest position in which the needle tip 11 is seated on valve seat 8").)

181. Movement of Wirbeleit's needle between closed and open positions is shown in the below demonstrative prepared using Wirbeleit's figure.

182. Closed position: In the figure on the left, Wirbeleit's needle is forced against the valve seat at the end of the injector body closing the injector. This is the closed position.

183. Open position: In the figure on the right, Wirbeleit's needle has moved out of the injector body and off the valve seat exposing the slot orifices and allowing fuel (shown in yellow) to be injected. This is the open position:

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(Ex. 1004; Fig.)

184. Further, as noted above, the "lift position" of Wirbeleit's needle can both be controlled by an "electronic control unit" and measured using a "needle lift sensor." (*Id.*, 2:4-10.)

[1(c)] "(c) a needle spring associated with said valve needle, wherein said needle spring applies a closing force to said valve needle for biasing said valve needle in said closed position;"

185. In my opinion, Wirbeleit includes the claimed ***"needle spring."***

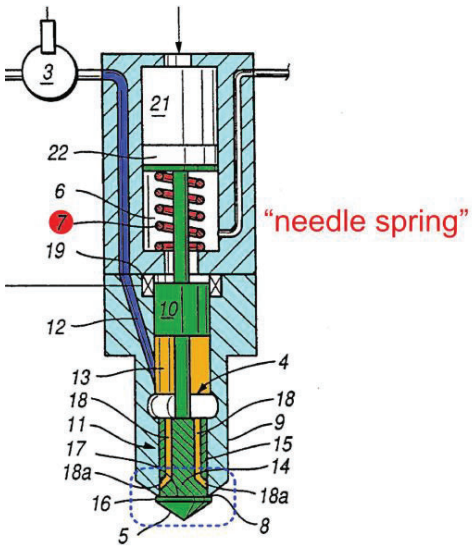
186. Wirbeleit explains that its injector includes a "return spring 7 disposed in [a] spring chamber 6." (Ex. 1004, 2:35-36.)

187. According to Wirbeleit, this spring "force[s]" the "injector orifice control needle 5 … onto the valve seat 8 on the injector body 9" to close the valve. (*Id.*, 2:31-36.) Similarly, Wirbeleit explains that its "injectors" have "fuel injection control needle engaged by springs so as to be normally seated on a valve seat." (*Id.*,

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Abstract.) Likewise, "the orifice control needle is returned by the return spring 7 to a rest position in which the needle tip 11 is seated on the valve seat 8." (*Id.,* 3:7-11; *see also* 1:48-50.)

188. Wirbeleit's spring 7 is shown in red below:



(*Id.*, Fig. (annotated).)

[1(d)] "(d) an actuator assembly associated with said valve needle, wherein said actuator assembly may be activated to apply an opening force to said valve needle stronger than said closing force, for moving said valve needle to said open position; and"

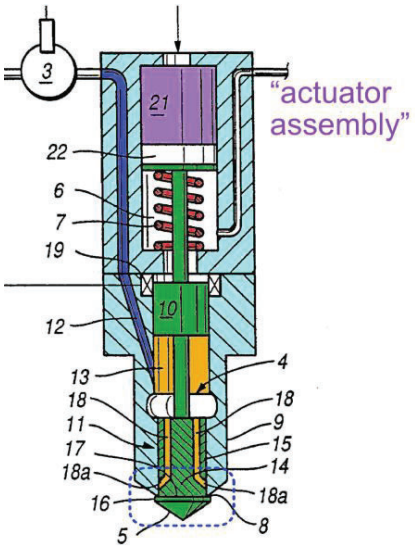
189. In my opinion, Wirbeleit's injector includes the claimed ***"actuator assembly."***

190. More particularly, Wirbeleit's injector includes a "magnetostrictive actuator 21"—or alternatively a "piezo actuator" —that is located "[a]t the rear end of the orifice control needle 5 opposite its tip 11…." (Ex. 1004, 2:60-64.)

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191. Additionally, the "[o]pening of the slot-injection orifices can be controlled by energizing [the] piezo actuator which acts on the injector needle … against a compression spring with a voltage-dependent force." (*Id.*, 2:1-4; *see also* Abstract; 1:50-52.)

192. Wirbeleit's actuator is highlighted in purple below:



(*Id.*, Fig. (annotated).)

[1(e)] "(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is activated and wherein said thickness of said hydraulic link is adjustable while said actuator is not activated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve needle lift upon activation of said actuator assembly."

193. In my opinion, the combination of Wirbeleit and Klügl teach everything this particular claim limitation requires.

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194. As an initial matter, a POSITA would consider Wirbeleit's injector to already employ a ***"hydraulic link assembly" "through which … opening and closing forces are transmitted."***

195. Wirbeleit explains that its "magnetostrictive actuator 21 … operates the orifice control needle 5 by way of a hydraulic transmission element 22…." (Ex. 1004, 2:60-64.).

196. Likewise, according to Wirbeleit either a "magnetostrictive actuator" or "a piezo actuator" can "act[] on the injector needle by way of a hydraulic transmission element against a compression spring…." (*Id.*, 2:1-3, 2:61.)

197. This hydraulic transmission element is the claimed ***"hydraulic link."***

198. According to Wirbeleit, during valve opening, force is exerted by the actuator and imparted through the hydraulic transmission element to the needle. In contrast, during valve closing, force is exerted from the spring, to the needle, and back through the hydraulic transmission element until a rest position is reached. (*See id.*; *see also* 3:5-11.)

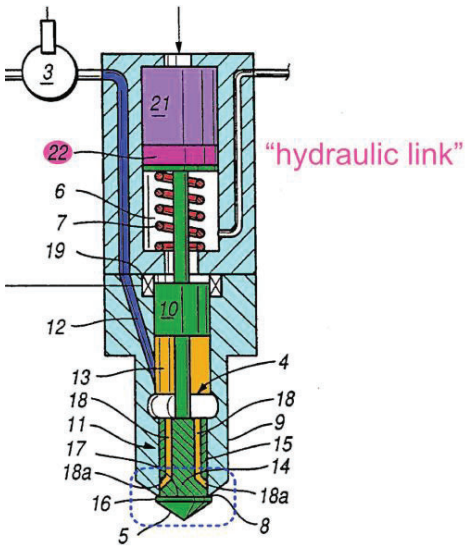
199. Moreover, a POSITA would, in my opinion, understand this hydraulic link to be ***"passive"*** as required. There are two primary reasons for this.

200. First, Wirbeleit characterizes its "hydraulic transmission element" as a simple force pathway through which force from the actuator passes to the needle.

(*Id.*, 2:1-3.) The hydraulic transmission element does not generate or amplify the force.

201. Second, the "hydraulic transmission element" is located in an enclosed cylindrical space between the actuator and needle. It has nowhere to flow during actuation and thus can only serve to passively transmit force. (*See id.*, *see also* Fig.)

202. Wirbeleit's hydraulic transmission element highlighted below in pink:



(*Id.*, Fig.)

203. Next, in my opinion, a POSITA would have considered the remainder of what this limitation requires obvious in view of the teachings of Klügl.

204. Klügl relates to a device that can be used in an "automotive" fuel injector "to transmit the movement of a piezoelectric actuator to an actuator in … an injection valve." (Ex. 1006, 1:7-12.)

205. Like Wirbeleit's injector, Klügl's injector has an outer "housing 12" surrounding its various components. (*Id.*, 1:47-51.)

206. A "piezoelectric actuator 1" is located within this housing. (*Id.*)

207. A "transmission module 2" is located between the actuator 1 and the "drive piston 3." (*Id.*, 1:48-51; 2:23-41; Fig. 1.)

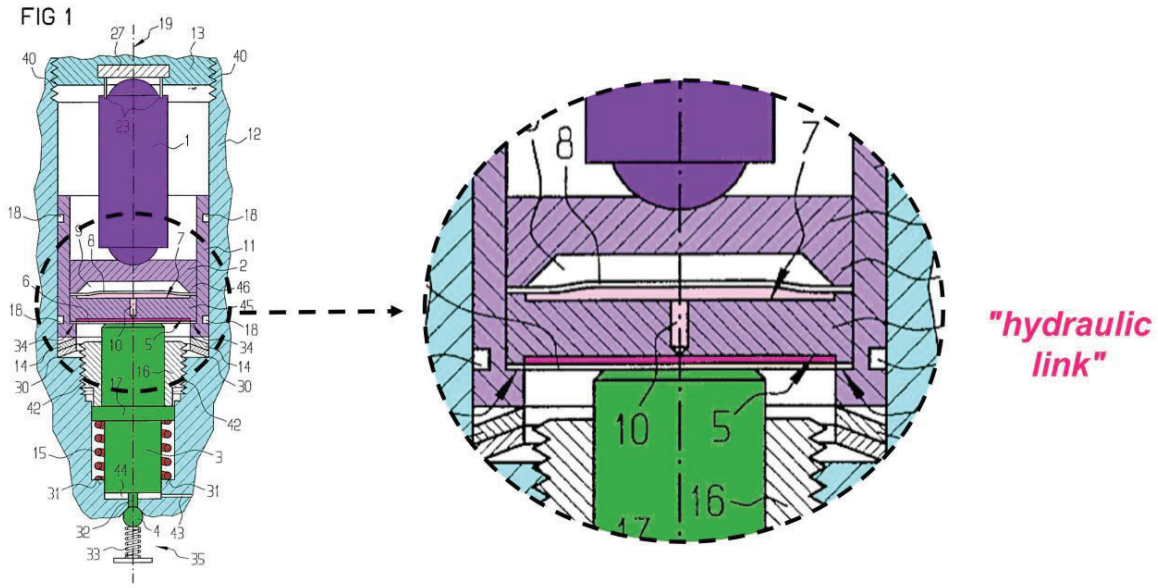
208. The drive piston 3 is attached to control needle 32 and in contact with ball 4, which Klügl also calls a "closing element 4." The ball/closing element 4 forms a "servo valve [that] is used to control an injection needle." (*Id.*, 2:50-57.)

209. A "spring 15" exerts an upward force on the drive piston to close the valve. (*Id.*, 2:35-36.)

210. The transmission module 2 includes a "pressure chamber 5" filled with "transmission medium" such as "a hydraulic fluid, which has low compressibility." (*Id.*, 1:60-2:4.) The transmission module also includes a "throttl[e]" (orifice) or "connecting bore 10" that connects the "pressure chamber 5 to a compensating chamber 7." (*Id.*) The compensating chamber 7 is filled with the same transmission medium as the pressure chamber 5. (*Id.*) The transmission fluid/hydraulic fluid is completely captured and contained within the transmission module. (*See id.;* Fig. 1.) As such, there is no external fluid source. (*See id.*)

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211. These components are shown in the below annotated version of Fig. 1. The region of Fig. 1 showing chamber 5 has also been excerpted and expanded in size to the right for emphasis purposes:



(*Id.*, Fig. 1 (annotated).)

212. The same coloring scheme used when comparing Wirbeleit to claim 1 has been employed. More particularly:

213. **Teal**: Housing 12 (Klügl's "valve housing").

214. **Dark and light purple**: The piezoelectric actuator 1 and transmission module 2 (Klügl's "actuator assembly").

215. **Green**: The drive piston, needle, and ball (Klügl's "valve needle").

216. **Red**: The valve-closing spring (Klügl's "needle spring").

217. **Dark pink**: The pressure chamber 5 (Klügl's "hydraulic link")

218. **Light pink**: Throttle 10 and compensation chamber 7.

219. During valve opening, when the "piezoelectric actuator 1 is … controlled" (energized) by application of an appropriate signal, the actuator expands causing "pressure" to be "exerted on the drive piston 3 via … the transmission medium located in the pressure chamber 5…." (*Id.*, 3:23-29.)

220. In the embodiment shown in Klügl's Figure 1, the movement of the actuator results in the same amount of movement of the piston without amplification. In other words, there is no change in the "stroke translation." (*id.*, Fig. 1; 1:41-42, 3:23-29.) As the fluid in chamber 5 is held in place by a membrane 6 and moves through a cylindrical space of constant width and unchanging shape, the thickness of the fluid in chamber 5 will remain constant throughout actuation. (*See id.*)

221. Showing this, Klügl itself explains that in opposition to its Figure 3, the injector of Figure 1 does not "achieve[] a stroke ratio between defection of the piezoelectric actuator 1 and the deflection of the drive piston 3." (*Id.*, 7:12-13.)

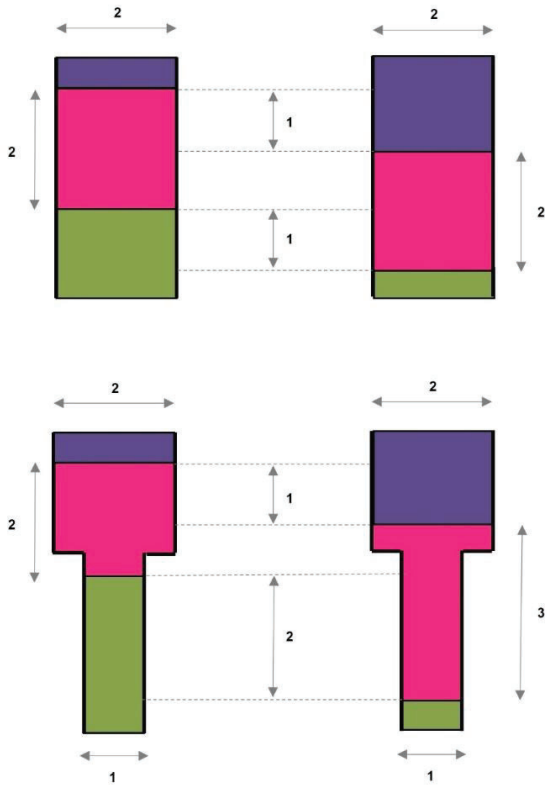
222. Klügl contrasts this with the embodiment show in Figure 3, which does provide a change in "stroke translation" by applying a "stroke ratio" such that the movement of the piston exceeds that of the actuator. (*Id.*, 1:41-46; 7:12-13.) This occurs because the dimensions of chamber 5 change during actuation in that particular figure's embodiment. (*See id.*, Fig. 3.)

223. Klügl also explains that in the embodiment shown in Fig. 1, the chamber 5 is filled with hydraulic fluid of "low compressibility." (*Id.*, 2:1-2.) Additionally, while the transmission module includes a "throttle 10" that connects chamber 5 to chamber 7, this throttle is "dimensioned in relation to the transmission medium such that during normal activation" "only an insignificant amount of transmission medium flows into the compensation chamber." (*Id.*, 4:11-22.)

224. It follows that the hydraulic fluid in chamber 5 will not flow, will maintain substantially the same thickness, and will act substantially as a solid during actuation. The fluid is unable to leave chamber 5 during actuation (it cannot flow through throttle 10 and is held in place by a membrane 6). It is incompressible (so it will not change volume upon application of pressure). As a result, during the actuation, the distance between the actuator and piston remains constant (so as to ensure that there is a unity stroke ratio).

225. As a further clarification, I have prepared the below demonstrative. The figures on the top represent Klügl's injector from Figure 1. The figures on the bottom represent Klügl's injector from Figure 3. The actuator is shown in purple. The intermediate hydraulic fluid is shown in pink. The control piston (which pushes on the needle) is shown in green.

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226. As shown in the top figures, when the actuator is expanded, the control piston moves by a distance equal to the amount of actuator expansion. Because the hydraulic fluid is incompressible and located in a cylindrical space, its thickness stays the same. Again, this is representative of Klügl's Figure 1 and is what the '829 patent's claims require.

227. But, when the actuator in the bottom set of figures expands, the hydraulic fluid is pushed from a cylinder of larger diameter into a cylinder of smaller diameter. While the volume of the fluid stays constant (as it is incompressible), its thickness changes (as it is now contained in a differently shaped space). This causes the needle to be moved by a distance greater than the expansion of the actuator.

Again, this is representative of Klügl's Figure 3 and is what Klügl means when it refers to a "stroke ratio" or "stroke translation." In the bottom figure here the actuator to control piston stroke ratio is 1:2.

228. In addition to teaching a passive hydraulic link that acts as a solid with constant thickness during actuation (i.e., the fluid in chamber 5 of Figure 1), Klügl also explains that "if there are long-lasting pressure differences between the pressure chamber 5 and the compensation chamber 7 … the transmission medium is exchanged between the compensation chamber 7 and the pressure chamber 5 via the throttle 10." (*Id.*, 4:25-31.)

229. According to Klügl, this allows its injector to account for "thermal expansion differences and gradual wear" and ensures that the "drive piston 3" remains in contact with the transmission module. (*Id.*, 3:50-4:31.)

230. Again, Wirbeleit already employs a hydraulic transmission element 22 to transfer the movement of its actuator 21 to its needle 5 through piston 10. As I have explained, this element is passive in that it simply transfers force instead of generating it.

231. Wirbeleit explains that this element 22 "is not shown in detail." (Ex. 1004, 2:64.) As discussed above, however, Klügl discusses how such a hydraulic element should be structured and operate.

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232. In Klügl, as in Wirbeleit, force from an actuator passes through the hydraulic fluid in chamber 5 to the piston 3 for purposes of opening a valve during actuation. As I have explained, in Figure 1, the fluid in the chamber 5 simply transmits the actuator force. It does not generate force or engage in amplification.

233. Further, Klügl explains that fluid does not flow into or out of chamber 5 during actuation. Thus, in my opinion this chamber and the fluid it contains, just like Wirbeleit's hydraulic transmission element 22, is the claimed ***"passive hydraulic link"*** that acts as a ***"solid."***

234. As I have noted, Klügl states that the fluid in chamber 5 has a low compressibility. And, as I have also explained, in the embodiment of Figure 1, no stroke amplification or change in translation distance occurs and chamber 5 does not change dimension during actuation. As a result, its ***"thickness"*** is ***"substantially constant"***

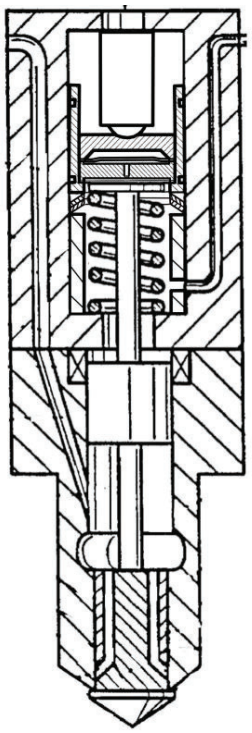
235. Finally, Klügl explains that fluid can flow between chambers 5 and 7 through the throttle 10 during times of rest to account for thermal expansion or wear so as to ensure that the various components (such as the piston 3 and transmission module 2) remain in contact. Thus, in my opinion, its ***"thickness … is adjustable while said actuator is not activated in response to changes in the dimensional relationship between components."***

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236. Further, Wirbeleit's system is meant to facilitate control of the amount of "needle lift." (Ex. 1004, 2:1-12)

237. Because Klügl's transmission module 2 is designed to keep the injector's components in contact, a POSITA would have understood that when applied to Wirbeleit, Klügl's transmission module 2 would maintain the intended needle lift or position range despite wear and thermal expansion. Thus, my opinion, the references teach the maintenance of the claimed ***"desired valve needle lift upon activation."***

238. An example application of Klügl to Wirbeleit—with Wirbeleit's hydraulic transmission element 22 replaced with Klügl's transmission module—is shown in the demonstrative below:



b. Claim 2

239. Claim 2 depends on claim 1 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by differential thermal expansion."

240. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

241. In my opinion, Klügl teaches the claimed ***"auto-adjustable" "hydraulic link."***

242. In particular, Klügl explains that when its actuator is "in the rest position," "if there are long-lasting pressure differences between the pressure chamber 5 and the compensation chamber 7, … transmission medium is exchanged between the compensation chamber 7 and the pressure chamber 5 via the throttle 10." (Ex. 1006, 3:50-4:31.)

243. According to Klügl, this "automatic adjustment" accounts for the effects of "thermal expansion differences and gradual wear" of its components and ensures that the "drive piston 3" remains in contact with the "transmission module 2" even if temperature changes or wear cause size changes. (*Id.*, 3:52-62; 4:25-31.)

c. Claim 3

244. Claim 3 depends on claim 2 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by wear to components of said injection valve."

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245. As explained above, Wirbeleit and Klügl teach everything claim 2 requires.

246. In my opinion, Klügl teaches the additional limitation of claim 3 for the same reasons discussed in connection with claim 2: its transmission module 2 allows for fluid flow between chambers 5 and 7 during injector idle periods to account for not only thermal expansion, but also component wear.

d. Claim 6

247. Claim 6 depends on claim 1 and further requires:

"wherein said actuator assembly comprises a magnetostrictive member or a piezoelectric stack."

248. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

249. In my opinion, Wirbeleit teaches the additional limitation of claim 6.

250. In particular, Wirbeleit's injector includes either a "magnetostrictive actuator 21" or "piezo actuator" that expands to open or close the injector. (Ex. 1004, 2:60-65; *see also* 2:1-4, 13-17.)

e. Claim 11

251. Claim 11 depends on claim 6 and further requires:

"wherein when said actuator assembly is controllable to control said desired lift to between 10 and 100 percent of maximum lift."

252. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

253. In my opinion, Wirbeleit teaches the additional limitation of claim 11.

254. Wirbeleit explains that the "[o]pening of the slot-injection orifices can be controlled by energizing a piezo actuator which acts on the injector needle by way of a hydraulic transmission element…" (Ex. 1004, 2:1-3.)

255. The "desired injector orifice cross-section can be obtained by way of voltage control of the piezo actuator" which enables a variable and controllable "momentary lift position of the orifice needle." (*Id.*, 2:4-12.) Similarly, Wirbeleit explains that "[a]n appropriate slot orifice cross-section" can be "maintained by way of voltage control of the actuator." (*Id.*, 3:5-6.)

256. This means that in Wirbeleit, different, controllable amounts of needle lift are employed so as to allow "the injection orifice cross-section of the injector" to be "variable and … controlled depending on the requirements" for "engine performance…" (*Id.*, 1:59-63; *see also* 3:13-14.)

257. Wirbeleit does not specifically reference adjustment of its valve needle lift by an amount ***"between 10 and 100 percent of maximum lift."***

258. Regardless, as I explain above, Wirbeleit does teach a valve needle that allows for a controllable amount of lift that is achieved by supplying the actuator with a specific voltage.

259. In my opinion, a POSITA would consider it highly obvious to control the lift of Wirbeleit's needle across this claimed range. Wirbeleit already allows for

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100% lift (the position providing fully open orifices). And, it also allows for variable lift less than 100%, which a POSITA would have recognized obviously includes 10% lift (the position providing mostly closed injection orifices). Allowing for a particular range of needle lift control—such as 10% to 100%—would have been considered nothing more than a routine design choice that could be achieved by simply supplying the actuator with the correct signal needed to achieve a desired lift.

260. In my opinion, the fact that the '829 patent identifies no importance or significance to the use of a range of "10 to 100 percent of maximum lift" confirms that this range would have been considered obvious by a POSITA and amounts to be a routine, obvious design choice.

261. Rather than identifying anything important about the claimed range, the '829 patent notes that its actuator is meant to allow for "full or partial lift, as desired." (Ex. 1001, 4:50-55.)

262. This is exactly what Wirbeleit's injector does: it allows for either full or partial needle lift, as desired.

f. Claim 12

263. Claim 12 depends on claim 11 and further requires:

"wherein said lift is controllable by controlling the electric current directed or voltage applied to said respective magnetostrictive or piezoelectric actuator assembly."

264. As explained above, Wirbeleit and Klügl teach everything claim 11 requires.

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265. The additional limitation of claim 12 is taught by Wirbeleit.

266. In particular, Wirbeleit explains that its needle "lift position" and the corresponding "[o]pening of the slot-injection orifices can be controlled by energizing a piezo actuator which acts on the injector needle … with a voltage-dependent force." (Ex. 1004, 2:1-4; *see also* 2:10-12; 3:1-7.)

g. Claim 14

267. Claim 14 depends on claim 6 and further requires:

"wherein said valve needle is controllable to move between said open and closed positions in less than about 200 microseconds."

268. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

269. In my opinion, the additional limitation of claim 14 is taught by Wirbeleit and Klügl.

270. Wirbeleit explains that its valve "injection time is adjustable depending on engine operating parameters." (Ex. 1004, 3:15-16.)

271. Klügl provides an example of standard injection times known at the time the '829 patent was filed.

272. In particular, according to Klügl the "actuation times" of an injection valve should be "in the range of milliseconds, preferably between 0 ms and 10 ms. Rapid actuation times are 0.1 to 1 ms" (or 100 to 1000 microseconds). (Ex. 1006, 4:22-24.)

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h. Claim 15

273. Claim 15 depends on claim 6 and further requires:

"a compression spring member for applying a compressive force to said magnetostrictive or piezoelectric member."

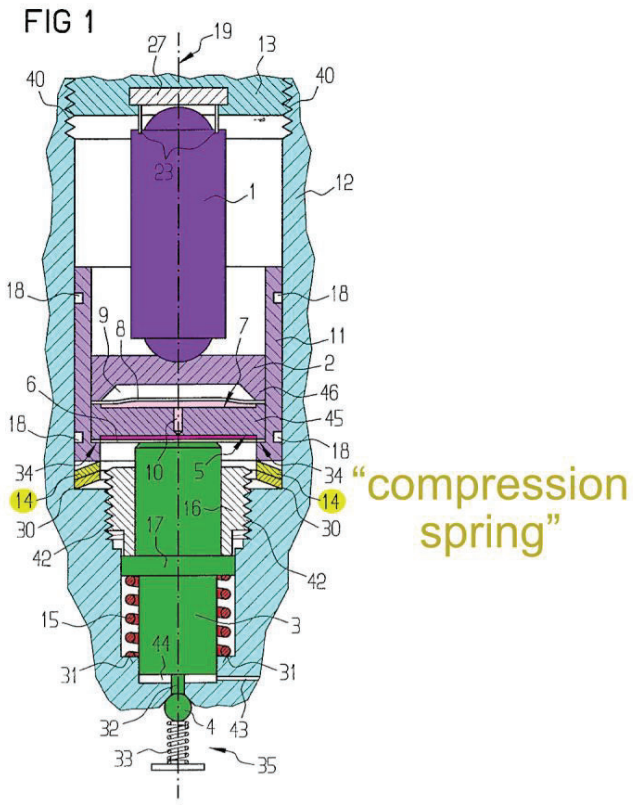
274. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

275. In my opinion, the ***"compressing spring member"*** required by claim 15 is taught by Klügl.

276. In particular, Klügl's injector includes a "disk spring 14" that allows the piezoelectric actuator 1 to be "pre-stress[ed] against" the valve "housing 12" via the "transmission module 2." (Ex. 1006, 2:11-21; 3:16-19.)

277. This disk spring 14 is highlighted in yellow below:

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(*Id.*, Fig. 1 (annotated).)

278. In my opinion, a POSITA would have considered it obvious to use this disk spring 14 along with Klügl's transmission module 2 as it will maintain contact between the transmission module 2 and the actuator 1, and improve the injector's performance by pre-stressing the actuator.

i. Claim 18

279. Claim 18 depends on claim 1 and further requires:

"wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 MPa)."

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280. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

281. In my opinion, a POSITA would have considered the additional limitation of claim 18 obvious in view of Wirbeleit.

282. Wirbeleit states that its injection valve is meant for use with a "high pressure" fuel injection system. (Ex. 1004, 2:27-30.)

283. As of the '829 patent's filing, it was well known that "high pressure" fuel injection systems were able to inject fuel at pressures well in excess of 2000 psi.

284. For instance, it was known that injection pressure should vary with engine speed, from a "relatively low pressure … of approximately 2000 psi" at lower/idle speed and load, to pressures as high as 15,000 psi at higher engine speeds/loads. (*E.g.*, Ex. 1012, 5:48-52, 7:1-14; *see also* Ex. 1013, 11:25-31 (referencing injection pressures up to 1550.9 bar, or approximately 22,000 psi).)

j. Claim 19

285. Claim 19 depends on claim 1 and further requires:

"wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body."

286. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

287. In my opinion, both Wirbeleit and Klügl teach sealed valve housings with a ***"plurality"*** of ***"joined" "parts."***

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288. As shown in Wirbeleit's figure, Wirbeleit's "injector body 9" includes an upper and lower piece that together form an interior, sealed "slot orifice 4" and "fuel admission passage." (*See* Ex. 1004, 2:31-39; Fig.)

289. Klügl's injector also has a multi-part structure. In particular, the injector includes an "upper stop 13 [that] is connected to the housing 12 via a screw thread 40." (Ex. 1006, 1:57-60.)

290. This was a very common fuel injector design when the '829 patent was filed. Fuel injectors routinely included housings formed from multiple parts. This renders the injectors less costly to manufacture and easier to assemble (forming the housing from one piece, in contrast, would make it very difficult to make and install the various required injector components within that housing).

2. Motivation to Combine

291. A POSITA would have considered it obvious and would have been motivated to combine the teachings of Wirbeleit and Klügl.

292. As I have explained, Wirbeleit employs a "hydraulic transmission element 22" that is, according to Wirbeleit, "not shown in detail." (Ex. 1004, 2:60-64.)

293. Given that Wirbeleit requires the use but does not depict the specifics of its hydraulic transmission element, a POSITA would have been required to

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consult their own background knowledge and other available designs known in the art at the time the '829 patent was filed when implementing Wirbeleit.

294. In my opinion, a POSITA would have considered Klügl to be an example of one such design for use with Wirbeleit.

295. In my opinion, a POSITA would have considered Klügl's "transmission module 2" to be particularly suitable for use with Wirbeleit. As discussed in the following paragraphs, there are several reasons for this.

296. As an initial matter, Wirbeleit and Klügl are structurally and functionally similar.

297. Klügl's "transmission module 2" is like Wirbeleit's "hydraulic transmission element 22" in that it is hydraulic-based and can passively transfer force from an actuator to a fuel injector control piston or needle for purposes of opening a valve. (*E.g.*, Ex. 1006, 1:60-2:10, 3:23-29.)

298. Further, both Wirbeleit and Klügl employ a piezoelectric (or alternatively magnetostrictive) actuator that applies force to a control piston through a hydraulic element so as to open a valve.

299. Both Wirbeleit and Klügl also employ a spring that applies force to the needle for purposes of closing the valve.

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300. In my opinion, these structural and functional similarities would have provided a POSITA with a strong motivation to use Klügl's transmission module 2 when implementing Wirbeleit's hydraulic transmission element 22.

301. A POSITA would also, in my opinion, have been motivated to use Klügl's "transmission module 2" with Wirbeleit because doing so would be understood to provide other important benefits that would improve Wirbeleit's operation.

302. Primary among these is the ability to account for the effects of differential thermal expansion and wear.

303. As I have explained, Klügl's "transmission module 2" uses an incompressible hydraulic fluid that does not flow out of a chamber 5 during actuation but can move between a chamber 5 and chamber 7 during periods of rest.

304. This, according to Klügl, not only allows for transmission of force without application of a non-unity stroke ratio (i.e., the needle still moves by the same distance the actuator expands) but also allows for "automatic adjustment" of the injector to account for the effects of "wear," "aging," and "thermal expansion." (Ex. 1006, 3:50-4:31.)

305. In my opinion, when the '829 patent was filed, a POSITA would have recognized that one "known" "aim" when designing an injection valve should be to

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"compensat[e]" for the "effects of temperature changes, wear and manufacturing tolerances" on the valve's "actuating displacement." (*E.g.*, Ex. 1009, 1:9-16.)

306. This same design goal is expressed repeatedly in the prior art. (*See, e.g.,* Ex. 1010, 1:41-52 (explaining that an injector "valve needle and its valving element" must "always perform the same opening stroke" regardless of "temperature fluctuations," "wear," or "manufacturing tolerances").).

307. In my opinion, a POSITA would have known that Wirbeleit is no different and is subject to the same issues as other known fuel injectors. Thus, the same design considerations discussed above apply equally to Wirbeleit.

308. In particular, a POSITA would have understood that temperature changes, wear, or manufacturing issues could cause Wirbeleit's injector components—like the components of any injector—to also become misaligned, inefficient, or even non-functional.

309. Indeed, because Wirbeleit's injector is intended to allow for precise control over the amount of travel of its needle, a POSITA would have considered it particularly important that its injector components remain in proper alignment. Otherwise, application of control signals to Wirbeleit's actuator could result in the incorrect amount of needle movement. Similarly, Wirbeleit's needle lift sensor 19 is designed to sense the position of the control piston 10. If this control piston does

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not move by the same distance as the actuator, Wirbeleit's control system would not allow for the same, straightforward operation it currently does.

310. In my opinion, a POSITA would have understood that use of Klügl's "transmission module 2" would address this problem.

311. In particular, using Klügl's transmission module 2 (in particular that shown in Figure 1), force would still be transmitted between Wirbeleit's actuator and its needle.

312. But, during periods of rest when the injector is idle, hydraulic fluid could flow between chambers 5 and 7 to account for any dimensional changes resulting from thermal expansion and wear.

313. A POSITA would have recognized that this would substantially improve Wirbeleit by rendering it more able to account for and automatically adapt to the types of conditions routinely encountered by a fuel injector. It would also ensure that Wirbeleit's injector continues to deliver the range of needle movement intended when different signals are applied to its actuator.

314. A POSITA would have recognized that there are further benefits that would have derived from application of Klügl's transmission module 2 to Wirbeleit. These would, in my opinion, have also motivated combination.

315. For instance, Klügl explains that its device, which of course includes its transmission module 2, is "particularly compact and easy-to-assemble." (Ex.

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1006, 1:20-22.) Similarly, the device is structured such that its components can be "pre-assembled." (*Id.*, 1:26-38.)

316. In my opinion, a POSITA would have recognized that this would further improve Wirbeleit's injector.

317. Using use Klügl's "transmission module 2," Wirbeleit's injector would be more compact, leading to an overall smaller injector allowing it to be more readily integrated into an engine.

318. For instance, it would no longer be necessary to reserve a large space between the actuator and control piston to house a substantial amount of hydraulic fluid as depicted in Wirbeleit's figure. Nor would it be necessary include separate seals, gaskets, or the other types of structure to keep this element's hydraulic fluid in place and prevent it from escaping or leaking out of its designated space. Instead, only a small amount of hydraulic fluid would need to be housed in transmission module 2, which is itself already structured to keep fluid in place.

319. Relatedly, a smaller sized element 22 would also be understood by a POSITA to be beneficial in that it would allow for further design flexibility elsewhere in the injector. For example, differently sized or shaped interior chambers, fuel supply pathways, or nozzles that may not have been available previously due, for instance, to the length of the injector caused by the amount of hydraulic fluid used by Wirbeleit, would now be able to be more readily accommodated.

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320. In the same fashion, a POSITA would have recognized that the injector's performance would be improved by keeping the volume of fluid in element 22 small so as to ensure that the fluid has low compressibility and effectively eliminate the possibility of delays of motion transmission from the actuator to control piston.

321. Further, a POSITA would have recognized that use of Klügl's separate, preassembled, "particularly simple [to] manufacture" transmission module 2 in place of Wirbeleit's built-in "hydraulic transmission element 22" would have simplified the overall process of manufacturing Wirbeleit's injector. (*Id.*, 1:26-34.)

322. Manufacturing Wirbeleit's injector would require a step during injector assembly in which a substantial amount of hydraulic fluid must be supplied to the interior of its injector as no provision has been made to fill 22 through operation, such as through fuel or hydraulic ports or leak paths. This necessitates the presence of equipment capable of supplying this liquid without contaminating it in some way that will impede its operation. This step would be eliminated using Klügl's transmission module 2: the transmission module 2 (including the hydraulic fluid it contains) can be assembled separate from the injector. The transmission module 2 then simply needs to be inserted into the injector housing during injector assembly.

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323. A POSITA would also have understood that Klügl's "transmission module 2" allows for the use of other injector components that would further improve Wirbeleit's operation.

324. For example, Klügl's injector includes an "upper stop 13" and a "lower stop 16" that are both attached via "screw" connections and can be used to set the compression of the piezoelectric actuator, disk spring 14 and spring 15. (Ex. 1006, 1:57-60; 2:35-39.)

325. Klügl explains that this allows "the piezoelectric actuator 1," the "transmission module 2," and "the drive piston 3" to be "pre-adjusted" "[d]uring … production of the injection valve." (*Id.*, 3:1-10.)

326. In my opinion, this would have further motivated application of Klügl to Wirbeleit. Using similar adjustment mechanisms (which are again allowed by Klügl's injector design, including its use of transmission module 2) would allow Wirbeleit's injector be adjusted at the time of manufacture to account for slight variations of component size, or to refine the load on the injector's components. A POSITA would have understood that this would have had the potential to improve (or at the very least refine) the operation of the injector.

327. In my opinion, a POSITA would also have been motivated to retain Wirbeleit's directly actuated and controllable valve design when applying the teachings of Klügl.

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328. As I have summarized above, Wirbeleit identifies its injector's ability to control the orifice openings an important feature as it allows for the injection amount to be controlled "depending on engine operating parameters." (Ex. 1004, 1:52-58, 2:1-12.)

329. In my opinion, a POSITA would have similarly recognized this to be a highly beneficial feature.

330. For instance, it was known that controlling injection in this manner allows the "opening stroke of the valve member and the injection time" to be adjusted based on the engine's current operating conditions to "optimize[]" fuel "consumption" and minimize "emission." (*E.g.*, Ex. 1015 at 3; *see also id.* at 1 (explaining that adjusting needle lift allows for "low fuel consumption and emissions … over a wide range[]" of engine operating conditions).)

331. Engaging in the type of control taught by Wirbeleit also allows injector performance to be tailored to ensure "smooth running of the internal combustion engine." (*Id.* at 3.)

332. Further, the control provided by Wirbeleit allows for valve adjustment "dynamically" during operation allowing for even further refinement of engine performance. (*Id*.)

333. In my opinion, these benefits would have not only provided a POSITA with a strong motivation to use Wirbeleit in the first place, but would also have led

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a POSITA to maintain the ability to control valve lift even if making other changes, including the application of Klügl's transmission module as discussed above, to Wirbeleit's injector. In order to accomplish this, a POSITA would have maintained Wirbeleit's direct acting configuration when including Klügl's transmission module.

334. Next, in my opinion, a POSITA would have considered the use of Klügl's "transmission module 2" with Wirbeleit to be nothing more than a routine design choice.

335. As I have explained, Wirbeleit teaches a fuel injector with controllable valve lift that allows the injection amount to be tailored to engine operation. Further, it already includes a passive hydraulic force transmission element.

336. Klügl teaches a hydraulic transmission element like that employed by Wirbeleit. Further, it explains that this element is designed to automatically adjust to account for the effects of thermal expansion and wear.

337. A POSITA would have understood that combining these two references' teachings results in an injector that continues to exhibit these very same benefits: the combined injector would still allow for controllable lift as taught by Wirbeleit, would still transmit force through a hydraulic element as taught by both references, and would now be able to account for thermal expansion and wear as taught by Klügl.

338. In my opinion, a POSITA would also have had a reasonable expectation of success when combining Wirbeleit and Klügl.

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339. As I explain above, a POSITA would have recognized that both Wirbeleit and Klügl are directed to injector valves. Indeed, both references teach injector valves that are structurally and functionally similar: both transmit the force of an actuator through a hydraulic element to a control piston for purposes of opening a valve. And, both employ a spring to exert a valve closing force.

340. In my opinion, this similarity would have led a POSITA to conclude that Klügl's "transmission module 2" and the other injector components associated with this module could be readily incorporated into Wirbeleit.

341. I note that Klügl does provide an example where a piezoelectric actuator is employed to open a "servo" or pilot valve (which in turn opens the injector's nozzle valve).

342. In my opinion, a POSITA would not have considered Klügl to be limited to only this type of injector.

343. Instead, a POSITA would have understood that Klügl's "transmission module 2" could also be readily and successfully used in other types of injectors.

344. This, in my opinion, includes injectors like Wirbeleit's, where the actuator directly controls a needle valve that opens the flow path into an engine's combustion chamber.

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345. Showing this, Klügl itself explains that use of its transmission module in connection with a servo valve is intended to be just an "example." (Ex. 1006, 1:7-12.)

346. It then goes on to explain that its teachings—including its use of transmission module 2 to account for thermal expansion and wear—can be more broadly applied to the transmission of "movement of a piezoelectric actuator in an injection valve to" any "control element." (*Id.*)

C. Ground 2: Claim 20 is Obvious Over Wirbeleit, Klügl, and Newcomb

347. In my opinion, a POSITA would have considered Wirbeleit, Klügl, and Newcomb to be within the scope of the prior art and highly relevant to the patentability of the '829 patent's claims.

348. In my opinion, when viewed and considered in light of the knowledge possessed by a POSITA, Wirbeleit, Klügl, and Newcomb together disclose all the limitations of and render claim 20 of the '829 patent obvious.

349. Claim 20 depends on claim 1 and further requires:

"wherein said valve housing, said valve needle, and said actuator assembly, are selected from materials with similar thermal expansion coefficients to reduce changes in the dimensional relationship between said components caused by changes in temperature."

350. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

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351. In my opinion, a POSITA would have considered the additional limitation of claim 20 to be obvious in view of the teachings of Newcomb (Ex. 1014).

352. Newcomb, like Wirbeleit and Klügl, relates to a "control valve such as a … fuel injection valve…" (*Id.*, 1:5-7.)

353. Newcomb explains that when such a valve employs a "piezoelectric element" as an actuator, "the potential stroke of the valve is usually small, for example, of the order to 10 or 20 micrometers." (*Id.*, 1:31-34.)

354. Newcomb then explains that "[i]t is therefore essential to minimize the effects of thermal expansion on the valve parts so that flow through the valve will vary only slightly with changes of ambient temperature." (*Id.*, 1:34-38.)

355. "One solution to [this] problem is to choose a material" (like "a nickel-iron alloy") "for the valve housing" that "has a similar thermal expansion coefficient to that of the piezoelectric element." (*Id.*, 1:38-41.)

356. Newcomb explains that as an alternative, different materials can be used so long as those materials have "coefficient[s] of thermal expansion" and dimensions that result in "equal" "linear expansion." (*Id.*, 1:50-59.)

357. Newcomb provides an example of this where a "valve body 21" and valve opening "lower end piece 2a" are made from "steel having a thermal expansion coefficient of 12 μm K^{-1}," while the piezoelectric "actuating member 2" is formed from a ceramic that "has a thermal expansion coefficient of 4 μm K^{-1}." Above the

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piezoelectric actuator is located a "spacer 22b" "made from aluminum having a thermal expansion coefficient of 23 μm K^{-1}." (*Id.*, 3:39-47.)

358. Newcomb explains that the "length" of the spacer may be chosen in such a way that the piezo actuator and spacer together "maintain[e]" "a substantially fixed position with respect to the" "valve housing 21 even though changes in the temperature of the valve may take place." (*Id.*, 3:52-68.)

359. In my opinion, applying this to the injector of Wirbeleit and Klügl results in what the claim requires: the injector's housing, needle, and actuator would have been made from materials with sufficiently similar thermal expansion coefficients or compatibly selected materials in such a way as to reduce the overall influence of thermal expansion. As a result, using either approach, any change in relative dimension would be minimized.

360. A POSITA would have been motivated to combine these references' teachings.

361. For instance, Klügl itself already recognizes that injector valves should be designed to account for the effects of thermal expansion. (Ex. 1006, 3:52-55, 4:25-31, 6:29-33.)

362. Newcomb confirms this, explaining that it is "essential" that a fuel injector be designed to "minimize the effect[s] of thermal expansion." (Ex. 1014, 1:34-38.)

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363. Use of Newcomb's first thermal coefficient selection teachings would serve to further this known design goal: use of materials with matching thermal expansion coefficients would minimize (or at least reduce) the effects of thermal expansion.

364. I also understand that Patent Owner itself has stated that "[i]n order to minimize dimensional variations from changes in temperature expected in internal combustion engine applications, a reasonable engineer would select materials with similar thermal expansion coefficients for use in an injection valve." (*E.g.*, Ex. 1022, p. 20).) A POSITA as of the '829 patent's filing would have engaged in this same material selection process.

365. Moreover, Newcomb explains that its valve design approach "enable[s] the effects of thermal expansion to be reduced without the use of comparatively costly … materials." (Ex. 1014, 1:45-49.)

366. In my opinion, this potential for cost reduction through the use of less expensive materials would have served to further motivate a POSITA to apply Newcomb's teachings.

367. A POSITA would also have had a reasonable expectation of success.

368. Showing this, Newcomb itself explains that its material usage teachings are specifically intended for use with a "control valve such as a … fuel injection

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valve." (Ex. 1014, 1:5-7.) As I have explained, both Wirbeleit and Klügl teach fuel injection valves.

D. Ground 3: Claims 1-3, 6, 11-12, 14-15, and 18-19 Are Obvious Over Klügl and Hayes

369. In my opinion, a POSITA would have considered Klügl and Hayes to be within the scope of the prior art and highly relevant to the patentability of the '829 patent's claims.

370. In my opinion, moreover, when viewed and considered in light of the knowledge possessed by a POSITA as shown by Hayes, Klügl itself discloses all the limitations of and renders claims 1-3, 6, 11-12, 14-15, and 18-19 of the '829 patent obvious when Patent Owner's understanding of the claims is applied.

1. Claim-by-Claim Analysis

a. Claim 1

[1-p] "An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:"

371. To the extent the preamble is limiting, it is taught by Klügl.

372. In particular, Klügl teaches an "automotive" "injection valve." (Ex. 1006, 1:7-12.)

373. Further, Klügl explains that this valve controls injection into an "internal combustion engine." (*Id.*, 2:54-57.) In my opinion, a POSITA would understand this to be a direct injection valve for injecting fuel into the combustion chamber.

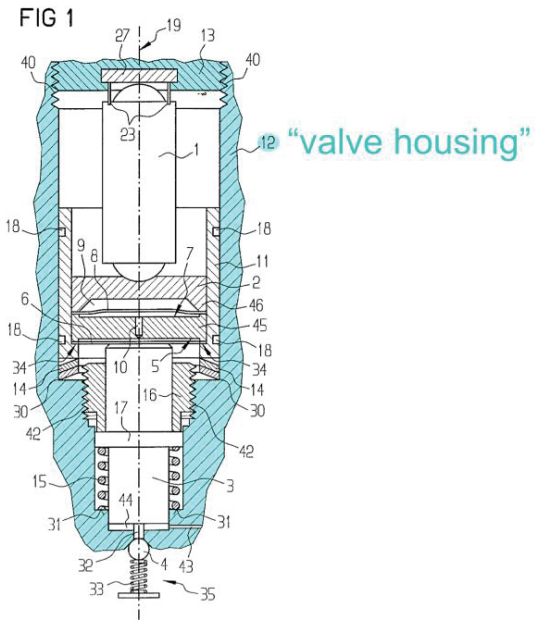
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[1(a)] "(a) a valve housing comprising:"

374. In my opinion, Klügl's injector includes the claimed ***"valve housing."***

375. In particular, Klügl's injector includes an "upper stop 13" and an outer "housing 12" that surrounds the valve components. (*Id.*, 1:47-51.)

376. This housing is shown below in teal:



(*Id.*, Fig. 1 (annotated).)

[1(a)-1] "a fuel inlet port;"

377. In my opinion, Klügl would obviously include the claimed ***"fuel inlet port."***

378. Klügl explains that a "servo valve" formed by "ball 4" (also referred to as a "closing member 4") "control[s] an injection needle, which controls the injection of an internal combustion engine." (Ex. 1006, 2:54-57.)

379. This "ball" is lifted from or lowered onto the "valve seat 35" by the "control needle 32" to "begin[]" or "end[]" "injection." (*Id.*, 3:23-38, 39-49.)

380. The opening of the ball servo valve allows the opening of an injector nozzle needle–not shown in Klügl's figure–as a "pressure chamber" that normally applies "high pressure to the injection needle" to be vented through the "relief line 43" to start fuel injection. (*Id.*, 3:33-38.)

381. Conversely, closing the servo valve allows "high pressure" to be "again applied" to the nozzle needle to close it and stop injection. (*Id.*, 3:39-49.)

382. In sum, in Klügl, the "injection needle" is moved to open/close a pathway to the combustion chamber.

383. While Klügl's figures do not show the structure around its "injection needle," in my opinion a POSITA would have understood that there would be a passage, conduit, line or other similar structure to supply fuel to the space adjacent to the "injection needle" such that fuel can be injected when the needle opens.

384. The purpose of the injection needle is to allow high pressure fuel to be sprayed into the combustion chamber when open, and stop the fuel spray when closed. To perform this function, high pressure fuel must be supplied to and stored behind the injection needle.

385. Other prior art shows how a POSITA would understand Klügl to be structured and operated. In my opinion, Hayes (Ex. 1024) provides an example.

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386. Hayes relates to an indirectly actuated fuel injector. (*Id.*, 1:7-14.) As I have explained, this is an injector where the nozzle needle valve is indirectly controlled by a pilot valve.

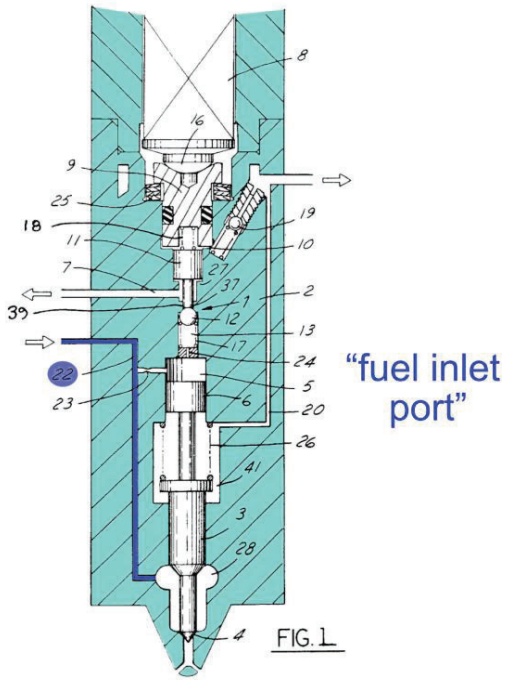
387. Hayes's injector includes an intermediate "control valve 1" sealed by a ball-shaped "component 12." (*Id.*, 2:7-15, 30-36.) This is analogous to the servo valve sealed by ball 4 in Klügl.

388. Actuating Hayes's injector opens the control valve. (*Id.*, 3:24-45.) This in turn lowers the pressure in a "chamber 5" which causes a separate "valve needle 3" to lift and open a passage into combustion chamber. (*Id.*, 3:53-63.) Fuel supplied by a "feeding line 22, which feeds the fuel at high pressure" is then injected through the passage opened by the needle. (*Id.*, 2:45-48, 3:53-63.)

389. This operation is also analogous to that in Klügl. Activating Klügl's injector opens the servo valve formed by ball 4, lowers the pressure in a "pressure chamber," and causes an "injection needle" to unseat so fuel can be injected.

390. Given the structural and functional similarity between Klügl and Hayes, in my opinion a POSITA would have understood that Klügl would include a "feeding line" like that in Hayes to supply high pressure fuel to the area behind its injection needle. This line is the claimed ***"fuel inlet port"*** and is shown in blue below:

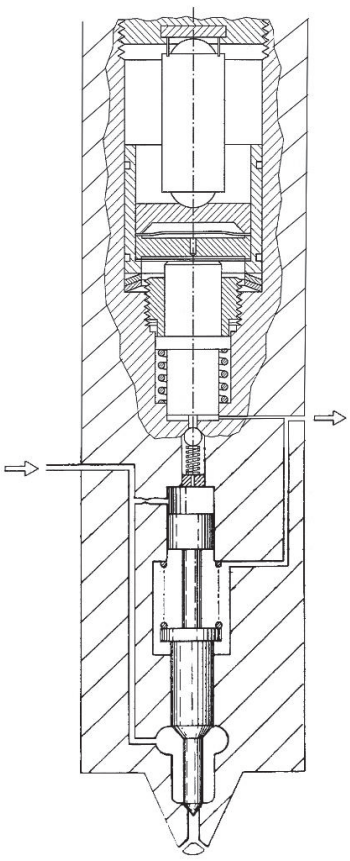
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(*Id.*, Fig. 1 (annotated).)

391. As a further clarification, the below demonstrative summarizes how, in my opinion, a POSITA would understand the portion of the injector below Klügl's servo valve and in the area of its injection needle to be structured. To create this demonstrative, I have applied the relevant portions of the injector shown in Fig. 1 of Hayes to Fig. 1 of Klügl. As explained, a lower injection needle—controlled by the intermediate servo valve—opens/closes a passage into the combustion chamber to allow fuel supplied by the inlet to be injected:

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(*See* Ex. 1006, Fig. 1; Ex. 1024, Fig. 1.)

[1(a)-2] "an interior chamber fluidly connected to said fuel inlet port;"

392. In my opinion, Klügl would obviously include the claimed ***"interior chamber."***

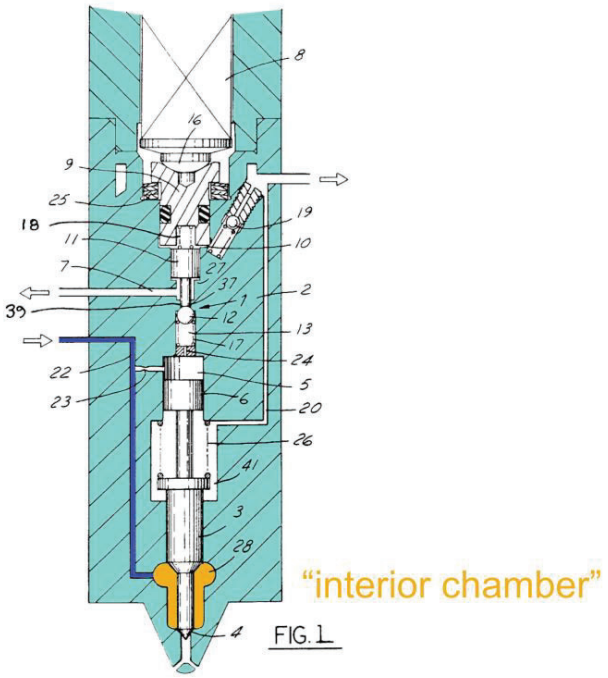
393. Again, as I have just explained, Klügl includes an "injection needle" that opens to the combustion chamber. (Ex. 1006, 3:33-38.)

394. As I have also explained, Hayes provides an example of how a POSITA would have understood the portion of Klügl's injector around this needle to be structured.

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395. In Hayes, fuel feed line 22 terminates in an "injection valve pressure chamber 28" located within the injector interior. (Ex. 1024, 2:45-47.)

396. This chamber 28 is shown in orange below. It corresponds to the claimed ***"interior chamber"***:



(*Id.*, Fig. 1 (annotated).)

397. In my opinion, a POSITA would have understood that Klügl would include a similar interior space adjacent to its injection needle: this would ensure that an adequate distribution of fuel is present behind the needle to provide uniform injection into the combustion chamber when the needle opens.

[1(a)-3] "a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber;"

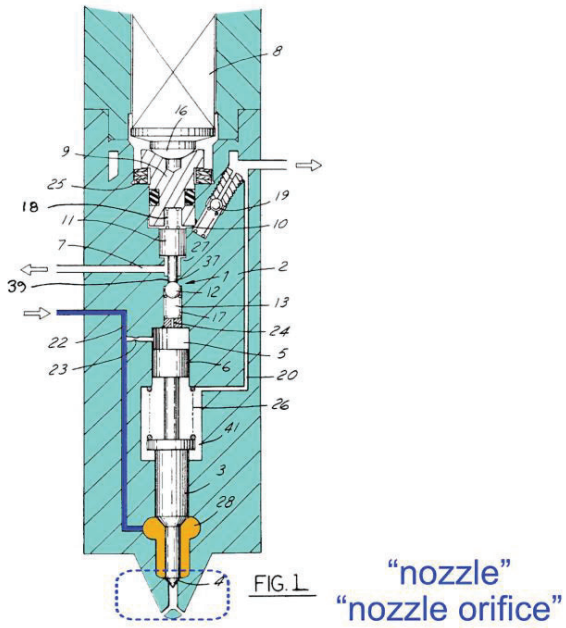
398. In my opinion, Klügl teaches the claimed ***"nozzle"*** and ***"nozzle orifice."***

399. As I have explained above, Klügl's injector includes an "injection needle" that is opened/closed to facilitate fuel "injection." (Ex. 1006, 3:23-49.)

400. In my opinion, the end of Klügl's injector that includes this injection needle is the claimed ***"nozzle."***

401. Further, the opening the needle creates from the pressure chamber to the combustion chamber is the claimed ***"nozzle orifice."***

402. In my opinion, Hayes again provides an example of a how POSITA would have understood Klügl to be structured:



(Ex. 1024, Fig. 1 (annotated).)

403. Consistent with what is shown in this figure, Hayes explains that its "nozzle needle" is "for opening and closing" its "nozzle." (*Id.*, 1:27-29.)

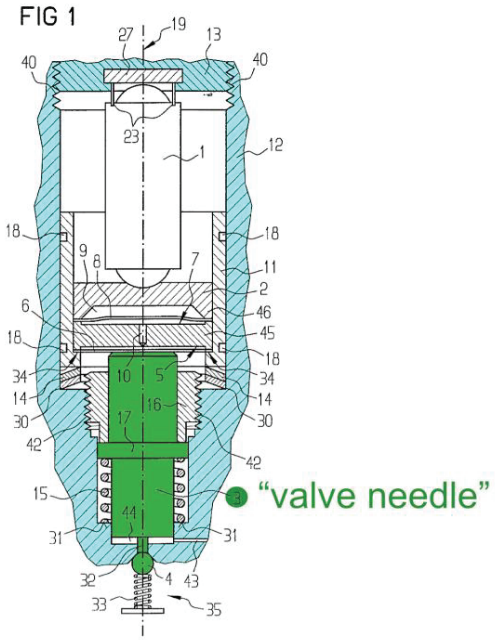
[1(b)] "(b) a valve needle disposed within said valve housing wherein said valve needle is movable between a closed position at which a sealing end of said valve needle contacts a valve seat to fluidly seal said interior chamber from said nozzle orifice, and an open position at which said sealing end of said valve needle is spaced apart from said valve seat whereby said interior chamber is fluidly connected with said nozzle orifice, wherein valve needle lift equals the distance traveled by said sealing end away from said valve seat;"

404. In my opinion, Klügl includes the claimed ***"valve needle"*** when Patent Owner's understanding of the claim (with reference to an indirectly controlled injection valve) is applied. (*See* Section VIII above).

405. In particular, Klügl's injector includes a "drive piston 3" that "merges into a control needle 32" at its lower end. (Ex. 1006, 2:50-53.) The "control needle 32 … extends … to a valve seat 35…." (*Id.*) There is a "ball 4," which Klügl also calls a "closing element 4," attached to this control needle that acts as a "closing element" when "pressed against the valve seat." (*Id.*, 2:54-57.)

406. In my opinion, the piston 3, control needle 32, and ball 4 together form Klügl's ***"valve needle"*** that ***"contacts a valve seat."*** These components are all highlighted in green below:

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(*Id.*, Fig. 1 (annotated).)

407. In my opinion, Klügl's valve needle moves between a ***"closed"*** to an ***"open"*** position to either ***"fluidly seal"*** or ***"fluidly connect[]"*** the ***"interior chamber"*** from or to the ***"nozzle orifice"*** as this claim limitation requires.

408. To open the injector, Klügl's actuator expands causing "[t]he drive piston 3" to be pressed downward or displaced. This in turn causes the "closing element 4" that is attached to the piston to be "lifted off the valve seat 35 by the control needle 32." (*Id.*, 3:23-33.)

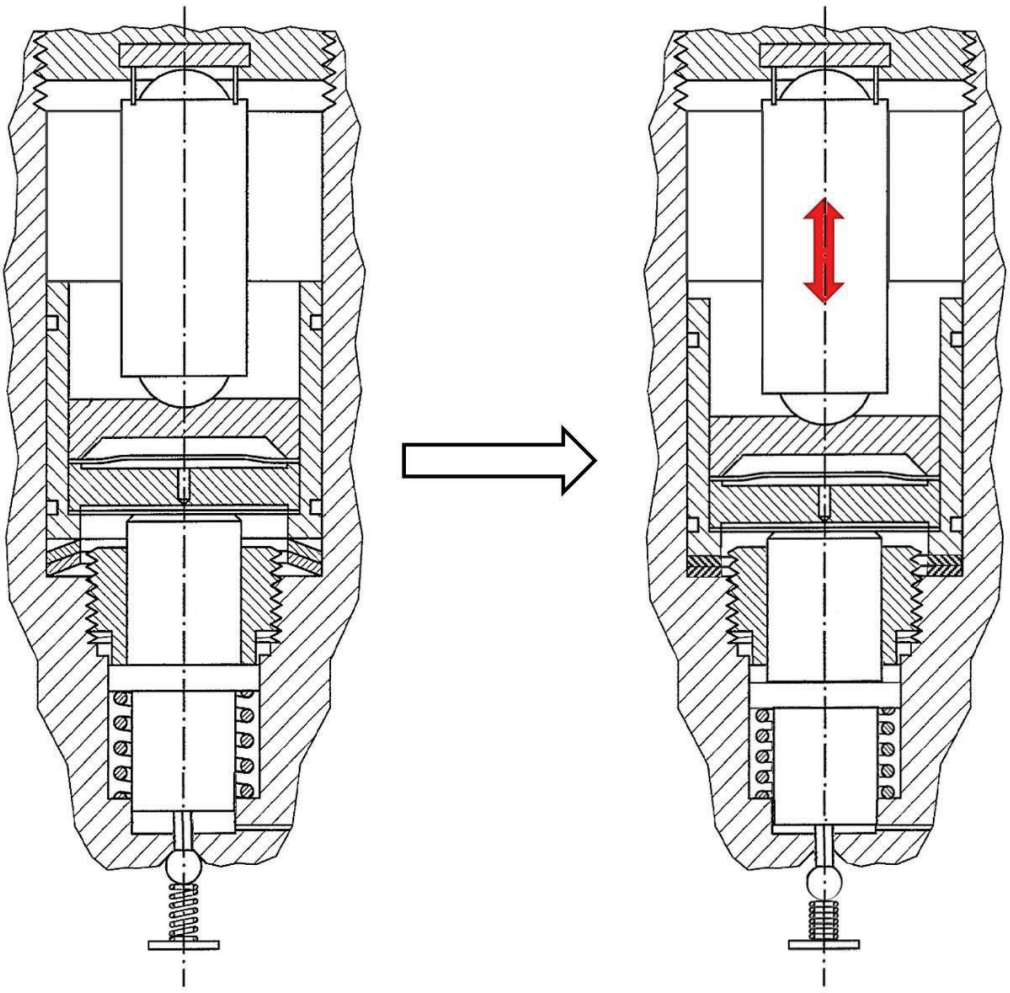
409. This lifting of element 4 off its seat causes "the pressure in the pressure chamber [to] drop[]" and "the injection needle" to "lift" so that injection to the combustion chamber can begin. (*Id.*, 3:33-38.) This is the ***"open"*** position (at least under Patent Owner's understanding of this claim term): the piston/needle/ball has

moved so as to cause the fluid connection—via the injection needle—from the fuel supply to the combustion chamber.

410. To close the valve, the actuator is deenergized causing it to shrink. This in turn causes the spring to exert pressure on the piston so that "closing element 4" is "pushed … back onto the assigned valve seat 35[.]" The pressure in the "pressure chamber" returns to a high level lowering the "injection needle" and ending injection. (*Id.*, 3:34-49.) This is the ***"closed position"*** (at least under Patent Owner's understanding of this claim term): the piston/needle/ball has again moved so as to cause the injection needle to seal the fuel supply from the combustion chamber.

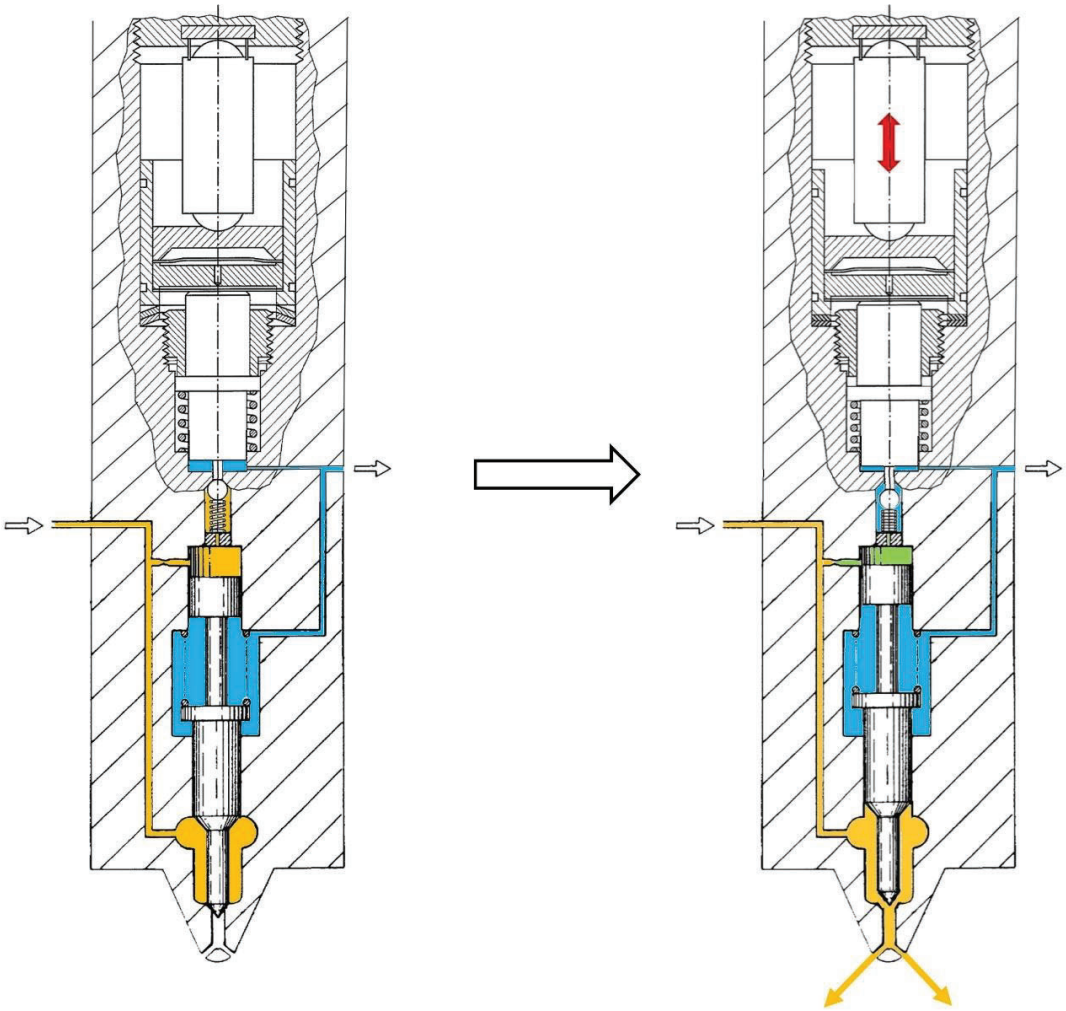
411. These positions are shown in the below demonstrative prepared using Figure 1 of Klügl. The closed position is shown to the left, while the open position is shown to the right. The piston size has been slightly modified in the figures to allow for an exaggerated depiction of movement while ensuring that the relief line is maintained, i.e., the piston wouldn't block the relief line in operation:

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412. In the combined injector of Hayes and Klügl, the figures below show the impact the opening/closing of Klügl's servo valve has on its injection needle (and how this results in fuel injection). Yellow represents areas of high pressure where high-pressure fuel is present. Blue represents areas of low pressure connected to the relief line. Green represents areas of intermediate pressure:

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413. As noted above, movement of Klügl's piston 3, control needle 32, and ball/closing element 4 does not directly open a passage from Klügl's fuel inlet to the combustion chamber—the only Klügl's injection needle does this.

414. Regardless, movement of Klügl's piston 3, control needle 32, and ball/closing element 4 indirectly opens this passage by lowering the pressure in Klügl's pressure chamber causing Klügl's injection needle to unseat so that fuel can be injected into the combustion chamber.

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415. Again, as I have explained, in my opinion this type of indirect actuation is not what claim 1 requires. (*See supra* Section VIII.)

416. But, as I have also explained, I understand that Patent Owner has taken the opposite position.

417. Applying Patent Owner's understanding of claim 1 to embrace indirectly actuated injectors, Klügl teaches what the claim requires.

418. In particular, it includes a "valve needle" (its piston 3, control needle 32, and ball/closing element 4) that operates (indirectly) to "fluidly seal" or "fluidly connect" an "interior chamber" (the interior space adjacent to Klügl's injection needle) from or to a "nozzle orifice" (the opening created by Klügl's injection needle to the combustion chamber when pressure in the pressure chamber drops).

[1(c)] "(c) a needle spring associated with said valve needle, wherein said needle spring applies a closing force to said valve needle for biasing said valve needle in said closed position;"

419. In my opinion, Klügl includes the claimed ***"needle spring."***

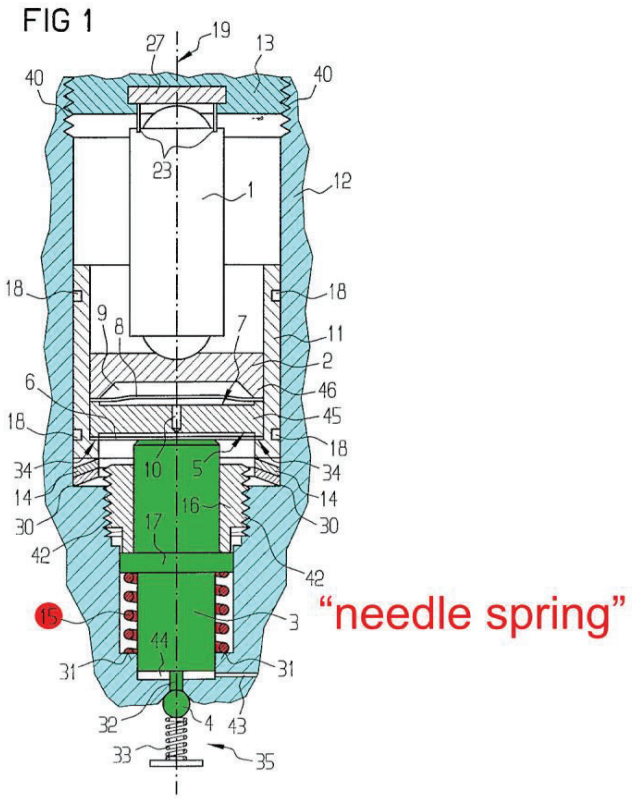
420. In particular, Klügl's injector includes a "spring 15" that "bias[es]" the "drive piston 3 … against a lower stop 16" located within the injector housing. (Ex. 1006, 2:35-36.)

421. The force exerted by this spring through the piston, along with cooperating force exerted on the ball 4 by a "valve spring 33", causes "closing

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element 4" to be "seated on the valve seat 35" when the injector is in its "rest" state. (*Id.*, 3:11-13, 19-22, 39-45.)

422. Spring 15 is highlighted in red below:



(*Id.*, Fig. 1 (annotated).)

[1(d)] "(d) an actuator assembly associated with said valve needle, wherein said actuator assembly may be activated to apply an opening force to said valve needle stronger than said closing force, for moving said valve needle to said open position; and"

423. In my opinion, Klügl's injector includes the claimed ***"actuator assembly."***

424. Klügl explains that a "piezoelectric actuator 1 is placed in" its "housing 12" "between an upper stop 13 and a transmission module 2…." (Ex. 1006, 1:47-51.)

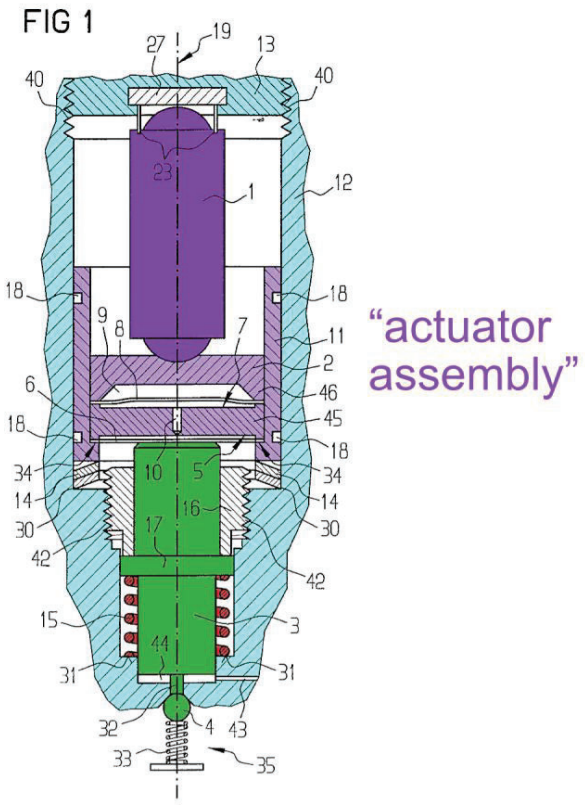
425. The "length" of this actuator can be "adjusted" via application of a voltage over "control lines 23." (*Id.*, 1:51-56.)

426. To open the injector, "the piezoelectric actuator 1 is … controlled" "press[ing] the entire transmission module 2 … in the direction of the drive piston 3" so as to "move[]" the piston "against the spring force of the tension spring 15…." (*Id.*, 3:23-33.)

427. To close the injector, "activation of the piezo actuator 1 ends" causing "the piezoelectric actuator 1" to be "shortened" and "transmission module 2" to be "pushed" back "in the direction of the piezoelectric actuator 1." (*Id.*, 3:39-45.)

428. The actuator 1 and transmission module 2 together constitute Klügl's "actuator assembly." The actuator 1 is shown in dark purple below, while the transmission module 2 is shown in light purple:

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(Fig. 1 (annotated).)

[1(e)] "(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is activated and wherein said thickness of said hydraulic link is adjustable while said actuator is not activated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve needle lift upon activation of said actuator assembly."

429. In my opinion, Klügl teaches the claimed ***"hydraulic link."***

430. I have already explained above in Section IX.B.1.a.[1(e)] (when discussing Wirbeleit and claim 1), Klügl's injector includes a chamber 5 filled with incompressible hydraulic fluid. When Klügl's actuator expands, force from the

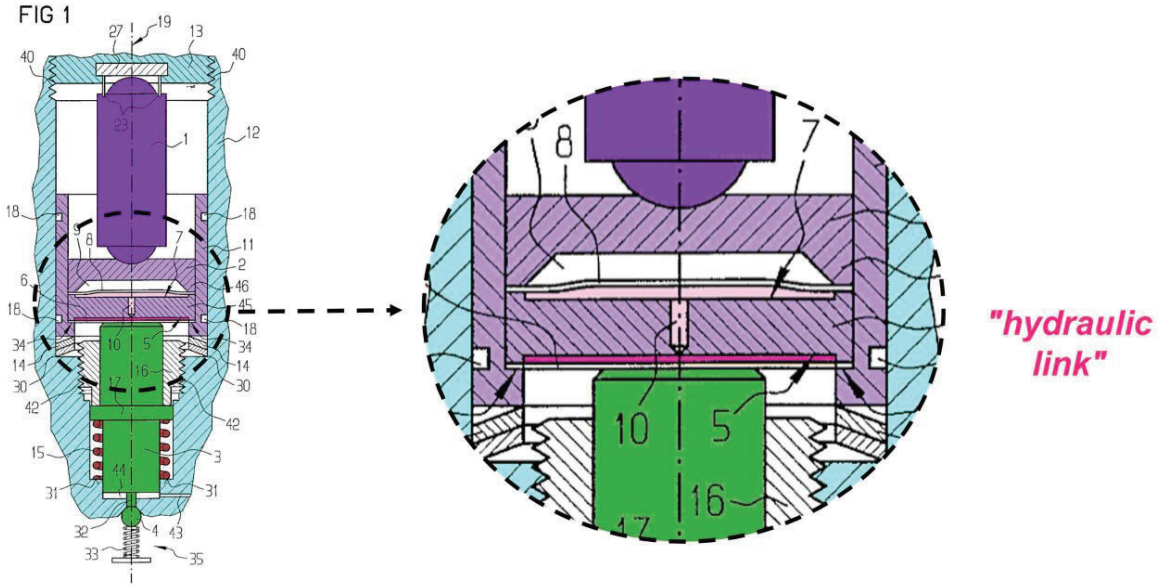
actuator is transmitted to piston 3 through the fluid in this chamber to open the injector. Then, when the actuator is deactivated to close the injector, the closing force of the spring 15 is transmitted back through this same chamber 5 until a rest point is reached.

431. As I have also explained, the fluid in this chamber passively transmits force from the actuator 1 to the piston 3. The piston 3 moves by the same distance that the actuator 1 expands. Further, because the fluid is incompressible and cannot flow out of chamber 5 during actuation, the fluid acts as solid with constant thickness.

432. Further, due to the presence of bore or throttle 10 that connects to a chamber 7, during periods of rest and valve inactivity, fluid can move from the chamber 5 through bore 10 to chamber 7 to automatically adjust and compensate for effects of thermal expansion and wear.

433. As a result, this fluid-filled chamber 5 corresponds to claimed ***"hydraulic link."*** This link is highlighted dark pink below. The bore 10 and chamber 7 that allow for auto-adjustment during idle or rest periods are shown in light pink. As done earlier in this declaration, the central portion of the figure has been expanded to the right to better focus on the chamber 5:

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(Fig. 1 (annotated).)

b. Claim 2

434. Claim 2 depends on claim 1 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by differential thermal expansion."

435. As explained above, Klügl and Hayes teach everything claim 1 requires.

436. In my opinion, Klügl teaches the additional limitation of this claim for the same reasons discussed above: fluid can move from Klügl's chamber 5 to chamber 7 when the injector is at rest to account for the effects of thermal expansion. (*See supra* Section IX.B.1.b.)

c. Claim 3

437. Claim 3 depends on claim 2 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not activated in response to changes in said dimensional relationship caused by wear to components of said injection valve."

438. As explained above, Klügl and Hayes teach everything claim 2 requires.

439. In my opinion, Klügl teaches same reasons discussed above: fluid can move from Klügl's chamber 5 to chamber 7 when the injector is at rest to account for the effects of wear. (*See supra* Section IX.B.1.c.)

d. Claim 6

440. Claim 6 depends on claim 1 and further requires:

"wherein said actuator assembly comprises a magnetostrictive member or a piezoelectric stack."

441. As explained above, Klügl and Hayes teach everything claim 1 requires.

442. In my opinion, the additional limitation of this claim is taught by Klügl. Klügl employs a "piezoelectric actuator 1" that "preferably consists of a stack of piezoelectric elements." (Ex. 1006, 1:52-56.)

e. Claim 11

443. Claim 11 depends on claim 6 and further requires:

"wherein when said actuator assembly is controllable to control said desired lift to between 10 and 100 percent of maximum lift."

444. As explained above, Klügl and Hayes teach everything claim 6 requires.

445. In my opinion, the additional limitation of this claim is rendered obvious by Klügl.

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446. Klügl explains that "the length" of its "piezoelectric actuator 1 can be adjusted" via a signal sent over "control lines 23" by a "control means 27." (Ex. 1006, 1:51-56.)

447. In my opinion, even in an indirectly actuated injector, it is advantageous to be able to open the valve proportionally as Klügl teaches from small to full valve lifts. For instance, in the combined embodiment of Klügl and Hayes presented above, the proportional control of Klügl's servo valve could additionally act as Hayes's control volume vent orifice 24 and would allow for control of the injection needle valve's opening and closing rates to improve noise and emissions.

448. Klügl teaches the general conditions of this claim. It is an injector with variable, controllable lift. Given this, in my opinion a POSITA would consider the claim to be obvious for the same reasons I note above. (*See supra* Section IX.B.1.e.)

f. Claim 12

449. Claim 12 depends on claim 11 and further requires:

"wherein said lift is controllable by controlling the electric current directed or voltage applied to said respective magnetostrictive or piezoelectric actuator assembly."

450. As explained above, Klügl and Hayes teach everything claim 11 requires.

451. In my opinion, the additional limitation of this claim is taught by Klügl for the same reasons I discuss for claim 11: the lift of Klügl's injector servo valve can be adjusted by controlling the voltage supplied to a piezoelectric actuator.

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g. Claim 14

452. Claim 14 depends on claim 6 and further requires:

"wherein said valve needle is controllable to move between said open and closed positions in less than about 200 microseconds."

453. As explained above, Klügl and Hayes teach everything claim 6 requires.

454. In my opinion, the additional limitation of this claim is rendered taught by Klügl for the same reasons discussed above: Klügl's valve can transition from an open to closed state in as little as 100 microseconds. (*See supra* Section IX.B.1.g.)

h. Claim 15

455. Claim 15 depends on claim 6 and further requires:

"a compression spring member for applying a compressive force to said magnetostrictive or piezoelectric member."

456. As explained above, Klügl and Hayes teach everything claim 6 requires.

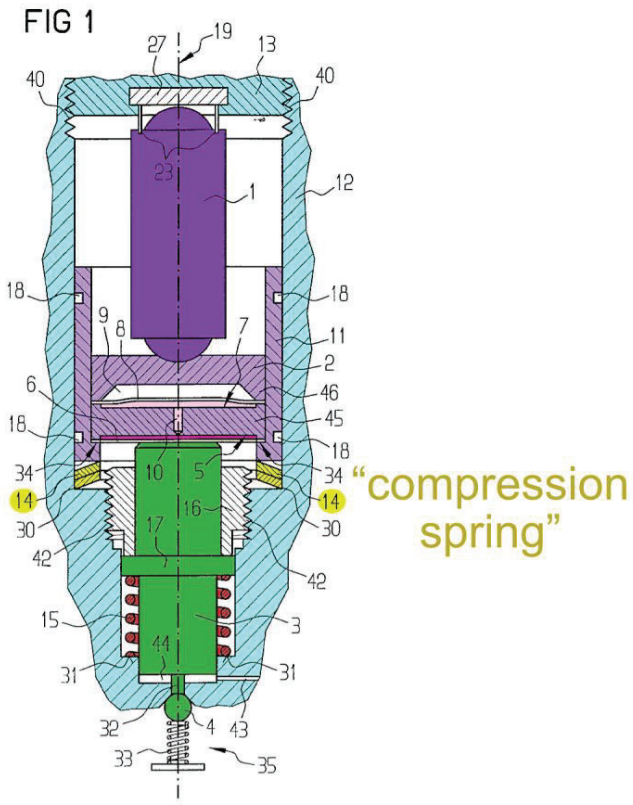
457. In my opinion, the additional limitation of this claim is taught by Klügl.

458. In particular, Klügl's injector includes a "disk spring 14" that "pre-stress[es]" the "piezoelectric actuator 1" against the injector housing. (Ex. 1006, 2:11-21, 3:16-19.)

459. This disk spring 14 is, in my opinion, the claimed ***"compressing spring member"***

460. The disk spring is highlighted yellow below:

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(*Id.*, Fig. 1 (annotated).)

i. Claim 18

461. Claim 18 depends on claim 1 and further requires:

"wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 MPa)."

462. As explained above, Klügl and Hayes teach everything claim 1 requires.

463. Klügl's injector employs a "high pressure" chamber to facilitate injection from its injector into an engine's combustion chamber. (*E.g.*, 1006, 3:33-38.)

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464. As I have explained above, a POSITA would have recognized that in such a high-pressure system, injection pressure would greatly exceed 2000 psi (particularly in a diesel engine). (*See supra* Section IX.B.1.i.)

j. Claim 19

465. Claim 19 depends on claim 1 and further requires:

"wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body."

466. As explained above, Klügl and Hayes teach everything claim 1 requires.

467. In my opinion, the additional limitation of this claim is taught by Klügl. In particular, Klügl's injector housing includes at least a "housing 12" and an "upper stop 13" that together form its sealed interior. (Ex. 1006, 1:49-51; Fig. 1.)

2. Motivation to Combine

468. This ground points to Hayes as an example of what a POSITA would understand Klügl to already teach. In other words, Hayes simply provides elaboration. Klügl is not being modified or changed in view of Hayes's teachings.

469. Regardless, in my opinion, a POSITA would have been motivated to look to Hayes—and would have had a reasonable expectation of success when doing so—not only because of the structural and functional similarity of Hayes and Klügl, but also because Hayes teaches that its injector is designed to be "simple," and "compensate[s] for tolerances and shifts due to temperature and wear." (Ex. 1024, 1:32-35.) Klügl's injector is designed with similar goals in mind.

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E. Ground 4: Claim 20 is Obvious Over Klügl, Hayes, and Newcomb

470. In my opinion, a POSITA would have considered Klügl, Hayes, and Newcomb to be within the scope of the prior art and highly relevant to the patentability of the '829 patent's claims.

471. In my opinion, when viewed and considered in light of the knowledge possessed by a POSITA, Klügl, Hayes, and Newcomb together disclose all the limitations of and render claim 20 of the '829 patent obvious.

472. Claim 20 depends on claim 1 and further requires:

"wherein said valve housing, said valve needle, and said actuator assembly, are selected from materials with similar thermal expansion coefficients to reduce changes in the dimensional relationship between said components caused by changes in temperature."

473. As explained above, Klügl and Hayes teach everything claim 1 requires.

474. In my opinion, a POSITA would have considered the additional limitation of claim 20 to be obvious in view of the teachings of Newcomb (Ex. 1014) for the same reasons I have already discussed.

475. In particular, Klügl already recognizes that an injector should be designed to account for the effects of wear or thermal expansion. And, Newcomb teaches that these effects can be further minimized by employing materials with compatible thermal expansion coefficients as this particular claim requires. (*See supra* Section IX.C.)

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F. Secondary Considerations of Non-Obviousness

476. Based on my review of the ’829 patent’s prosecution history, I note that no secondary considerations of non-obviousness were identified in connection with the patent’s claims.

477. I am not separately aware of any evidence of commercial success, skepticism, failure of others, industry praise, unexpected results, or the like. Instead, as discussed above, it is my opinion that the subject matter embraced by the ’829 patent’s claims was known in the art and would have been expected to function as a working fuel injector.

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

Date: 12/9/2022

Location: Monument, Colorado

Signature: 

Dr. J. Matt Quinlan

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ATTACHMENT A

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combustion.uccs.edu

EXPERIENCE

Assistant Professor August 2019 to Present
University of Colorado—Colorado Springs, Colorado Springs, CO

- Designed, constructed, and tested an outwardly-opening pintle fuel injector to study hydrodynamics and atomization
- Designed, constructed, and tested a rocket baffle nonlinear acoustic damping facility, now developing software to calculate the theoretical damping magnitude
- Simulated 3-D detonation wave fronts with detailed (skeletal) chemical models to develop next generation rotating detonation engines
- Developing diffuse interface methods for reacting, two-phase flow simulations
- First co-PI on funded five-year NSF MRI project to purchase and oversee UCCS's first supercomputer (over 125 TFLOPS) in 2020—installed and rolling out to users currently
- Appointed as a fellow in 2022 and 2020 for the Air Force Research Lab Summer Faculty Fellowship—funding for faculty and graduate student for research at the United States Air Force Academy in combustion diagnostics and detonation simulations
- Was awarded a UCCS CRCW Seed Grant for work in hydrodynamic instabilities
- Taught eleven undergraduate and graduate courses

Consultant/Owner 2005 to Present
Quinlan Engineering and Design, LLC, Woodland Park, CO

- Diesel fuel system design, development, and analysis
- Mechanical component design, structural analysis, and failure analysis
- Combustion instability analysis and mitigation
- Hydraulic hybrid vehicle powertrain design and analysis

Visiting Assistant Professor August 2018 to August 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

- Taught eight courses over the year

Adjunct Instructor August 2016 to August 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Research Engineer April 2014 to August 2015
Georgia Institute of Technology, Atlanta, GA

- Co-Principal Investigator on NASA supported (about $150,000/year) acoustic sensing in liquid rocket engine project
- Designed, built, and tested swirling, co-axial rocket injector with adjustable swirl.
- Developed pseudo-linear techniques to analyze high-amplitude acoustic sensor ports

Diesel Fuel System Engineer 2001 to 2006
Sturman Industries, Fuel System group, Woodland Park, CO

- Developed advanced prototype hydraulically intensified diesel fuel injectors, 3000 bar capable
- Developed advanced prototype common-rail diesel fuel injectors
- Primary structural analyst for Fuel System group
- Designed of mechanical components and assemblies for fuel systems
- Created print packages with geometric dimensioning and tolerancing (GD&T)
- Performed installations twice for German universities with a major automobile manufacturer
- Performed dynamometer and emissions mapping

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EDUCATION

Doctor of Philosophy, Aerospace Engineering
Georgia Institute of Technology, Atlanta, GA December 2015
Thesis: Investigation of Driving Mechanisms of Combustion Instabilities in Liquid Rocket Engines via the Dynamic Mode Decomposition
Advisor: Ben T. Zinn
Concentration: Thermoacoustic instability
Minor: Mathematics
Focus areas: Combustion, acoustics, viscous flow, turbulence, and high-temperature gas dynamics
Research:

- Developed data analysis techniques to experimentally find stability determining Floquet multipliers for systems with periodic governing equations
- Responsible for laboratory-scale facility concept, design, analysis, and development capable of exhibiting full-scale-like combustion instabilities
- Used sub-scale facility to study mechanisms that drive combustion instability, including the acquisition and analysis of data from high-speed diagnostics
- Performed synchronized 10 kHz OH-planar laser induced fluorescence, particle image velocimetry, CH^*-chemiluminescence, and acoustic pressure measurements to probe complex reacting/swirling flow
- Developed technique to analyze data based on dynamic mode decomposition, which preserves spatial/temporal relationship between synchronized diagnostics, extracting coupled dynamical modes
- Used the sub-scale facility, two-microphone wave decomposition, and real-time active acoustic impedance control to simulate a full-scale combustion instability at a frequency that is not a natural acoustic frequency of the system
- Wrote a finite element method based code to find the acoustic modes for geometrically complex combustion chambers

Masters of Science, Mechanical Engineering
Colorado State University, Fort Collins, CO May 2009
Thesis: Combustion Stability in Baffled Rocket Engines
Advisor: Charles E. Mitchell
Co-Advisor: Allan T. Kirkpatrick
Concentration: Thermoacoustic instability
Other focus areas: Structural mechanics
Research:

- Developed and delivered new liquid rocket engine combustion stability code
- Code uses a Fourier matching technique allowing stability predictions for more complex combustion chambers
- Demonstrated ability to locate the stability boundary based on a number of parameters including acoustic mode, frequency, combustion gain, and combustion phase
- Code currently being used by commercial rocket engine manufacturer

Bachelor of Science, Mechanical Engineering
Colorado State University, Fort Collins, CO May 2001

- Co-Captain FSAE Formula car team, 2000–2001

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PUBLICATIONS & PATENTS

Refereed Journals

- Schmidt, E. M., **Quinlan, J. M.**, and Runnels, B. "Self-similar Diffuse Boundary Method for Phase Boundary Driven Flow," *Physics of Fluids*, Vol. 34, No, 11, 2022.
- Kanagraajan, B., **Quinlan, J. M.**, Bojko, B., and Runnels, B. "A Diffuse Interface Method for Solid-Phase Modeling of Regression Behavior in Solid Composite Propellants," *Combustion and Flame* Vol. 242, 2022.
- Alsulami, R., Lucas, S., Hageman, M., Knadler, M., **Quinlan, J. M.**, and Windom, B., "Coupling Effects of Physical and Chemical Properties on Jet Fuel Spray Flame Blowout," *Proceedings of the Combustion Institute* Vol. 38, No. 2, 2021
- **Quinlan, J. M.**, and Zinn, B. T. "Development and Dynamical Analysis of Laboratory Facility Exhibiting Full-Scale Combustion Instability Characteristics," *AIAA Journal*, Vol 55, No. 12, 2017.
- Emerson, B., Jagtap, S., **Quinlan, J. M.**, Renfro, M. W., Cetegen, B. M., Lieuwen, T. "Stability Analysis of Reacting Wakes: Flow and Density Asymmetry Effects," *Physics of Fluids*, Vol. 28, No. 4, 2016.
- **Quinlan, J. M.**, Kirkpatrick, A., Milano, D., Mitchell, C. E., and Hinerman, T. D. "Analytical and Numerical Development of a Baffled Liquid Rocket Combustion Stability Code," *Journal of Propulsion and Power*, Vol. 28, No. 1, 2012.

U.S. Patents

- 8,622,859 – Systems and methods for hybridization of a motor vehicle using hydraulic components – 2014
  patentimages.storage.googleapis.com/98/12/19/b5196276017a4a/US8622859.pdf
- 8,366,018 – Oil intensified common rail injectors – 2013
  patentimages.storage.googleapis.com/bc/bf/15/7f6af484c4c669/US8366018.pdf
- 8,282,020 – Three-way valves and fuel injectors using the same – 2012
  patentimages.storage.googleapis.com/18/27/4d/b43fe73b70ab64/US8282020.pdf
- 7,681,592 – Three-way poppet valves with floating seat – 2010
  patentimages.storage.googleapis.com/20/70/33/24dfd50ac9b5e0/US7681592B2.pdf

Journal Manuscripts in Preparation or Review
For current preprints visit www.researchgate.net/profile/Matt-Quinlan

- **Quinlan, J. M.** "Parametric Combustion Instabilities," *AIAA Journal*.
- **Quinlan, J. M.** "Data Based Analysis of Periodic Phenomena: Floquet Theory Extended Dynamic Mode Decomposition," *Journal of Fluid Mechanics*.

Conference Papers

- Day, J., **Quinlan, J. M.** "Modeling Nonlinear Acoustic Damping Due to Flow Separation," *183rd Meeting of the Acoustical Society of America*. Vol. 1pEA8, Nashville, Tennessee, 2022.
- Schmidt, E. M., **Quinlan, J. M.**, Runnels, B. "A Self-Similar Diffuse Interface Method for a Rotating Ablating Cylinder," *75th Meeting of the American Physical Society—Division of Fluid Dynamics*. Vol. Z16.07, Indianapolis, Indiana, 2022.
- **Quinlan, J. M.** "Parametric Combustion Instabilities," *AIAA Science and Technologies Forum and Exposition*. Vol. AIAA-2022-1857, San Diego, California, 2022.
- Schmidt, E. M., **Quinlan, J. M.**, and Runnels, B. "Diffuse Interface Method for Coupling of Solid and Gaseous Phases in a 1D Verification Problem for Combustion of AP/HTPB," *AIAA Science and Technologies Forum and Exposition*. Vol. AIAA-2022-2196, San Diego, California, 2022.
- Day, J. A., Erazo Papagayo, S., and **Quinlan, J. M.** "Baffle Blade Acoustic Damping," *AIAA Propulsion and Energy Forum*. Vol. AIAA-2021-3573, Denver, Colorado, 2021.
- Erazo Papagayo, S., Day, J. A., Gamertsfelder, J. , Khare, P., and **Quinlan, J. M.** "Pintle Injector Spray Atomization: Liquid Sheet Breakup Quantification," *AIAA Propulsion and*

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Energy Forum. Vol. AIAA-2021-3630, Denver, Colorado, 2021.

- Rehl, A., **Quinlan, J. M.**, Scarborough, D., and Zinn, B. T. "Nonlinear Acoustic Response of Stand-Off Tubes Used in Acoustic Pressure Measurements—Part I: Experimental Study," *170th Meeting of the Acoustical Society of America*. Vol. 2PEA4, Jacksonville, Florida, 2015.
- **Quinlan, J. M.**, Scarborough, D., Rehl, A., and Zinn, B. T. "Nonlinear Acoustic Response of Stand-Off Tubes Used in Acoustic Pressure Measurements—Part II: Analysis," *170th Meeting of the Acoustical Society of America*. Vol. 2PEA5, Jacksonville, Florida, 2015.
- Damião, A., **Quinlan, J. M.**, Kim, Y. J., and Zinn, B. T. "Determination of Combustion Stability Margin Using the Filter Diagonalization Method," *51st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2015-4019, Orlando, Florida, 2015.
- **Quinlan, J. M.**, and Zinn, B. T. "Transverse Combustion Instabilities: Modern Experimental Techniques and Analysis," *50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2014-3682, Cleveland, Ohio, 2014.
- **Quinlan, J. M.**, and Zinn, B. T. "Simulating Full-Scale Transverse Combustion Instabilities in a Lab-scale Facility," *49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2013-4019, San Jose, California, 2013.
- Bibik, A. V., Lubarsky, E., **Quinlan, J. M.**, Shcherbik, D., and Zinn, B. T. "Control of Tangential Combustion Instability by Asymmetric Baffle," *Critical Phenomena under Extreme Impact (CPUEI-2012)*, Kharkov, Ukraine, 2012.
- **Quinlan, J. M.**, Bibik, O., and Zinn, B. T. "Experimental and Numerical Combustion Instability Modes in Asymmetric Baffled Chambers," *46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2010-6802, Nashville, Tennessee, 2010.
- **Quinlan, J. M.**, Kirkpatrick, A., Milano, D., Mitchell, C. E., and Hinerman, T. D. "Analytical and Numerical Development of a Baffled Liquid Rocket Combustion Stability Code," *45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2009-4865, Denver, Colorado, 2009.
- Milano, D., **Quinlan, J. M.**, Kirkpatrick, A., Mitchell, C. E., and Hinerman, T. D. "Computation of Acoustic Oscillations and Combustion Stability in a Rocket Engine with Combined Hub/Blade Baffles," *45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2009-4866 Denver, Colorado, 2009.
- Wolverton, M. A., Giordano, D., **Quinlan, J. M.**, and Zukouski, R. "Evaluation of a 3-Way Direct Needle Control Unit Injector on Hydraulic Test Bench and V8 Engine," *2004 SAE World Congress*. Vol. SAE-2004-01-0024, Detroit, Michigan, 2004.

Talks

- **Quinlan, J. M.** "Swirling Flames and Floquet Multipliers: Parametric Combustion Instabilities," *Invited talk—Department of Mechanical Engineering, Colorado State University*, Fort Collins, Colorado, January 2022.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, October 2021.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado—Colorado Springs*, Colorado Spring, Colorado, October 2020.
- **Quinlan, J. M.** "Global Variational Methods: Numerical Approximations for Ordinary Differential Equations," *Invited talk—Computational Science & Engineering Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, July 2019.
- **Quinlan, J. M.** "Swirling Flames and Floquet Multipliers: Parametric Combustion Instabilities," *Invited talk—Department of Mechanical and Aerospace Engineering, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, March 2019.
- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Air Force Office of Scientific Research (AFOSR) 2015 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2015.

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- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T., Law, C. K. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Triservice Basic Science Energetic Materials Program Review*, Arlington, Virginia, 2014.
- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T., Law, C. K. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Air Force Office of Scientific Research (AFOSR) 2013 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2013.
- **Quinlan, J. M.**, Kim, Y. J., Baroncelli, M., Dumitrache, C., Zinn, B. T. "Development Of Actively Controlled LRE Simulator (ACLRES) Rig," *Air Force Office of Scientific Research (AFOSR) 2012 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2012.

HONORS

Award: Abe Zarem Graduate Award For Distinguished Achievement—Astronautics 2022
AIAA
Advisee, Joseph Day won this national award for paper presented at a AIAA Student Conference. Joseph was awarded a funded trip to the 2023 AIAA SciTech Forum and Exposition to accept the award and a trip to present his work at the 2022 International Astronautical Congress in Paris. www.aiaa.org/get-involved/honors-awards/awards/award/award-abe-zarem-graduate-award-for-distinguished-achievement-astronautics

Fellowship: Air Force Research Lab Summer Faculty Fellowship 2022
AFOSR
Appointed as a fellow at the USAFA to perform research simulating detonations for application to rotating detonation engines; grant received with student Santiago Erazo for summer research

Fellowship: UCCS Undergraduate Research Academy 2022
University of Colorado–Colorado Springs
Research grant received with undergraduate student Duncan Schlueter for summer research

Fellowship: UCCS Undergraduate Research Academy 2021
University of Colorado–Colorado Springs
Research grant received with undergraduate student Sarah Chancellor for summer research

Fellowship: Air Force Research Lab Summer Faculty Fellowship 2020
AFOSR
Appointed as a fellow at the USAFA to perform research on combustion diagnostics for monopropellant, pintle injectors for various liquids; grant received with student Joseph Day for summer research

Fellowship: UCCS Undergraduate Research Academy 2019
University of Colorado–Colorado Springs
Research grant received with undergraduate student Joseph Day for summer research

Fellowship: UCCS EAS Undergraduate Research Scholars Program 2019
University of Colorado–Colorado Springs
Research grant received with undergraduate student Joseph Day

Scholarship: Combustion Energy Frontier Research Center—Summer School 2012
Princeton University, Princeton, NJ
Combustion Theory and Internal Combustion Engines

Scholarship: Combustion Energy Frontier Research Center—Summer School 2011
Princeton University, Princeton, NJ
Combustion Theory and Combustion Chemistry

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TEACHING

Principles of Combustion (full responsibility for course—Grad) Fall 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Compressible Flow (full responsibility for course—Grad) Spring 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Spring 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Rocket Propulsion (full responsibility for course—Grad) Fall 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Incompressible Flow (full responsibility for course—Grad) Spring 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course—two sections) Fall 2020
University of Colorado—Colorado Springs, Colorado Springs, CO

Principles of Combustion (full responsibility for course—Grad) Spring 2020
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course—two sections) Fall 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Summer 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

Machine Design I (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Materials Engineering (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Measurement Lab (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Machine Design I (full responsibility for course—two sections) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Mechanics I (full responsibility for course) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Measurement Lab (full responsibility for course) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Summer 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Liquid Rocket Engines: Fundamentals and Green Propellants Summer 2018
AIAA Joint Propulsion Conference Short Course, Cincinnati, OH

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Control of Aero. and Mech. Systems (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2017
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Mechanics II (full responsibility for course) Fall 2016
University of Colorado—Colorado Springs, Colorado Springs, CO

Introduction to Thermal Sciences (full responsibility for course) Summer 2008
Colorado State University, Fort Collins, CO

Teaching Assistant – **Mechanics and Thermodynamics of Flow Processes** Fall 2008
Colorado State University, Fort Collins, CO

Mentoring – Undergraduate and Graduate Students 2010 to 2015
Georgia Institute of Technology, Atlanta, GA

- Mentored one PhD student—primary supervisor of his research
- Mentored two Masters students, both went on to pursue doctoral degrees
- Supervised undergraduate research with multiple students for multiple semesters

DISSERTATION AND THESIS COMMITTEES

Committee member 2022
Sean Coughenour—Masters of Science in Mechanical Engineering
"Design and Validation of a Microbubble Levitation Chamber Using an Acoustic Vortex Beam"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2022
Andrew Gibson—Masters of Science in Mechanical Engineering
"Application of Koopman Linear Quadratic Regulator to the Control of a Spherical Microbubble"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2021
Danny Paredes—Masters of Science in Mechanical Engineering
"Inviscid Flow Past Canonical Bodies"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2020
Lluís Umbert Amat—Masters of Science in Mechanical Engineering
"Tethered Aerobraking Design for Repeatable Maneuvers"
University of Colorado—Colorado Springs, Colorado Springs, CO

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SERVICE

Committees

- Technical Discipline Co-Chair—AIAA SciTech Liquid Propulsion Technical Committee 2023
- Member—UCCS CRCW Seed Grant Review Committee 2022
- Technical Discipline Chair—AIAA SciTech Liquid Propulsion Technical Committee 2022
- Member—AIAA Liquid Propulsion Technical Committee 2015–2022
  - Education Subcommittee
  - Helped develop and teach content for rocket propulsion short course
  - Chaired technical sessions
- Member—UCCS Aerospace BS/MS Degree Committee 2021–2022
- Member—UCCS INCLINE (supercomputer) Management Committee 2020–2022
- Member—UCCS MAE Graduate Committee 2019–2022
- Member—UCCS MAE Instructor Hiring Committee 2019–2020
- Volunteer reviewer—interviewed candidates for the 2020 Georgia Tech President's Scholars Program (four-year, full-ride scholarship for the top incoming student) and our recommended student was selected for the award 2020
- Member—UCCS MAE Curriculum Committee 2018–2019
- Member—ASA Engineering Acoustics Technical Committee 2016–2018
- Member—Aerospace Engineering Combustion Laboratory/Carbon-Neutral Energy Solutions Laboratory Safety Committee 2012–2015
  Helped develop and implement formal Safety Review Process plan to ensure safe operation of laboratory facilities and experiments
- Member—Combustion Laboratory Long Term Planning Committee 2014
  Helping formulate a 10-year plan for the direction of the laboratory
- Advisor—Aerospace Engineering Manufacturing and Prototyping Faculty Task Force 2014
  Recommended equipment and personnel that should be available to students to properly learn about manufacturing processes and communication
- Member—Aerospace Engineering Combustion Laboratory Calibration Committee 2013
  Committee proposed equipment and processes to properly calibrate the most commonly used measurements in the laboratory
- Member—Particle Image Velocimetry Error Analysis Group 2011–2012
  Group organized to study and attempt to quantify the level and sources of experimental error

Peer Review

- Reviewer—Combustion and Flame 2022
- Reviewer—AIAA SciTech Forum 2022
- Reviewer—AIAA Propulsion & Energy Conference 2016–2021
- Reviewer—Journal of Propulsion and Power 2015, 2021
- Reviewer—AIAA Journal 2019
- Reviewer—Journal of the Acoustical Society of America 2018
- Reviewer—ASME Turbo Expo: Turbine Technical Conference 2015, 2017, 2018, 2019
- Reviewer—ACS PRF grants 2020

Organizations

- Order of the Engineer
- American Institute of Aeronautics and Astronautics

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SKILLS

Certifications: Passed Fundamentals of Engineering Examination – 2000
Qualified to take Professional Engineering licensing exam

Programing Languages & Software: Fortran, Python, Julia, Git, CMake, LaTeX, Maple, Matlab, Tecplot, Chemkin, Cosmos (structural FEA), Abaqus (structural FEA), Mathcad, Ricardo Wave (engine simulation), Fluent (CFD), SolidWorks, Ubuntu, and Microsoft Office

Fabrication: CNC machining, EDM machining, milling, turning, forging, grinding, diamond tooling, engine building, MIG, TIG, and arc welding, injection molding, vacuum/pressure casting, metal matrix composites, material selections, heat treating, and carbon fiber composites

EXTRACURRICULAR ACTIVITIES

Outdoor Enthusiast

- Climbed Mount Rainer, July 2005
- Completed Imogene Pass Run three times (17.1 miles and over 5,000 feet elevation gain)

Avid Photographer

- 24 years experience developing film and photographs in personal darkroom
- Gallery Visitors' Choice Award during 2007 "Alternative Processes" show at nationally known Center for Fine Art Photography

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ROBERT BOSCH LLC, and
MERCEDES-BENZ USA LLC,
Petitioners,
v.
WESTPORT FUEL SYSTEMS CANADA INC.,
Patent Owner.

U.S. Patent No. 6,575,138
Case No. IPR2023-00293

DECLARATION OF DR. J. MATT QUINLAN

Quinlan 4/19/24 - KK
Exhibit
2

Quinlan Depo.
Exhibit
2

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I, Dr. J. Matt Quinlan, declare as follows:

I. INTRODUCTION

1. I have been retained by Robert Bosch Corp. ("Robert Bosch") as an independent expert consultant in this proceeding before the United States Patent and Trademark Office ("PTO"). I am not an employee of Robert Bosch or any affiliate or subsidiary of Bosch or any of the other petitioners or real parties-in-interest in this petition.

2. I have been asked to consider whether certain references teach or suggest the features recited in certain claims of U.S. Patent No. 6,575,138 B2 to Welch et al., which I refer to herein as the '138 patent.

3. My opinions and the bases for my opinions are set forth below.

4. I am being compensated at my ordinary and customary rate of $400 per hour for my work, plus reimbursement for any reasonable expenses. My compensation is based solely on the amount of time that I devote to activity related to this case and is in no way contingent on the nature of my findings, the presentation of my findings in testimony, or the outcome of this or any other proceeding. I have no other financial interest in this proceeding.

II. EDUCATION BACKGROUND, PROFESSIONAL EXPERIENCE, AND OTHER QUALIFICATIONS

5. My curriculum vitae ("CV") is attached hereto as Attachment A and provides an accurate identification of my background and experience.

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6. I am currently an assistant professor in the Mechanical and Aerospace Engineering department at the University of Colorado, Colorado Springs ("UCCS"). I am also the Director of UCCS's Combustion and Acoustics Lab.

7. I received a B.S. in mechanical engineering from Colorado State University in 2001.

8. From 2001 to 2006, I worked as a fuel systems engineer at Sturman Industries. My responsibilities included the development, testing, design, analysis, and customer interface/installation of diesel fuel injectors.

9. Starting in 2006, I returned to Colorado State University to continue my studies. I received a M.S. in mechanical engineering in 2009.

10. Starting in 2009, I attended the Georgia Institute of Technology. While there, I served as a Graduate Research Assistant and Research Engineer, focusing on combustion instability in liquid propellant rocket engines and the remote measurement of rocket engine chamber pressure dynamics.

11. I received a Ph.D. in aerospace engineering from the Georgia Institute of Technology in 2015.

12. From 2005 to the present, I also worked as a consultant engineer for my own consulting firm, known as Quinlan Engineering and Design, LLC. I engage in engineering design, development, and analysis in fuel systems.

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13. I joined the faculty at UCSS in 2018 as a visiting assistant professor and permanently in 2019 as an assistant professor.

14. I am the named inventor on a number of patents relating to automotive technology, including fuel injectors. These patents include, for example, U.S. Patent No. 7,681,592 (entitled "Three-way poppet valves with floating seat"), U.S. Patent No. 8,282,020 (entitled "Three-way valves and fuel injectors using the same"), and U.S. Patent No. 8,366,018 (entitled "Oil Intensified common rail injectors").

15. I have also co-authored papers relating to fuel injectors, including "Evaluation of a 3-Way Direct Needle Control Unit Injector on Hydraulic Test Bench and V8 Engine," SAE Technical Paper 2004-01-0024 (2004).

16. A complete list of my patents and publications is included as part of my attached CV.

III. ASSIGNMENT AND MATERIALS CONSIDERED

17. I have been asked to provide analysis and explain the subject matter of the '138 patent, including the state of the art when the '138 patent application was filed. I have also been asked to consider, analyze, and explain certain prior art to the '138 patent, including how that art relates to the challenged claims of the '138 patent and to provide my opinions regarding whether that art invalidates the claimed subject matter.

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18. The opinions expressed in this declaration are not exhaustive of opinions I may offer in the future regarding the unpatentability of the claims of the ’138 patent. Therefore, the fact that I do not address a particular point should not be understood to indicate an agreement on my part that any claim complies with the requirements of any applicable patent or other rule.

19. I reserve the right to amend and supplement this declaration in light of additional evidence, arguments, or testimony presented during this IPR or related proceedings on the ’138 patent.

20. In forming the opinions set forth in this declaration, I have considered and relied upon my education, knowledge of the relevant field, knowledge of scientific and engineering principles, and my experience. I have also reviewed and considered the ’138 patent (Exhibit 1001), its prosecution history (Exhibit 1002), and the following additional materials:

Exhibit	Description
1004	U.S. Patent No. 5,479,902 to Wirbeleit et al. (“Wirbeleit”)
1005	DE 197 08 304 A1 to Klügl (“Klügl”)
1006	Certified translation of Klügl and associated translator’s declaration
1007	U.S. Patent No. 5,735,240 B1 to Ito et al. (“Ito”)
1008	U.S. Patent No. 6,295,969 B1 to Kato et al. (“Kato”)
1009	U.S. Patent No. 5,697,554 B1 to Auwaerter et al. (“Auwaerter”)
1010	U.S. Patent No. 4,725,002 to Trachte (“Trachte”)

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1011	U.S. Patent No. 5,630,550 to Kurishige et al. ("Kurishige")
1012	U.S. Patent No. 4,684,067 to Cotter et al. ("Cotter")
1013	EP 0 107 894 A2 to Beck et al. ("Beck")
1014	U.S. Patent No. 4,284,263 to Newcomb ("Newcomb")
1015	GB 2 318 390 A to Roessler et al. ("Roessler")
1022	Plaintiff Westport Fuel Systems Canada Inc.'s Disclosure of Asserted Claims and Infringement Contentions from *Westport Fuel Systems Canada Inc. v. Ford Motor Company,* Case No. 2:21-cv-00453 (E.D. Tex.)
1023	U.S. Patent No. 6,148,842 to Kappel et al. ("Kappel")
1024	U.S. Patent No. 5,779,149 to Hayes, Jr. ("Hayes")

IV. UNDERSTANDING OF THE LAW

21. I am not an attorney but have been instructed in and applied the law as described in this section.

22. I understand that the first step in comparing an asserted claim to the prior art is for the claim to be properly construed. I address how a person of ordinary skill in the art ("POSITA") would have understood the claims in Section VIII below.

23. I have been further instructed and understand that a patent claim is unpatentable and invalid as obvious if the subject matter of the claim as a whole would have been obvious to a POSITA of the claimed subject matter as of the time of the invention at issue. I understand that when assessing the obviousness of claimed subject matter, the following factors are evaluated: (1) the scope and content

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of the prior art; (2) the difference or differences between each claim of the patent and the prior art; and (3) the level of ordinary skill in the art at the time the patent was filed.

24. I understand that claimed subject matter may be obvious in view of more than one item of prior art. I understand, however, that it is not enough to show simply that all the limitations of the claimed subject matter are spread throughout the prior art. Instead, for claimed subject matter to be obvious over multiple references, there must be some reason or motivation for a POSITA to combine the prior art references to arrive at the claimed subject matter.

25. I have been informed that, in seeking to determine whether an invention that is a combination of known elements would have been obvious to a POSITA at the time of the invention, one must consider the references in their entirety to ascertain whether the disclosures in those references render the combination obvious to such a person.

26. I have been informed and understand that, while not required, the prior art references themselves may provide a teaching, suggestion, motivation, or reason to combine, but other times the motivation linking two or more prior art references may be supplied by common sense or the background knowledge of a POSITA at the time of the invention.

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27. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. I have been informed that, if a technique has been used to improve one device, and a POSITA would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.

28. I further understand that an obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references also may be supplied by the direction of the marketplace. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

29. I have been informed that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. Thus, where all of the elements of a claim are used in substantially the same manner, in devices in the same field of endeavor, the claim is likely obvious.

30. Additionally, I understand that a patent is likely to be invalid for obviousness if a POSITA can implement a predictable variation or if there existed

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at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims. Therefore, when a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one.

31. I further understand that combining embodiments related to each other in a single prior art reference would not ordinarily require a leap of inventiveness.

32. I also understand that a POSITA must have had a reasonable expectation of success when combining references for claimed subject matter to be obvious.

33. I have been informed and I understand that factors referred to as "objective indicia of non-obviousness" or "secondary considerations" are also to be considered when assessing obviousness when such evidence is available. I understand that these factors can include: (1) commercial success; (2) long-felt but unresolved needs; (3) copying of the invention by others in the field; (4) initial expressions of disbelief by experts in the field; (5) failure of others to solve the problem the claimed subject matter solved; and (6) unexpected results.

34. I also understand that evidence of objective indicia of non-obviousness must be commensurate in scope with the claimed subject matter. I further understand that there must be a relationship, sometimes referred to as a "nexus," between any such secondary indicia and the claimed invention.

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35. Finally, I have been informed that one cannot use hindsight to determine that an invention was obvious.

36. I provide my opinions in this declaration based on the guidelines set forth above.

V. LEVEL OF SKILL IN THE ART

37. I have been informed and understand that the level of ordinary skill in the relevant art at the time of the invention is relevant to inquiries such as the meaning of claim terms, the meaning of disclosures found in the prior art, and the reasons a POSITA may have for combining references.

38. I have been informed and understand that factors that may be considered in determining the level of ordinary skill include: (1) the education of the inventor; (2) the type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology; and (6) education level of active workers in the relevant field. I have been further informed and understand that a POSITA is also a person of ordinary creativity.

39. A POSITA in the technology field of the '138 patent would, in my opinion, have had a degree in mechanical engineering or a similar discipline, along with 2 years of professional experience working with the design and development

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of fuel injection systems for internal combustion engines or an equivalent level of skill, knowledge, and experience.

40. In my opinion, this POSITA would have been aware of and generally knowledgeable about how fuel injectors and the valves used within are structured and operate, and how they are used to deliver fuel to an engine's combustion chambers.

41. In my opinion, a POSITA would have had the same basic level of skill and background knowledge regardless of whether the'138 patent is entitled to an October 1999, March 2000, or May 2001 filing date.

42. In view of my educational background (e.g., a M.S. in mechanical engineering and Ph.D. in aerospace engineering) and work experience in the fuel injector field, I am a person of more than the ordinary level of skill in the art of the '138 patent. In forming my opinion, I have drawn on my academic background and professional experiences. My opinions herein, however, were formed taking into account the perspective of an ordinarily skilled artisan.

VI. THE '138 PATENT'S EFFECTIVE FILING DATE

43. I understand that the application leading to the '138 patent was filed on May 23, 2001.

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44. Based on my review of the ’138 patent, I note that it both identifies itself as a continuation-in-part of a March 9, 2000 application, and makes reference to an October 15, 1999 provisional application.

45. For purposes of this declaration, I have been instructed to use October 15, 1999 as the effective filing date of the ’138 patent. My opinions in this declaration were formed from the perspective of a POSITA as of October 15, 1999, including both the knowledge of a POSITA at that time as well as how a POSITA would have understood the prior art. Nevertheless, the opinions I express in this declaration would be the same regardless of whether the ’138 patent has an October 15, 1999, a March 9, 2000, or a May 23, 2001 effective filing date.

VII. THE ’138 PATENT

A. Overview

46. The ’138 patent relates to fuel “injectors for internal combustion engines” that are “directly controllable” by a piezoelectric or magnetostrictive actuator. (Ex. 1001, 1:16-20.)

47. According to the patent, the injector also includes a “passive hydraulic link.” (*Id.*, 1:21.)

48. The patent begins by discussing prior art fuel injectors.

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49. Here, the patent explains that as of its filing, it was known to be beneficial to engage in "[d]irect injection." Direct injection entails injection directly into the combustion chamber of an internal combustion engine. (*Id.*, 1:23-40.)

50. The patent explains that this type of injection—in contrast to indirect injection into the manifold and outside of the combustion chamber—is "desirable" because it improves engine performance and reduces emissions. (*Id.*)

51. The patent also explains that prior direct fuel injection systems that were "hydraulically actuated" or "use piezoelectric actuator[s]" were known and available. (*E.g.*, *id.*, 2:13-17, 2:52-55.)

52. The patent goes on, however, to identify certain purported problems with these known systems.

53. For instance, hydraulically actuated systems require "additional hydraulic hardware," which adds "increased bulkiness" and subjects the system to a "delayed response" and reduced "controllability of movement of the injection valve." (*Id.*, 2:23-46.)

54. Further, known piezoelectric actuators were purportedly only used to "operate a control valve, which in turn controls the flow of a hydraulic fluid to operate an injection valve" resulting in delayed injector operation and increased complication. (*Id.*, 2:52-64.)

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55. After discussing these known fuel injectors, the ’138 patent proposes a “directly actuated” injector that does not include “an intermediate active hydraulic operator generating any actuating forces.” (*Id.*, 2:64-67.)

56. The ’138 patent explains that its injector does include a “passive hydraulic link.” (*Id.*, 4:10-12, 34-38; 7:23-37.)

57. The patent explains however, that in contrast to “[c]onventional active hydraulic operators,” the “passive hydraulic link” employed by its injector “merely transmits the actuating forces” or serves as a “load path” “but is not employed to generate an actuating force for actuating the valve.” (*Id.*)

58. The patent also notes that the “passive hydraulic link” provides a “further advantage” in that it “may be employed to correct for differential thermal expansion, wear and dimensional variability within permitted manufacturing and assembly tolerances.” (*Id.*, 7:57-60.)

59. The link does this by “auto-adjusting itself in response to these effects by allowing movement of hydraulic fluid between opposite sides of [a] hydraulic piston” to “re-zero[] itself to ensure that a desired valve member lift is maintained.” (*Id.*, 7:60-65.)

60. The below annotated versions of Figures 1 and 2 of the ’138 patent provide an example of an “outwardly opening directly actuated fuel injection valve.” (*Id.*, 8:61-63.)

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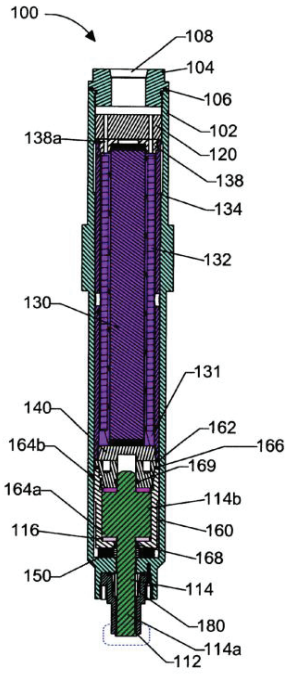


FIG. 1

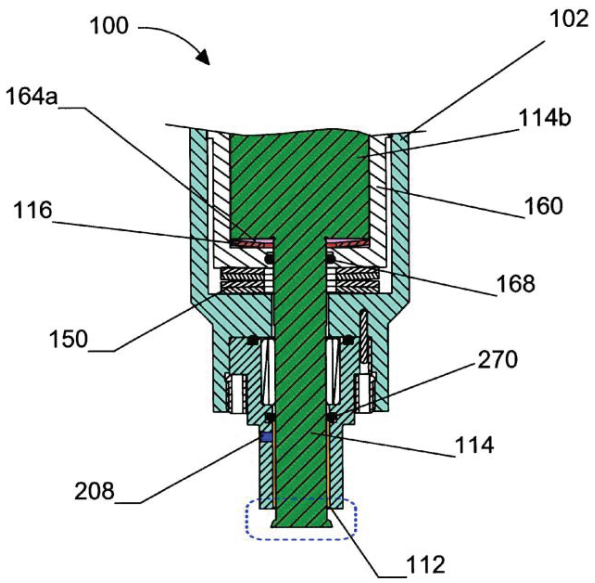


FIG. 2

(*Id.*, Figs. 1-2 (annotated).)

61. The elements of this injector have been annotated as follows:

62. **Teal:** A "valve housing 102" and "[v]alve cap 104" that "provide a fluidly sealed valve body." (*Id.*, 9:4-6.)

63. **Blue:** A "fuel inlet 208," as shown in Figure 2. (*Id.*, 13:34.)

64. **Orange:** The injector interior that receives fuel from the inlet. (*Id.*, 9:4-9.)

65. **Green:** A "valve member 114" located within the injector. (*Id.*, 9:23-27.)

66. **Dashed blue outline:** A "valve seat 112" that is contacted by one end of the valve member 114 to close the injector. (*Id.*, 9:23-27, 59-64.)

67. **Red:** A "valve spring 116" in the form of a "disc or washer spring" (or a "coil spring") that "biases" the member 114 "in the closed position." (*Id.*, 10:13-19.)

68. **Purple:** A "magnetostrictive actuator" including a member 130, bobbin 131, coil 132, and flux tube 134 located within the housing. (*Id.*, 10:41-46.)

69. **Pink:** "[H]ydraulic fluid 164b" of "a hydraulic link assembly." (*Id.*, 11:65-67; 14:16-22.)

70. The patent also explains how the injector operates. More particularly, to open the injector, current is applied to the actuator causing it to "grow[] in length." (*Id.*, 10:51-60.)

71. This causes the actuator to push an intermediate "sliding pole 140" towards the "valve member 114 to provid[e] a force for opening injection valve 100." (*Id.*, 10:59-62.)

72. "The opening force generated by the actuator assembly is transmitted to valve member 114 through" "hydraulic fluid 164b" of the "a hydraulic link assembly." (*Id.*, 11:65-67; 14:16-22.) During actuation, fluid "does not have time to flow" out of the space that contains it and fluid 164b thus "acts as a solid." (*Id.*, 14:26-40.)

73. The patent also explains that the injector allows for "[a]uto-adjustments" via "the migration of hydraulic fluid from chamber 164b on one side

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of the hydraulic piston 114b to chamber 164a" (light pink) "on the other side" of the piston. (*Id.*, 15:14-25.)

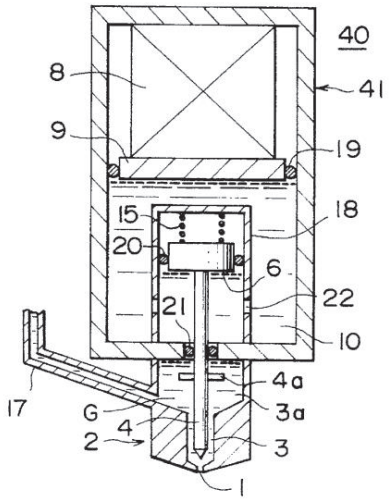
B. Prosecution History of the '138 Patent

74. As noted above, I have reviewed the '138 patent's prosecution history.

75. The originally filed were rejected in a November 2002 office action as obvious over Kurishige (Ex. 1011). (*See* Ex. 1002, pp. 123-125.)

76. I have reviewed the Kurishige reference. Fig. 1 of Kurishige is reproduced below:

FIG. 1



(Ex. 1011, Fig. 1.)

77. To open the depicted injector, element 8 is actuated and expands. This then forces piston 9 down. The movement of piston 9 applies force to fluid in chamber 10, shown in the figure, which flows from the outer chamber 10, through holes 22, and into the narrower inner cylinder 18 causing piston 6 to move by an

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amplified distance. Needle 4, which is connected to the piston 6, then lifts and valve 1 opens. (*Id.*, 5:45-67.)

78. The applicant responded to the Examiner's rejection in February 2003 by noting that Kurishige is a "conventional 'dynamic' hydraulic system, which relies upon the flow of hydraulic fluid" from chamber 10 to the inner cylinder "to actuate a needle valve." (Ex. 1002, pp. 134, 136-37.)

79. The applicant then argued that Kurishige is "structurally and functionally distinguished from the applicants' 'passive' hydraulic link. In a 'dynamic' hydraulic system, the hydraulic fluid does not 'act substantially as a solid with the thickness being substantially constant while the actuator assembly is actuated', as recited in claim 1 … because the hydraulic fluid must flow from one chamber to another to cause needle movement." (*Id.*)

80. The claims were allowed immediately after this response. (*See id.*, pp. 166-168.).

C. The '138 Patent's Claims

81. For reference, claims 1-3, 6, 13-14, 17-21, 26-28, and 41 of the '138 patent are reproduced below:

> **1.** An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:
>
> (a) a valve housing comprising:

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a fuel inlet port;

an interior chamber fluidly connected to said fuel inlet port; and

a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed;

(b) said valve member having one end disposed within said valve housing and an opposite end extendable from said valve seat toward said combustion chamber, wherein said valve member comprises a sealing surface that fluidly seals against said valve seat when said injection valve is closed and that is liftable away from said valve seat when said injection valve is open;

(c) a biasing mechanism associated with said valve member, said biasing mechanism applying a closing force to said valve member when said valve member is in said closed position;

(d) an actuator assembly associated with said valve member, wherein said actuator assembly may be actuated to apply an opening force to said valve member stronger than said closing force, for moving said valve member to said open position; and

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(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is actuated and wherein said thickness of said hydraulic link is adjustable while said actuator assembly is not actuated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve lift upon actuation of said actuator assembly.

2. The injection valve of claim **1** wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by differential thermal expansion.

3. The injection valve of claim **2** wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by wear to components of said injection valve.

6. The injection valve of claim **1** wherein said actuator assembly comprises a dimensionally responsive member.

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13. The injection valve of claim **6** wherein said dimensionally responsive member is formed from a piezoelectric material.

14. The injection valve of claim **6** further comprising a compression spring member for applying a compressive force to said dimensionally responsive member.

17. The injection valve of claim **6** wherein said actuator assembly is controllable to maintain said desired lift between 10 and 100 percent of maximum lift.

18. The injection valve of claim **17** wherein said lift is controllable by varying at least one of the electric current, the electric voltage and the magnetic field imposed upon said dimensionally responsive member.

19. The injection valve of claim **6** wherein said valve member is controllable such that said valve member moves between said open and closed positions in less than about 200 microseconds.

20. The injection valve of claim **6** further comprising a biasing mechanism for applying a compressive force to said dimensionally responsive member.

21. The injection valve of claim **1** wherein said biasing mechanism comprises a spring.

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26. The injection valve of claim **1** wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 Mpa).

27. The injection valve of claim **1** wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body.

28. The injection valve of claim **1** wherein said valve housing, said valve member and said actuator assembly are selected from materials having thermal expansion coefficients sufficiently compatible such that changes in the dimensional relationship between said components caused by changes in temperature are reduced.

41. A method of operating a fuel injection valve for an internal combustion engine, said injection valve having a longitudinal axis, said method comprising:

(a) actuating a dimensionally responsive member comprising at least one of a magnetostrictive material and a piezoelectric material, said dimensionally responsive member expanding in length in the direction of said longitudinal axis upon actuation of said actuator;

(b) transferring movement caused by said actuated dimensionally responsive member through a passive hydraulic link to cause a corresponding movement of a valve member to open said valve by

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lifting said valve member away from a valve seat and compressing a biasing mechanism that biases said valve in a closed position, said passive hydraulic link comprising a hydraulic cylinder which houses a piston and is filled with a hydraulic fluid, wherein said hydraulic fluid forms a layer between said piston and a cylinder head and because of the short duration that said valve is open, said hydraulic fluid does not have time to flow from one side of said piston to the other side and while said injection valve is open, said layer of hydraulic fluid acts as an incompressible solid so that movement caused by the actuation of said dimensionally responsive member is transmitted through said fluid layer;

(c) deactuating said dimensionally responsive member to contract the length of said dimensionally responsive member to unload said biasing mechanism and cause a corresponding movement of said valve member to close said valve;

(d) providing sufficient time between consecutive valve openings to allow at least some of said hydraulic fluid within said passive hydraulic link to flow from one side of said piston to the other side of said piston.

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VIII. CLAIM CONSTRUCTION

82. I am not a legal expert or an attorney and offer no opinions on the law. I understand that claim construction is a matter of law. I have been informed by counsel of the legal standards that apply to claim construction in an *inter partes* review, and I have applied them in forming my opinions. I understand that during an *inter partes* review, however, the same claim construction standard used in federal district court is applied when addressing the meaning of claim terms.

83. I have been informed that the words of a claim are generally given the ordinary and customary meaning that the term or phrase would have to a POSITA at the time of the invention in view of the surrounding claim language, the specification and the file history (collectively, the "intrinsic evidence" or "intrinsic record").

84. I also understand that courts may consider extrinsic evidence, such as expert and inventor testimony, dictionaries, and learned treatises (collectively, the "extrinsic evidence" or the "extrinsic record"), but that such extrinsic evidence should be given less weight than the intrinsic evidence.

85. In my opinion, the terms of the '138 patent's claims do not require further construction and can be afforded their plain and ordinary meaning.

86. I understand that Patent Owner has alleged that the claims cover a nozzle/needle injection valve that is controlled indirectly through a pilot valve. This type of pilot valve may also be called a first-stage or indirect-acting valve. A pilot

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actuated nozzle injector valve is one where the pilot valve armature acted upon by the actuator does not itself open a fluid pathway into the combustion chamber but instead only opens the pilot valve that in turn triggers other components to open the injection pathway. (*See, e.g.*, Ex. 1022, p. 24 (pointing to an alleged "valve seat" and "valve member" that form an intermediate valve that does not open to the combustion chamber).) Care must be taken in understanding the context when the term valve is used in this case.

87. I disagree that the claims can be properly interpreted to extend to an indirectly actuated valve.

88. First, it is contrary to the claim language itself.

89. Claim 1 requires a "valve member" that "cooperat[es] with" a "valve seat" "to seal" an "interior chamber from [the] combustion chamber." (Ex. 1001, claim 1.)

90. In my opinion, this shows that it is the valve member itself, and not some other structure, that operates to open and close/seal a fluid path from the injector's "interior chamber" to the "combustion chamber."

91. Claim 1 also provides that the "valve member" has "one end disposed within said valve housing and an opposite end extendable from said valve seat toward said combustion chamber."

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92. This means that one end of the "valve member" must exist at a point inside of the housing and the other end must exist on the combustion chamber side of the nozzle valve seat. Furthermore, the valve member opens the nozzle—connecting the interior of the injector interior chamber to the combustion chamber—by moving away from the nozzle valve seat, towards the combustion chamber. It is not an intermediate valve located entirely inside and within the housing.

93. In my opinion, the specification confirms that the '138 patent's claims require a directly actuated injector.

94. In particular, the specification repeatedly and consistently characterizes the invention is a "directly actuated injector." (*Id.*, 8:32-33; *see also* Abstract, 1:16-21; 2:66-67; 16:37-39.)

95. Moreover, the patent contrasts its directly actuated valve with prior art valves that are indirectly actuated. (*See, e.g., id.*, 2:52-3:7.)

96. The '138 patent is even entitled "Directly Actuated Injection Valve." (*Id.*, Cover.)

IX. UNPATENTABILITY ANALYSIS

97. For the reasons I explain in greater detail below, it is my opinion that as of the effective filing date of the '138 patent, a POSITA would have considered claims 1-3, 6, 13-14, 17-21, 26-28, and 41 of the '138 patent to be unpatentable as obvious over the prior art discussed in this declaration.

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A. Overview of the Prior Art

98. The following paragraphs provide an overview of the main prior art references I discuss throughout this declaration.

1. Wirbeleit

99. Wirbeleit indicates on its face that it issued January 2, 1996. (Ex. 1004, Cover.) In view of this date of issuance, which predates the '138 patent's filing by more than a year, I understand that Wirbeleit is prior art to the '138 patent under at least 35 U.S.C. § 102(b).

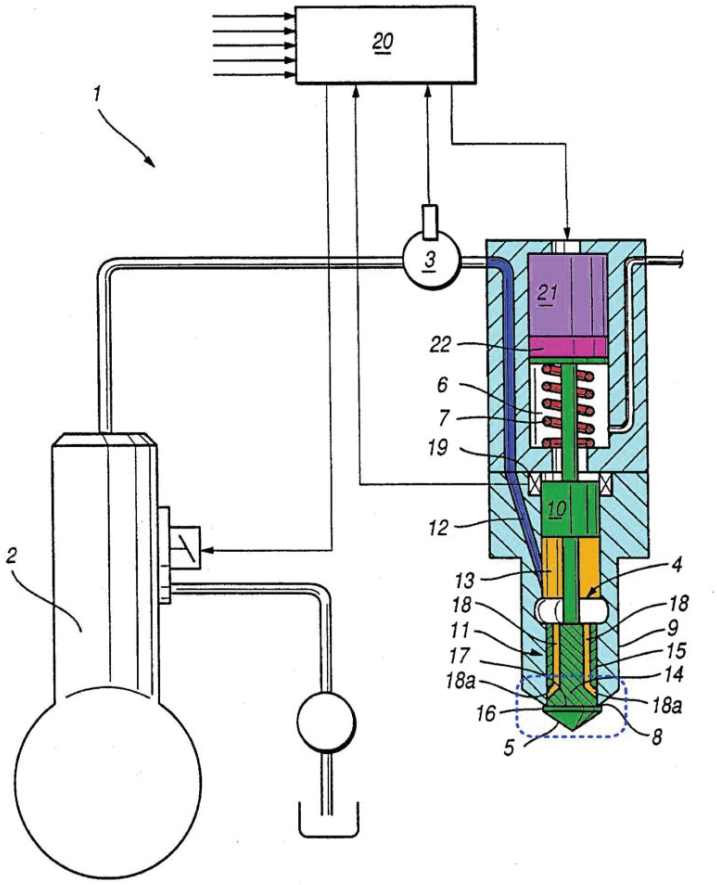
100. Wirbeleit is not cited on the face of the '138 patent. It also was not discussed or mentioned during the '138 patent's prosecution history.

101. Wirbeleit relates to a "fuel injection system for a Diesel engine." (*Id.*, 1:45-46.)

102. Wirbeleit's injector has a "control needle" with fuel injection orifices that can be "exposed to a degree controllable … depending on engine operating parameters." (*Id.*, 1:52-57.) This allows for different, controllable amounts of fuel injection. (*See id.*)

103. Wirbeleit's injector is shown in the below annotated figure:

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(*Id.*, Fig.) The below paragraphs provide additional details regarding the depicted injector's components.

104. **Teal**: The injector's outer "body 9." (*Id.*, 2:31-35.)

105. **Green**: A "control needle 5" and "piston 10." (*Id.*, 2:35-39.)

106. **Blue**: A "fuel admission passage 12" (*Id.*)

107. **Orange**: A "pressure chamber 13," grooves 18, and orifices 18a inside the injector through which fuel from the admission passage passes on its way out of the end of injector (**circled blue**) into the combustion chamber. (*Id.*)

108. **Red**: A "spring 7" that forces the tip of a "control needle 5" (green) onto a "valve seat 8" to close the injector. (*Id.*)

109. **Purple**: A "piezo" or "magnetostrictive actuator 21." (*Id.*, 2:60-65.)

110. **Pink**: A "hydraulic transmission element 22" through which the force exerted by the actuator is passed to the control piston/needle for purposes of opening the injector. (*Id.*)

111. Again, Wirbeleit explains that the desired needle lift off the valve seat and the corresponding amount by which the needle's orifices are exposed "is maintained by voltage control of the actuator 21." (*Id.*, 3:1-7.)

2. Klügl

112. Klügl indicates on its face that it published September 10, 1998. (*See* Ex. 1006, Cover.) In view of this date of publication, which predates the '138 patent's filing by more than a year, I understand that Klügl is prior art to the '138 patent under at least 35 U.S.C. § 102(b).

113. Klügl is not cited on the face of the '138 patent. It also was not discussed or mentioned during the '138 patent's prosecution history.

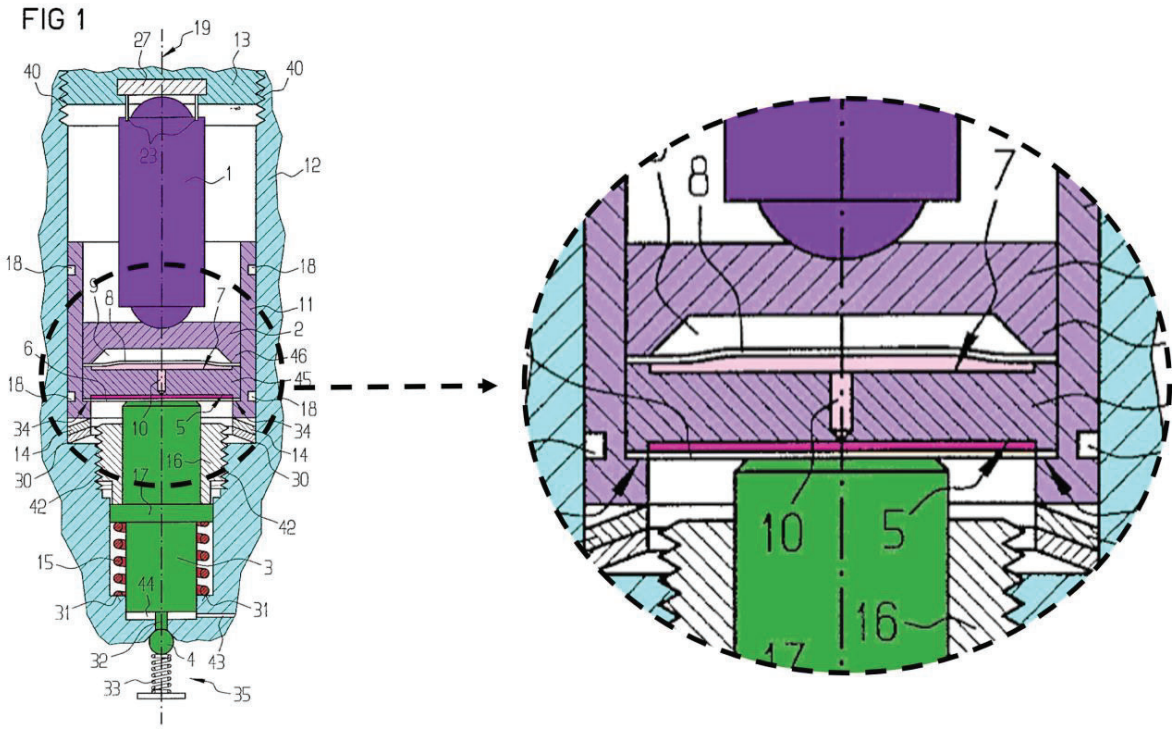
114. Klügl published in German. Throughout this declaration I will refer to and cite to a certified translation (Ex. 1006) of Klügl.

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115. Klügl related to a "power transmission device" to "transmit the movement of a piezoelectric actuator" for valve opening and closing in a fuel injector. (*Id.*, 1:7-12.)

116. Klügl explains that a chamber of hydraulic fluid within this device not only transfers this opening force, but also allows the injector to adjust for the effects of "thermal expansion differences and gradual wear." (*Id.*, 3:63-4:31.)

117. Klügl's injector is shown in the below annotated figure. The central portion of the figure has been excerpted and expanded to the right to better show the chamber of hydraulic fluid:



(*Id.*, Fig. 1.)

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118. The various injector components shown in this figure are discussed in more detail below:

119. **Teal:** The injector includes an outer "housing 12" and "upper stop 13" that surround its components. (*Id.*, 1:47-51.)

120. **Green:** A "drive piston 3"—along with connected "drive needle 32," "ball 4," and "shoulder ring 17"—are located within the injector. (*Id.,* 2:35-39, 50-57.)

121. **Red:** A "spring 15" forces the "drive piston 3" (green) upwards, allowing "spring 33" to force the "drive needle 32" and "ball 4" (both also green) upwards to close the injector. (*Id.,* 2:35-39, 50-57.)

122. **Dark purple:** A "piezoelectric actuator 1" to which a signal can be applied causing it to expand for purposes of opening the injector. (*Id.*, 1:47-51.)

123. **Light purple**: A "transmission module 2" that is pressed downward towards the piston 3 by the expanding actuator. (*Id.*, 3:23-33.)

124. **Dark pink:** Force is transmitted from the actuator to the piston through incompressible hydraulic fluid "located in [a] pressure chamber 5." (*Id.*, 3:26-29.) Klügl explains that during actuation, only "an insignificant amount" of hydraulic fluid flows out of chamber 5. (*Id.*, 4:11-22.) But, during idle periods, hydraulic fluid can move from chamber 5 through "throttle 10" (an orifice) to chamber 7 (**light pink**) to "automatic[ally] adjust[]" for "thermal expansion differences and gradual

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wear" and keep the "drive piston 3" in contact with "transmission module 2." (*Id.*, 3:50-4:33.) The hydraulic fluid is completely captured and contained within the transmission module. (*See id.*; Fig. 1.) There is no external fluid source. (*See id.*)

125. When the injector is actuated, the piston's ball 4 is moved off its seat causing the pressure in a "pressure chamber" to drop, an "injection needle" to open, and fuel to be injected. (*Id.*, 3:30-38.)

3. Newcomb

126. Newcomb indicates on its face that it issued August 18, 1981. (*See* Ex. 1014, Cover.) In view of this date of issuance, which predates the '138 patent's filing by more than a year, I understand that Newcomb is prior art to the '138 patent under at least 35 U.S.C. § 102(b).

127. Newcomb is not cited on the face of the '138 patent. It also was not discussed or mentioned during the '138 patent's prosecution history.

128. Newcomb relates to a "control valve such as a … fuel injection valve for controlling flow of a medium." (*Id.*, 1:5-7.)

129. Newcomb explains that the materials used to make such a valve should be chosen such that the materials' coefficients of thermal expansion are selected so as to "enable[] the effects of thermal expansion to be reduced…." (*Id.*, 1:45-49.)

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4. Hayes

130. Hayes indicates on its face that it issued July 14, 1998. (*See* Ex. 1024, Cover.) In view of this date of issuance, which predates the '138 patent's filing by more than a year, I understand that Hayes is prior art to the '138 patent under at least 35 U.S.C. § 102(b).

131. While Hayes is listed on the face of the '138 patent, it was not discussed or mentioned by the examiner during the '138 patent's prosecution history.

132. Hayes relates to an indirectly actuated fuel injector. (*Id.*, 1:7-9.) This is an injector where the nozzle needle valve is indirectly controlled by a pilot valve.

133. Hayes explains that such an injector includes an intermediate "control valve 1" sealed by a ball-shaped "component 12." (*Id.*, 2:7-15, 30-33.)

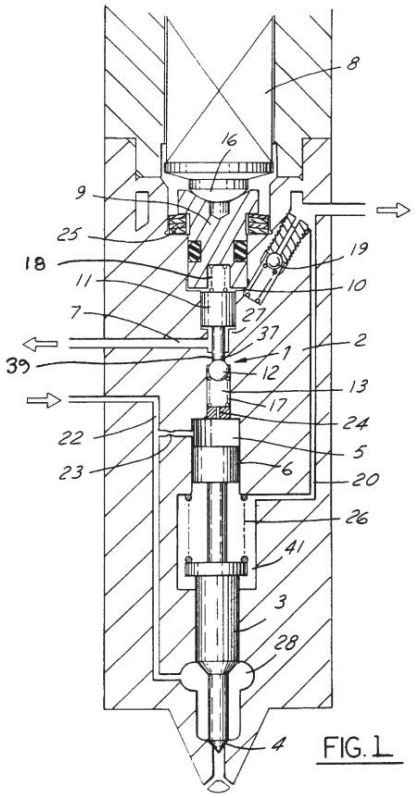
134. Activating the actuator of the injector opens this control valve. (*Id.*, 3:24-45.)

135. Hayes also explains how this in turn opens a valve into the combustion chamber.

136. In particular, opening the intermediate control valve lowers the pressure in a "chamber 5," which causes a separate "valve needle 3" to lift and open a passage into combustion chamber. (*Id.*, 3:53-63.) Fuel supplied by a "feeding line 22 which feeds the fuel at high pressure," is then injected through the passage opened by the needle. (*Id.*, 2:45-48, 3:53-63.)

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137. Figure 1 of Hayes shows these various components:



(*Id.*, Fig. 1.)

B. Ground 1: Claims 1-3, 6, 13-14, 17-21, 26-27, and 41 Are Obvious Over Wirbeleit and Klügl

138. In my opinion, a POSITA would have considered Wirbeleit and Klügl to be within the scope of the prior art and highly relevant to the patentability of the '138 patent's claims.

139. In my opinion, moreover, when viewed and considered in light of the knowledge possessed by a POSITA, Wirbeleit and Klügl together disclose all the

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limitations of and render claims 1-3, 6, 13-14, 17-21, 26-27, and 41 of the '138 patent obvious.

140. In addition, not only would a POSITA have been motived to combine and collectively consider the teachings of these references to arrive at the subject matter claimed by the '138 patent, but they would have had a reasonable expectation of success when doing so.

1. Claim-By-Claim Analysis

a. Claim 1

[1-p] "An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:"

141. In my opinion, to the extent the preamble is limiting, Wirbeleit teaches the claimed ***"injection valve."***

142. Wirbeleit explains that it relates to a "fuel injection system for a Diesel engine…." (Ex. 1004, 1:7-8.)

143. Wirbeleit's fuel injection system includes "valve-controlled injectors [for] the injection of fuel under the control of an electronic control unit." (*Id.*, 1:8-12.)

144. Wirbeleit also explains that its injector valve is meant for use with "direct-injection Diesel engines." (*Id.*, 1:30-37.)

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145. As of the filing of the ’138 patent, a POSITA would have understood that a “direct-injection” engine is one in which fuel is injected directly into an engine’s combustion chamber, and not indirectly into the engine manifold.

146. Showing this, numerous prior art references explain that this is what “direct” injection entails.

147. For instance, a “direct cylinder injection system” was known to be one in which “the fuel injector is mounted in the cylinder block and sprays … into the cylinder bore” (*See* Ex. 1007, 2:7-10.)

148. Similarly, in contrast to an “indirect injection” system that injects fuel into the manifold, a “direct injection system[]” “inject[s] fuel directly into the combustion chamber.” (Ex. 1008, 1:16-24.)

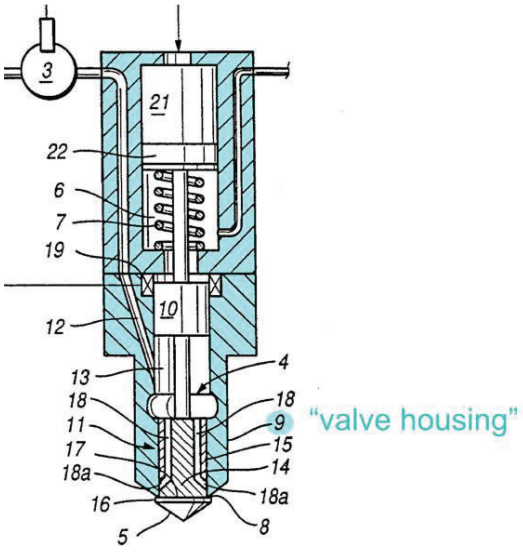
[1(a)] “(a) a valve housing comprising:”

149. In my opinion, Wirbeleit includes the claimed ***“valve housing.”***

150. Wirbeleit explains that its “injector” includes an “injector body 9” that surrounds and contains the other injector components. (Ex. 1004, 2:31-35.)

151. Body 9 of Wirbeleit’s injector has been highlighted in teal in the figure below. Note that this figure (which is Wirbeleit’s only figure) has been cropped throughout this declaration to better focus on the depicted injector:

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(*Id.*, Fig. (annotated).)

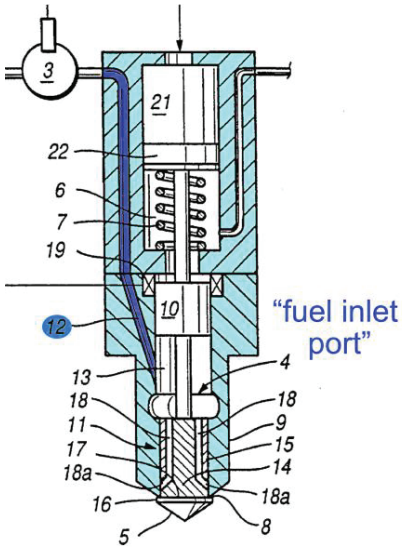
[1(a)-1] "a fuel inlet port;"

152. In my opinion, Wirbeleit includes the claimed ***"fuel inlet port."***

153. Wirbeleit's "fuel inject[or]" includes "a fuel injection conduit structure with a common supply conduit 3 for all injectors." (Ex. 1004, 2:27-30.)

154. A "fuel admission passage 12" in "communication with the common supply conduit 3" allows fuel to enter the injector. (*Id.*, 2:35-40.)

155. Wirbeleit's fuel admission passage 12 is highlighted below in blue:



(*Id.*, Fig. (annotated).)

[1(a)-2] "an interior chamber fluidly connected to said fuel inlet port; and"

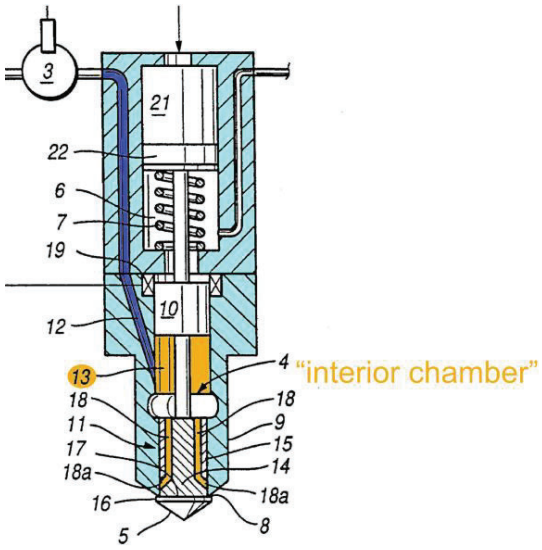
156. In my opinion, Wirbeleit includes the claimed ***"interior chamber."***

157. Wirbeleit explains that its injector includes a "slot orifice 4" within its injector body that contains "an injector orifice control needle 5." (Ex. 1004, 2:31-32.)

158. Wirbeleit also explains its needle "delimit[s] a pressure chamber 13 which is in communication with the common supply conduit 3 by way of [the] fuel admission passage 12." (*Id.*, 2:35-40.) This pressure chamber 13 is connected to grooves 18 and orifices 18a within the needle through which fuel can flow to exit the injector. (*See id.*)

159. In my opinion, these spaces within Wirbeleit's injector—including the chamber 13, grooves 18, and orifices 18a—are the claimed "interior chamber." Further, fuel flows from the admission passage 12 to these spaces as required.

160. The spaces are highlighted below in orange:



(*Id.*, Fig. (annotated).)

1(a)-3] "a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed;"

[1-b] "(b) said valve member having one end disposed within said valve housing and an opposite end extendable from said valve seat toward said combustion chamber, wherein said valve member comprises a sealing surface that fluidly seals against said valve seat when said injection valve is closed and that is liftable away from said valve seat when said injection valve is open;"

161. In my opinion, Wirbeleit also includes the claimed ***"valve seat"*** and ***"valve member."***

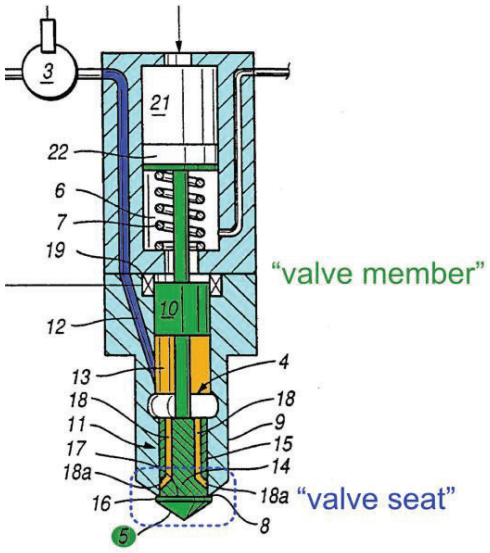
162. Wirbeleit's injector includes "an injector orifice control needle 5" within its "injector body 9." (Ex. 1004, 2:31-32; *see also* Abstract, 1:48-49.)

163. Wirbeleit's needle 5 includes a "piston-like needle tip 11" with a "collar 16 which is disposed outside the injector body 9…." (*Id.*, 2:35-37, 40-45.) The "rear side 17" of the "collar 16" "forms the valve seating surface." (*Id.*, 2:43-45.)

To close the injector, the rear side 17 of collar 16 is "forced onto the valve seat 8 on the injector body 9." (*Id.*, 2:31-35; *see also* Abstract, 1:48-52.)

164. Because it includes an end (tip 11 with collar 16 and rear side 17) that corporates with a valve seating surface to seal the injector, Wirbeleit includes the claimed ***"valve member"*** that ***"cooperat[es] … to seal"*** with a ***"valve seat."***

165. Wirbeleit's valve member is highlighted green below. The valve seat is circled:



(*Id.*, Fig. (annotated).)

166. Wirbeleit's needle is also, in my opinion, ***"extendable from said valve seat toward said combustion chamber,"*** and can both ***"fluidly seal[] against said valve seat"*** to close Wirbeleit's injector, and "***lift[] away from said valve seat"*** to open the injector as claimed.

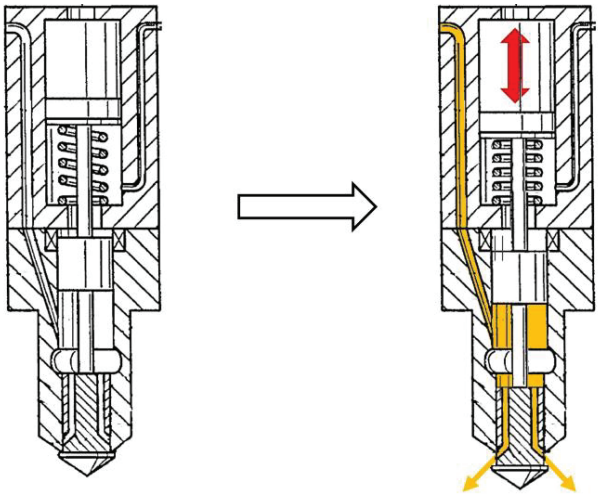
167. In this regard, Wirbeleit explains that its "control needle 5" is both "movable outwardly for opening the orifice" to facilitate fuel injection, and can be "forced onto the valve seat 8 on the injector body 9" to close the valve and stop injection. (Ex. 1004, 2:31-35.)

168. Similarly, according to Wirbeleit, its needle moves between a position where the needle's "slot-shaped orifices" are "fully covered when the control needle is seated" to another position where the orifices are "exposed" *(Id.,* Abstract; 1:52-58 (likewise explaining that the needle's "slot-shaped orifices … are fully covered when the control needle is seated but which are exposed" by moving the needle); 3:5-11 (again explaining that the needle moves from one position where "[a]n appropriate injector slot orifice cross-section 18a … is maintained" and a "rest position in which the needle tip 11 is seated on valve seat 8").)

169. Movement of Wirbeleit's needle between closed and open positions is shown in the below demonstrative prepared using Wirbeleit's figure.

170. Closed position: In the figure on the left, Wirbeleit's needle is forced against the valve seat at the end of the injector body closing the injector. This is the closed position.

171. Open position: In the figure on the right, Wirbeleit's needle has moved out of the injector body and off the valve seat exposing the slot orifices and allowing fuel (shown in yellow) to be injected. This is the open position:



(*See* Ex. 1004; Fig.)

172. Further, as noted above, the "lift position" of Wirbeleit's needle can both be controlled by an "electronic control unit" and measured using a "needle lift sensor." (*Id.*, 2:4-10.)

[1(c)] "(c) a biasing mechanism associated with said valve member, said biasing mechanism applying a closing force to said valve member when said valve member is in said closed position;"

173. In my opinion, Wirbeleit includes the claimed ***"biasing mechanism."***

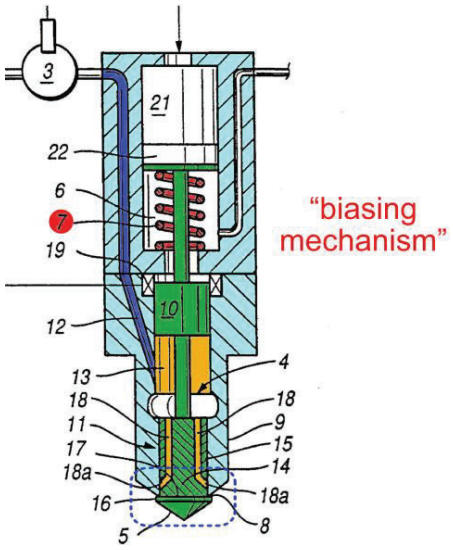
174. Wirbeleit explains that its injector includes a "return spring 7 disposed in [a] spring chamber 6." (Ex. 1004, 2:35-36.)

175. According to Wirbeleit, this spring "force[s]" the "injector orifice control needle 5 … onto the valve seat 8 on the injector body 9" to close the valve. (*Id.*, 2:31-36.) Similarly, Wirbeleit explains that its "injectors" have "fuel injection control needle engaged by springs so as to be normally seated on a valve seat." (*Id.*, Abstract.) Likewise, "the orifice control needle is returned by the return spring 7 to

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a rest position in which the needle tip 11 is seated on the valve seat 8." (*Id.,* 3:7-11; *see also* 1:48-50.)

176. Wirbeleit's spring 7 is shown in red below:



(*Id.*, Fig. (annotated).)

[1(d)] "(d) an actuator assembly associated with said valve member, wherein said actuator assembly may be actuated to apply an opening force to said valve member stronger than said closing force, for moving said valve member to said open position; and"

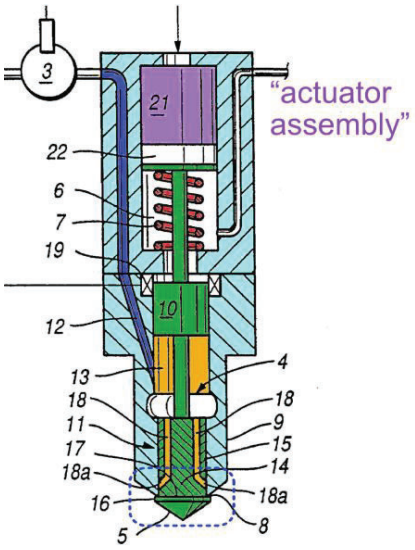
177. In my opinion, Wirbeleit's injector includes the claimed ***"actuator assembly."***

178. More particularly, Wirbeleit's injector includes a "magnetostrictive actuator 21"—or alternatively a "piezo actuator" —that is located "[a]t the rear end of the orifice control needle 5 opposite its tip 11…." (Ex. 1004, 2:60-64.)

179. Additionally, the "[o]pening of the slot-injection orifices can be controlled by energizing [the] piezo actuator which acts on the injector needle …

against a compression spring with a voltage-dependent force." (*Id.*, 2:1-4; *see also* Abstract; 1:50-52.)

180. Wirbeleit's actuator is highlighted in purple below:



(*Id.*, Fig. (annotated).)

[1(e)] "(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is actuated and wherein said thickness of said hydraulic link is adjustable while said actuator assembly is not actuated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve lift upon actuation of said actuator assembly"

181. In my opinion, the combination of Wirbeleit and Klügl teach everything this particular claim limitation requires.

182. As an initial matter, a POSITA would consider Wirbeleit's injector to already employ a ***"hydraulic link assembly" "through which … opening and closing forces are transmitted."***

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183. Wirbeleit explains that its "magnetostrictive actuator 21 … operates the orifice control needle 5 by way of a hydraulic transmission element 22…." (Ex. 1004, 2:60-64.).

184. Likewise, according to Wirbeleit either a "magnetostrictive actuator" or "a piezo actuator" can "act[] on the injector needle by way of a hydraulic transmission element against a compression spring…." (*Id.*, 2:1-3, 2:61.)

185. This hydraulic transmission element is the claimed hydraulic link.

186. According to Wirbeleit, during valve opening, force is exerted by the actuator and imparted through the hydraulic transmission element to the needle. In contrast, during valve closing, force is exerted from the spring, to the needle, and back through the hydraulic transmission element until a rest position is reached. (*See id.*; *see also* 3:5-11.)

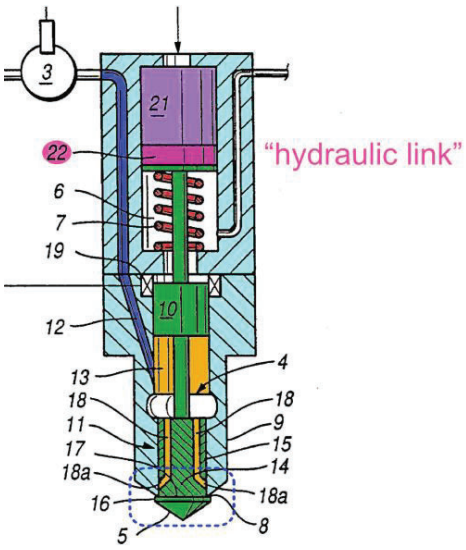
187. Moreover, a POSITA would, in my opinion, understand this hydraulic link to be ***"passive"*** as required. There are two primary reasons for this.

188. First, Wirbeleit characterizes its "hydraulic transmission element" as a simple force pathway through which force from the actuator passes to the needle. (*Id.*, 2:1-3.) The hydraulic transmission element does not generate or amplify the force.

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189. Second, the "hydraulic transmission element" is located in an enclosed cylindrical space between the actuator and needle. It has nowhere to flow during actuation and thus can only serve to passively transmit force. (*See id.*, *see also* Fig.)

190. Wirbeleit's hydraulic transmission element highlighted below in pink:



(*Id.*, Fig.)

191. Next, in my opinion, a POSITA would have considered the remainder of what this limitation requires obvious in view of the teachings of Klügl.

192. Klügl relates to a device that can be used in an "automotive" fuel injector "to transmit the movement of a piezoelectric actuator to an actuator … in an injection valve." (Ex. 1006, 1:7-12.)

193. Like Wirbeleit's injector, Klügl's injector has an outer "housing 12" surrounding its various components. (*Id.*, 1:47-51.)

194. A "piezoelectric actuator 1" is located within this housing. (*Id.*)

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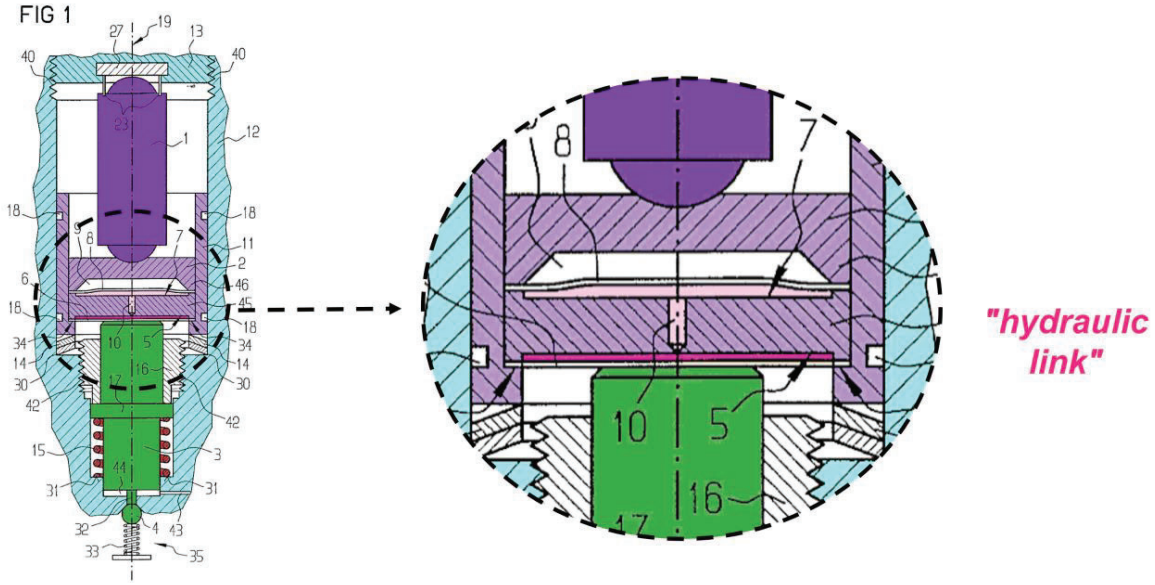
195. A "transmission module 2" is located between the actuator 1 and the "drive piston 3." (*Id.*, 1:48-51; 2:23-41; Fig. 1.)

196. The drive piston 3 is attached to control needle 32 and in contact with ball 4, which Klügl also calls a "closing element 4." The ball/closing element 4 forms a "servo valve" that "is used to control an injection needle." (*Id.*, 2:50-57.)

197. A "spring 15" exerts an upward force on the drive piston 3 via the attached check ring 17 to close the valve. (*Id.*, 2:35-44.)

198. The transmission module 2 includes a "pressure chamber 5" filled with "transmission medium" such as "a hydraulic fluid, which has low compressibility." (*Id.*, 1:60-2:4.) The transmission module also includes a "throttl[e]" (orifice) or "connecting bore 10" that connects the "pressure chamber 5 to a compensating chamber 7." (*Id.*) The compensating chamber 7 is filled with the same transmission medium as the pressure chamber 5. (*Id.*) The transmission medium/hydraulic fluid is completely captured and contained within the transmission module. (*See id.;* Fig. 1.) As such, there is no external fluid source. (*See id.*)

199. These components are shown in the below annotated version of Fig. 1. The region of Fig. 1 showing chamber 5 has also been excerpted and expanded in size to the right for emphasis purposes:



(*Id.*, Fig. 1 (annotated).)

200. The same coloring scheme used when comparing Wirbeleit to claim 1 has been employed. More particularly:

201. **Teal**: Housing 12 (Klügl's "valve housing").

202. **Dark and light purple**: The piezoelectric actuator 1 and transmission module 2 (Klügl's "actuator assembly").

203. **Green**: The drive piston, needle, and ball (Klügl's "valve member").

204. **Red**: The valve-closing spring (Klügl's "biasing mechanism").

205. **Dark pink**: The pressure chamber 5 (Klügl's "hydraulic link")

206. **Light pink**: Throttle 10 and compensation chamber 7.

207. During valve opening, when the "piezoelectric actuator 1 is … controlled" (energized) by application of an appropriate signal, the actuator expands

causing "pressure" to be "exerted on the drive piston 3 via … the transmission medium located in the pressure chamber 5…." (*Id.*, 3:23-29.)

208. In the embodiment shown in Klügl's Figure 1, the movement of the actuator results in the same amount of movement of the piston without amplification. In other words, there is no change in the "stroke translation." (*Id.*, Fig. 1; 1:41-42, 3:23-29.) As the fluid in chamber 5 is held in place by a membrane 6 and moves through a cylindrical space of constant width and unchanging shape, the thickness of the fluid in chamber 5 will remain constant throughout actuation. (*See id.*)

209. Showing this, Klügl itself explains that in opposition to its Figure 3, the injector of Figure 1 does not "achieve[] a stroke ratio between defection of the piezoelectric actuator 1 and the deflection of the drive piston 3." (*Id.*, 7:12-13.)

210. Klügl contrasts this with the embodiment show in Figure 3, which does provide a change in "stroke translation" by applying a "stroke ratio" such that the movement of the piston exceeds that of the actuator. (*Id.*, 1:41-46; 7:12-13.) This occurs because the dimensions of chamber 5 change during actuation in that particular figure's embodiment. (*See id.*, Fig. 3.)

211. Klügl also explains that in the embodiment shown in Fig. 1, the chamber 5 is filled with hydraulic fluid of "low compressibility." (*Id.*, 2:1-2.) Additionally, while the transmission module includes a "throttle 10" that connects chamber 5 to chamber 7, this throttle is "dimensioned in relation to the transmission

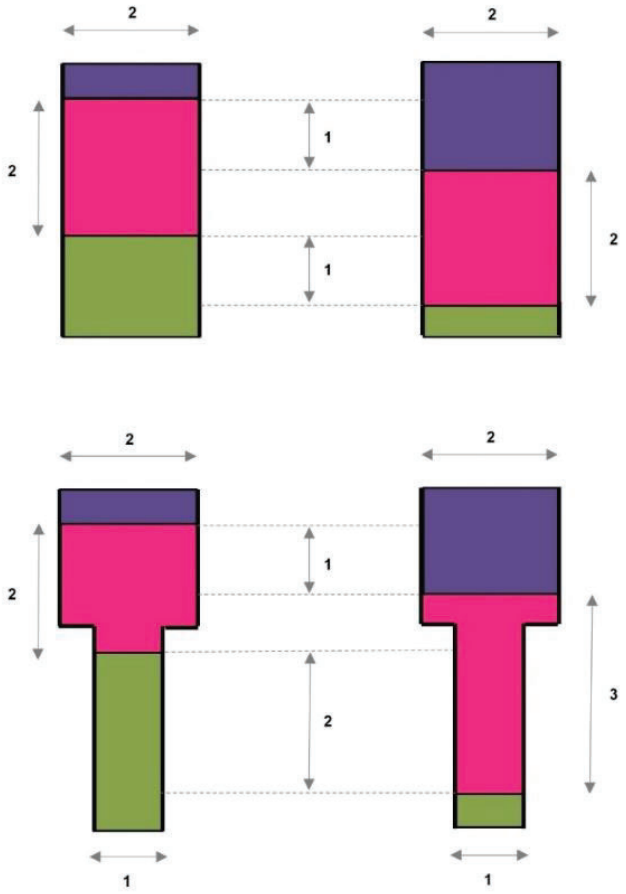
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medium such that during normal activation" "only an insignificant amount of transmission medium flows into the compensation chamber." (*Id.*, 4:11-22.)

212. It follows that the hydraulic fluid in chamber 5 will not flow, will maintain substantially the same thickness, and will act substantially as a solid during actuation. The fluid is unable to leave chamber 5 during actuation (it cannot flow through throttle 10 and is held in place by a membrane 6). It is incompressible (so it will not change volume upon application of pressure). As a result, during the actuation, the distance between the actuator and piston remains constant (so as to ensure that there is a unity stroke ratio).

213. As a further clarification, I have prepared the below demonstrative. The figures on the top represent Klügl's injector from Figure 1. The figures on the bottom represent Klügl's injector from Figure 3. The actuator is shown in purple. The intermediate hydraulic fluid is shown in pink. The control piston (which pushes on the needle) is shown in green.

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214. As shown in the top figures, when the actuator is expanded, the control piston moves by a distance equal to the amount of actuator expansion. Because the hydraulic fluid is incompressible and located in a cylindrical space, its thickness stays the same. Again, this is representative of Klügl's Figure 1 and is what the '138 patent's claims require.

215. But, when the actuator in the bottom set of figures expands, the hydraulic fluid is pushed from a cylinder of larger diameter into a cylinder of smaller diameter. While the volume of the fluid stays constant (as it is incompressible), its thickness changes (as it is now contained in a differently shaped space). This causes

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the needle to be moved by a distance greater than the expansion of the actuator. Again, this is representative of Klügl's Figure 3 and is what Klügl means when it refers to a "stroke ratio" or "stroke translation." In the bottom figure here the actuator to control piston stroke ratio is 1:2.

216. In addition to teaching a passive hydraulic link that acts as a solid with constant thickness during actuation (i.e., the fluid in chamber 5 of Figure 1), Klügl also explains that "if there are long-lasting pressure differences between the pressure chamber 5 and the compensation chamber 7 … the transmission medium is exchanged between the compensation chamber 7 and the pressure chamber 5 via the throttle 10." (*Id.*, 4:25-31.)

217. According to Klügl, this allows its injector to account for "thermal expansion differences and gradual wear" and ensures that the "drive piston 3" remains in contact with the transmission module. (*Id.*, 3:50-4:31.)

218. Again, Wirbeleit already employs a hydraulic transmission element 22 to transfer the movement of its actuator 21 to its needle 5 through piston 10. As I have explained, this element is passive in that it simply transfers force instead of generating it.

219. Wirbeleit explains that this element 22 "is not shown in detail." (Ex. 1004, 2:64.) As discussed above, however, Klügl discusses how such a hydraulic element should be structured and operate.

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220. In Klügl, as in Wirbeleit, force from an actuator passes through the hydraulic fluid in chamber 5 to the piston 3 for purposes of opening a valve during actuation. As I have explained, in Figure 1, the fluid in the chamber 5 simply transmits the actuator force. It does not generate force or engage in amplification.

221. Further, Klügl explains that fluid does not flow into or out of chamber 5 during actuation. Thus, in my opinion this chamber and the fluid it contains, just like Wirbeleit's hydraulic transmission element 22, is the claimed ***"passive hydraulic link"*** that acts as a ***"solid."***

222. As I have noted, Klügl states that the fluid in chamber 5 has a low compressibility. And, as I have also explained, in the embodiment of Figure 1, no stroke amplification or change in translation distance occurs and chamber 5 does not change dimension during actuation. As a result, its ***"thickness"*** is ***"substantially constant"***

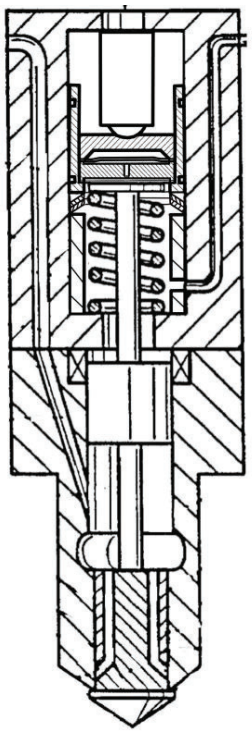
223. Finally, Klügl explains that fluid can flow between chambers 5 and 7 through the throttle 10 during times of rest to account for thermal expansion or wear so as to ensure that the various components (such as the piston 3 and transmission module 2) remain in contact. Thus, in my opinion, its ***"thickness … is adjustable while said actuator is not activated in response to changes in the dimensional relationship between components."***

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224. Further, Wirbeleit's system is meant to facilitate control of the amount of "needle lift." (Ex. 1004, 2:1-12)

225. Because Klügl's transmission module 2 is designed to keep the injector's components in contact, a POSITA would have understood that when applied to Wirbeleit, Klügl's transmission module 2 would maintain the intended needle lift or position range despite wear and thermal expansion. Thus, my opinion, the references teach the maintenance of the claimed ***"desired valve lift upon activation."***

226. An example application of Klügl to Wirbeleit—with Wirbeleit's hydraulic transmission element 22 replaced with Klügl's transmission module—is shown in the demonstrative below:



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b. Claim 2

227. Claim 2 depends on claim 1 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by differential thermal expansion."

228. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

229. In my opinion, Klügl teaches the claimed ***"auto-adjustable" "hydraulic link."***

230. In particular, Klügl explains that when its actuator is "in the rest position," "if there are long-lasting pressure differences between the pressure chamber 5 and the compensation chamber 7, … transmission medium is exchanged between the compensation chamber 7 and the pressure chamber 5 via the throttle 10." (Ex. 1006, 3:50-4:31.)

231. According to Klügl, this "automatic adjustment" accounts for the effects of "thermal expansion differences and gradual wear" of its components and ensures that the "drive piston 3" remains in contact with the "transmission module 2" even if temperature changes or wear cause size changes. (*Id.*, 3:52-62; 4:25-31.)

c. Claim 3

232. Claim 3 depends on claim 2 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by wear to components of said injection valve."

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233. As explained above, Wirbeleit and Klügl teach everything claim 2 requires.

234. In my opinion, Klügl teaches the additional limitation of claim 3 for the same reasons discussed in connection with claim 2: its transmission module 2 allows for fluid flow between chambers 5 and 7 during injector idle periods to account for not only thermal expansion, but also component wear.

d. Claim 6

235. Claim 6 depends on claim 1 and further requires:

"wherein said actuator assembly comprises a dimensionally responsive member."

236. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

237. In my opinion, Wirbeleit teaches the additional limitation of claim 6.

238. In particular, Wirbeleit's injector includes either a "magnetostrictive actuator 21" or "piezo actuator" that expands in length (i.e., is dimensionally responsive) to open or close the injector. (Ex. 1004, 2:60-64; *see also* 2:1-4, 13-17.)

e. Claim 13

239. Claim 13 depends on claim 6 and further requires:

"wherein said dimensionally responsive member is formed from a piezoelectric material."

240. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

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241. In my opinion, Wirbeleit teaches the additional limitation of claim 13: Wirbeleit includes a piezoelectric actuator 21. (Ex. 1004, 2:60-65; *see also* 2:1-4, 13-17.)

f. Claim 14

242. Claim 14 depends on claim 6 and further requires:

"a compression spring member for applying a compressive force to said dimensionally responsive member."

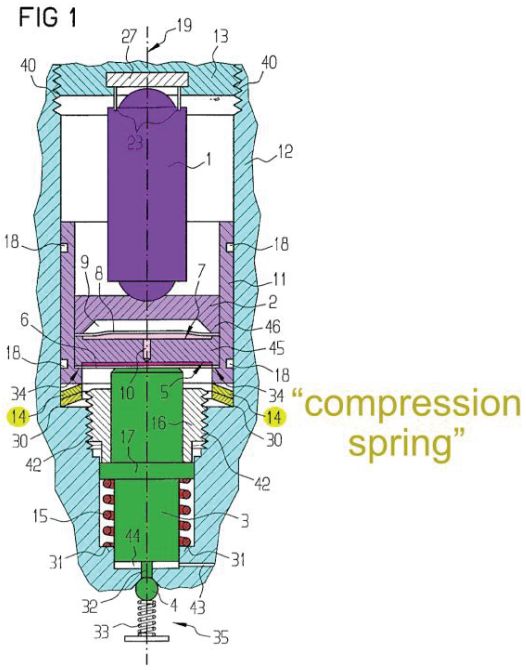
243. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

244. In my opinion, the ***"compressing spring member"*** required by claim 14 is taught by Klügl.

245. In particular, Klügl's injector includes a "disk spring 14" that allows the piezoelectric actuator 1 to be "pre-stress[ed] against" the valve housing 12 via the "transmission module 2." (Ex. 1006, 2:11-21; 3:16-19.)

246. This disk spring 14 is highlighted in yellow below:

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(*Id.*, Fig. 1 (annotated).)

247. In my opinion, a POSITA would have considered it obvious to use this disk spring 14 along with Klügl's transmission module 2 as it will maintain contact between the transmission module 2 and the actuator 1, and improve the injector's performance by pre-stressing the actuator.

g. Claim 17

248. Claim 17 depends on claim 6 and further requires:

"wherein when said actuator assembly is controllable to maintain said desired lift between 10 and 100 percent of maximum lift."

249. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

250. In my opinion, Wirbeleit teaches the additional limitation of claim 17.

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251. Wirbeleit explains that the "[o]pening of the slot-injection orifices can be controlled by energizing a piezo actuator which acts on the injector needle by way of a hydraulic transmission element…" (Ex. 1004, 2:1-3.)

252. The "desired injector orifice cross-section can be obtained by way of voltage control of the piezo actuator" which enables a variable and controllable "momentary lift position of the orifice needle." (*Id.*, 2:4-12.) Similarly, Wirbeleit explains that "[a]n appropriate slot orifice cross-section" can be "maintained by way of voltage control of the actuator." (*Id.*, 3:5-6.)

253. This means that in Wirbeleit, different, controllable amounts of needle lift are employed so as to allow "the injection orifice cross-section of the injector" to be "variable and … controlled depending on the requirements" for "engine performance…" (*Id.*, 1:59-63; *see also* 3:13-14.)

254. Wirbeleit does not specifically reference adjustment of its valve needle lift by an amount ***"between 10 and 100 percent of maximum lift."***

255. Regardless, as I explain above, Wirbeleit does teach a valve needle that allows for a controllable amount of lift that is achieved by supplying the actuator with a specific voltage.

256. In my opinion, a POSITA would consider it highly obvious to control the lift of Wirbeleit's needle across this claimed range. Wirbeleit already allows for 100% lift (the position providing fully open orifices). And, it also allows for variable

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lift less than 100%, which a POSITA would have recognized obviously includes 10% lift (the position providing mostly closed injection orifices). Allowing for a particular range of needle lift control—such as 10% to 100%—would have been considered nothing more than a routine design choice that could be achieved by simply supplying the actuator with the correct signal needed to achieve a desired lift.

257. In my opinion, the fact that the '138 patent identifies no importance or significance to the use of a range of "10 to 100 percent of maximum lift" confirms that this range would have been considered obvious by a POSITA and amounts to be a routine, obvious design choice.

258. Rather than identifying anything important about the claimed range, the '138 patent notes that its actuator is meant to "provide for" a degree of "partial lifting." (Ex. 1001, 8:19-21.)

259. This is exactly what Wirbeleit's injector does: it allows for either full or partial needle lift, as desired.

h. Claim 18

260. Claim 18 depends on claim 17 and further requires:

"wherein said lift is controllable by varying at least one of the electric current, the electric voltage and the magnetic field imposed upon said dimensionally responsive member."

261. As explained above, Wirbeleit and Klügl teach everything claim 17 requires.

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262. The additional limitation of claim 18 is taught by Wirbeleit.

263. In particular, Wirbeleit explains that its needle "lift position" and the corresponding "[o]pening of the slot-injection orifices can be controlled by energizing a piezo actuator which acts on the injector needle … with a voltage-dependent force." (Ex. 1004, 2:1-4; *see also* 2:10-12; 3:1-7.)

i. Claim 19

264. Claim 19 depends on claim 6 and further requires:

"wherein said valve member is controllable such that said valve member moves between said open and closed positions in less than about 200 microseconds."

265. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

266. In my opinion, the additional limitation of claim 19 is taught by Wirbeleit and Klügl.

267. Wirbeleit explains that its valve "injection time is adjustable depending on engine operating parameters." (Ex. 1004, 3:15-16.)

268. Klügl provides an example of standard injection times known at the time the '138 patent was filed.

269. In particular, according to Klügl the "actuation times" of an injection valve should be "in the range of milliseconds, preferably between 0 ms and 10 ms. Rapid actuation times are 0.1 to 1 ms" (or 100 to 1000 microseconds). (Ex. 1006, 4:22-24.)

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j. Claim 20

270. Claim 20 depends on claim 6 and further requires:

"a biasing mechanism for applying a compressive force to said dimensionally responsive member."

271. As explained above, Wirbeleit and Klügl teach everything claim 6 requires.

272. In my opinion, the additional limitation of claim 20 is taught by Klügl for the same reasons discussed for claim 14: Klügl includes a disk spring 14 that applies a pre-loading force to its piezoelectric actuator 1. (*See supra* Section IX.B.1.f.)

k. Claim 21

273. Claim 21 depends on claim 1 and further requires:

"wherein said biasing mechanism comprises a spring."

274. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

275. In my opinion, the additional limitation of claim 21 is taught by Wirbeleit for the same reasons discussed for claim 1: Wirbeleit's injector includes a return spring 7 that applies force to close the injector. (*See supra* Section IX.B.1.a.[1(c)].)

l. Claim 26

276. Claim 26 depends on claim 1 and further requires:

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"wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 Mpa)."

277. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

278. In my opinion, a POSITA would have considered the additional limitation of claim 26 obvious in view of Wirbeleit.

279. Wirbeleit states that its injection valve is meant for use with a "high pressure" fuel injection system. (Ex. 1004, 2:27-30.)

280. As of the '138 patent's filing, it was well known that "high pressure" fuel injection systems were able to inject fuel at pressures well in excess of 2000 psi.

281. For instance, it was known that injection pressure should vary with engine speed, from a "relatively low pressure … of approximately 2000 psi" at lower/idle speed and load, to pressures as high as 15,000 psi at higher engine speeds/loads. (*E.g.*, Ex. 1012, 5:48-52, 7:1-14; *see also* Ex. 1013, 11:25-31 (referencing injection pressures up to 1550.9 bar, or approximately 22,000 psi).)

m. Claim 27

282. Claim 27 depends on claim 1 and further requires:

"wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body."

283. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

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284. In my opinion, both Wirbeleit and Klügl teach sealed valve housings with a ***"plurality"*** of ***"joined" "parts."***

285. As shown in Wirbeleit's figure, Wirbeleit's "injector body 9" includes an upper and lower piece that together form an interior, sealed "slot orifice 4" and "fuel admission passage." (*See* Ex. 1004, 2:31-39; Fig.)

286. Klügl's injector also has a multi-part structure. In particular, the injector includes an "upper stop 13 [that] is connected to the housing 12 via a screw thread 40." (Ex. 1006, 1:57-60; Fig. 1.)

287. This was a very common fuel injector design when the '138 patent was filed. Fuel injectors routinely included housings formed from multiple parts. This renders the injectors less costly to manufacture and easier to assemble (forming the housing from one piece, in contrast, would make it very difficult to make and install the various required injector components within that housing).

n. Claim 41

288. Claim 41 is another independent claim. For reference, I have reproduced the entirety of this claim above. (*See* Section VII.C.)

289. Claim 41 is directed to a ***"method of operating a fuel injection valve"*** like that required by claim 1.

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290. Due to the similarity between what claim 41 and claim 1 require, in my opinion, the combination of Wirbeleit and Klügl teach everything required by this method for the same reasons I have already explained for claim 1.

291. Though I have included some additional discussion regarding claim 41 below, a fuller explanation can be found above in the discussion of claim 1.

292. In my opinion, injector taught by the Wirbeleit and Klügl references ***"(a) actuate[es] a dimensionally responsive member"*** and ***"(c) deactuat[es] said dimensionally responsive member"*** to open and close an injector.

293. In this regard, Wirbeleit includes a piezoelectric actuator 21 that expands in length along the injector's longitudinal axis when voltage is applied, and contracts in length when voltage is removed. (*See supra* Section IX.B.1.a.[1(d)].)

294. Further, Wirbeleit's spring 7 facilitates valve closing during de-actuation. (*See supra* Section IX.B.1.a.[1(c)].)

295. Wirbeleit and Klügl's injector also ***"(b) transfer[s] movement caused by said actuated dimensionally responsive member through a passive hydraulic link"*** to move a ***"valve member"*** and cause it to lift from a ***"valve seat."***

296. Here, Wirbeleit teaches that the force exerted by its actuator is passed through a hydraulic transmission element 22 to a valve needle 3 causing it to unseat. (*See supra* Section IX.B.1.a.[1(e)].)

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297. Further, as I have explained, when Klügl's teachings are applied, a POSITA would understand that this element would act as a solid and maintain its thickness during actuation. (*See id.*)

298. Klügl also, in my opinion, includes the claimed ***"hydraulic cylinder which houses a piston"*** (which the claim provides are part of the "passive hydraulic link").

299. In particular, Klügl transmission module 2, which includes hydraulic fluid filled chamber 5 through which the actuating forces are passed, is designed to move up and down. (*See* Ex. 1006, 2:7-16; Fig. 1.) Thus, it corresponds to the claimed "piston."

300. Further, this module is surrounded by a cylindrical "guide sleeve 11" located within the hollow interior of the injector's housing 12. The portion of the housing through which this sleeve moves is the claimed "hydraulic cylinder" that "houses" the "piston."

301. Finally, in my opinion, the references teach ***"(d) providing sufficient time between consecutive valve openings to allow at least some of said hydraulic fluid within said passive hydraulic link to flow from one side of said piston to the other side of said piston."***

302. In particular, Klügl teaches that its transmission module 2 includes a bore 10 (throttle/orifice), which allows the fluid from chamber 5 on one side of the

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module to flow to chamber 7 on the other side of the module during injector idle periods. (*See supra* Section IX.B.1.a.[1(e)].)

2. Motivation to Combine

303. A POSITA would have considered it obvious and would have been motivated to combine the teachings of Wirbeleit and Klügl.

304. As I have explained, Wirbeleit employs a "hydraulic transmission element 22" that is, according to Wirbeleit, "not shown in detail." (Ex. 1004, 2:60-64.)

305. Given that Wirbeleit requires the use but does not depict the specifics of its hydraulic transmission element, a POSITA would have been required to consult their own background knowledge and other available designs known in the art at the time the '138 patent was filed when implementing Wirbeleit.

306. In my opinion, a POSITA would have considered Klügl to be an example of one such design for use with Wirbeleit.

307. In my opinion, a POSITA would have considered Klügl's "transmission module 2" to be particularly suitable for use with Wirbeleit. As discussed in the following paragraphs, there are several reasons for this.

308. As an initial matter, Wirbeleit and Klügl are structurally and functionally similar.

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309. Klügl's "transmission module 2" is like Wirbeleit's "hydraulic transmission element 22" in that it is hydraulic-based and can passively transfer force from an actuator to a fuel injector control piston or needle for purposes of opening a valve. (*E.g.*, Ex. 1006, 1:60-2:10, 3:23-29.)

310. Further, both Wirbeleit and Klügl employ a piezoelectric (or alternatively magnetostrictive) actuator that applies force to a control piston through a hydraulic element so as to open a valve.

311. Both Wirbeleit and Klügl also employ a spring that applies force to the needle for purposes of closing the valve.

312. In my opinion, these structural and functional similarities would have provided a POSITA with a strong motivation to use Klügl's transmission module 2 when implementing Wirbeleit's hydraulic transmission element 22.

313. A POSITA would also, in my opinion, have been motivated to use Klügl's "transmission module 2" with Wirbeleit because doing so would be understood to provide other important benefits that would improve Wirbeleit's operation.

314. Primary among these is the ability to account for the effects of differential thermal expansion and wear.

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315. As I have explained, Klügl's "transmission module 2" uses an incompressible hydraulic fluid that does not flow out of a chamber 5 during actuation but can move between a chamber 5 and chamber 7 during periods of rest.

316. This, according to Klügl, not only allows for transmission of force without application of a non-unity stroke ratio (i.e., the needle still moves by the same distance the actuator expands) but also allows for "automatic adjustment" of the injector to account for the effects of "wear," "aging," and "thermal expansion." (Ex. 1006, 3:50-4:31.)

317. In my opinion, when the '138 patent was filed, a POSITA would have recognized that one "known" "aim" when designing an injection valve should be to "compensat[e]" for the "effects of temperature changes, wear and manufacturing tolerances" on the valve's "actuating displacement." (*E.g.*, Ex. 1009, 1:9-16.)

318. This same design goal is expressed repeatedly in the prior art. (*See, e.g.,* Ex. 1010, 1:41-52 (explaining that an injector "valve needle and its valving element" must "always perform the same opening stroke" regardless of "temperature fluctuations," "wear," or "manufacturing tolerances").).

319. In my opinion, a POSITA would have known that Wirbeleit is no different and is subject to the same issues as other known fuel injectors. Thus, the same design considerations discussed above apply equally to Wirbeleit.

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320. In particular, a POSITA would have understood that temperature changes, wear, or manufacturing issues could cause Wirbeleit's injector components—like the components of any injector—to also become misaligned, inefficient, or even non-functional.

321. Indeed, because Wirbeleit's injector is intended to allow for precise control over the amount of travel of its needle, a POSITA would have considered it particularly important that its injector components remain in proper alignment. Otherwise, application of control signals to Wirbeleit's actuator could result in the incorrect amount of needle movement. Similarly, Wirbeleit's needle lift sensor 19 is designed to sense the position of the control piston 10. If this control piston does not move by the same distance as the actuator, Wirbeleit's control system would not allow for the same, straightforward operation it currently does.

322. In my opinion, a POSITA would have understood that use of Klügl's "transmission module 2" would address this problem.

323. In particular, using Klügl's transmission module 2 (in particular that shown in Figure 1), force would still be transmitted between Wirbeleit's actuator and its needle.

324. But, during periods of rest when the injector is idle, hydraulic fluid could flow between chambers 5 and 7 to account for any dimensional changes resulting from thermal expansion and wear.

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325. A POSITA would have recognized that this would substantially improve Wirbeleit by rendering it more able to account for and automatically adapt to the types of conditions routinely encountered by a fuel injector. It would also ensure that Wirbeleit's injector continues to deliver the range of needle movement intended when different signals are applied to its actuator.

326. A POSITA would have recognized that there are further benefits that would have derived from application of Klügl's transmission module 2 to Wirbeleit. These would, in my opinion, have also motivated combination.

327. For instance, Klügl explains that its device, which of course includes its transmission module 2, is "particularly compact and easy-to-assemble." (Ex. 1006, 1:20-22.) Similarly, the device is structured such that its components can be "pre-assembled." (*Id.*, 1:26-38.)

328. In my opinion, a POSITA would have recognized that this would further improve Wirbeleit's injector.

329. Using use Klügl's "transmission module 2," Wirbeleit's injector would be more compact, leading to an overall smaller injector allowing it to be more readily integrated into an engine.

330. For instance, it would no longer be necessary to reserve a large space between the actuator and control piston to house a substantial amount of hydraulic fluid as depicted in Wirbeleit's figure. Nor would it be necessary include separate

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seals, gaskets, or the other types of structure to keep this element's hydraulic fluid in place and prevent it from escaping or leaking out of its designated space. Instead, only a small amount of hydraulic fluid would need to be housed in transmission module 2, which is itself already structured to keep fluid in place.

331. Relatedly, a smaller sized element 22 would also be understood by a POSITA to be beneficial in that it would allow for further design flexibility elsewhere in the injector. For example, differently sized or shaped interior chambers, fuel supply pathways, or nozzles that may not have been available previously due, for instance, to the length of the injector caused by the amount of hydraulic fluid used by Wirbeleit, would now be able to be more readily accommodated.

332. In the same fashion, a POSITA would have recognized that the injector's performance would be improved by keeping the volume of fluid in element 22 small so as to ensure that the fluid has low compressibility and effectively eliminate the possibility of delays of motion transmission from the actuator to control piston.

333. Further, a POSITA would have recognized that use of Klügl's separate, preassembled, "particularly simple [to] manufacture" transmission module 2 in place of Wirbeleit's built-in "hydraulic transmission element 22" would have simplified the overall process of manufacturing Wirbeleit's injector. (*Id.*, 1:26-34.)

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334. Manufacturing Wirbeleit's injector would require a step during injector assembly in which a substantial amount of hydraulic fluid must be supplied to the interior of its injector as no provision has been made to fill 22 through operation, such as through fuel or hydraulic ports or leak paths. This necessitates the presence of equipment capable of supplying this liquid without contaminating it in some way that will impede its operation. This step would be eliminated using Klügl's transmission module 2: the transmission module 2 (including the hydraulic fluid it contains) can be assembled separate from the injector. The transmission module 2 then simply needs to be inserted into the injector housing during injector assembly.

335. A POSITA would also have understood that Klügl's "transmission module 2" allows for the use of other injector components that would further improve Wirbeleit's operation.

336. For example, Klügl's injector includes an "upper stop 13" and a "lower stop 16" that are both attached via "screw" connections and can be used to set the compression of the piezoelectric actuator, disk spring 14, and spring 15. (Ex. 1006, 1:57-60; 2:35-39.)

337. Klügl explains that this allows "the piezoelectric actuator 1," transmission module 2," and "drive piston 3" to be "pre-adjusted" "[d]uring … production of the injection valve." (*Id.*, 3:1-10.)

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338. In my opinion, this would have further motivated application of Klügl to Wirbeleit. Using similar adjustment mechanisms (which are again allowed by Klügl's injector design, including its use of transmission module 2) would allow Wirbeleit's injector be adjusted at the time of manufacture to account for slight variations of component size, or to refine the load on the injector's components. A POSITA would have understood that this would have had the potential to improve (or at the very least refine) the operation of the injector.

339. In my opinion, a POSITA would also have been motivated to retain Wirbeleit's directly actuated and controllable valve design when applying the teachings of Klügl.

340. As I have summarized above, Wirbeleit identifies its injector's ability to control the orifice openings an important feature as it allows for the injection amount to be controlled "depending on engine operating parameters." (Ex. 1004, 1:52-58, 2:1-12.)

341. In my opinion, a POSITA would have similarly recognized this to be a highly beneficial feature.

342. For instance, it was known that controlling injection in this manner allows the "opening stroke of the valve member and the injection time" to be adjusted based on the engine's current operating conditions to "optimize[]" fuel "consumption" and minimize "emission." (*E.g.*, Ex. 1015 at 3; *see also id.* at 1

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(explaining that adjusting needle valve lift allows for "low fuel consumption and emissions … over [a] wide range[]" of engine operating conditions).)

343. Engaging in the type of control taught by Wirbeleit also allows injector performance to be tailored to ensure "smooth running of the internal combustion engine." (*Id.* at 3.)

344. Further, the control provided by Wirbeleit allows for valve adjustment "dynamically" during operation allowing for even further refinement of engine performance. (*Id*.)

345. In my opinion, these benefits would have not only provided a POSITA with a strong motivation to use Wirbeleit in the first place, but would also have led a POSITA to maintain the ability to control valve lift even if making other changes, including the application of Klügl's transmission module as discussed above, to Wirbeleit's injector. In order to accomplish this, a POSITA would have maintained Wirbeleit's direct acting configuration when including Klügl's transmission module.

346. Next, in my opinion, a POSITA would have considered the use of Klügl's "transmission module 2" with Wirbeleit to be nothing more than a routine design choice.

347. As I have explained, Wirbeleit teaches a fuel injector with controllable valve lift that allows the injection amount to be tailored to engine operation. Further, it already includes a passive hydraulic force transmission element.

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348. Klügl teaches a hydraulic transmission element like that employed by Wirbeleit. Further, it explains that this element is designed to automatically adjust to account for the effects of thermal expansion and wear.

349. A POSITA would have understood that combining these two references' teachings results in an injector that continues to exhibit these very same benefits: the combined injector would still allow for controllable lift as taught by Wirbeleit, would still transmit force through a hydraulic element as taught by both references, and would now be able to account for thermal expansion and wear as taught by Klügl.

350. In my opinion, a POSITA would also have had a reasonable expectation of success when combining Wirbeleit and Klügl.

351. As I explain above, a POSITA would have recognized that both Wirbeleit and Klügl are directed to injector valves. Indeed, both references teach injector valves that are structurally and functionally similar: both transmit the force of an actuator through a hydraulic element to a control piston for purposes of opening a valve. And, both employ a spring to exert a valve closing force.

352. In my opinion, this similarity would have led a POSITA to conclude that Klügl's "transmission module 2" and the other injector components associated with this module could be readily incorporated into Wirbeleit.

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353. I note that Klügl does provide an example where a piezoelectric actuator is employed to open a "servo" or pilot valve (which in turn opens the injector's nozzle valve).

354. In my opinion, a POSITA would not have considered Klügl to be only applicable to this type of injector.

355. Instead, a POSITA would have understood that Klügl's "transmission module 2" could also be readily and successfully used in other types of injectors.

356. This, in my opinion, includes injectors like Wirbeleit's, where the actuator directly controls a needle valve that opens the flow path into an engine's combustion chamber.

357. Showing this, Klügl itself explains that use of its transmission module in connection with a servo valve is intended to be just an "example." (Ex. 1006, 1:7-12.)

358. It then goes on to explain that its teachings—including its use of transmission module 2 to account for thermal expansion and wear—can be more broadly applied to the transmission of "movement of a piezoelectric actuator in an injection valve to" any "control element." (*Id.*)

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C. Ground 2: Claim 28 is Obvious Over Wirbeleit, Klügl, and Newcomb

359. In my opinion, a POSITA would have considered Wirbeleit, Klügl, and Newcomb to be within the scope of the prior art and highly relevant to the patentability of the ’138 patent’s claims.

360. In my opinion, when viewed and considered in light of the knowledge possessed by a POSITA, Wirbeleit, Klügl, and Newcomb together disclose all the limitations of and render claim 28 of the ’138 patent obvious.

361. Claim 28 depends on claim 1 and further requires:

“wherein said valve housing, said valve member and said actuator assembly are selected from materials having thermal expansion coefficients sufficiently compatible such that changes in the dimensional relationship between said components caused by changes in temperature are reduced.”

362. As explained above, Wirbeleit and Klügl teach everything claim 1 requires.

363. In my opinion, a POSITA would have considered the additional limitation of claim 28 to be obvious in view of the teachings of Newcomb (Ex. 1014).

364. Newcomb, like Wirbeleit and Klügl, relates to a “control valve such as a … fuel injection valve…” (*Id.*, 1:5-7.)

365. Newcomb explains that when such a valve employs a “piezoelectric element” as an actuator, “the potential stroke of the valve is usually small, for example, of the order to 10 or 20 micrometers.” (*Id.*, 1:31-34.)

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366. Newcomb then explains that "[i]t is therefore essential to minimize the effects of thermal expansion on the valve parts so that flow through the valve will vary only slightly with changes of ambient temperature." (*Id.*, 1:34-38.)

367. "One solution to [this] problem is to choose a material" (like "a nickel-iron alloy") "for the valve housing" that "has a similar thermal expansion coefficient to that of the piezoelectric element." (*Id.*, 1:38-41.)

368. Newcomb explains that as an alternative, different materials can be used so long as those materials have "coefficient[s] of thermal expansion" and dimensions that result in "equal" "linear expansion." (*Id.*, 1:50-59.)

369. Newcomb provides an example of this where a "valve body 21" and valve opening "lower end piece 2a" are made from "steel having a thermal expansion coefficient of 12 μm K^{-1}," while the piezoelectric "actuating member 2" is formed from a ceramic that "has a thermal expansion coefficient of 4 μm K^{-1}." Above the piezoelectric actuator is located a "spacer 22b" "made from aluminum having a thermal expansion coefficient of 23 μm K^{-1}." (*Id.*, 3:39-47.)

370. Newcomb explains that the "length" of the spacer may be chosen in such a way that the piezo actuator and spacer together "maintain[e]" "a substantially fixed position with respect to the" "valve housing 21 even though changes in the temperature of the valve may take place." (*Id.*, 3:52-68.)

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371. In my opinion, applying this to the injector of Wirbeleit and Klügl results in what the claim requires: the injector's housing, valve member, and actuator would have been made from materials with sufficiently similar thermal expansion coefficients or compatibly selected materials in such a way as to reduce the overall influence of thermal expansion. As a result, using either approach, any change in relative dimension would be minimized.

372. A POSITA would have been motivated to combine these references' teachings.

373. For instance, Klügl itself already recognizes that injector valves should be designed to account for the effects of thermal expansion. (Ex. 1006, 3:52-55, 4:25-31, 6:29-33.)

374. Newcomb confirms this, explaining that it is "essential" that a fuel injector be designed to "minimize the effect[s] of thermal expansion." (Ex. 1014, 1:34-38.)

375. Use of Newcomb's first thermal coefficient selection teachings would serve to further this known design goal: use of materials with matching thermal expansion coefficients would minimize (or at least reduce) the effects of thermal expansion.

376. I also understand that Patent Owner itself has stated that "[i]n order to minimize dimensional variations from changes in temperature expected in internal

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combustion engine applications, a reasonable engineer would select materials with similar thermal expansion coefficients for use in an injection valve." (*E.g.*, Ex. 1022, p. 20).) A POSITA as of the '138 patent's filing would have engaged in this same material selection process.

377. Moreover, Newcomb explains that its valve design approach "enable[s] the effects of thermal expansion to be reduced without the use of comparatively costly … materials." (Ex. 1014, 1:45-49.)

378. In my opinion, this potential for cost reduction through the use of less expensive materials would have served to further motivate a POSITA to apply Newcomb's teachings.

379. A POSITA would also have had a reasonable expectation of success.

380. Showing this, Newcomb itself explains that its material usage teachings are specifically intended for use with a "control valve such as a … fuel injection valve." (Ex. 1014, 1:5-7.) As I have explained, both Wirbeleit and Klügl teach fuel injection valves.

D. Ground 3: Claims 1-3, 6, 13-14, 17-21, 26-27, and 41 Are Obvious Over Klügl and Hayes

381. In my opinion, a POSITA would have considered Klügl and Hayes to be within the scope of the prior art and highly relevant to the patentability of the '138 patent's claims.

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382. In my opinion, moreover, when viewed and considered in light of the knowledge possessed by a POSITA as shown by Hayes, Klügl itself discloses all the limitations of and render claims 1-3, 6, 13-14, 17-21, 26-27, and 41 of the '138 patent obvious when Patent Owner's understanding of the claims is applied.

1. Claim-by-Claim Analysis

a. Claim 1

[1-p] "An injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:"

383. To the extent the preamble is limiting, it is taught by Klügl.

384. In particular, Klügl. teaches an "automotive" "injection valve." (Ex. 1006, 1:7-12.)

385. Further, Klügl explains that this valve controls injection into an "internal combustion engine." (*Id.*, 2:54-57.) In my opinion, a POSITA would understand this to be a direct injection valve for injecting fuel into the combustion chamber.

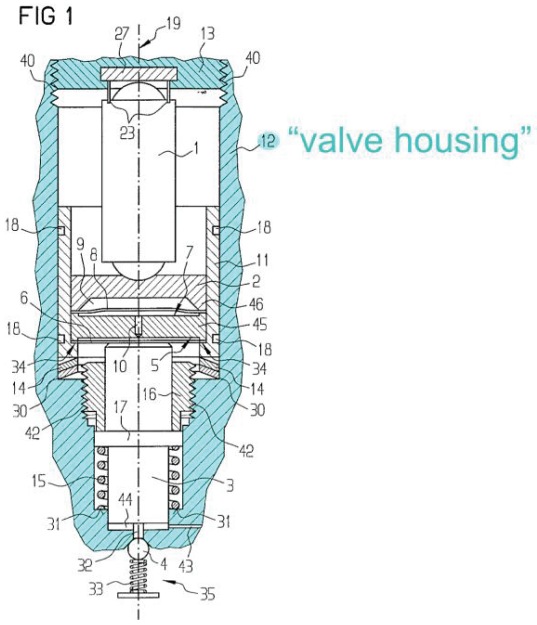
[1(a)] "(a) a valve housing comprising:"

386. In my opinion, Klügl's injector includes the claimed ***"valve housing."***

387. In particular, Klügl's injector includes an "upper stop 13" and an outer "housing 12" that surrounds the valve components. (*Id.*, 1:47-51.)

388. This housing is shown below in teal:

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(*Id.*, Fig. 1 (annotated).)

[1(a)-1] "a fuel inlet port;"

389. In my opinion, Klügl obviously includes the claimed ***"fuel inlet port."***

390. Klügl explains that a "servo valve" formed by "ball 4" (also referred to as a "closing member 4") "control[s] an injection needle, which controls the injection of an internal combustion engine." (Ex. 1006, 2:54-57.)

391. This "ball" is lifted from or lowered onto the "valve seat 35" by the "control needle 32" to "begin[]" or "end[]" "injection." (*Id.*, 3:23-38, 39-49.)

392. The opening of the ball servo valve allows the opening of an injector nozzle needle—not shown in Klügl's figure—as a "pressure chamber" that normally applies "high pressure to the injection needle" to be vented through the "relief line 43" to start fuel injection. (*Id.*, 3:33-38.)

393. Conversely, closing the servo valve allows "high pressure" to be "again applied" to the nozzle needle to close it and stop injection. (*Id.*, 3:39-49.)

394. In sum, in Klügl, the "injection needle" is moved to open/close a pathway to the combustion chamber.

395. While Klügl's figures do not show the structure around its "injection needle," in my opinion a POSITA would have understood that there would be a passage, conduit, line or other similar structure to supply fuel to the space adjacent to the "injection needle" such that fuel can be injected when the needle opens.

396. The purpose of the injection needle is to allow high pressure fuel to be sprayed into the combustion chamber when open, and stop the fuel spray when closed. To perform this function, high pressure fuel must be supplied to and stored behind the injection needle.

397. Other prior art shows how a POSITA would understand Klügl to be structured and operated. In my opinion, Hayes (Ex. 1024) provides an example.

398. Hayes relates to an indirectly actuated fuel injector. (*Id.*, 1:7-14.) In other words, an injector where the nozzle needle valve is indirectly controlled by a pilot valve.

399. Hayes's injector includes an intermediate "control valve 1" sealed by a ball-shaped "component 12." (*Id.*, 2:7-15, 30-36.) This is analogous to the servo valve sealed by ball 4 in Klügl.

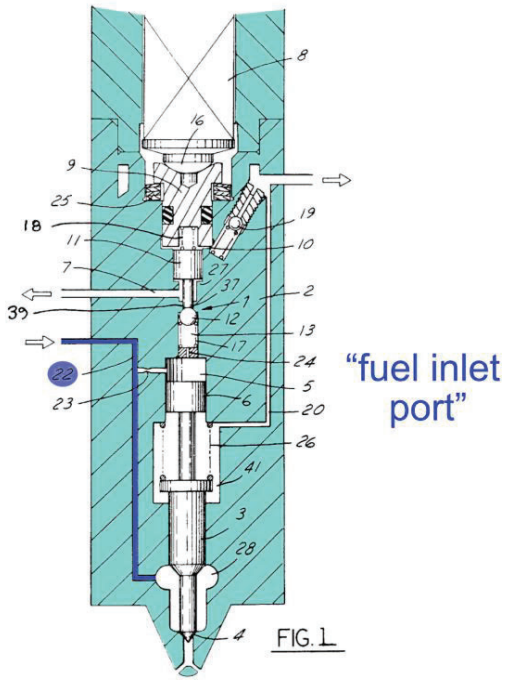
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400. Actuating Hayes's injector opens the control valve. (*Id.*, 3:24-45.) This in turn lowers the pressure in a "chamber 5," which causes a separate "valve needle 3" to lift and open a passage into combustion chamber. (*Id.*, 3:53-63.) Fuel supplied by a "feeding line 22, which feeds the fuel at high pressure" is then injected through the passage opened by the needle. (*Id.*, 2:45-48, 3:53-63.)

401. This operation is also analogous to that in Klügl. Activating Klügl's injector opens the servo valve formed by ball 4, lowers the pressure in a "pressure chamber," and causes an "injection needle" to unseat so fuel can be injected.

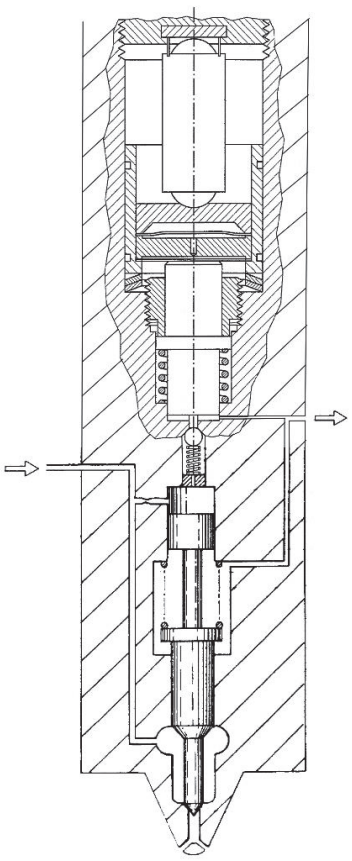
402. Given the structural and functional similarity between Klügl and Hayes, in my opinion a POSITA would have understood that Klügl would include a "feeding line" like that in Hayes to supply high pressure fuel to the area behind its injection needle. This line is the claimed ***"fuel inlet port"*** and is shown in blue below:

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(Fig. 1 (annotated).)

403. As a further clarification, the below demonstrative summarizes how, in my opinion, a POSITA would understand the portion of the injector below Klügl's servo valve and in the area of its injection needle to be structured. To create this demonstrative, I have applied the relevant portions of the injector shown in Fig. 1 of Hayes to Fig. 1 of Klügl. As explained, a lower injection needle—controlled by the intermediate servo valve—opens/closes a passage into the combustion chamber to allow fuel supplied by the inlet to be injected:



(*See* Ex. 1006, Fig. 1; Ex. 1024, Fig. 1.)

[1(a)-2] "an interior chamber fluidly connected to said fuel inlet port; and"

404. In my opinion, Klügl would obviously include the claimed ***"interior chamber."***

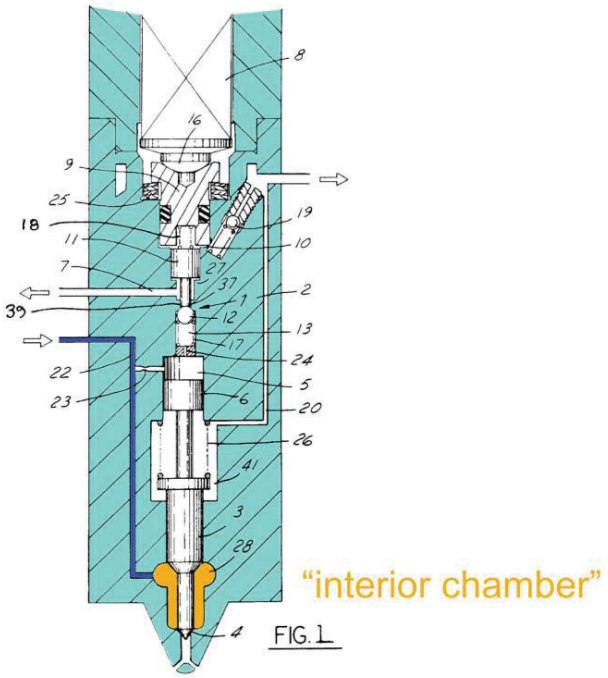
405. Again, as I have just explained, Klügl includes an "injection needle" that opens to the combustion chamber. (Ex. 1006, 3:33-38.)

406. As I have also explained, Hayes provides an example of how a POSITA would have understood the portion of Klügl's injector around this needle to be structured.

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407. In Hayes, fuel feed line 22 terminates in an "injection valve pressure chamber 28" located within the injector interior. (Ex. 1024, 2:45-47.)

408. This chamber 28 is shown in orange below. It corresponds to the claimed ***"interior chamber"***:



(*Id.*, Fig. 1 (annotated).)

409. In my opinion, a POSITA would have understood that Klügl would include a similar interior space adjacent to its injection needle: this would ensure that an adequate distribution of fuel is present behind the needle to provide uniform injection into the combustion chamber when the needle opens.

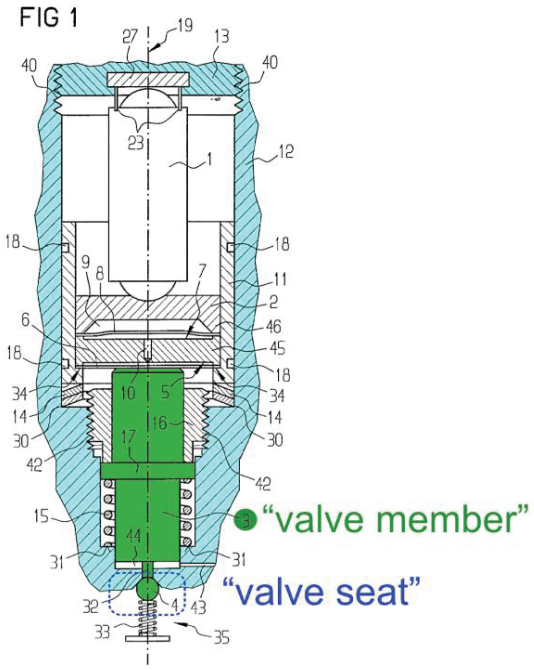
[1(a)-3] "a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed;"

[1-b] "(b) said valve member having one end disposed within said valve housing and an opposite end extendable from said valve seat toward said combustion chamber, wherein said valve member comprises a sealing surface that fluidly seals against said valve seat when said injection valve is closed and that is liftable away from said valve seat when said injection valve is open;"

410. In my opinion, Klügl includes the claimed ***"valve seat"*** and ***"valve member"*** when Patent Owner's understanding of the claim (with reference to an indirectly controlled injection valve) is applied. (*See* Section VIII above).

411. In particular, Klügl's injector includes a "drive piston 3" that "merges into a control needle 32" at its lower end. (Ex. 1006, 2:50-53.) The "control needle 32 … extends … to a valve seat 35…." (*Id.*) There is a "ball 4," which Klügl also calls a "closing element 4," attached to this control needle that acts as a "closing element" when "pressed against the valve seat." (*Id.*, 2:54-57.)

412. In my opinion, the piston 3, control needle 32, and ball 4 together form Klügl's ***"valve member."*** Klügl's valve seat 35 is the claimed ***"valve seat."*** The components making up the valve member area all highlighted in green below. The valve seat is circled:



(*Id.*, Fig. 1 (annotated).)

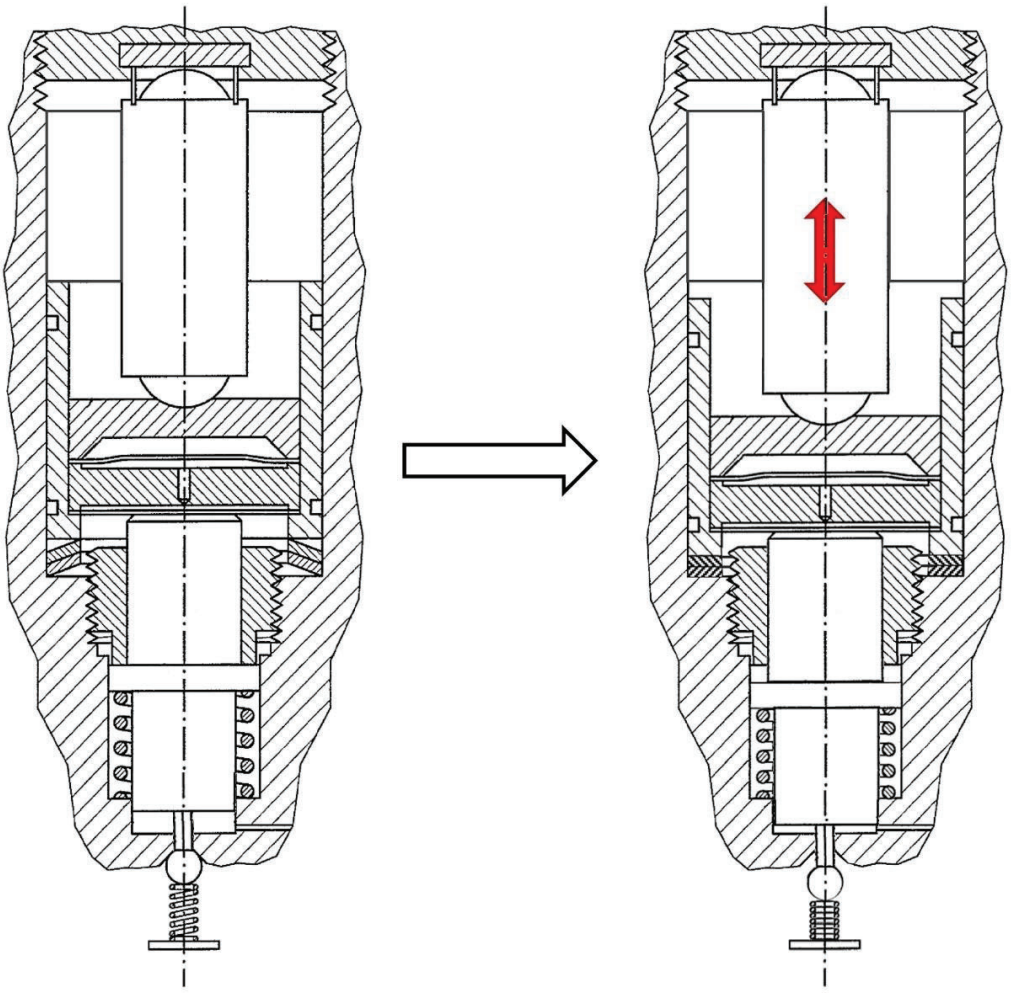
413. In my opinion, Klügl's valve member is ***"extendable from said valve seat toward said combustion chamber"*** such that it "***lift[s] away from said valve seat"*** to open the injector. It also ***"cooperat[es] with"*** the valve seat ***"to seal said interior chamber from said combustion chamber"*** to close the injector as this claim limitation requires.

414. To open the injector, Klügl's actuator expands causing "[t]he drive piston 3" to be pressed downward or displaced towards the combustion chamber. This in turn causes the "closing element 4" that is attached to the piston to be "lifted off the valve seat 35 by the control needle 32." (*Id.*, 3:23-33.)

415. This lifting of element 4 off its seat causes "the pressure in the pressure chamber [to] drop[]" and "the injection needle" to "lift" so that injection to the combustion chamber can begin. (*Id.*, 3:33-38.) This is the open or lifted position (at least under Patent Owner's understanding of this claim term): the valve member has moved so as to cause the fluid connection from the fuel supply to the combustion chamber via the injection needle.

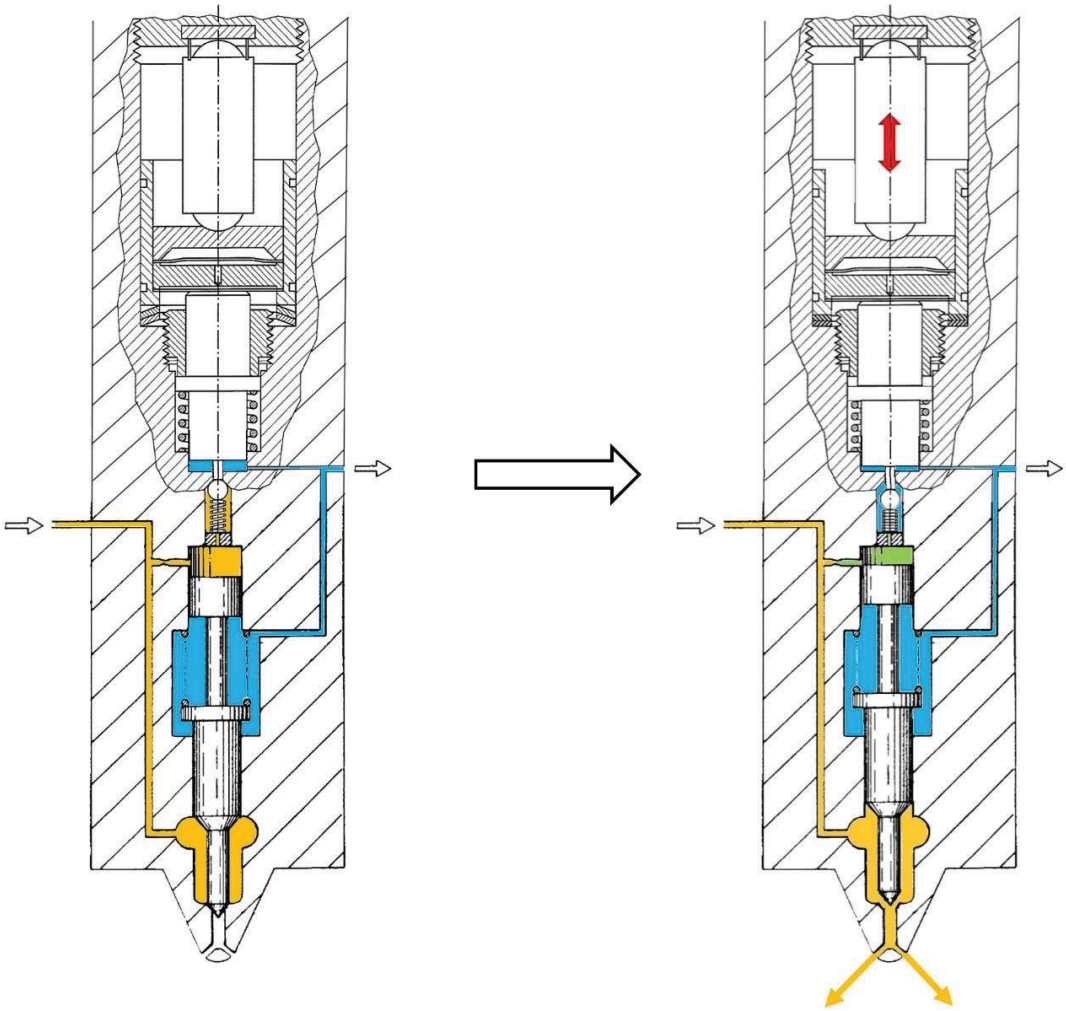
416. To close the valve, the actuator is deenergized causing it to shrink. This in turn causes the spring to exert pressure on the piston so that "closing element 4" is "pushed … back onto the assigned valve seat 35[.]" The pressure in the "pressure chamber" returns to a high level lowering the "valve needle" and ending injection. (*Id.*, 3:39-49.) This is the closed or sealed position (at least under Patent Owner's understanding of this claim term): the valve member has again moved so as to cause the injection needle to seal the passage from the fuel supply to the combustion chamber.

417. These positions are shown in the below demonstrative prepared using Figure 1 of Klügl. The closed/sealed position is shown to the left, while the open position is shown to the right. The piston size has been slightly modified in the figures to allow for an exaggerated depiction of movement while ensuring that the relief line is maintained, *i.e.*, the piston wouldn't block the relief line in operation.



418. In the combined injector of Hayes and Klügl, the figures below show the impact the opening/closing of Klügl's servo valve has on its injection needle (and how this results in fuel injection). Yellow represents areas of high pressure where high-pressure fuel is present. Blue represents areas of low pressure connected to the relief line. Green represents areas of intermediate pressure:

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419. As noted above, movement of Klügl's piston 3, control needle 32, and ball/closing element 4 does not directly open a passage to the combustion chamber—only Klügl's injection needle does this.

420. Regardless, movement of Klügl's piston 3, control needle 32, and ball/closing element 4 indirectly opens this passage by lowering the pressure in Klügl's pressure chamber causing Klügl's injection needle to unseat so that fuel can be injected into the combustion chamber.

421. Again, as I have explained, in my opinion this type of indirect actuation is not what claim 1 requires. (*See supra* Section VIII.)

422. But, as I have also explained, I understand that Patent Owner has taken the opposite position.

423. Applying Patent Owner's understanding of claim 1 to embrace indirectly actuated injectors, Klügl teaches what the claim requires.

424. In particular, it includes a "valve member" (its piston 3, control needle 32, and ball/closing element 4) that operates (indirectly) to either "fluidly seal[]" with a "valve seat" (valve seat 35) to stop injection, or "lift[]" (towards the combustion chamber) from that seat to start injection.

[1(c)] "(c) a biasing mechanism associated with said valve member, said biasing mechanism applying a closing force to said valve member when said valve member is in said closed position;"

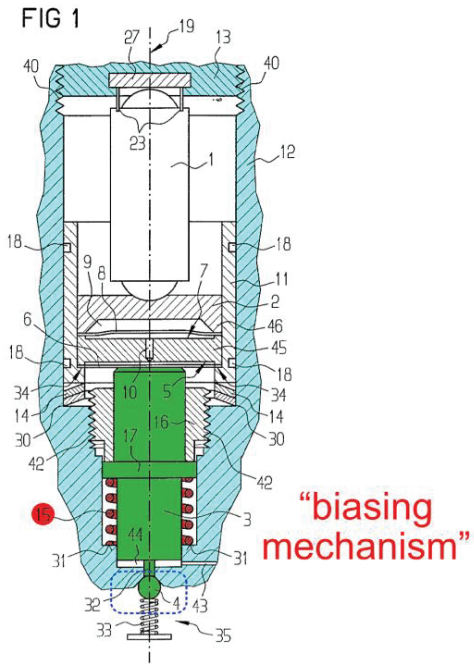
425. In my opinion, Klügl includes the claimed ***"biasing mechanism."***

426. In particular, Klügl's injector includes a "spring 15" that "bias[es]" the "drive piston 3 … against a lower stop 16" located within the injector housing. (Ex. 1006, 2:35-36.)

427. The force exerted by this spring through the piston, along with cooperating force exerted on the ball 4 by a "valve spring 33", causes "closing element 4" to be "seated on the valve seat 35" when the injector is in its "rest" state. (*Id.*, 3:11-13, 19-22, 39-45.)

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428. Spring 15 is highlighted in red below:



(*Id.*, Fig. 1 (annotated).)

[1(d)] "(d) an actuator assembly associated with said valve member, wherein said actuator assembly may be actuated to apply an opening force to said valve member stronger than said closing force, for moving said valve member to said open position; and"

429. In my opinion, Klügl's injector includes the claimed ***"actuator assembly."***

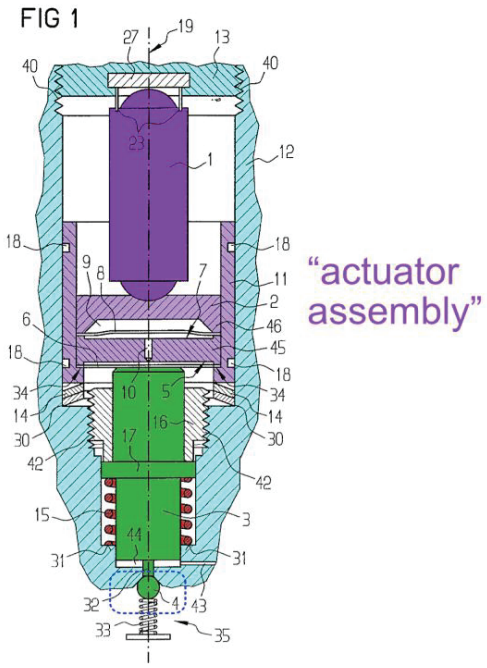
430. Klügl explains that a "piezoelectric actuator 1 is placed in" its "housing 12" "between an upper stop 13 and a transmission module 2…." (Ex. 1006, 1:47-51.)

431. The "length" of this actuator can be "adjusted" via application of a voltage over "control lines 23." (*Id.*, 1:51-56.)

432. To open the injector, "the piezoelectric actuator 1 is … controlled" "press[ing] the entire transmission module 2 … in the direction of the drive piston 3" so as to "move[]" the piston "against the spring force of the tension spring 15…." (*Id.*, 3:23-33.)

433. To close the injector, "activation of the piezo actuator 1 ends" causing "the piezoelectric actuator 1" to be "shortened" and "transmission module 2" to be "pushed" back "in the direction of the piezoelectric actuator 1." (*Id.*, 3:39-45.)

434. The actuator 1 and transmission module 2 together constitute Klügl's "actuator assembly." The actuator 1 is shown in dark purple below, while the transmission module 2 is shown in light purple:



(Fig. 1 (annotated).)

[1(e)] "(e) a hydraulic link assembly comprising a passive hydraulic link having a hydraulic fluid thickness through which said opening and closing forces are transmitted, whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is actuated and wherein said thickness of said hydraulic link is adjustable while said actuator assembly is not actuated in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve lift upon actuation of said actuator assembly."

435. In my opinion, Klügl teaches the claimed ***"hydraulic link."***

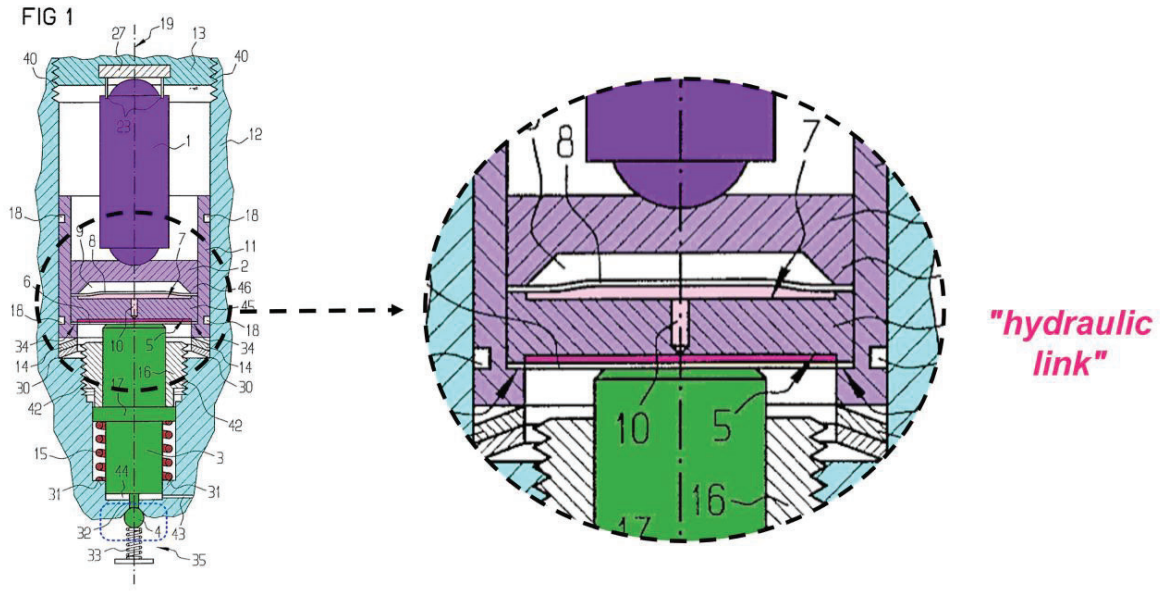
436. I have already explained above in Section IX.B.1.a.[1(e)] (when discussing Wirbeleit and claim 1), Klügl's injector includes a chamber 5 filled with incompressible hydraulic fluid. When Klügl's actuator expands, force from the actuator is transmitted to piston 3 through the fluid in this chamber to open the injector. Then, when the actuator is deactivated to close the injector, the closing force of the spring 15 is transmitted back through this same chamber 5 until a rest point is reached.

437. As I have also explained, the fluid in this chamber passively transmits force from the actuator 1 to the piston 3. The piston 3 moves by the same distance that the actuator 1 expands. Further, because the fluid is incompressible and cannot flow out of chamber 5 during actuation, the fluid acts as solid with constant thickness.

438. Further, due to the presence of bore or throttle 10 that connects to a chamber 7, during periods of rest and valve inactivity, fluid can move from the

chamber 5 through bore 10 to chamber 7 to automatically adjust and compensate for effects of thermal expansion and wear.

439. As a result, this fluid-filled chamber 5 corresponds to claimed ***"hydraulic link."*** This link is highlighted dark pink below. The bore 10 and chamber 7 that allow for auto-adjustment during idle or rest periods are shown in light pink. As done earlier in this declaration, the central portion of the figure has been expanded to the right to better focus on the chamber 5:



(Fig. 1 (annotated).)

b. Claim 2

440. Claim 2 depends on claim 1 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by differential thermal expansion."

441. As explained above, Klügl and Hayes teach everything claim 1 requires.

442. In my opinion, Klügl teaches the additional limitation of this claim for the same reasons discussed above: fluid can move from Klügl's chamber 5 to chamber 7 when the injector is at rest to account for the effects of thermal expansion. (*See supra* Section IX.B.1.b.)

c. Claim 3

443. Claim 3 depends on claim 2 and further requires:

"wherein said thickness of said hydraulic link is auto-adjustable while said actuator assembly is not actuated in response to changes in said dimensional relationship caused by wear to components of said injection valve."

444. As explained above, Klügl and Hayes teach everything claim 2 requires.

445. In my opinion, Klügl teaches same reasons discussed above: fluid can move from Klügl's chamber 5 to chamber 7 when the injector is at rest to account for the effects of wear. (*See supra* Section IX.B.1.c.)

d. Claim 6

446. Claim 6 depends on claim 1 and further requires:

"wherein said actuator assembly comprises a dimensionally responsive member."

447. As explained above, Klügl and Hayes teach everything claim 1 requires.

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448. In my opinion, the additional limitation of this claim is taught by Klügl. Klügl employs a "piezoelectric actuator 1" that "preferably consists of a stack of piezoelectric elements" that extend in length in response to an applied voltage to open Klügl's injector. (Ex. 1006, 1:52-56.)

e. Claim 13

449. Claim 13 depends on claim 6 and further requires:

"wherein said dimensionally responsive member is formed from a piezoelectric material."

450. As explained above, Klügl and Hayes teach everything claim 6 requires.

451. In my opinion, the additional limitation of this claim is taught by Klügl. Klügl employs a "piezoelectric actuator 1" that "preferably consists of a stack of piezoelectric elements." (Ex. 1006, 1:52-56.)

f. Claim 14

452. Claim 14 depends on claim 6 and further requires:

"a compression spring member for applying a compressive force to said dimensionally responsive member."

453. As explained above, Klügl and Hayes teach everything claim 6 requires.

454. In my opinion, the additional limitation of this claim is taught by Klügl for the reasons discussed above: Klügl's injector includes a "disk spring 14" to "pre-

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stress[]" its piezoelectric actuator 1. (Ex. 1006, 2:11-21; 3:16-19; *see also supra* Section IX.B.1.f.)

g. Claim 17

455. Claim 17 depends on claim 6 and further requires:

"wherein when said actuator assembly is controllable to control said desired lift to between 10 and 100 percent of maximum lift."

456. As explained above, Klügl and Hayes teach everything claim 6 requires.

457. In my opinion, the additional limitation of this claim is rendered obvious by Klügl.

458. Klügl explains that "the length" of its "piezoelectric actuator 1 can be adjusted" via a signal sent over "control lines 23" by a "control means 27." (Ex. 1006, 1:51-56.)

459. In my opinion, even in an indirectly actuated injector, it is advantageous to be able to open the valve proportionally as Klügl teaches from small to full valve lifts. For instance, in the combined embodiment of Klügl and Hayes presented above, the proportional control of Klügl's servo valve could additionally act as Hayes's control volume vent orifice 24 and would allow for control of the injection needle valve's opening and closing rates to improve noise and emissions.

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460. Klügl teaches the general conditions of this claim. It is an injector with variable, controllable lift. Given this, in my opinion a POSITA would consider the claim to be obvious for the same reasons I note above. (*See supra* Section IX.B.1.g.)

h. Claim 18

461. Claim 18 depends on claim 17 and further requires:

"wherein said lift is controllable by varying at least one of the electric current, the electric voltage and the magnetic field imposed upon said dimensionally responsive member."

462. As explained above, Klügl and Hayes teach everything claim 17 requires.

463. In my opinion, these references also teach the additional limitation of claim 18 for the reasons discussed in connection with claim 17: the lift of Klügl's injector servo valve can be adjusted by controlling the voltage supplied to a piezoelectric actuator. This will in turn impact the hydraulic balance of the needle. (*See supra* Section IX.D.1.g.)

i. Claim 19

464. Claim 19 depends on claim 6 and further requires:

"wherein said valve member is controllable such that said valve member moves between said open and closed positions in less than about 200 microseconds."

465. As explained above, Klügl and Hayes teach everything claim 6 requires.

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466. In my opinion, the additional limitation of this claim is rendered taught by Klügl for the same reasons discussed above: Klügl's valve can transition from an open to closed state in as little as 100 microseconds. (*See supra* Section IX.B.1.i.)

j. Claim 20

467. Claim 20 depends on claim 6 and further requires:

"a biasing mechanism for applying a compressive force to said dimensionally responsive member."

468. As explained above, Klügl and Hayes teach everything claim 6 requires.

469. In my opinion, the further limitation of this claim this is taught by Klügl for the same reasons explained for claim 14: Klügl includes a disk spring 14 that applies a pre-loading force to its piezoelectric actuator 1. (*See supra* Section IX.D.1.f.)

k. Claim 21

470. Claim 21 depends on claim 1 and further requires:

"wherein said biasing mechanism comprises a spring."

471. As explained above, Klügl and Hayes teach everything claim 6 requires.

472. In my opinion, the additional limitation of this claim is taught by Klügl. In particular, as I explained when discussing claim 1, Klügl's injector includes a

spring 15 that applies force that causes the ball 4 to be pressed against its seat to seal and close the injector. (*See supra* Section IX.D.1.a.[1(c)].)

l. Claim 26

473. Claim 26 depends on claim 1 and further requires:

"wherein said fuel is injected into said combustion chamber at a pressure greater than about 2000 psi (about 13.8 Mpa)."

474. As explained above, Klügl and Hayes teach everything claim 1 requires.

475. Klügl's injector employs a "high pressure" chamber to facilitate injection from its injector into an engine's combustion chamber. (*E.g.*, 1006, 3:33-38.)

476. As I have explained above, a POSITA would have recognized that in such a high-pressure system, injection pressure would greatly exceed 2000 psi (particularly in a diesel engine). (*See supra* Section IX.B.1.l.)

m. Claim 27

477. Claim 27 depends on claim 1 and further requires:

"wherein said valve housing comprises a plurality of parts which are joined with each other to provide a fluidly sealed body."

478. As explained above, Klügl and Hayes teach everything claim 1 requires.

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479. In my opinion, the additional limitation of this claim is taught by Klügl. In particular, Klügl's injector housing includes at least a "housing 12" and an "upper stop 13" that together form its sealed interior. (Ex. 1006, 1:49-51; Fig. 1.)

n. Claim 41

480. Claim 41 is another independent claim. For reference, I have reproduced the entirety of this claim above. (*See* Section VII.C.)

481. Claim 41 is directed to a ***"method of operating a fuel injection valve"*** like that required by claim 1.

482. Due to the similarity between what claim 41 and claim 1 require, in my opinion, the combination of Klügl and Hayes teach everything required by this method for the same reasons I have already explained for claim 1 (at least when Patent Owner's understanding of the claim is applied).

483. Though I have included some additional discussion regarding claim 41 below, a fuller explanation can be found above in the discussion of claim 1.

484. In my opinion, the injector taught by the Klügl and Hayes references ***"(a) actuate[es] a dimensionally responsive member"*** and ***"(c) deactuat[es] said dimensionally responsive member"*** to open and close an injector.

485. In this regard, Klügl includes a piezoelectric actuator 1 that expands in length along the injector's longitudinal axis when voltage is applied, and contracts in length when voltage is removed. (*See supra* Section IX.D.1.a.[(d)].)

486. Further, Klügl's spring 15 facilitates valve closing during de-actuation. (*See supra* Section IX.D.1.a.[1(c)].)

487. Klügl and Hayes's injector also ***"(b) transfer[s] movement caused by said actuated dimensionally responsive member through a passive hydraulic link"*** to move a ***"valve member"*** and cause it to lift from a ***"valve seat."***

488. Here, Klügl teaches that the force exerted by its actuator is passed through incompressible hydraulic fluid in chamber 5 that is part of transmission module 2 to a piston 3 / needle 32 / ball 4 causing it to unseat. (*See supra* Section IX.D.1.a.[1(e)].)

489. The fluid in this chamber acts as a solid and maintain its thickness during actuation. (*See id.*)

490. Klügl also, in my opinion, includes the claimed ***"hydraulic cylinder which houses a piston"*** (which the claim provides are part of the "passive hydraulic link").

491. In particular, Klügl transmission module 2, which includes hydraulic fluid filled chamber 5 through which the actuating forces are passed, is designed to move up and down. (*See* Ex. 1006, 2:12-21; Fig. 1.) Thus, it corresponds to the claimed "piston."

492. Further, this module is surrounded by a cylindrical "guide sleeve 11" located within the hollow interior of the injector's housing 12. The portion of the

housing through which this sleeve moves is the claimed "hydraulic cylinder" that "houses" the "piston." (*See id.*)

493. Finally, in my opinion, the references teach ***"(d) providing sufficient time between consecutive valve openings to allow at least some of said hydraulic fluid within said passive hydraulic link to flow from one side of said piston to the other side of said piston."***

494. In particular, Klügl teaches that its transmission module 2 includes a bore 10 (throttle/orifice) which allows the fluid from chamber 5 on one side of the module to flow to chamber 7 on the other side of the module during injector idle periods. (*See supra* Section IX.D.1.a.[1(e)].)

2. Motivation to Combine

495. This ground points to Hayes as an example of what a POSITA would understand Klügl to already teach. In other words, Hayes simply provides elaboration. Klügl is not being modified or changed in view of Hayes's teachings.

496. Regardless, in my opinion, a POSITA would have been motivated to look to Hayes—and would have had a reasonable expectation of success when doing so—not only because of the structural and functional similarity of Hayes and Klügl, but also because Hayes teaches that its injector is designed to be "simple," and "compensate[s] for tolerances and shifts due to temperature and wear." (Ex. 1024, 1:32-35.) Klügl's injector is designed with similar goals in mind.

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E. Ground 4: Claim 28 is Obvious Over Klügl, Hayes, and Newcomb

497. In my opinion, a POSITA would have considered Klügl, Hayes, and Newcomb to be within the scope of the prior art and highly relevant to the patentability of the '138 patent's claims.

498. In my opinion, when viewed and considered in light of the knowledge possessed by a POSITA, Klügl, Hayes, and Newcomb together disclose all the limitations of and render claim 28 of the '138 patent obvious.

499. Claim 28 depends on claim 1 and further requires:

"wherein said valve housing, said valve member and said actuator assembly are selected from materials having thermal expansion coefficients sufficiently compatible such that changes in the dimensional relationship between said components caused by changes in temperature are reduced."

500. As explained above, Klügl and Hayes teach everything claim 1 requires.

501. In my opinion, a POSITA would have considered the additional limitation of claim 28 to be obvious in view of the teachings of Newcomb (Ex. 1014) for the same reasons I have already discussed.

502. In particular, Klügl already recognizes that an injector should be designed to account for the effects of wear or thermal expansion. And, Newcomb teaches that these effects can be further minimized by employing materials with compatible thermal expansion coefficients as this particular claim requires. (*See supra* Section IX.C.)

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F. Secondary Considerations of Non-Obviousness

503. Based on my review of the ’138 patent’s prosecution history, I note that no secondary considerations of non-obviousness were identified in connection with the patent’s claims.

504. I am not separately aware of any evidence of commercial success, skepticism, failure of others, industry praise, unexpected results, or the like. Instead, as discussed above, it is my opinion that the subject matter embraced by the ’138 patent’s claims was known in the art and would have been expected to function as a working fuel injector.

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

Date: 12/9/2022

Location: Monument, Colorado

Signature: J. M. Quinlan

Dr. J. Matt Quinlan

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ATTACHMENT A

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John "Matt" Quinlan
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EXPERIENCE

Assistant Professor August 2019 to Present
University of Colorado—Colorado Springs, Colorado Springs, CO

- Designed, constructed, and tested an outwardly-opening pintle fuel injector to study hydrodynamics and atomization
- Designed, constructed, and tested a rocket baffle nonlinear acoustic damping facility, now developing software to calculate the theoretical damping magnitude
- Simulated 3-D detonation wave fronts with detailed (skeletal) chemical models to develop next generation rotating detonation engines
- Developing diffuse interface methods for reacting, two-phase flow simulations
- First co-PI on funded five-year NSF MRI project to purchase and oversee UCCS's first supercomputer (over 125 TFLOPS) in 2020—installed and rolling out to users currently
- Appointed as a fellow in 2022 and 2020 for the Air Force Research Lab Summer Faculty Fellowship—funding for faculty and graduate student for research at the United States Air Force Academy in combustion diagnostics and detonation simulations
- Was awarded a UCCS CRCW Seed Grant for work in hydrodynamic instabilities
- Taught eleven undergraduate and graduate courses

Consultant/Owner 2005 to Present
Quinlan Engineering and Design, LLC, Woodland Park, CO

- Diesel fuel system design, development, and analysis
- Mechanical component design, structural analysis, and failure analysis
- Combustion instability analysis and mitigation
- Hydraulic hybrid vehicle powertrain design and analysis

Visiting Assistant Professor August 2018 to August 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

- Taught eight courses over the year

Adjunct Instructor August 2016 to August 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Research Engineer April 2014 to August 2015
Georgia Institute of Technology, Atlanta, GA

- Co-Principal Investigator on NASA supported (about $150,000/year) acoustic sensing in liquid rocket engine project
- Designed, built, and tested swirling, co-axial rocket injector with adjustable swirl.
- Developed pseudo-linear techniques to analyze high-amplitude acoustic sensor ports

Diesel Fuel System Engineer 2001 to 2006
Sturman Industries, Fuel System group, Woodland Park, CO

- Developed advanced prototype hydraulically intensified diesel fuel injectors, 3000 bar capable
- Developed advanced prototype common-rail diesel fuel injectors
- Primary structural analyst for Fuel System group
- Designed of mechanical components and assemblies for fuel systems
- Created print packages with geometric dimensioning and tolerancing (GD&T)
- Performed installations twice for German universities with a major automobile manufacturer
- Performed dynamometer and emissions mapping

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EDUCATION

Doctor of Philosophy, Aerospace Engineering
Georgia Institute of Technology, Atlanta, GA December 2015
Thesis: Investigation of Driving Mechanisms of Combustion Instabilities in Liquid Rocket Engines via the Dynamic Mode Decomposition
Advisor: Ben T. Zinn
Concentration: Thermoacoustic instability
Minor: Mathematics
Focus areas: Combustion, acoustics, viscous flow, turbulence, and high-temperature gas dynamics
Research:

- Developed data analysis techniques to experimentally find stability determining Floquet multipliers for systems with periodic governing equations
- Responsible for laboratory-scale facility concept, design, analysis, and development capable of exhibiting full-scale-like combustion instabilities
- Used sub-scale facility to study mechanisms that drive combustion instability, including the acquisition and analysis of data from high-speed diagnostics
- Performed synchronized 10 kHz OH-planar laser induced fluorescence, particle image velocimetry, CH^*-chemiluminescence, and acoustic pressure measurements to probe complex reacting/swirling flow
- Developed technique to analyze data based on dynamic mode decomposition, which preserves spatial/temporal relationship between synchronized diagnostics, extracting coupled dynamical modes
- Used the sub-scale facility, two-microphone wave decomposition, and real-time active acoustic impedance control to simulate a full-scale combustion instability at a frequency that is not a natural acoustic frequency of the system
- Wrote a finite element method based code to find the acoustic modes for geometrically complex combustion chambers

Masters of Science, Mechanical Engineering
Colorado State University, Fort Collins, CO May 2009
Thesis: Combustion Stability in Baffled Rocket Engines
Advisor: Charles E. Mitchell
Co-Advisor: Allan T. Kirkpatrick
Concentration: Thermoacoustic instability
Other focus areas: Structural mechanics
Research:

- Developed and delivered new liquid rocket engine combustion stability code
- Code uses a Fourier matching technique allowing stability predictions for more complex combustion chambers
- Demonstrated ability to locate the stability boundary based on a number of parameters including acoustic mode, frequency, combustion gain, and combustion phase
- Code currently being used by commercial rocket engine manufacturer

Bachelor of Science, Mechanical Engineering
Colorado State University, Fort Collins, CO May 2001

- Co-Captain FSAE Formula car team, 2000–2001

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PUBLICATIONS & PATENTS

Refereed Journals

- Schmidt, E. M., **Quinlan, J. M.**, and Runnels, B. "Self-similar Diffuse Boundary Method for Phase Boundary Driven Flow," *Physics of Fluids*, Vol. 34, No, 11, 2022.
- Kanagraajan, B., **Quinlan, J. M.**, Bojko, B., and Runnels, B. "A Diffuse Interface Method for Solid-Phase Modeling of Regression Behavior in Solid Composite Propellants," *Combustion and Flame* Vol. 242, 2022.
- Alsulami, R., Lucas, S., Hageman, M., Knadler, M., **Quinlan, J. M.**, and Windom, B., "Coupling Effects of Physical and Chemical Properties on Jet Fuel Spray Flame Blowout," *Proceedings of the Combustion Institute* Vol. 38, No. 2, 2021
- **Quinlan, J. M.**, and Zinn, B. T. "Development and Dynamical Analysis of Laboratory Facility Exhibiting Full-Scale Combustion Instability Characteristics," *AIAA Journal*, Vol 55, No. 12, 2017.
- Emerson, B., Jagtap, S., **Quinlan, J. M.**, Renfro, M. W., Cetegen, B. M., Lieuwen, T. "Stability Analysis of Reacting Wakes: Flow and Density Asymmetry Effects," *Physics of Fluids*, Vol. 28, No. 4, 2016.
- **Quinlan, J. M.**, Kirkpatrick, A., Milano, D., Mitchell, C. E., and Hinerman, T. D. "Analytical and Numerical Development of a Baffled Liquid Rocket Combustion Stability Code," *Journal of Propulsion and Power*, Vol. 28, No. 1, 2012.

U.S. Patents

- 8,622,859 – Systems and methods for hybridization of a motor vehicle using hydraulic components – 2014
  patentimages.storage.googleapis.com/98/12/19/b5196276017a4a/US8622859.pdf
- 8,366,018 – Oil intensified common rail injectors – 2013
  patentimages.storage.googleapis.com/bc/bf/15/7f6af484c4c669/US8366018.pdf
- 8,282,020 – Three-way valves and fuel injectors using the same – 2012
  patentimages.storage.googleapis.com/18/27/4d/b43fe73b70ab64/US8282020.pdf
- 7,681,592 – Three-way poppet valves with floating seat – 2010
  patentimages.storage.googleapis.com/20/70/33/24dfd50ac9b5e0/US7681592B2.pdf

Journal Manuscripts in Preparation or Review
For current preprints visit www.researchgate.net/profile/Matt-Quinlan

- **Quinlan, J. M.** "Parametric Combustion Instabilities," *AIAA Journal*.
- **Quinlan, J. M.** "Data Based Analysis of Periodic Phenomena: Floquet Theory Extended Dynamic Mode Decomposition," *Journal of Fluid Mechanics*.

Conference Papers

- Day, J., **Quinlan, J. M.** "Modeling Nonlinear Acoustic Damping Due to Flow Separation," *183rd Meeting of the Acoustical Society of America*. Vol. 1pEA8, Nashville, Tennessee, 2022.
- Schmidt, E. M., **Quinlan, J. M.**, Runnels, B. "A Self-Similar Diffuse Interface Method for a Rotating Ablating Cylinder," *75th Meeting of the American Physical Society—Division of Fluid Dynamics*. Vol. Z16.07, Indianapolis, Indiana, 2022.
- **Quinlan, J. M.** "Parametric Combustion Instabilities," *AIAA Science and Technologies Forum and Exposition*. Vol. AIAA-2022-1857, San Diego, California, 2022.
- Schmidt, E. M., **Quinlan, J. M.**, and Runnels, B. "Diffuse Interface Method for Coupling of Solid and Gaseous Phases in a 1D Verification Problem for Combustion of AP/HTPB," *AIAA Science and Technologies Forum and Exposition*. Vol. AIAA-2022-2196, San Diego, California, 2022.
- Day, J. A., Erazo Papagayo, S., and **Quinlan, J. M.** "Baffle Blade Acoustic Damping," *AIAA Propulsion and Energy Forum*. Vol. AIAA-2021-3573, Denver, Colorado, 2021.
- Erazo Papagayo, S., Day, J. A., Gamertsfelder, J. , Khare, P., and **Quinlan, J. M.** "Pintle Injector Spray Atomization: Liquid Sheet Breakup Quantification," *AIAA Propulsion and*

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Energy Forum. Vol. AIAA-2021-3630, Denver, Colorado, 2021.

- Rehl, A., **Quinlan, J. M.**, Scarborough, D., and Zinn, B. T. "Nonlinear Acoustic Response of Stand-Off Tubes Used in Acoustic Pressure Measurements—Part I: Experimental Study," *170th Meeting of the Acoustical Society of America*. Vol. 2PEA4, Jacksonville, Florida, 2015.
- **Quinlan, J. M.**, Scarborough, D., Rehl, A., and Zinn, B. T. "Nonlinear Acoustic Response of Stand-Off Tubes Used in Acoustic Pressure Measurements—Part II: Analysis," *170th Meeting of the Acoustical Society of America*. Vol. 2PEA5, Jacksonville, Florida, 2015.
- Damião, A., **Quinlan, J. M.**, Kim, Y. J., and Zinn, B. T. "Determination of Combustion Stability Margin Using the Filter Diagonalization Method," *51st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2015-4019, Orlando, Florida, 2015.
- **Quinlan, J. M.**, and Zinn, B. T. "Transverse Combustion Instabilities: Modern Experimental Techniques and Analysis," *50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2014-3682, Cleveland, Ohio, 2014.
- **Quinlan, J. M.**, and Zinn, B. T. "Simulating Full-Scale Transverse Combustion Instabilities in a Lab-scale Facility," *49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2013-4019, San Jose, California, 2013.
- Bibik, A. V., Lubarsky, E., **Quinlan, J. M.**, Shcherbik, D., and Zinn, B. T. "Control of Tangential Combustion Instability by Asymmetric Baffle," *Critical Phenomena under Extreme Impact (CPUEI-2012)*, Kharkov, Ukraine, 2012.
- **Quinlan, J. M.**, Bibik, O., and Zinn, B. T. "Experimental and Numerical Combustion Instability Modes in Asymmetric Baffled Chambers," *46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2010-6802, Nashville, Tennessee, 2010.
- **Quinlan, J. M.**, Kirkpatrick, A., Milano, D., Mitchell, C. E., and Hinerman, T. D. "Analytical and Numerical Development of a Baffled Liquid Rocket Combustion Stability Code," *45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2009-4865, Denver, Colorado, 2009.
- Milano, D., **Quinlan, J. M.**, Kirkpatrick, A., Mitchell, C. E., and Hinerman, T. D. "Computation of Acoustic Oscillations and Combustion Stability in a Rocket Engine with Combined Hub/Blade Baffles," *45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*. Vol. AIAA-2009-4866 Denver, Colorado, 2009.
- Wolverton, M. A., Giordano, D., **Quinlan, J. M.**, and Zukouski, R. "Evaluation of a 3-Way Direct Needle Control Unit Injector on Hydraulic Test Bench and V8 Engine," *2004 SAE World Congress*. Vol. SAE-2004-01-0024, Detroit, Michigan, 2004.

Talks

- **Quinlan, J. M.** "Swirling Flames and Floquet Multipliers: Parametric Combustion Instabilities," *Invited talk—Department of Mechanical Engineering, Colorado State University*, Fort Collins, Colorado, January 2022.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, October 2021.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado—Colorado Springs*, Colorado Spring, Colorado, October 2020.
- **Quinlan, J. M.** "Global Variational Methods: Numerical Approximations for Ordinary Differential Equations," *Invited talk—Computational Science & Engineering Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, July 2019.
- **Quinlan, J. M.** "Swirling Flames and Floquet Multipliers: Parametric Combustion Instabilities," *Invited talk—Department of Mechanical and Aerospace Engineering, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, March 2019.
- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Air Force Office of Scientific Research (AFOSR) 2015 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2015.

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- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T., Law, C. K. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Triservice Basic Science Energetic Materials Program Review*, Arlington, Virginia, 2014.
- **Quinlan, J. M.**, Kim, Y. J., Damião, A., Yang, V., Zinn, B. T., Law, C. K. "Theoretical, Numerical, and Experimental Investigations of the Fundamental Processes that Drive Combustion Instabilities in Liquid Rocket Engines," *Air Force Office of Scientific Research (AFOSR) 2013 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2013.
- **Quinlan, J. M.**, Kim, Y. J., Baroncelli, M., Dumitrache, C., Zinn, B. T. "Development Of Actively Controlled LRE Simulator (ACLRES) Rig," *Air Force Office of Scientific Research (AFOSR) 2012 Space Propulsion and Power Contractors Meeting*, Arlington, Virginia, 2012.

HONORS

Award: Abe Zarem Graduate Award For Distinguished Achievement—Astronautics 2022
AIAA
Advisee, Joseph Day won this national award for paper presented at a AIAA Student Conference. Joseph was awarded a funded trip to the 2023 AIAA SciTech Forum and Exposition to accept the award and a trip to present his work at the 2022 International Astronautical Congress in Paris. www.aiaa.org/get-involved/honors-awards/awards/award/award-abe-zarem-graduate-award-for-distinguished-achievement-astronautics

Fellowship: Air Force Research Lab Summer Faculty Fellowship 2022
AFOSR
Appointed as a fellow at the USAFA to perform research simulating detonations for application to rotating detonation engines; grant received with student Santiago Erazo for summer research

Fellowship: UCCS Undergraduate Research Academy 2022
University of Colorado–Colorado Springs
Research grant received with undergraduate student Duncan Schlueter for summer research

Fellowship: UCCS Undergraduate Research Academy 2021
University of Colorado–Colorado Springs
Research grant received with undergraduate student Sarah Chancellor for summer research

Fellowship: Air Force Research Lab Summer Faculty Fellowship 2020
AFOSR
Appointed as a fellow at the USAFA to perform research on combustion diagnostics for monopropellant, pintle injectors for various liquids; grant received with student Joseph Day for summer research

Fellowship: UCCS Undergraduate Research Academy 2019
University of Colorado–Colorado Springs
Research grant received with undergraduate student Joseph Day for summer research

Fellowship: UCCS EAS Undergraduate Research Scholars Program 2019
University of Colorado–Colorado Springs
Research grant received with undergraduate student Joseph Day

Scholarship: Combustion Energy Frontier Research Center—Summer School 2012
Princeton University, Princeton, NJ
Combustion Theory and Internal Combustion Engines

Scholarship: Combustion Energy Frontier Research Center—Summer School 2011
Princeton University, Princeton, NJ
Combustion Theory and Combustion Chemistry

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TEACHING

Principles of Combustion (full responsibility for course—Grad) Fall 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Compressible Flow (full responsibility for course—Grad) Spring 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Spring 2022
University of Colorado—Colorado Springs, Colorado Springs, CO

Rocket Propulsion (full responsibility for course—Grad) Fall 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Incompressible Flow (full responsibility for course—Grad) Spring 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2021
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course—two sections) Fall 2020
University of Colorado—Colorado Springs, Colorado Springs, CO

Principles of Combustion (full responsibility for course—Grad) Spring 2020
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course—two sections) Fall 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Summer 2019
University of Colorado—Colorado Springs, Colorado Springs, CO

Machine Design I (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Materials Engineering (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Measurement Lab (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Machine Design I (full responsibility for course—two sections) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Mechanics I (full responsibility for course) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Measurement Lab (full responsibility for course) Fall 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Summer 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Liquid Rocket Engines: Fundamentals and Green Propellants Summer 2018
AIAA Joint Propulsion Conference Short Course, Cincinnati, OH

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Control of Aero. and Mech. Systems (full responsibility for course) Spring 2018
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2017
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Mechanics II (full responsibility for course) Fall 2016
University of Colorado—Colorado Springs, Colorado Springs, CO

Introduction to Thermal Sciences (full responsibility for course) Summer 2008
Colorado State University, Fort Collins, CO

Teaching Assistant – **Mechanics and Thermodynamics of Flow Processes** Fall 2008
Colorado State University, Fort Collins, CO

Mentoring – Undergraduate and Graduate Students 2010 to 2015
Georgia Institute of Technology, Atlanta, GA

- Mentored one PhD student—primary supervisor of his research
- Mentored two Masters students, both went on to pursue doctoral degrees
- Supervised undergraduate research with multiple students for multiple semesters

DISSERTATION AND THESIS COMMITTEES

Committee member 2022
Sean Coughenour—Masters of Science in Mechanical Engineering
"Design and Validation of a Microbubble Levitation Chamber Using an Acoustic Vortex Beam"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2022
Andrew Gibson—Masters of Science in Mechanical Engineering
"Application of Koopman Linear Quadratic Regulator to the Control of a Spherical Microbubble"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2021
Danny Paredes—Masters of Science in Mechanical Engineering
"Inviscid Flow Past Canonical Bodies"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2020
Lluís Umbert Amat—Masters of Science in Mechanical Engineering
"Tethered Aerobraking Design for Repeatable Maneuvers"
University of Colorado—Colorado Springs, Colorado Springs, CO

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SERVICE

Committees

- Technical Discipline Co-Chair—AIAA SciTech Liquid Propulsion Technical Committee 2023
- Member—UCCS CRCW Seed Grant Review Committee 2022
- Technical Discipline Chair—AIAA SciTech Liquid Propulsion Technical Committee 2022
- Member—AIAA Liquid Propulsion Technical Committee 2015–2022
  - Education Subcommittee
  - Helped develop and teach content for rocket propulsion short course
  - Chaired technical sessions
- Member—UCCS Aerospace BS/MS Degree Committee 2021–2022
- Member—UCCS INCLINE (supercomputer) Management Committee 2020–2022
- Member—UCCS MAE Graduate Committee 2019–2022
- Member—UCCS MAE Instructor Hiring Committee 2019–2020
- Volunteer reviewer—interviewed candidates for the 2020 Georgia Tech President's Scholars Program (four-year, full-ride scholarship for the top incoming student) and our recommended student was selected for the award 2020
- Member—UCCS MAE Curriculum Committee 2018–2019
- Member—ASA Engineering Acoustics Technical Committee 2016–2018
- Member—Aerospace Engineering Combustion Laboratory/Carbon-Neutral Energy Solutions Laboratory Safety Committee 2012–2015
  Helped develop and implement formal Safety Review Process plan to ensure safe operation of laboratory facilities and experiments
- Member—Combustion Laboratory Long Term Planning Committee 2014
  Helping formulate a 10-year plan for the direction of the laboratory
- Advisor—Aerospace Engineering Manufacturing and Prototyping Faculty Task Force 2014
  Recommended equipment and personnel that should be available to students to properly learn about manufacturing processes and communication
- Member—Aerospace Engineering Combustion Laboratory Calibration Committee 2013
  Committee proposed equipment and processes to properly calibrate the most commonly used measurements in the laboratory
- Member—Particle Image Velocimetry Error Analysis Group 2011–2012
  Group organized to study and attempt to quantify the level and sources of experimental error

Peer Review

- Reviewer—Combustion and Flame 2022
- Reviewer—AIAA SciTech Forum 2022
- Reviewer—AIAA Propulsion & Energy Conference 2016–2021
- Reviewer—Journal of Propulsion and Power 2015, 2021
- Reviewer—AIAA Journal 2019
- Reviewer—Journal of the Acoustical Society of America 2018
- Reviewer—ASME Turbo Expo: Turbine Technical Conference 2015, 2017, 2018, 2019
- Reviewer—ACS PRF grants 2020

Organizations

- Order of the Engineer
- American Institute of Aeronautics and Astronautics

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SKILLS

Certifications: Passed Fundamentals of Engineering Examination – 2000
Qualified to take Professional Engineering licensing exam

Programing Languages & Software: Fortran, Python, Julia, Git, CMake, LaTeX, Maple, Matlab, Tecplot, Chemkin, Cosmos (structural FEA), Abaqus (structural FEA), Mathcad, Ricardo Wave (engine simulation), Fluent (CFD), SolidWorks, Ubuntu, and Microsoft Office

Fabrication: CNC machining, EDM machining, milling, turning, forging, grinding, diamond tooling, engine building, MIG, TIG, and arc welding, injection molding, vacuum/pressure casting, metal matrix composites, material selections, heat treating, and carbon fiber composites

EXTRACURRICULAR ACTIVITIES

Outdoor Enthusiast

- Climbed Mount Rainer, July 2005
- Completed Imogene Pass Run three times (17.1 miles and over 5,000 feet elevation gain)

Avid Photographer

- 24 years experience developing film and photographs in personal darkroom
- Gallery Visitors' Choice Award during 2007 "Alternative Processes" show at nationally known Center for Fine Art Photography

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(19) FEDERAL REPUBLIC GERMANY

GERMAN PATENT OFFICE

(12) **Patent Application**

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Siemens AG, 80333 Munich, DE

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(56) Citations:

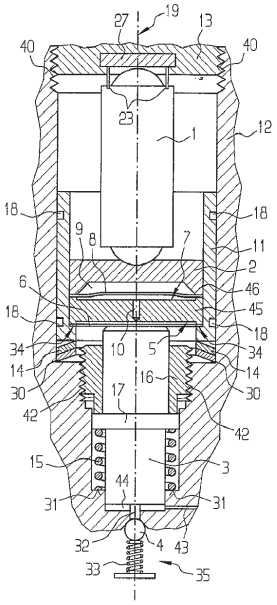
EP 04 77 400 A1
WO 94 19 598

The following information is taken from the documents submitted by the applicant

Examination request pursuant to § 44 PatG [*Patentgesetz* (German Patent Law)] has been submitted

(54) Device for transmitting a motion and an injector with a device for transmitting a motion

(57) A device for transmitting a movement for an injection valve is described, in which a transmission module 2 is arranged between a piezoelectric actuator and a drive piston, which transmission module has at least one pressure chamber 5 which is closed through a first membrane. The pressure chamber 5 is connected via a throttle 10 to a compensation chamber 7 which is also arranged in the transmission module 2.



DE 197 08 304 A 1

Quinlan Depo.
Exhibit
4

Quinlan 4/19/24 - KK
Exhibit
4

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Description

The invention relates to a device for transmitting a movement according to the preamble of claim 1 and injectors with a device for transmitting a movement according to the preamble of claims 6 and 7.

A power transmission device is used, for example, in automotive engineering to transmit the movement of a piezoelectric actuator in an injection valve to a control element, the control element opening a servo valve, for example, which in turn controls the opening and closing of an injection valve.

EP 0 477 400 A1 discloses an arrangement for adaptive tolerance compensation for the displacement transformer of a piezoelectric actuator, which acts in the lifting direction, in which the deflection of an actuator **1** is transmitted to a piston **3** via a hydraulic chamber **2**. For mechanical tolerance compensation, the hydraulic chamber **2** is connected to a compensation chamber **17** via a channel **16**.

The object of the invention is to provide a particularly compact and easy-to-assemble device for transmitting a movement of an actuator.

The object of the invention is achieved by the features of claim 1, by the features of claim 6 and by the features of claim 7.

An essential advantage of the invention is that the pressure chamber and the compensation chamber are incorporated in a compact housing, and that the housing is located between the actuator and the controlling element. This way it allows for a particularly simple manufacture of the device, in particular for an injection valve. The housing with the power transmission device is pre-assembled and is inserted into the housing of the injection valve during manufacture.

Advantageous developments and improvements of the invention are specified in the dependent claims. Furthermore, it is advantageous to provide a pressure medium in the compensation chamber, which applies a specifiable pressure to the transmission medium in the compensation chamber.

The invention is explained in more detail with reference to the figures; showing:

Fig. 1 shows a device for power transmission without stroke translation,

Fig. 2 shows a device for power transmission with a spring as a pressure medium and

Fig. 3 shows a device for power transmission with stroke translation.

Fig. 1 shows schematically part of an injection valve with a piezoelectric actuator **1** and a servo valve **4**. The piezoelectric actuator **1** is placed in a housing **12** and arranged between an upper stop **13** and a transmission module **2** in the longitudinal direction of the injection valve. The piezoelectric actuator **1** is connected via control lines **23** to a control means **27** with which the length of the piezoelectric actuator **1** can be adjusted. The piezoelectric actuator **1** preferably consists of a stack of piezoelectric elements, with which a greater deflection is achieved.

The upper stop **13** is connected to the housing **12** via a screw thread **40** and can be positioned in the longitudinal direction of the housing **12** depending on the desired pre-stressing of the piezoelectric actuator **1**. The transmission module **2** is essentially cylindrical and has a pressure chamber **5** which is delimited by a first membrane **6**. In the transmission module **2** there is a connecting bore **10** which has a throttling effect. The connecting bore **10** connects the first pressure chamber **5** to a compensation chamber **7**, which is also introduced into the transmission module **2**. The compensating chamber **7** is closed off by a pre-stressed spring plate **8**. The pressure chamber **5** is at least partially filled with a transmission medium, for example a hydraulic fluid, which has low compressibility. The pressure chamber **5** and the compensation chamber **7** are preferably completely filled with the transmission medium. Instead of the spring plate **8**, other means can also be provided which specify the pressure of the transmission medium in the compensation chamber **7**, such as an elastic membrane. The means are preferably designed in such a way that when transmission medium flows into the compensation chamber **7**, the pressure in the compensation chamber **7** is increased.

The transmission module **2** is surrounded by a guide sleeve **11** which is introduced into the injection valve housing **12** and which is pre-stressed against the housing **12** in the longitudinal direction of the injection valve with a disk spring **14**. The transmission module **2** rests in a circular edge area on an annular bearing surface **34** of the guide sleeve **11**. The disk spring **14** is supported against a ring-shaped peripheral first stop **30** which is introduced into the housing **12**. The transmission module **2** and the guide sleeve **11** are arranged to be movable against the disk spring **14** in the longitudinal direction of the injection valve.

The transmission module **2** is preferably divided into two separate components. The first component is a base plate **45** into which the connecting bore **10** is introduced and to which the first membrane **6** and the spring plate **8** are connected. A cover plate **46** is provided as the second component, which is arranged over the spring plate **8** and bears against the piezoelectric actuator **1**. A recess designed to correspond to the end section of the piezoelectric actuator **1** is preferably made in the cover plate, in which the end section of the piezoelectric actuator **1** is inserted. The cover plate **46** preferably rests on a circumferential annular surface on the base plate **45** and has a recess **9** which provides space for the spring plate **8** to bulge.

The first membrane **6** is associated with a drive piston **3** which is biased by a spring **15** against a lower stop **16**. The lower stop **16** is connected to the housing **12** via a screw connection **42** and is thus arranged so that it can be adjusted in the longitudinal direction. The lower stop **16** has the shape of a hollow cylinder, in the cylindrical recess of which the drive piston **3** is guided adequately. Below the lower stop **16**, the drive piston **3** has an check ring **17** which has a larger diameter than the hollow cylinder of the lower stop **16**. In addition, the spring **15**, which is designed as a cylindrical spring and encloses the drive piston **3** in the lower section, is clamped between a stop surface **31** and the check ring **17**. This presses the check ring **17** against the lower stop **16**. This way, the lower stop **16** specifies the rest position of the drive piston **3**.

At its lower end, the drive piston **3** merges into a control needle **32**, which extends through a relief chamber **44** to a valve seat **35** of a servo valve. The relief chamber **44** is connected to a relief line **43** introduced in the housing **12**.

A ball **4** is provided as the closing element and is pressed against the valve seat by a valve spring **33**. The servo valve is used to control an injection needle, which controls the injection of an internal combustion engine.

During the production of the injection valve, the piezoelectric actuator **1**, the transmission module **2** and the drive piston **3** are pre-adjusted via the upper stop **13** and the lower stop **16**. The piezoelectric actuator **1**, the transmission module **2** and the drive piston **3** are adjusted in such a way that the servo valve **4** is closed when the piezoelectric actuator **1** is not activated and the piezoelectric actuator **1** is in contact with the transmission module **2** with a predetermined pretension and the drive piston **3** is in contact with the first membrane **6**.

The functioning of **Fig.** 1 is explained in more detail below: In the rest state, the piezoelectric actuator **1** is not controlled and the closing element **4** is seated on the valve seat **35.** Furthermore, the piezoelectric actuator **1** and the drive piston **3** rest on opposite sides of the transmission module **2**, with the drive piston **3** placed on the first membrane **6**. In the rest position, the piezoelectric actuator **1** is pre-stressed against the upper stop **13** by the disk spring **14** via the guide sleeve **11** and the transmission module **2**. The drive piston **3** is pressed by the spring **15** against the lower stop **16**, which is adjusted in such a way that the drive piston **3** bears against the first membrane **6**.

If the piezoelectric actuator **1** is now controlled, the piezoelectric actuator **1** presses the entire transmission module **2** against the spring force of the disk spring **14** in the direction of the drive piston **3**, so that pressure is exerted on the drive piston **3** via the first membrane **6** and the transmission medium located in the pressure chamber **5** is exercised.

This moves the drive piston **3** against the spring force of the tension spring **15** in the direction of the closing element **4** so that the closing element **4** is lifted off the valve seat **35** by the control needle **32**. As a result, a pressure chamber which applies high pressure to the injection needle of the injection valve is connected to the relief chamber **44** and the relief line **42**, so that the pressure in the pressure chamber drops and the injection needle lifts off the assigned valve seat and injection begins.

If the activation of the piezoelectric actuator **1** ends, the piezoelectric actuator **1** is shortened and the transmission module **2** and the guide sleeve **11** are pushed by the disk spring **14** in the direction of the piezoelectric actuator **1**. The drive piston **3** is pushed away from the closing element **4** by the spring **15**, so that the closing element **4** is pushed by the valve spring **33** back onto the assigned valve seat **35**. This disconnects the connection between the pressure chamber and the relief line **43** and high pressure is again applied to the valve needle, so that the valve needle is pushed onto the assigned valve seat and this ends the injection.

The adjustment of the piezoelectric actuator **1**, the transmission module **2** and the drive piston **3** is carried out with a new injection valve and at a specified temperature. If, due to wear or a change in temperature, the adjustment no longer fits, the transmission module **2** achieves an automatic adjustment.

For this purpose, both the pressure chamber **5** and the compensation chamber **7** are preferably completely filled with the transmission medium and the drive piston **3** is pre-stressed against the first membrane **6** when the piezoelectric actuator **1** is in the rest position, so that the transmission medium in the pressure chamber **5** and in the compensation chamber **7** is at a specified pressure.

If the piezoelectric actuator **1** shortens in the rest position without being actuated due to thermal influences or signs of aging in relation to the housing **12**, the spring plate **8** pushes the transmission medium from the compensation chamber **7** via the throttle **10** into the pressure chamber **5**, so that the first membrane **6** is moved in the direction of the drive piston **3** and, as a result, the drive piston **3** bears against the first membrane **6** despite the shortening of the piezoelectric actuator **1**.

However, if the distance between the piezoelectric actuator **1** and the drive piston **3** is reduced, the first membrane **6** is pushed in by the drive piston **3** so that the transmission medium is pressed through the throttle **10** into the compensation chamber **7** against the spring force of the spring plate **8**. As a result, the drive piston **3** is always in contact with the first membrane **6** in this case as well.

The throttle **10** should preferably be dimensioned in relation to the transmission medium such that during normal activation of the drive piston **3** only so little of the transmission medium flows into the compensation chamber **7** that the activation of the drive piston is not impaired. For example, the drive piston **3** controls a servo valve of an injection valve or a nozzle needle of an injection valve. In these examples, the throttle **10** must be dimensioned in such a way that only an insignificant amount of transmission medium flows into the compensating chamber **7** during the actuation times for the servo valve or during the actuation times for the nozzle needle. The actuation times are in the range of milliseconds, preferably between 0 ms and 10 ms. Fast actuation times are around 0.1 to 1 ms.

However, if there are long-lasting pressure differences between the pressure chamber **5** and the compensation chamber **7** lasting from one second to minutes, the transmission medium is exchanged between the compensation chamber **7** and the pressure chamber **5** via the throttle **10**. This is especially the case in terms of thermal expansion differences and gradual wear.

Fig. 2 shows additional embodiment of the invention which corresponds essentially to the injection valve of **Fig**. 1, but in which a second membrane **20** is provided instead of the spring plate **8** to delimit the compensation chamber **7**. The second diaphragm **20** has a plunger **21** which is tensioned against the transmission module **2**, in particular, against the cover plate **46**, via a compression spring **22**. In this way, the deflection of the second membrane **20** from its rest position is counteracted by the spring force of the compression spring **22**. The pressure of the transmission medium prevailing in the pressure chamber **5** and in the compensation chamber **7** is thus adjusted by the spring force of the compression spring **22**. This also achieves an adjustment compensation through the compression spring **22** and the throttle **10** in that the pressure chamber **5** is filled with a transmission medium, which has a corresponding pressure, ensuring that the first membrane **6** is always in contact with the drive piston **3**. In this way, according to **Fig.** 1, it achieves an automatic adjustment.

Fig. 3 also shows part of an injection valve with a piezoelectric actuator **1**, which acts on a transmission module **2** and a drive piston **3** via a die **29**. The injection valve shown in **Fig.** 3 differs from the injection valves of **Fig.** 2 and 1 in the type of power transmission from the piezoelectric actuator **1** to the drive piston **3**. For this purpose, a die **29** is provided in the housing **12** adjacent to the piezoelectric actuator **1** and is mounted so that it is movable in the longitudinal direction of the housing **12** against a disk spring **14**. The disk spring **14** pre-stresses the piezoelectric actuator **1** via the die **29** against the upper stop **13**, which is connected to the housing **12** via a screw connection allowing it can be adjusted in the longitudinal direction. The disk spring **14** is supported against the transmission module **2**, which rests on a lower stop **16**, which is adjustable in the longitudinal direction of the housing **12**.

The lower stop **16** is connected to the housing **12** via a screw connection **42**. The lower stop **16** has a cylindrical recess in the middle, in which the drive piston **3** is movably mounted in the longitudinal direction. The drive piston **3** is pre-stressed against the lower stop **16** by a coil spring **15**, which rests against a check ring **17** of the drive piston **3** one side and against the housing **12**, while on the other side the coil spring **15** encloses the drive piston **3**.

In comparison to the transmission modules of Fig. **1** and **2**, the transmission module **2** now has a second pressure chamber **28** which is assigned to the die **29** and which is closed by a third membrane **26**, the third membrane **26** being assigned to the die **29**. The second pressure chamber **28** is connected to the first pressure chamber **5** via two lines **25**. One or more lines **25** can also be provided. In a simple embodiment, one line **25** suffices. The pressure chamber **5** is closed off by a first membrane **6**, which is assigned to the drive piston **3**. The lines **25** are each provided in the edge region of the transmission module **2** and are designed in such a way that the transmission medium located in the pressure chamber **5** and the second pressure chamber **28** can be exchanged between the second pressure chamber **28** and the pressure chamber **5** with almost no pressure loss.

Preferably, both the second pressure chamber **28,** the lines **25**, the first pressure chamber **5** and the compensation chamber **7** are completely filled with the transmission medium. In a simpler, less advantageous embodiment, the second pressure chamber **28**, the pressure chamber **5** and the compensation chamber **7** are only partially filled with the transmission medium.

The pressure chamber **5** is connected to the compensating chamber **7** via a connecting bore **10** which is designed as a throttle. The compensating chamber **7** is closed off by a membrane with a spring action, in this case a spring plate **8**. Instead of the spring plate **8**, another means can also be used, as shown in **Fig**. **2**, with which the pressure in the compensation chamber and the volume of the compensation chamber can be adjusted to specified values.

The arrangement according to Fig. **3** works as follows: In the rest position, the piezoelectric actuator **1** is pre-stressed against the upper stop **13** by the disk spring **14** via the die **29**. The disk spring **14** is supported against the housing **12** via the transmission module **2′** and the lower stop **16**.

The transmission module **2** rests with the third membrane **26** on the circular pressure surface of the die **29**. In addition, the transmission module **2** rests on the ring-shaped support surface **36** of the lower stop **16**. The drive piston **3** is pushed with its circular piston surface **37** against the first membrane **6** and the closing element **4** is pressed by the valve spring **33** onto the assigned valve seat **35**.

If the piezoelectric actuator **1** is now controlled by the control means **27** via the control lines **23**, the piezoelectric actuator **1** lengthens, so that as a result the die **29** is deflected against the spring force of the disk spring **14** in the direction of the transmission module **2**. However, the transmission module **2** is fixed in position by the lower stop **16** preventing it from following the longitudinal movement of the die **29**. As a result, the third membrane **26** is pushed downwards by the die **29** with the circular plunger surface **38** causing the transmission medium located in the second pressure chamber **28** to be pushed into the pressure chamber **5** via the lines **25**. This deflects first membrane **6** in the direction of the drive piston **3** and the drive piston **3** is thus moved against the spring force of the spring **15** in the direction of the closing element **4**. As a result of this, the closing element **4** is lifted off the valve seat **35** by the actuating needle **32** against the force of the valve spring **33**.

Although there is a connection between the pressure chamber **5** and the compensation chamber **7** via the connecting bore **10**, this is designed as a throttle causing brief pressure increases in the pressure chamber **5** to only a very small outflow of transmission medium into the compensation chamber **7**. At least the throttle **10** and the transmission medium are matched to one another in such a way that only a small amount of transmission medium flows into the compensation chamber **7** for the times in which the piezoelectric actuator **1** is actuated to actuate the closing element **4**, so that the actuation of the closing element is not affected.

After switching off the control of the piezoelectric actuator **1**, the piezoelectric actuator **1** is shortened, so that the die **29** is moved by the disk spring **14** in the direction of the piezoelectric actuator **1**. As a result of the force of spring **15** acting on membrane **6** via drive piston **3**, transmission medium flows from the first pressure chamber **5** through lines **25** into the second pressure chamber **28**, so that first and third membranes **6**, **26** return to their initial position.

As a result of the movement of the drive piston **3** in the direction of the transmission module **2**, the valve spring **33** pushes the closing element **4** back onto the assigned valve seat **35**. The transmission medium that flowed into the compensation chamber **7** during the activation of the piezoelectric actuator **1** is pushed back into the pressure chamber **5** by the spring plate **8** via the throttle **10**. In this way, the specified rest position is reached again.

If, due to different thermal expansion coefficients or signs of wear, the piezoelectric actuator **1**, the die **29**, the transmission module **2**, or the drive piston **3** change with respect to the preset adjustment, this maladjustment is automatically compensated for by the transmission module **2**. For example, if the piezoelectric actuator **1** and the die **29** are moved from the preset position in the direction of the drive piston **3**, the result is that the third membrane **26** is continuously arched, so that the transmission medium is pressed from the second pressure chamber **28** into the pressure chamber **5**. The first membrane **6** of the pressure chamber **5** is prevented from bending towards the drive piston **3** by the drive piston **3** through the spring force of the spring **15**. As a result of the high pressure in the pressure chamber **5**, the transmission medium flows into the compensation chamber **7** against the spring force of the spring plate **8**. This way, even with the present maladjustment, it achieves that the drive piston **3** remains in its specified position and the closing element **4** is not lifted off the valve seat **35**.

If the predetermined distance between the die **29** and the drive piston **3** is increased, there is a risk that either the die **29** and/or the drive piston **3** will no longer rest on the third membrane **26** or on the first membrane **6**. However, this is prevented by the fact that transmission medium flows out of the compensation chamber **7** through the connecting bore **10** into the pressure chamber **5** and via the lines **25** into the second pressure chamber **28**. This way, even with this misalignment, it is ensured that the die **29** and the drive piston **3** are in operative connection with one another directly via the transmission medium.

The spring force of the spring plate **8**, the spring force of the first membrane **6** and the third membrane **26**, as well as the cross section of the connecting bore **10**, i.e., also the transmission medium and the filling level of the pressure chamber **5**, the lines **25**, the second pressure chamber **28** and the compensation chamber **7** must be adjusted according to the circumstances so that an automatic adjustment is achieved.

The die surface **38** with which the die **29** bears against the third membrane **26** is advantageously larger than the piston surface **37** with which the drive piston **3** bears against the first membrane **6**. This way, it achieves a stroke ratio between the deflection of the piezoelectric actuator **1** and the deflection of the drive piston **3**. In addition, it is advantageous if the surface of the third membrane **26** is larger than the surface of the first membrane **6**, so that over the different sized surfaces of the first membrane **6** and the third membrane **26** a stroke transmission is already achieved between the deflection of the piezoelectric actuator **1** and the deflection of the drive piston **3**.

The transmission module **2** has sealing rings **18** in the edge area, which seal off the piezoelectric actuator **1** in regards to the drive piston **3** and the closing element **4** in a tight manner.

The arrangement of **Fig. 3** offers the advantage that when the deflection of the piezoelectric actuator **1** is transmitted to the drive piston **3**, the transmission module is not moved, but the deflection is transmitted directly via the first and the third membrane **6**, **26** and the transmission medium. This allows to only move small masses, making a rapid transfer of movement possible, in particular, for the control of an injection valve.

The parts of the injection valves shown in **Fig. 1** to **3** are rotationally symmetrical to the axis of symmetry **19**.

An advantageous adjustment of an injection valve according to Fig. **1** or **3** is achieved in that the upper stop **13** is adjusted in the direction of the drive piston **3** and consequently increasing the pressure of the piezoelectric actuator **1** via the transmission module **2** on the drive piston **3**. At the same time, the piezoelectric actuator **1** is controlled alternately by the control means **27**, so that the piezoelectric actuator **1** is alternately lengthened and shortened. At the same time, the opening characteristic of the servo valve **35**, **4** is measured and the screwing in of the upper stop **13** is stopped when the control characteristic is optimal. The adjustment primarily offers advantages with flexible membranes **6**, **8**, **26**, which have a progressive characteristic curve of the spring force in relation to the spring deflection. Systems with corresponding membranes are generally difficult to adjust. However, the method described allows for easy and precise adjustment. Preferably, both the screwing in and the control of the piezoelectric actuator **1** and the measurement of the opening characteristic of the servo valve **35**, **4** take place automatically via a correspondingly designed testing device.

In a continuation of the invention, instead of the opening characteristic of the servo valve **35**, **5**, the injection characteristic of the injection valve controlled by the servo valve is measured. This is preferably done by measuring the amount of fuel delivered by the injection valve during an injection process. Optimum adjustment of the injection valve is achieved in a simple manner in this way.

Claims

1. Device for transmitting a movement comprising a pressure chamber (**5**) which is at least partially filled with a transmission medium and which is at least partially delimited by a first flexible element (**6**), with a compensation chamber (**7**) connected via a connection (**10**) is connected to the pressure chamber (**5**), the connection (**10**) and the transmission medium being designed in such a way that there are hardly any short-term pressure differences between the pressure in the pressure chamber (**5**) and the pressure in the compensation chamber (**7**) and long-term pressure differences almost be completely compensated, **characterized in that**
the pressure chamber (**5**) and the compensation chamber (**7**) are incorporated into a transmission module (**2**), and that the compensation chamber (**7**) is operatively connected to means (**8**; **20**, **21**, **22**), which specify the pressure in the compensation chamber (**7**) and the volume of the compensation chamber (**7**).

2. Device according to claim **1**, characterized in that a second pressure chamber (**28**) is provided in the transmission module (**2**), which is filled at least partially, with the transmission medium, that the second pressure chamber (**28**) is connected to the first pressure chamber (**5**),
that the second pressure chamber (**28**) is delimited by a second, at least partially, flexible element (**26**).

3. Device according to claim **2**, characterized in that the area with which the first flexible element (**6**) delimits the first pressure chamber (**5**) is different from the area with which the second flexible element (**26**) delimits the second pressure chamber (**28**).

4. Device according to claim **1**, characterized in that a flexible membrane (**8**) is provided as a means which at least partially delimits the compensation chamber (**7**) and which adjusts the pressure in the compensation chamber (**7**) and the volume of the compensation chamber (**7**).

5. Device according to claim **1**, characterized in that an at least partially flexible membrane (**20**) is provided as the means, which delimits the compensation chamber (**7**), that spring means (**22**) are provided which are in operative connection with the membrane (**20**), and which counteract a deflection of the membrane (**20**).

6. Injection valve with an actuator (**1**) and a control element (**3**), which are operatively connected to one another by a transmission module (**2**), with the following features:
the transmission module (**2**) has a pressure chamber (**5**), which is filled with a transmission medium and is delimited by a first flexible membrane (**6**);
the transmission module (**2**) has a compensation chamber (**7**) which is connected to the pressure chamber (**5**) via a connection (**10**);
the connection (**10**) and the transmission medium are designed in such a way that short-term pressure differences between the pressure in the pressure chamber (**5**) and the pressure in the compensation chamber (**7**) are hardly compensated and long-lasting pressure differences are almost completely compensated;
the actuator (**1**) is assigned to an upper side of the transmission module (**2**);
the control element (**3**) is assigned to the first flexible element (**6**) on the lower side of the transmission module (**2**);
the transmission module (**2**) is movably arranged in the housing (**12**) of the injection valve, so that when the actuator (**1**) moves in the direction of the transmission module (**2**), the transmission module (**2**) in the housing (**12**) in the direction of the control element (**3**) is moved and the movement of the actuator (**1**) is at least partially transmitted to the control element (**3**) via a movement of the transmission module (**2**).

7. Injection valve with an actuator (**1**) and a control element (**3**), which are operatively connected to one another by a transmission module (**2**), with the following features:
the transmission module (**2**) has a pressure chamber (**5**), which is filled with a transmission medium and is delimited by a first flexible membrane (**6**);
the transmission module (**2**) has a compensation chamber (**7**) which is connected to the pressure chamber (**5**) via a connection (**10**);
the connection (**10**) and the transmission medium are designed in such a way that short-term pressure differences between the pressure in the pressure chamber (**5**) and the pressure in the compensation chamber (**7**) are hardly compensated and long-lasting pressure differences are almost completely compensated;
the transmission module (**2**) has a second pressure chamber (**28**) delimited by a second flexible element (**26**);
the first and the second pressure chamber (**5**,**28**) are connected to one another via a line (**25**);
the actuator (**1**) is associated with the second flexible element (**26**);
the control element (**3**) is assigned to the first flexible element (**6**);
the transmission module (**2**) is fixed in the direction of movement of the actuator (**1**), so that when the actuator (**1**) moves in the direction of the transmission module (**2**), the transmission module (**2**) is fixed in the housing (**12**) and the movement of the actuator (**1**) is transmitted to the control element (**3**) via the first flexible element (**6**), the transmission medium and the second flexible element (**26**).

8. Device according to claim **6**, characterized in that the transmission module (**2**) is connected to the housing (**12**) by means with spring action (**14**).

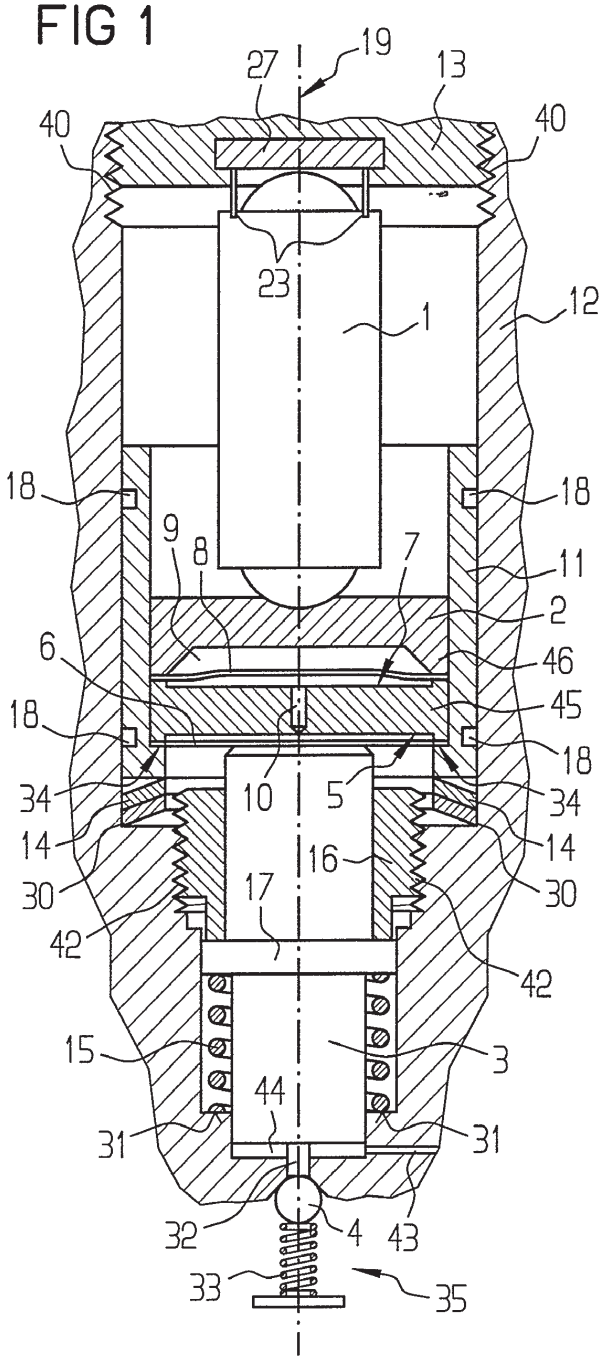
9. Method for adjusting an actuator (**1**) and a control element (**3**) and a transmission module (**2**) in an injection valve according to claim **6** or **7**, in which the control element (**3**) is operatively connected to a closing element (**4**) of a valve, characterized in that
- the actuator (**1**) is controlled intermittently,
- at the same time the position of the actuator (**1**) in the direction of the transmission module (**2**) is changed via adjustment means (**13**, **40**),
- depending on the controlling of the actuator (**1**), the opening characteristic of the valve is checked, and
- the adjustment is complete when the valve has a predetermined opening and closing characteristic.

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Number: **DE 197 08 304A1**
Int. Cl.[6]: **H 02 N 2/04**
Publication date: 10 September 1998

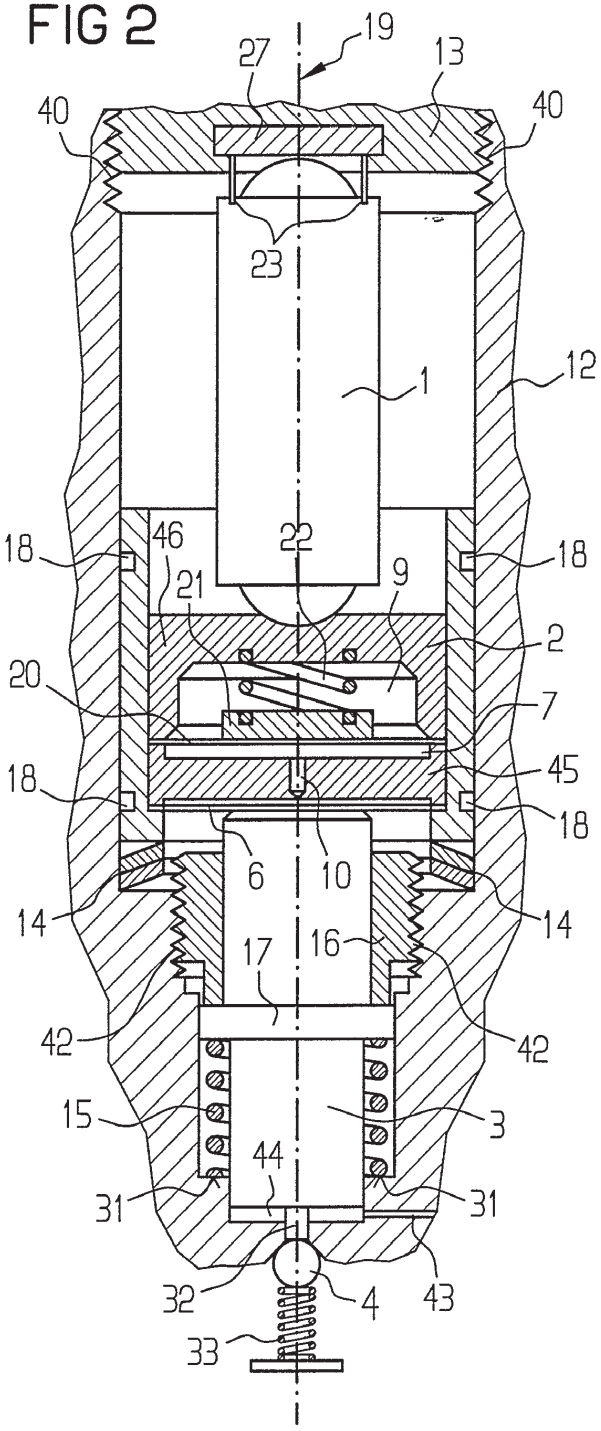
FIG 1



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Number: **DE 197 08 304A1**
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Publication date: 10 September 1998

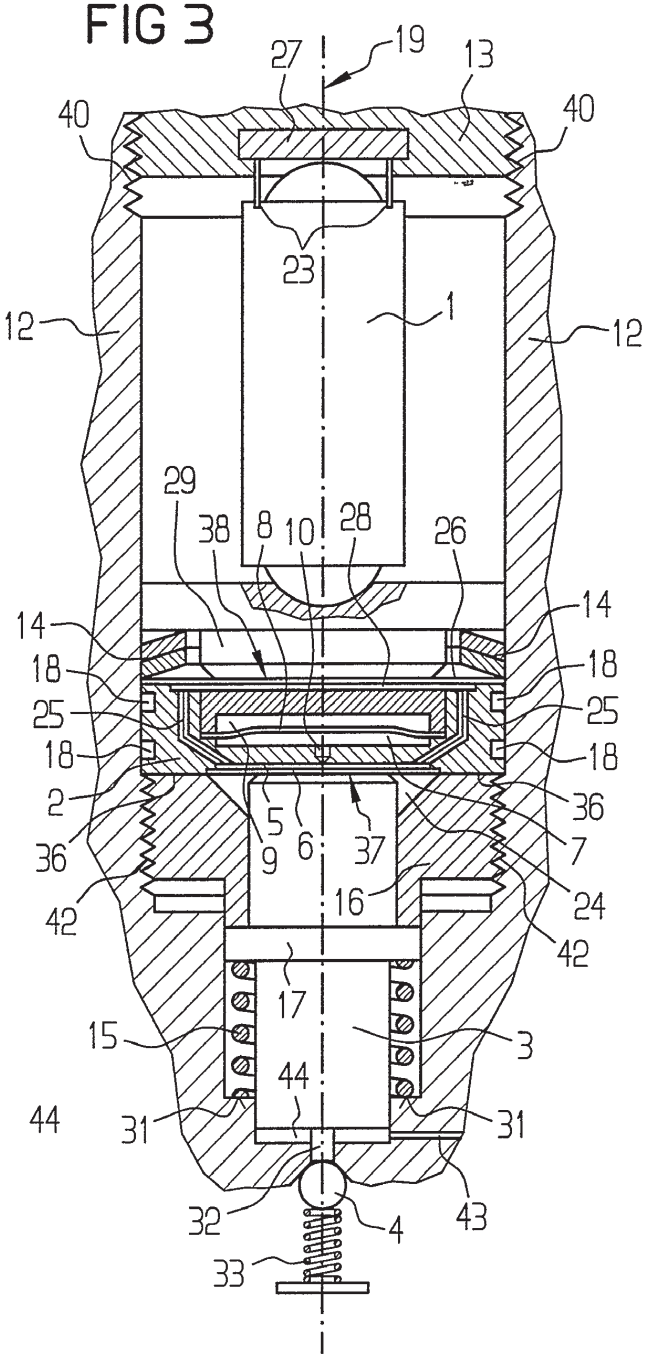
FIG 2



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Number: **DE 197 08 304A1**
Int. Cl.[6]: **H 02 N 2/04**
Publication date: 10 September 1998

FIG 3



802 037/91

TRANSPERFECT

Wednesday, October 5, 2022

Certification

Translator's Declaration:

I, Dominique Svamberk, hereby declare:

That I possess advanced knowledge of the German and English languages.

My qualifications are as follows:

- *Over 15 years of professional translation experience*
- *Areas of experise include technical, automotive, engineering, energy, IT subject matter*

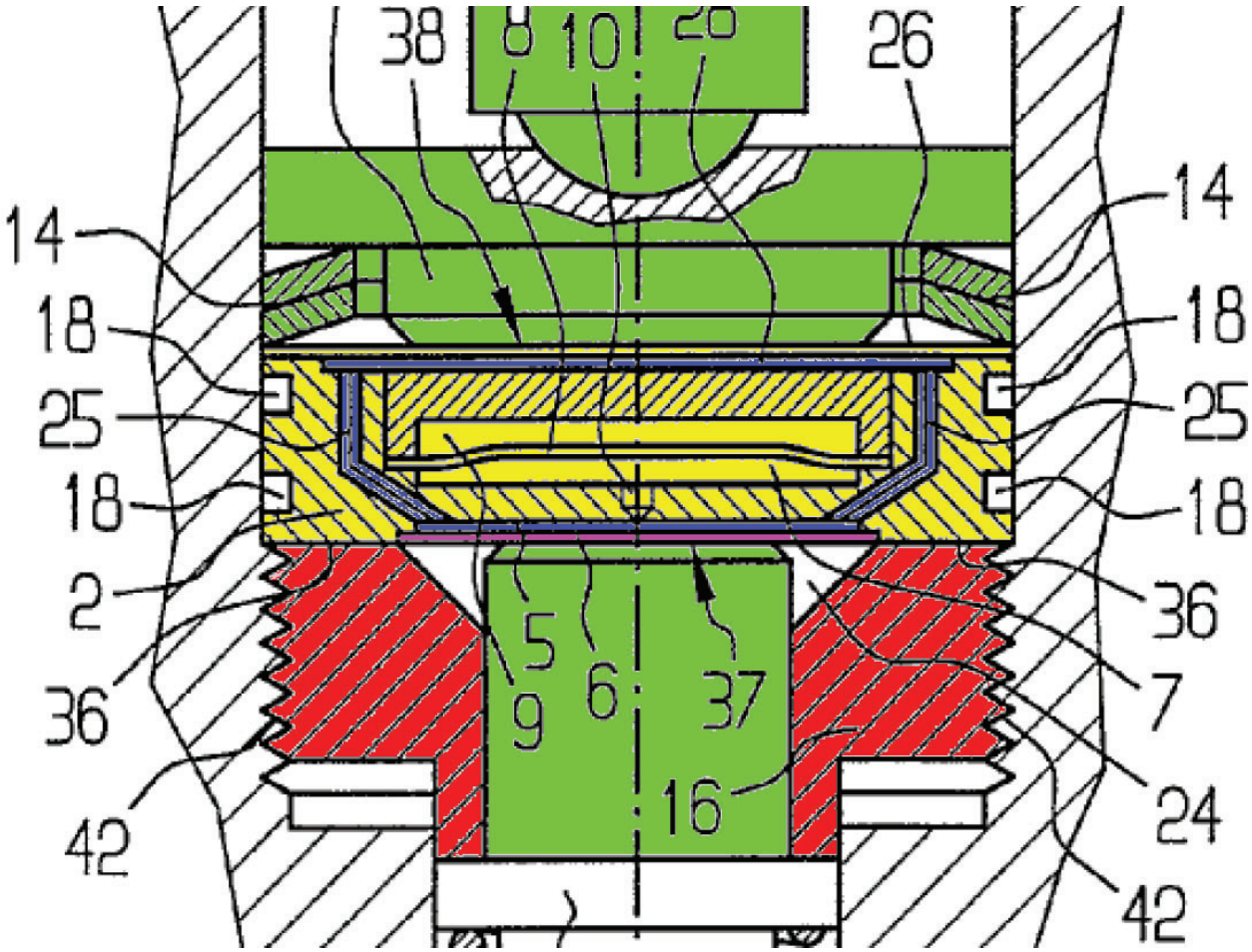
The attached German into English translation has been translated by me and to the best of my knowledge and belief, it is a true and accurate translation of:

DE 197 08 304 A1 (Klügl, Wendelin)

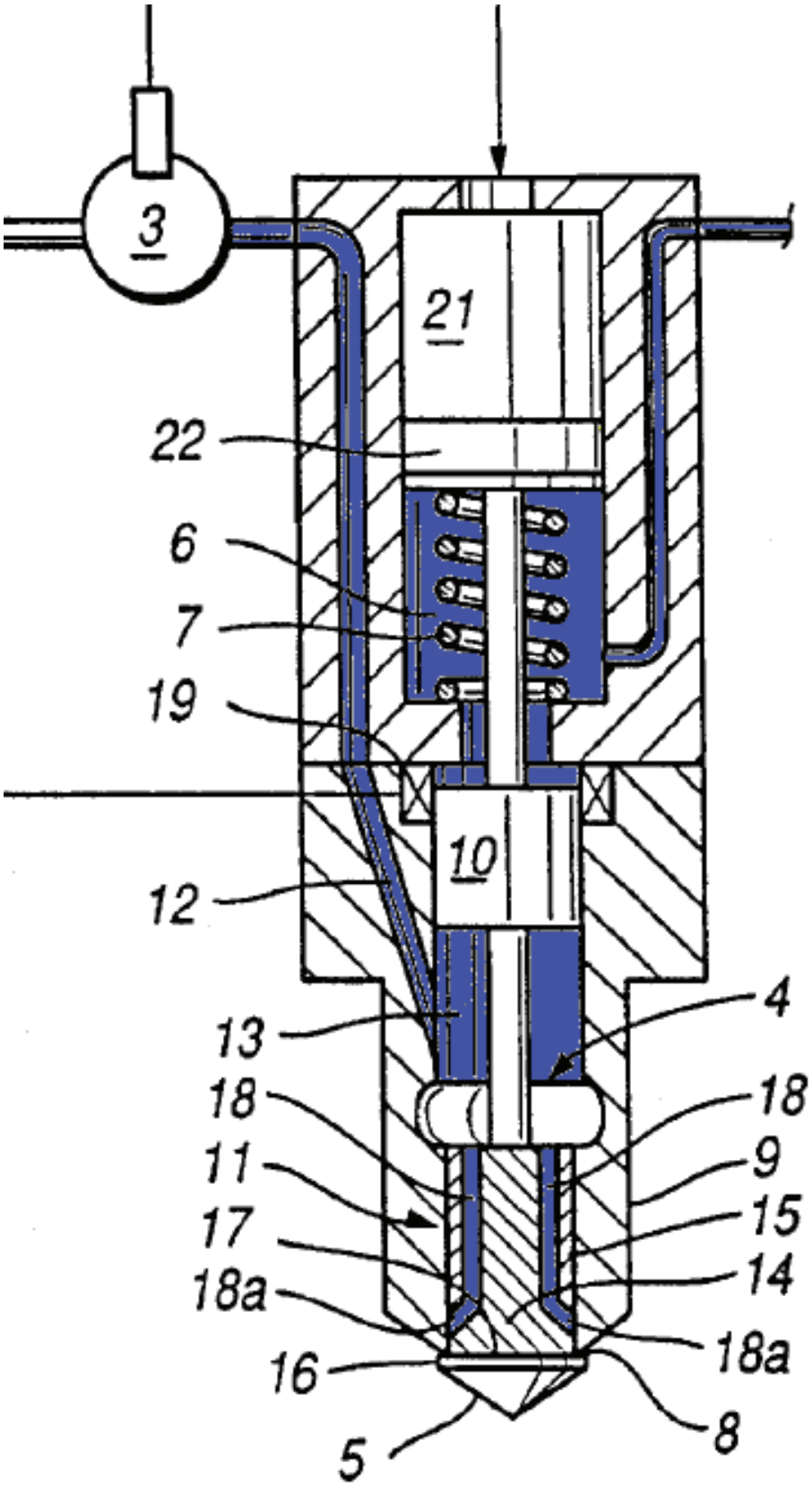
I understand that willful false statement and link are punishable by fine or imprisonment, or both (18 U.S.C. 1001) any may jeopardize the validity of the application or any patent issuing thereon. I declare under the penalty of the perjury that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true.

D. Svamberk

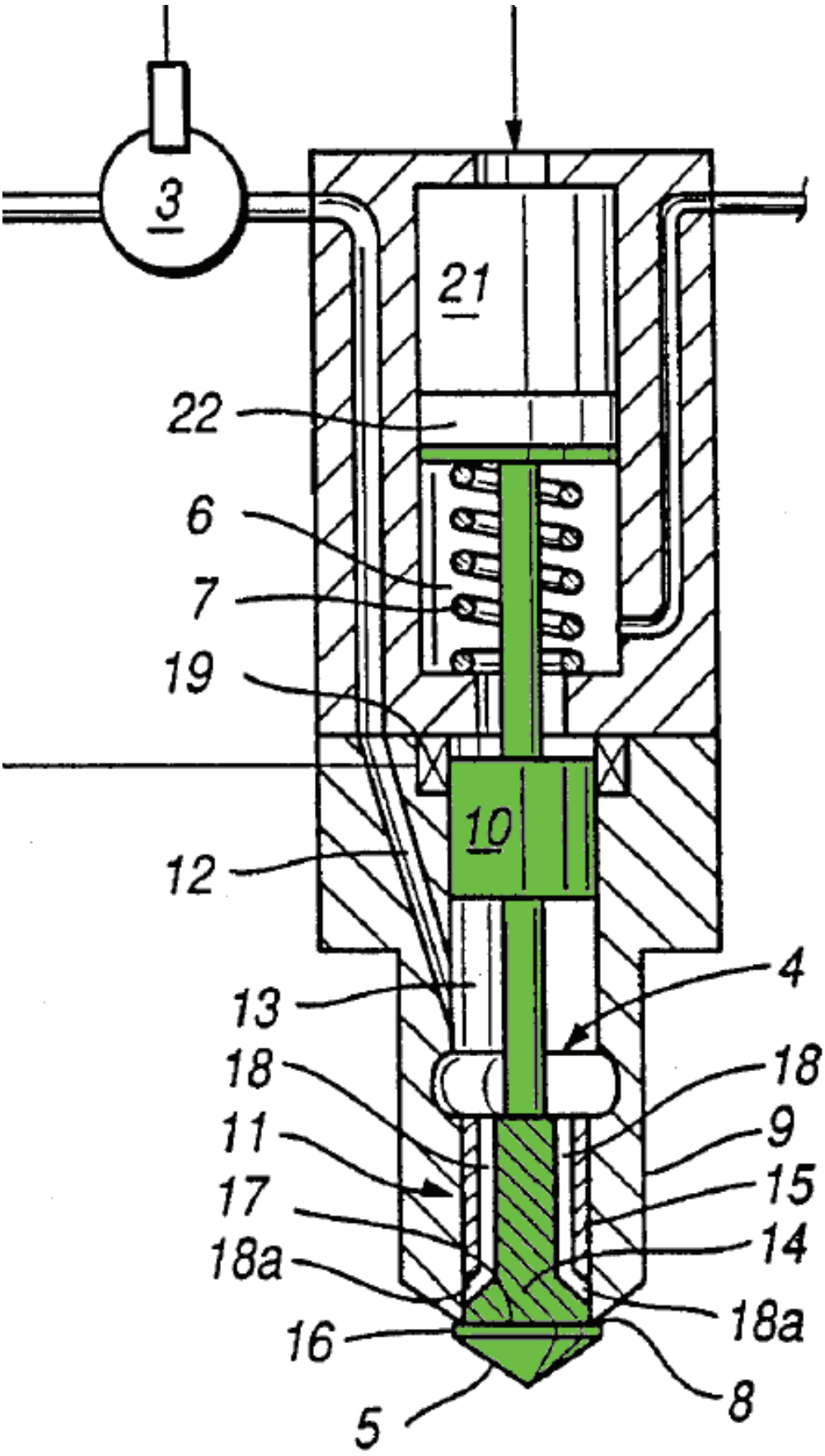
Dominique Svamberk



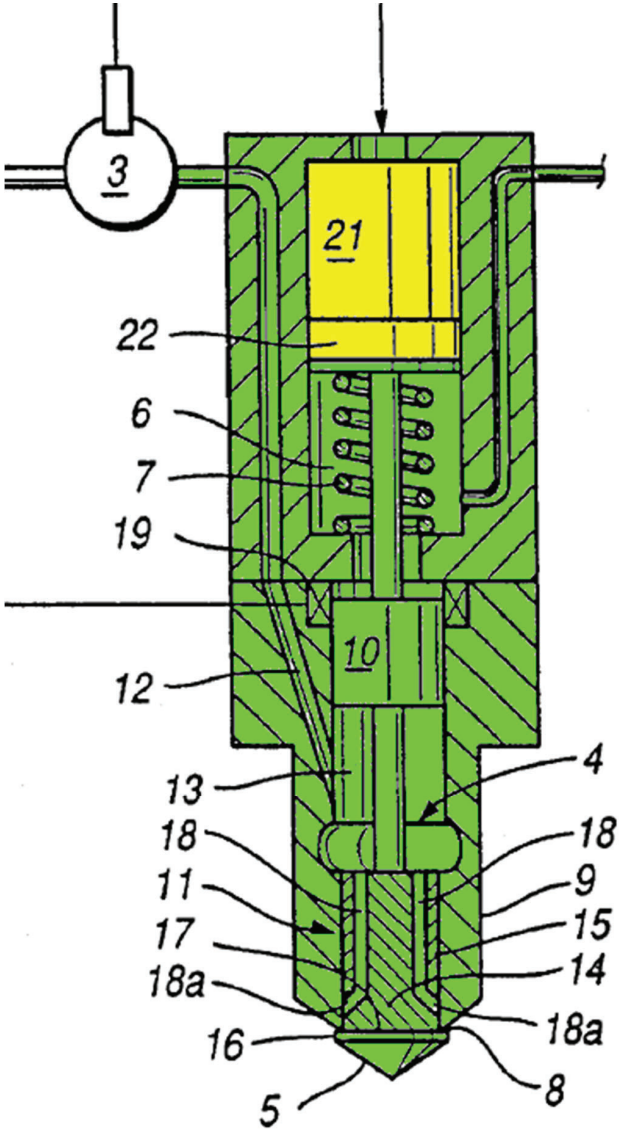
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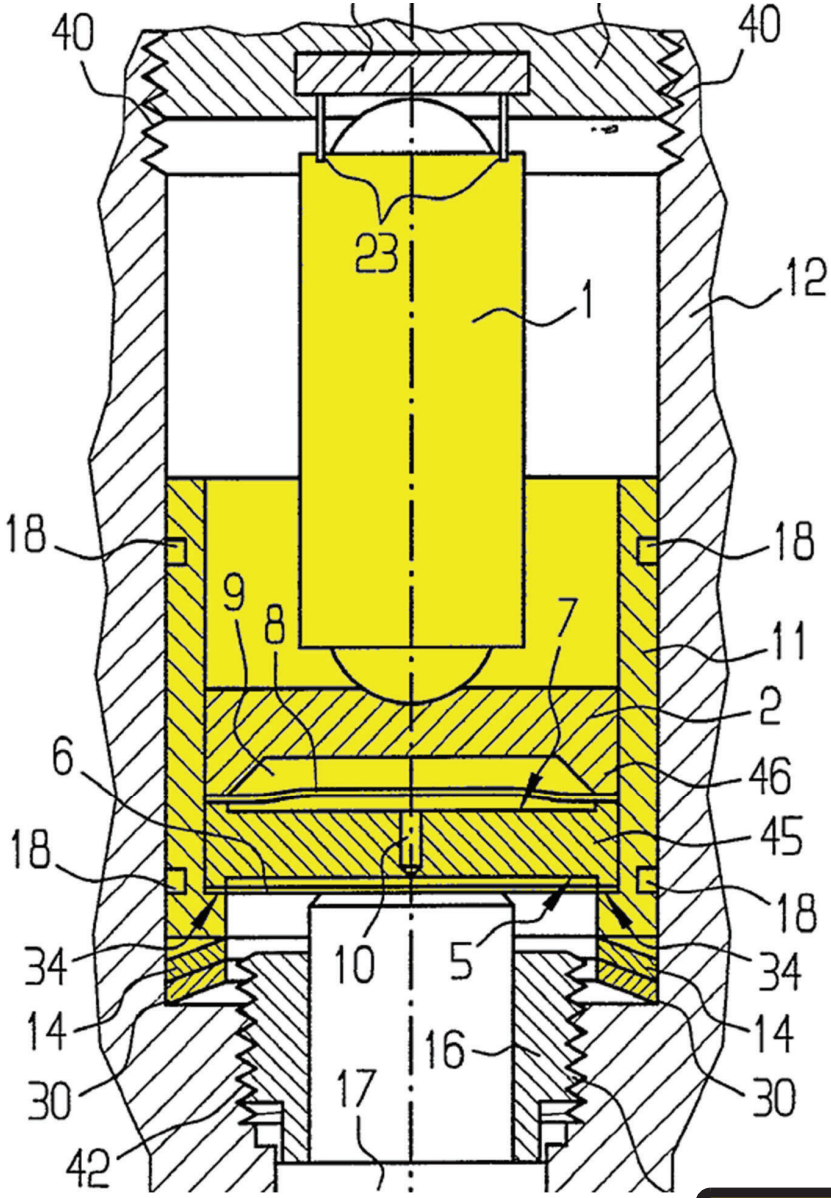


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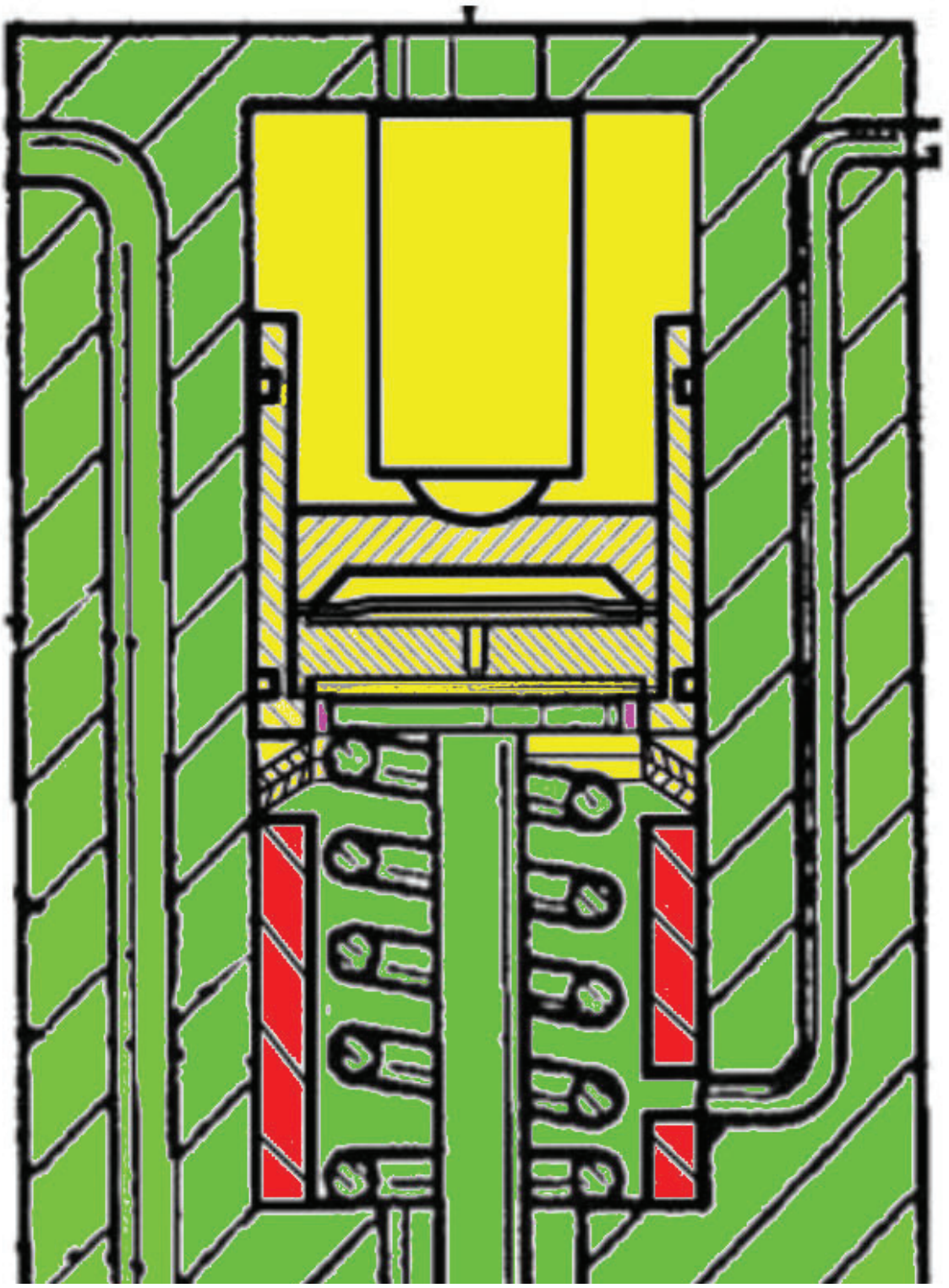


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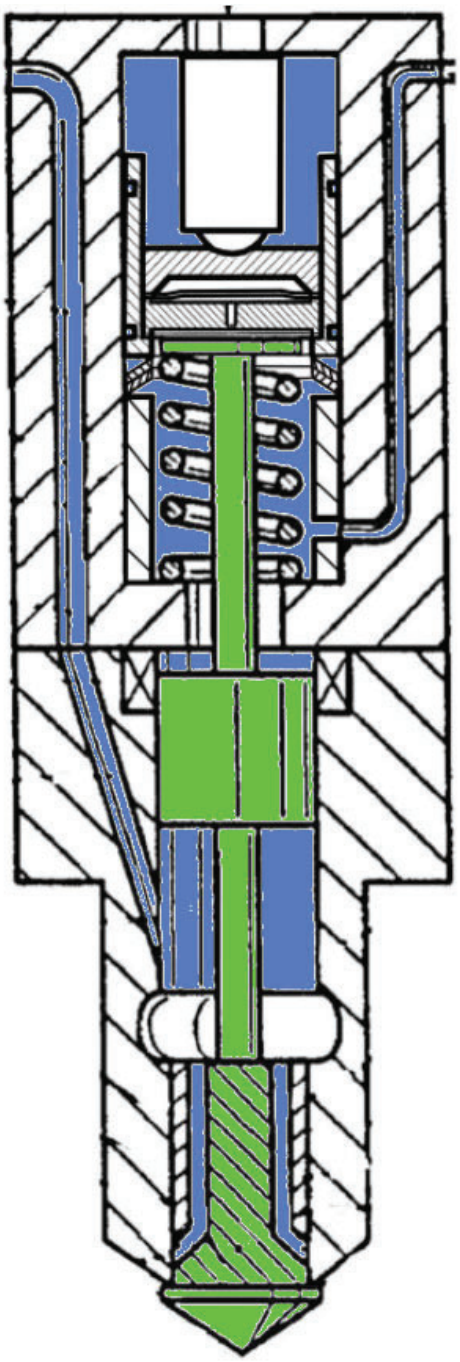




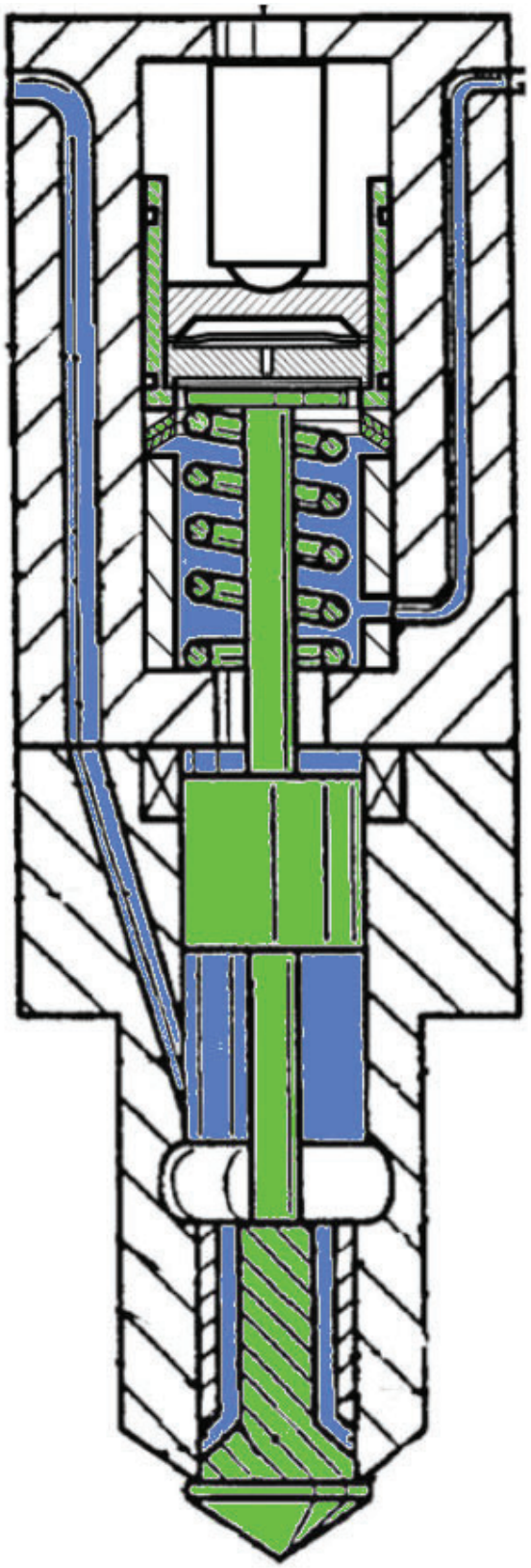
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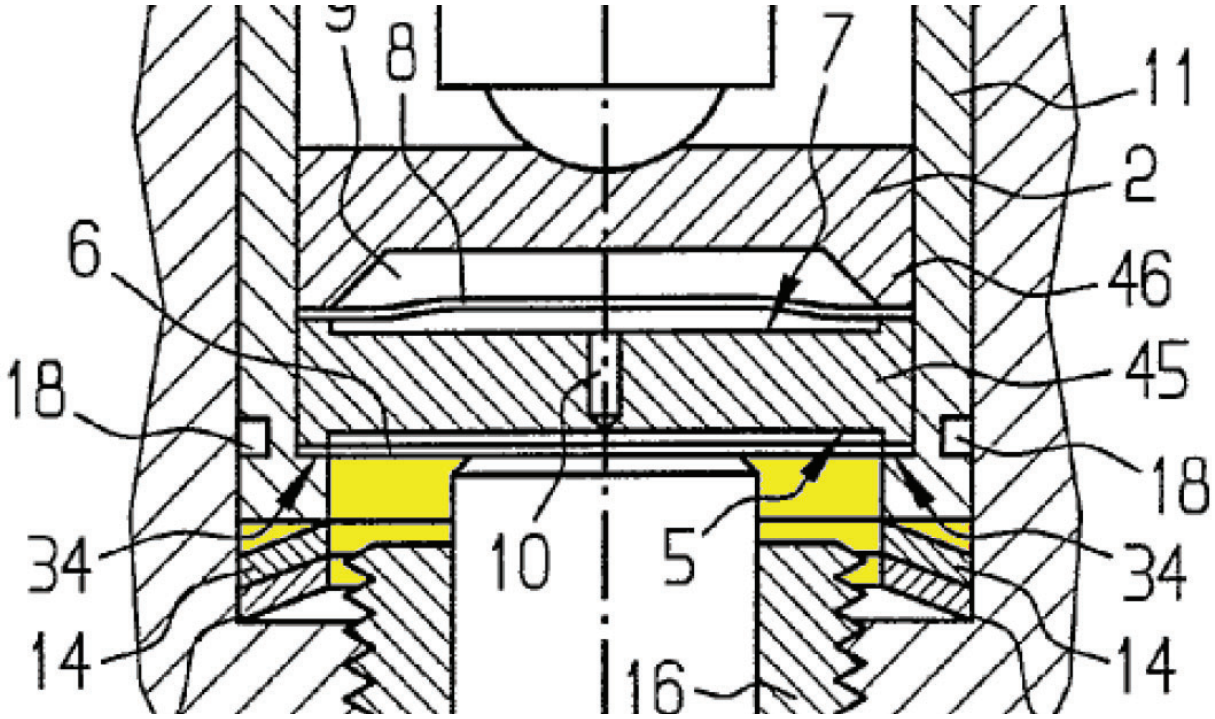
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