

Transcript of J. Matthew Quinlan

Date: March 1, 2024
Case: Robert Bosch, LLC -v- Westport Fuel Systems Canada, Inc.

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WORLDWIDE COURT REPORTING & LITIGATION TECHNOLOGY

IN THE UNITED STATES DISTRICT COURT

FOR THE EASTERN DISTRICT OF TEXAS

MARSHALL DIVISION

Civil No. 2:23-cv-00038-JRG-RSP

VIDEOTAPED DEPOSITION OF J. MATTHEW QUINLAN
March 1, 2024

ROBERT BOSCH, LLC,

Plaintiff/Counter-Defendant,
v.

WESTPORT FUEL SYSTEMS CANADA INC.,

Defendant/Counterclaim-plaintiff

A P P E A R A N C E S

For the Plaintiff Counter-Defendant Robert Bosch and the Witness:	MICHAEL C. CHOW, ESQ. Orrick, Herrington & Sutcliffe, LLP 2050 Main Street, Suite 1100 Irvine, CA 92614-8255 949-852-7733 mchow@orrick.com
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A P P E A R A N C E S (continued.)

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Videotaped Deposition of J. MATTHEW QUINLAN, called by the Defendant in the above-entitled matter on Friday, the 1st day of March, 2024, commencing at the hour of 9:06 a.m., at 55 E. Costilla Street, Colorado Springs, CO 80903, before Theresa L. Mendez, RPR, a Registered Professional Reporter and Notary Public within and for the State of Colorado, said deposition being taken pursuant to Rules 26 and 30(b)(1) of the Federal Rules of Civil Procedure and the Court's March 29, 2023 Scheduling Order (ECF No. 65).

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P R O C E E D I N G S

9:06 A.M. 09:06:00

THE VIDEOGRAPHER: Here begins the video deposition of Dr. John Matthew Quinlan in the matter of Robert Bosch, LLC v. Westport Fuel Systems Canada Incorporated, in the United States District Court for the Eastern District of Texas Marshall Division, Case Number 2:23-CV-0038-JRG-RSP. 09:06:00 09:06:01 09:06:04 09:06:09 09:06:13 09:06:16 09:06:18

Today's date is March 1, 2024. The time on the video monitor is 9:06 a.m., Mountain time. 09:06:29 09:06:34

The videographer today is Jeremy Hatfield representing Planet Depos. This video deposition is taking place at 55 East Costilla Street, Colorado Springs, Colorado, 80903. 09:06:37 09:06:40 09:06:44 09:06:48

Would counsel please voice identify themselves and state whom they represent. 09:06:52 09:06:55

MR. PHILBIN: Phillip Philbin of Winstead on behalf of the defendant -- or I'm sorry -- plaintiff Westport Fuel Systems. 09:06:58 09:07:00 09:07:01

MS. JONES: Miranda Jones from Winstead on behalf of Westport, the declaratory judgement defendant and counter-claim plaintiff in this case. 09:07:07 09:07:11 09:07:18

MR. CHOW: Michael Chow on behalf of Orrick Sutcliffe -- I'm sorry -- Philmore, 09:07:18 09:07:18

Herrington & Sutcliffe on behalf of plaintiff and counter-defendant Robert Bosch and the witness. 09:07:26 09:07:27

THE VIDEOGRAPHER: The court reporter today is Theresa Mendez representing Planet Depos. 09:07:30 09:07:31

The witness will now be sworn. 09:07:35

Whereupon, 09:07:37

J. MATTHEW QUINLAN, 09:07:37

the witness having been first duly sworn, was examined and testified on his oath as follows: 09:07:37 09:07:37

EXAMINATION 09:07:37

BY MR. PHILBIN: 09:07:37

Q. Good morning, sir. My name is Phillip Philbin, and I'm here on behalf of Westport as their lawyer. 09:07:48 09:07:52 09:07:57

Do you understand that? 09:07:57

A. I do. 09:07:57

Q. Great. We never met before this morning, correct? 09:07:59 09:08:01

A. Not that I'm aware of. 09:08:01

Q. How do you prefer to be addressed? 09:08:03

A. Dr. Quinlan is fine. 09:08:06

Q. Okay. 09:08:08

MR. CHOW: Sorry, I don't mean to interrupt. 09:08:14 09:08:16

Theresa, this went off. 09:08:17

(Short pause.) 09:08:33
Q. (BY MR. PHILBIN) Sir, you've had your deposition taken at least once before; is that correct? 09:08:33 09:08:37 09:08:39
A. That is. 09:08:39
Q. If at any point today I ask you a question that you don't understand for any reason, would you agree to let me know? 09:08:39 09:08:43 09:08:45
A. I will. 09:08:46
Q. If at any point during your deposition today you need to take a break for any reason, would you agree to let me know? 09:08:47 09:08:50 09:08:53
A. I will. 09:08:54
Q. And I would ask that in answering my questions, if you would agree to attempt to let me finish the question. And I will, in turn, attempt to let you finish the answer. 09:08:55 09:08:59 09:09:02 09:09:07
Is that agreeable? 09:09:09
A. Yes. 09:09:10
Q. And if you need a break, the request I would make is ask for the break while there's not a question pending, unless you need to consult with your lawyer in order to answer the question. 09:09:10 09:09:13 09:09:17 09:09:19
Is that agreeable? 09:09:23
A. Yes. 09:09:24

Q. Are you on any medication today or have any other physical conditions that would prevent you from testifying truthfully and recalling facts and circumstances? 09:09:25 09:09:29 09:09:35 09:09:42

A. No. 09:09:43

Q. You're here testifying today pursuant to our notice, correct? 09:09:43 09:09:47

A. That is correct. 09:09:48

Q. As you sit here today, have you had any other expert engagements other than the one in this case? 09:09:49 09:09:58 09:10:02

A. In related cases, yes. 09:10:03

Q. All related to these patents? 09:10:08

A. Correct. 09:10:12

Q. So other than your expert opinions related to the Westport patents in a variety of cases, you have not ever been retained as an expert by anyone else; is that correct? 09:10:13 09:10:15 09:10:21 09:10:24

A. That is correct. I do consulting and other things, other activities that are related, and I've worked on patents before, but -- in this capacity. 09:10:25 09:10:31 09:10:33

Q. Are you finished? 09:10:36

A. Yes. 09:10:38

Q. Okay. Who is your client in this case? 09:10:38

A. I work for Orrick. 09:10:41

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Q. Who is paying for your work in this case? 09:10:48
A. Orrick. 09:10:51
Q. Who retained you in this case? 09:10:52
A. Orrick. 09:10:54
Q. So would it be fair to say you have not been retained by Robert Bosch, LLC? 09:10:59 09:11:02
A. Maybe that's a legal term that I'm not exactly familiar with, you know, how you consider it. Obviously, we're -- you know, Orrick is retained by Bosch, and as far as I know, I'm retained by them. 09:11:05 09:11:12 09:11:17 09:11:26
Q. Okay. But you get paid by and take your instructions from the lawyers at Orrick. Would that be fair to say? 09:11:29 09:11:34 09:11:36
A. Yes. 09:11:37
Q. Who requested you to prepare the opinions you prepared in this case? 09:11:38 09:11:42
A. It's at the request of Orrick and Bosch. 09:11:43
Q. Have you ever spoken with anyone at Bosch in connection with your opinions in this case? 09:11:49 09:11:53
A. Yes. 09:11:55
MR. CHOW: I caution the witness not to reveal the contents of any privileged communications. 09:11:56 09:11:58 09:12:01
THE WITNESS: Yes. I have spoken with people associated with Bosch. 09:12:02 09:12:04

Q. (BY MR. PHILBIN) Okay. Let me be clear. I don't want to know about your conversations with Orrick. I'm asking about the entity that's separate from Orrick, one of the Bosch's entities. 09:12:05 09:12:08 09:12:10 09:12:14

Have you had conversations with individuals that work at Bosch, not Orrick, related to your opinions in this case? 09:12:18 09:12:19 09:12:23

MR. CHOW: Same caution. 09:12:24

You can answer yes or no to the question. 09:12:26

THE WITNESS: Yes. I have. 09:12:28

Q. (BY MR. PHILBIN) How many people? 09:12:32

A. Three. 09:12:34

Q. What are their names? 09:12:35

A. I do not recall all of their names right now. 09:12:39 09:12:43

Q. Do you recall any of their names? 09:12:43

A. It's Sarah, and I do not remember the other two gentlemen's names. 09:12:45 09:12:49

Q. Do you know if any of those are lawyers? 09:12:52

A. I believe they might all be. 09:12:56

Q. Okay. Have you spoken with anyone at Bosch that is not a lawyer? 09:12:58 09:13:01

A. No. Not that I'm aware of. 09:13:02

Q. So would it be fair to say that all of your opinions in this case, the only people that you have 09:13:05 09:13:09

spoken to related to those opinions are lawyers? 09:13:12
A. Yes. As far as I'm aware. 09:13:15
Q. Have you ever worked for General Motors? 09:13:22
A. I was retained by -- let's see. I can't remember the law firm right now, on behalf of GM previously in this case. 09:13:26 09:13:40 09:13:45
Q. Okay. Have you ever done any consulting work for General Motors? 09:13:46 09:13:49
A. No. I don't think so. 09:13:50
Q. So would it be fair to say that the only work you've ever done for General Motors is in connection with the Westport patent? 09:13:55 09:13:58 09:14:02
A. As far as I can remember. 09:14:04
Q. Okay. Have you ever worked for Ford? 09:14:05
A. I worked for companies that worked with Ford closely. 09:14:08 09:14:12
Q. Okay. Let's see if we can take that in pieces. 09:14:13 09:14:15
A. Yep. 09:14:16
Q. Have you ever worked for Ford? 09:14:17
A. I have never worked for Ford. 09:14:19
Q. What companies have you worked with that worked with Ford closely? 09:14:21 09:14:26
A. I worked for the company named Sturman Industries, as you can see on my CV, and they worked 09:14:28 09:14:35

with International Truck and Engine Corp. 09:14:40

Q. So you worked for Sturman, Sturman worked 09:14:45

for International Truck and Engine that worked for 09:14:50

Ford; would that be correct? 09:14:53

A. Yes. 09:14:54

Q. Any other connections to Ford? 09:14:56

A. I have done consulting that was maybe 09:14:59

consulting back to Sturman in the same kind of 09:15:10

association. 09:15:16

Q. Okay. Anything else? 09:15:16

A. Not that I can think of right now. 09:15:18

Q. Have you ever worked for Mercedes Benz? 09:15:20

A. I have not. 09:15:24

Q. Have you ever worked for BMW? 09:15:25

A. I have not. 09:15:28

Q. Have you ever worked for Cooneys? 09:15:29

A. No. 09:15:33

Q. Have you ever worked for Bosch other than 09:15:33

in this case? 09:15:36

A. No. I don't think so. 09:15:38

Q. In any of your roles at Sturman, Quinlan, 09:15:39

Consulting, or otherwise, have you ever worked for or 09:15:45

been paid by Bosch other than this case? 09:15:47

A. No. 09:15:50

Q. Same question for Ford. 09:15:50

A. No. 09:15:54
Q. General Motors? 09:15:55
A. Just through, you know, the work in this 09:16:00
case. 09:16:02
Q. Mercedes Benz? 09:16:03
A. No. 09:16:10
Q. BMW? 09:16:11
A. No. 09:16:12
Q. Cummings (ph)? 09:16:15
A. No. 09:16:15
Q. All right. Let's see if we can sum that 09:16:15
up. 09:16:18
Any of your roles at Sturman, Quinlan 09:16:19
Consulting, or otherwise, you've never worked for 09:16:21
or been paid by Bosch, Ford, General Motors, 09:16:24
Mercedes, BMW, or Cummings, other than your work in 09:16:27
this case, correct? 09:16:28
A. That sounds correct. 09:16:29
Q. At Quinlan Consulting, who did you do 09:16:31
diesel fuel system design development analysis for? 09:16:35
A. My major customer was Sturman Industries. 09:16:38
Q. When did that work take place? 09:16:46
A. Primarily from maybe 2005 to 2009 through 09:16:48
the Quinlan Consulting. 09:17:08
Q. Okay. From 2009 to the present, have you 09:17:09

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done any diesel fuel system design development and analysis? 09:17:14 09:17:19

MR. CHOW: Objection; form. 09:17:20

MR. PHILBIN: What's your objection? 09:17:23

MR. CHOW: It is -- I guess, what do you mean by "diesel fuel system design analysis"? 09:17:24 09:17:27

Q. (BY MR. PHILBIN) I'll just tell you, I'm taking that right off of your CV. So if you don't know what diesel fuel system design development analysis means as written on your CV, just let me know. 09:17:31 09:17:31 09:17:34 09:17:37 09:17:40

A. I would say I have done other diesel work -- maybe not in that capacity -- at my time during -- when I was at Georgia Tech. 09:17:42 09:17:45 09:17:52

Q. When was that? 09:17:55

A. 2009 to 2015. 09:17:56

Q. You don't list any of that on your resume or your CV, correct? 09:17:58 09:18:03

A. I mean, I think that's encompassed with just my overall background. 09:18:05 09:18:09

Q. Okay. 09:18:11

A. It wasn't any paid work. 09:18:13

MR. PHILBIN: Would you mark that as Exhibit 1, please. 09:18:16 09:18:18

(Exhibit Number 1 was marked for 09:18:18

identification.) 09:19:01

Q. (BY MR. PHILBIN) The court reporter has handed you what's been marked as Exhibit 1 to your deposition. Do you recognize that document, sir? 09:19:01 09:19:07 09:19:10

A. I do. 09:19:12

Q. What is it? 09:19:12

A. It appears to be my CV. 09:19:14

Q. If you need more time to look at it to confirm it's your CV, take as much time as you need. 09:19:32 09:19:34

A. It looks complete, from what I see. 09:19:38

Q. Okay. Is Exhibit 1, your CV, true and accurate as of today? 09:19:41 09:19:45

A. I might have a conference paper or something that hasn't gone on there yet from January, but, otherwise, I think it is correct. 09:19:46 09:19:51 09:19:54

Q. Other than a conference paper that may have happened in early 2004, is Exhibit 1, your CV, complete as of today? 09:19:56 09:20:03 09:20:08

A. You know -- 09:20:10

MR. CHOW: Objection; form. 09:20:12

Q. (BY MR. PHILBIN) Do you know what "complete" means? 09:20:14 09:20:16

A. Yes. 09:20:17

Q. Okay. You can answer. 09:20:17

A. I believe it has -- it represents my 09:20:19

experience well. 09:20:25

Q. Who prepared Exhibit Number 1? 09:20:26

A. I did. 09:20:29

Q. You did. Why did you prepare Exhibit Number 1? 09:20:29

A. I was asked to provide a CV. 09:20:36

Q. Who asked you? 09:20:40

A. Orrick. 09:20:41

Q. So would it be fair to say that Exhibit Number 1, your CV, was prepared at the request of Orrick specifically for this case? 09:20:42

MR. CHOW: Objection; form. 09:20:52

THE WITNESS: I mean, it's very closely related to my standard CV, I would say, in form. I don't know if I made any specific adjustments to supply it to them, but it's very close to one I would supply to anyone else. 09:20:53

Q. (BY MR. PHILBIN) Let me see if I can break that in pieces. 09:21:14

Exhibit Number 1 was prepared at the request of your lawyers, Orrick, correct? 09:21:17

MR. CHOW: Objection; form. 09:21:20

THE WITNESS: I already had a CV. I maybe made sure it was complete and sent it to -- sent it to Orrick. So in that sense, yes, I 09:21:22

prepared it for them. 09:21:41

Q. (BY MR. PHILBIN) Okay. So you 09:21:43

testified -- I said, "Why did you prepare Exhibit 09:21:44

Number 1," and you testified, "I was asked to provide 09:21:47

a CV." And I said, "Who asked you?" And you said, 09:21:49

"Orrick." 09:21:54

And this CV is different than your 09:21:55

standard CV, correct? 09:21:57

A. I do not recall if it's different than my 09:21:59

standard CV. I try to keep pretty much a standard 09:22:03

CV. 09:22:08

Q. Okay. So as you sit here today, you cannot 09:22:08

testify that Exhibit Number 1 is your standard CV, 09:22:11

can you? 09:22:14

A. As far as I know, I think it's -- I don't 09:22:15

know anything that I would have done differently on 09:22:24

this than any other one that I prepared. 09:22:27

Q. Okay. So yes or no, is this your standard 09:22:29

CV? 09:22:33

A. I would say yes, then. 09:22:33

Q. Okay. At the time you submitted your CV, 09:22:35

you knew the subject matter at issue in this case, 09:22:39

correct? 09:22:41

A. Correct. 09:22:41

Q. So you knew it involved diesel fuel 09:22:42

injectors, correct? 09:22:45
A. Correct. 09:22:46
Q. And you knew it would be of utmost 09:22:47
importance for you to list each and every 09:22:51
qualification you have related to diesel fuel 09:22:53
injectors on Exhibit 1 when you prepared and 09:22:55
submitted it, correct? 09:22:59
A. I clearly understand that that's what the 09:23:00
case is about, but, yeah. 09:23:02
Q. Do you have any diesel fuel injection 09:23:08
experience or expertise that you failed to disclose 09:23:12
on Exhibit Number 1? 09:23:15
A. I mean, I wouldn't say I failed to disclose 09:23:16
it. I'm saying that I have done work as, you know, 09:23:25
my role as a consultant and owner of a consulting 09:23:31
firm in that field. Whether or not it was paid or 09:23:35
not, that is surely on the CV, as far as I'm 09:23:39
concerned. 09:23:45
Q. You understood that the purpose of you 09:23:45
providing Exhibit Number 1 was to give us fair notice 09:23:47
of your qualifications; is that correct? 09:23:50
A. Sure. And I think I have done that. 09:23:51
Q. Okay. And you listed all the information 09:23:53
you considered relevant to this case in any way on 09:23:58
Exhibit Number 1, correct? 09:24:02

A. Yes. 09:24:04
Q. How long have you lived in Colorado? 09:24:07
A. Well, let's see, I believe, 40 years. 09:24:10
Q. Have you ever lived in Florida? 09:24:19
A. I have not. 09:24:23
Q. Are you sure? 09:24:23
A. Yes, I am sure. 09:24:30
Q. Okay. So it would be inaccurate to represent to a governmental entity that you were a resident of Florida at any point in time in your life? 09:24:32 09:24:36 09:24:39 09:24:43
A. I have never lived in Florida. And as far as I know, I have never represented that I lived in Florida. 09:24:44 09:24:46 09:24:49
Q. While at Sturman, did you ever do any work for a Bosch entity? 09:24:52 09:24:55
A. Not that I recall. 09:24:57
Q. Who was the major automobile manufacturer involved with installation for the German university? 09:24:59 09:25:05
A. Can you repeat that? 09:25:12
Q. Who was the major automobile manufacturer involved with installation for the German university? 09:25:12 09:25:16
MR. CHOW: Objection; form. 09:25:21
THE WITNESS: I performed two installations for Sturman Industries, and I believe 09:25:21 09:25:23

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that their contract was with Volkswagon. 09:25:30

Q. (BY MR. PHILBIN) Who were the German universities? 09:25:38 09:25:40

A. One was University of Magdeburg, and the other one was the University of Stuttgart, I believe. 09:25:42 09:25:46

Q. I'll do the court reporter's job. 09:25:50

And do you know how to spell either one of those? 09:25:52 09:25:54

A. No clue. 09:26:00

Q. How many patents are you a named inventor on? 09:26:00 09:26:16

A. Four. 09:26:16

(Court reporter asked for clarification.) 09:26:16

Q. (BY MR. PHILBIN) How many United States patents are you a named inventor on? 09:26:16 09:26:23

A. Four. 09:26:24

Q. Three of the four patents on which you are named inventor are assigned to Sturman Industries; is that correct? 09:26:26 09:26:32 09:26:36

A. I believe so. 09:26:36

Q. Would it be fair to say that the patents on which you are a named inventor and have been assigned to Sturman Industries related to diesel fuel injector design? 09:26:37 09:26:39 09:26:41 09:26:46

A. Among other topics, yeah. 09:26:46

Q. Based on the CV that you created and provided in this case, you have five years of diesel fuel system engineering experience; is that correct? 09:26:50 09:26:54 09:26:58

A. While at Sturman. But I have, you know, worked, again, as a consultant through QED (ph) on these topics before since then. 09:27:01 09:27:07 09:27:12

Q. So I would direct you to the first page of your CV, Exhibit Number 1. Do you see "Diesel Fuel System Engineer" above "Sturman Industries"? 09:27:16 09:27:19 09:27:24

A. Let's see. 09:27:28

Q. On the first page, at the bottom. 09:27:29

And the first page of Exhibit Number 1 that you prepared and submitted is where you listed your experience, correct? 09:27:31 09:27:33 09:27:36

A. Yes. 09:27:37

Q. Can you show me where else on the first page of Exhibit Number 1 you referenced diesel fuel system engineering experience? 09:27:38 09:27:40 09:27:44

A. Sure. Below "Quinlan Engineering and Design, LLC, Woodland Park, Colorado." The next line says, "Diesel fuel system design development and analysis." 09:27:46 09:27:51 09:27:55 09:27:58

Q. Okay. And that was the 2005 to 2009? 09:27:58

A. No. That is 2005 to present. 09:28:02

Q. Well, now do you recall, when I asked you 09:28:06

earlier, I said, "At Quinlan Consulting, who did you do diesel fuel system design development and analysis for," and you said, "Sturman Industries, 2005 to 2009." 09:28:08 09:28:13 09:28:17 09:28:21

Are you amending that answer now? 09:28:22

A. I would say that is when I did that work with them. 09:28:23 09:28:25

Q. Okay. 09:28:28

A. Because that's what you asked, as far as how I understood the question. 09:28:30 09:28:33

Q. So on your CV, I asked you about the first bullet point. Where else on your CV, other than that first bullet point, is there anything related to diesel fuel injection or system design? 09:28:34 09:28:39 09:28:43 09:28:46

A. Additionally, I have a paper listed on page 4. "Wolverton, Giordano, Quinlan and Zukouski Evaluation of a 3-Way Direct Needle Control Unit Injector on Hydraulic Test Bench and V8 Engine." 09:28:50 09:29:00 09:29:06 09:29:11

Q. Okay. What's the date of that paper? 09:29:16

A. That was the spring of 2004. I think that's the 2004. 09:29:18 09:29:20

Q. Anything else? 09:29:22

A. On page 5, under "Expert Witness Experience," I was deposed in the case between Westport and General Motors. 09:29:27 09:29:35 09:29:38

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Q. Okay. Anything else? 09:29:39

A. In -- under "Teaching," there's one, two, 09:29:41

three, four, five places where Thermodynamics II -- 09:30:06

Engineering Thermodynamics II is listed. And I teach 09:30:14

on diesel cycles, mixed cycles and how diesel engines 09:30:21

and injectors work in that case. 09:30:27

Q. Okay. And you didn't list "diesel" next to 09:30:30

any of those teachings, correct? 09:30:33

A. No. But that's a standard topic for that 09:30:34

type of course. 09:30:37

Q. Okay. Anything else? 09:30:37

A. Let's see. That's what I see right now. 09:31:12

Q. And you just testified to all the instances 09:31:33

on your Exhibit 1, CV, that you have diesel system 09:31:38

fuel engineering experience or diesel fuel injector 09:31:44

design experience? 09:31:48

A. I guess one more point I would bring up, 09:31:49

while it may not be explicitly diesel, it's 09:31:55

definitely very closely related. It's the same, 09:32:02

essentially, type of injection. Under bullet point 09:32:04

number 1, under "Experience, Assistant Professor, 09:32:09

University of Colorado, Colorado Springs" is 09:32:13

"designed, constructed, and tested an 09:32:14

outwardly-opening pintle fuel injector to study 09:32:14

hydrodynamics and atomization." 09:32:22

The injector is a generic injector, but surely of the type that can be used in a diesel. 09:32:24 09:32:29

Q. Any other fuel system engineering experience or fuel system or diesel fuel injector experience? 09:32:34 09:32:36 09:32:41

MR. CHOW: Objection to form. 09:32:43

THE WITNESS: If you want to know about -- are you asking about fuel system experience or diesel fuel system experience? 09:32:44 09:32:47 09:32:51

Q. (BY MR. PHILBIN) Diesel. 09:32:54

A. Okay. 09:32:56

Q. Anything else? 09:32:56

A. That's what I see on specific diesel fuel system experience on this. Well, there's other fuel system experience on here. 09:32:57 09:33:19 09:33:24

Q. Have you ever been a member of SAE? 09:33:24

A. I have. 09:33:27

Q. When? 09:33:28

A. I do not recall the specific dates, but probably from -- let's see. Let's see. Maybe 1999, maybe 2000 for, you know, mostly the next, I would guess, seven years. But I do not recall any specifics. I mean, I could have or could have not. I was a student member for a while, and... 09:33:29 09:33:43 09:33:57 09:34:08 09:34:11 09:34:15

Q. Are you currently a member of SAE? 09:34:18

A. I am not currently a member of SAE. 09:34:20
Q. What does SAE stand for? 09:34:22
A. Society of Automobile Engineers. 09:34:25
Q. You listed several of your patents in this case amongst your qualifications in the declaration that you prepared, correct? 09:34:35 09:34:38 09:34:42
A. I did. 09:34:43
Q. Is the art for the patents-in-suit, the same or different than the art on the patents in which you're a named inventor? 09:34:44 09:34:48 09:34:52
MR. CHOW: Objection; form. 09:34:54
Q. (BY MR. PHILBIN) You can answer. 09:35:12
A. By "art," do you mean the topic of the patents? 09:35:13 09:35:17
Q. You understand you're representing yourself today as someone skilled in the art? 09:35:17 09:35:20
A. Yes. 09:35:22
Q. Okay. That's the art I'm talking about. 09:35:22
A. Okay. 09:35:24
Q. So is the art of your patents the same as the art in the patents-in-suit, or is it different? 09:35:25 09:35:28
A. I believe it's the same. 09:35:33
Q. Thank you. 09:35:35
Have you ever lived in Georgia? 09:35:43
A. I have. 09:35:45

Q. How long did you live in Georgia? 09:35:45
A. For six years. 09:35:47
Q. When? 09:35:49
A. 2009 to 2015, I believe. 09:35:49
Q. Did you meet with your legal team to prepare for your deposition today? 09:35:54 09:36:11
A. I did. 09:36:13
Q. How long did you meet? 09:36:13
A. Probably eight hours total. 09:36:15
Q. Did you review any documents? 09:36:24
A. Yes. 09:36:27
Q. Do you recall which ones? 09:36:27
MR. CHOW: I caution the witness to the extent that those documents were reviewed at the request of counsel, I'm going to instruct the witness not to answer. 09:36:31 09:36:37 09:36:40 09:36:44
Q. (BY MR. PHILBIN) Can you answer my question given your lawyers's instruction? 09:36:45 09:36:46
A. I will refer [sic] to my lawyer and follow his advice. 09:36:49 09:36:52
Q. Did any of the documents you reviewed refresh your recollection? 09:36:53 09:36:56
A. No. 09:36:57
Q. Did you speak with anyone other than lawyers in preparing to testify today? 09:36:58 09:37:04

A. No. 09:37:08
Q. You understand you're being paid to offer 09:37:09
an opinion on what certain terms mean to a person of 09:37:16
ordinary skill in the art at the time of the 09:37:21
invention, correct? 09:37:24
MR. CHOW: Objection; form. 09:37:24
THE WITNESS: I do. 09:37:25
Q. (BY MR. PHILBIN) Was that a yes? 09:37:26
A. Yes. 09:37:27
Q. How much have you been paid for your 09:37:28
opinions in this case? 09:37:33
A. I'm not sure. 09:37:36
Q. Any idea? 09:37:37
A. I honestly do not know. 09:37:38
Q. Less than a hundred million dollars? 09:37:42
A. Yes. 09:37:45
Q. Can you be any more specific than less than 09:37:45
a hundred million dollars? 09:37:48
A. I -- I really don't know a specific number. 09:37:50
Q. Okay. So the best we can do is somewhere 09:37:58
between zero and a hundred million dollars, correct? 09:38:01
MR. CHOW: Objection; form. 09:38:04
Q. (BY MR. PHILBIN) I'm not trying to be 09:38:06
funny. I'm trying to figure out how much you've been 09:38:08
paid. 09:38:12

A. Okay -- I -- it's less than a hundred thousand dollars, I believe, but it's considered really less, I believe. 09:38:12 09:38:19 09:38:22

Q. Greater than any number? 09:38:23

A. It's over $10,000. 09:38:25

Q. So the best you can do is somewhere between ten and a hundred thousand dollars; is that correct? 09:38:31 09:38:35

A. I don't really recall. Like I said, it's not something I've paid attention to. 09:38:37 09:38:42

Q. What was the first task you did to form your opinions in this case after being retained by Orrick? 09:38:43 09:38:47 09:38:50

A. So I -- Orrick supplied me with the relevant documents, so I reviewed documents at their request. 09:38:50 09:39:04 09:39:08

Q. Anything else? 09:39:14

A. You asked for the first step. 09:39:15

Q. Okay. 09:39:17

A. First step. 09:39:18

Q. Did you list the documents in your declaration that you reviewed as the first task that you performed in this case? 09:39:18 09:39:20 09:39:25

A. I reviewed the documents that were -- that I was asked to review. 09:39:26 09:39:34

Q. Okay. I will get to your declaration. 09:39:35

There's a section where you've got -- 09:39:39
A. I think -- 09:39:41
Q. Okay. So were the patents-in-suit amongst 09:39:42
the documents that you were sent by Orrick to review 09:39:47
as your first task in this case? 09:39:52
A. I believe that the patents that were at 09:39:53
issue here were one of the first things that we 09:39:56
reviewed. 09:39:59
Q. Prior to Orrick sending you the patents in 09:39:59
connection with your work in this case, had you ever 09:40:05
seen the patents-in-suit before? 09:40:07
A. So in this case, being this specific case, 09:40:11
or the overall topic? 09:40:19
Q. Fair enough. Let me see if I can break 09:40:21
that down. 09:40:25
If I put in two buckets; one, your work 09:40:25
with lawyers; and two, your work not with lawyers. 09:40:29
A. Okay. 09:40:33
Q. Okay. Did you review the patents-in-suit 09:40:33
in connection with your work not with lawyers? 09:40:37
A. I did not. Not that I'm aware of. 09:40:40
Q. So would it be fair to say that the first 09:40:43
time you learned about the patents-in-suit is when 09:40:46
lawyers sent them to you? 09:40:49
A. I mean, they were contemporary patents for 09:40:51

when I was working in the field and we were doing a lot of patent reviewing. 09:40:56 09:40:59

Q. That's my question, sir. 09:41:02

A. So that was 20 years ago. I'm not sure if I saw those patents or not at that time. 09:41:04 09:41:07

Q. Okay. 09:41:13

A. But from what I remember, this was the first time. 09:41:13 09:41:16

Q. Okay. And had you seen the patents contemporaneous with your work in the field, you would have disclosed those to the patent office in connection with your patent applications related to the very same art, correct? 09:41:16 09:41:20 09:41:24 09:41:27 09:41:30

MR. CHOW: Objection; form. 09:41:31

THE WITNESS: I would say I was relying on my colleagues and my lawyers on what was disclosed as patents that were used in the generation of our patents. 09:41:32 09:41:35 09:41:42 09:41:47

Q. (BY MR. PHILBIN) How did you go about finding prior references in this case? 09:41:49 09:41:56

MR. CHOW: Objection; form. 09:41:59

Q. (BY MR. PHILBIN) By "this case" I mean any of the work that you have done with the lawyers on behalf of Bosch or any other GM. 09:42:00 09:42:02 09:42:04

A. Okay. 09:42:08

Q. Any other people you worked for? 09:42:09
MR. CHOW: Objection; scope. 09:42:11
Q. (BY MR. PHILBIN) Okay. Let me back up. 09:42:13
In connection with your work related to the patents-in-suit, how did you go about finding a prior art reference? 09:42:17 09:42:18 09:42:23
MR. CHOW: Objection; scope. 09:42:24
Counsel, this deposition is supposed to be related to his declaration. I don't understand how prior art is related to his declaration. 09:42:26 09:42:26 09:42:28
MR. PHILBIN: Are you going to instruct him not to answer? 09:42:31 09:42:32
MR. CHOW: No. But I'm just making that clear on the record. 09:42:33 09:42:35
MR. PHILBIN: You can answer. 09:42:36
THE WITNESS: I reviewed the documents that were supplied from Orrick. And so, I mean, I think that's the main source of these documents. 09:42:37 09:42:40 09:42:48
Q. (BY MR. PHILBIN) Let me ask it this way. You didn't go out and do your own prior art search, correct? 09:42:52 09:42:53 09:42:58
A. I used things like the prosecution history to see what was prior art. 09:42:58 09:43:08
Q. And that was provided by lawyers, correct? 09:43:11
A. Correct. 09:43:15

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Q. And the prior art that you looked at was provided by lawyers, correct? 09:43:16 09:43:18

A. Correct. 09:43:19

Q. You didn't go out and do a search or hire a search firm on your own to look for prior art; is that correct? 09:43:20 09:43:23 09:43:27

A. I did not hire anyone to do a search on this. 09:43:27 09:43:30

Q. Since being retained in this case, what have you done to educate yourself about the state of the art in October of 1999? 09:43:30 09:43:35 09:43:38

A. Sir, are you asking what the state of the art was in 1999 and what I have done or... 09:43:41 09:43:46

Q. That's not my question. 09:43:50

A. Please repeat your question. 09:43:52

Q. My question is: Since being retained in this case, what have you done to educate yourself about the state of the art in October of 1999? 09:43:53 09:43:55 09:44:00

MR. CHOW: Objection to form. 09:44:02

THE WITNESS: I think reviewing the patents at issue since they were -- that's when this was filed, and the prior art to those is how I educated myself on that -- 09:44:03 09:44:07 09:44:13 09:44:21

Q. (BY MR. PHILBIN) Anything else? 09:44:23

A. -- along with my experience in the field -- 09:44:24

Q. Okay. 09:44:26
A. -- in a very similar time. 09:44:27
Q. Anything else? 09:44:29
A. Nope. 09:44:30
Q. Okay. So your expertise related to the state of the art in 1999 is based on your experience listed on your CV, Exhibit Number 1, plus reviewing the patents in prior art supplied to you by lawyers, correct? 09:44:32 09:44:37 09:44:41 09:44:44 09:44:49
A. I think -- 09:44:49
MR. CHOW: Objection; form. 09:44:53
THE WITNESS: -- my experience as a whole, beyond, you know, just my experience in academia, working, consulting, all of those things inform that. My time in industry informs that. 09:44:55 09:44:58 09:45:05 09:45:08
I think that the reviewing of contemporary patents -- for example, the prior art and the histories -- all go towards that, towards my understanding of what a person of the ordinary skill in the art would be in 1999. 09:45:12 09:45:15 09:45:19 09:45:25 09:45:30
Q. (BY MR. PHILBIN) Okay. So since being retained in this case, you've reviewed the patents sent to you by lawyers and the prior art sent to you by lawyers about the state of the art in October of 1999, correct? 09:45:33 09:45:34 09:45:38 09:45:40 09:45:43

MR. CHOW: Objection; form. 09:45:44
THE WITNESS: I have reviewed those. 09:45:45
Q. (BY MR. PHILBIN) Have you done anything else since you have been retained in this case, to educate yourself about the state of the art in October of 1999? 09:45:46 09:45:48 09:45:52 09:45:54
A. I don't think I totally understand your question. I feel like I have made the analysis to see what someone in 1999 that was working in the field would understand, and that's how I formed my opinions. 09:45:58 09:46:04 09:46:09 09:46:14 09:46:19
Q. And the analysis -- when you say "made the analysis," you relied upon the qualifications you prepared in Exhibit Number 1 and disclosed to us, plus the materials, the patents and prior art sent to you by the lawyers, correct? 09:46:20 09:46:22 09:46:27 09:46:32 09:46:36
A. I did rely on those. 09:46:37
Q. Anything else? 09:46:39
A. Just -- I think it's the whole experience, again, that I have. 09:46:40 09:46:45
Q. Okay. And I'm asking a question particularly about October of 1999. 09:46:46 09:46:48
A. Okay. 09:46:51
Q. In connection with your work in this case, have you done anything other than review materials 09:46:52 09:46:54

sent to you by the lawyers to educate yourself about the state of the art in 1999? 09:46:57 09:47:01

MR. CHOW: Objection to form. 09:47:03

THE WITNESS: I believe that by doing the analysis of these patents, the history, the prior art, that I am using, then, my experience to understand what someone in 1999 would feel. 09:47:04 09:47:11 09:47:15 09:47:20

Q. (BY MR. PHILBIN) Your experience is reflected on Exhibit A that you prepared and submitted, correct? 09:47:26 09:47:27 09:47:31

A. It is -- it is a representative sample of my experience. 09:47:32 09:47:36

Q. Let me be clear. Are you hiding experience that's not reflected on Exhibit Number 1? 09:47:37 09:47:39

A. No, I'm not. 09:47:41

Q. Okay. 09:47:43

A. I'm saying, it represents my experience. 09:47:43

Whether everything I've ever done is on my CV, I -- surely not, right? You can't put everything you've ever done on a CV, every thought you've had. 09:47:47 09:47:50 09:47:53 09:47:59

Q. Have you spoken -- strike that. 09:48:06

Since being retained in this case, have you spoken with anyone about the state of the art in October of 1999? 09:48:08 09:48:10 09:48:13

MR. CHOW: Objection; form. 09:48:15
THE WITNESS: I have not spoken to anyone 09:48:16
specifically about that. I have made my own 09:48:20
opinion on that. 09:48:23
Q. (BY MR. PHILBIN) Have you reviewed any 09:48:24
Bosch documents in connection with forming your 09:48:29
opinions related to the patents-in-suit? 09:48:32
MR. CHOW: Objection; form. 09:48:35
THE WITNESS: The documents that I have 09:48:36
reviewed were supplied to me by Orrick, and whether 09:48:43
they were Bosch documents or not, I don't think 09:48:48
that that's -- I don't know whether that would be 09:48:50
the case or not. 09:48:55
Q. (BY MR. PHILBIN) So is it fair to say that 09:48:56
you were supplied a batch of documents from your 09:48:58
lawyers, and whether they were Bosch documents or 09:49:01
not, you don't know? 09:49:03
A. I mean, I don't recall any Bosch documents 09:49:04
being supplied, but you know, again, it's patents 09:49:09
histories, that kind of thing. 09:49:24
Q. Have you asked for access to any Bosch 09:49:25
documents? 09:49:29
A. I have not. 09:49:29
Q. Have you been provided access to Bosch 09:49:29
documents? 09:49:33

A. I have not. 09:49:33
Q. You have a Ph.D. in aerospace engineering 09:49:34
with at concentration in thermoacoustic instability, 09:49:37
correct? 09:49:41
A. Correct. 09:49:42
Q. Are there any airplanes that run on diesel 09:49:42
fuel? 09:49:45
A. So airplanes run on Jet-A or JP-8, which is 09:49:45
essentially a very similar fuel to diesel fuel, 09:49:52
essentially all kerosene derivatives. 09:49:56
Q. Let me see if I can ask my question again. 09:49:58
Are there any airplanes that run on 09:49:58
diesel fuel? 09:50:02
A. Again, I'm saying they essentially are 09:50:03
very, very similar fuels. 09:50:06
Q. That was not my question. 09:50:07
A. I do not know if there is specific 09:50:09
airplanes that run on, specifically, diesel, but 09:50:13
essentially, all airplanes run on something. Most 09:50:16
real airplanes run on something very similar. 09:50:20
Q. In all of your studies of aerospace 09:50:22
engineering, can you identify a single plane that 09:50:26
uses a diesel fuel injector? 09:50:28
A. I don't study, essentially, airplanes, so 09:50:31
that's -- 09:50:34

Q. Is that a no? 09:50:34
A. I am not aware of planes whether they do or 09:50:37
do not. 09:50:40
Q. So you can't identify a single airplane 09:50:40
that uses a diesel fuel injector, correct? 09:50:43
A. I am not aware whether they do or not. 09:50:47
Q. Can you identify a single airplane that 09:50:50
runs on diesel fuel? 09:50:53
A. It's the same question, I believe, right? 09:50:55
Q. Can you identify one plane that runs on 09:50:57
diesel fuel? 09:51:00
A. On diesel specifically, I'm not sure. 09:51:01
Q. Is it your opinion that kerosene-based 09:51:06
fuels is very similar to diesel fuel? 09:51:17
A. Kerosenes and diesel are very similar. 09:51:20
Q. Would you consider kerosene-based fuels and 09:51:23
diesel fuels to be the same art? 09:51:27
MR. CHOW: Objection; form. 09:51:30
THE WITNESS: I would say there's a 09:51:31
very -- you know, there is many similarities 09:51:34
between, you know, the propulsion devices that use 09:51:37
kerosene and diesel. 09:51:47
Q. (BY MR. PHILBIN) All right. So I'm just a 09:51:48
simple guy from Oklahoma. So if I take my car to the 09:51:50
gas station, are there similarities between unleaded 09:51:53

and diesel? 09:51:56
A. I mean, there're similarities. 09:51:57
Q. Just like there's similarities between 09:51:58
diesel and kerosene-based-fuels, correct? 09:52:02
A. There are similarities between diesel and 09:52:05
water, so I'm not sure I understand your question. 09:52:08
Q. So based on all of your experience with 09:52:12
fuels, if I put diesel fuel in my car that requires 09:52:15
unleaded fuel, what's going to happen? 09:52:19
A. It will not run. 09:52:21
Q. Even though they're similar? 09:52:23
A. Well, again, I mean, it depends on what 09:52:24
we're saying when we mean similar, right? 09:52:27
Q. You have a master's in mechanical 09:52:31
engineering with a concentration, again, in 09:52:34
thermoacoustic instability, correct? 09:52:36
A. Correct. 09:52:39
Q. Your master's thesis was entitled 09:52:39
"Combustion stability in baffled rocket engines," 09:52:40
correct? 09:52:45
A. Correct. 09:52:45
Q. Can you identify a single rocket that runs 09:52:46
on diesel fuel? 09:52:48
A. Again, so rockets, many of them run on RP1, 09:52:50
which is a derivative that's, you know, very, very 09:52:55

similar to kerosene or diesel. 09:53:00
Q. Okay. Let's restrict -- 09:53:03
A. Specifically, do I fill the tank with diesel? I do not know a rocket that does that. Does it mean there isn't? I don't know. 09:53:05 09:53:08 09:53:11
Q. You can't identify a single rocket or single rocket engine that runs on diesel fuel; is that correct? 09:53:13 09:53:16 09:53:20
A. Not specifically diesel, but the underlying technology is very similar. 09:53:20 09:53:23
Q. So you believe diesel fuel, rocket fuel, and jet fuel. Are very similar, correct? 09:53:25 09:53:31
A. Depending on what we're talking about, yes, I would say they are -- they have certain things that are very similar between them. 09:53:34 09:53:38 09:53:43
Q. From 2007 to the present, your primary focus has been on rockets and airplanes, correct? 09:53:45 09:53:49
A. It's in rocket combustors and gas turbine combustors. So whether that's airplanes or not -- it can be stationary gas turbine generators or arrow derivatives. But it's been in, essentially, injection and combustion. 09:53:53 09:54:00 09:54:05 09:54:11 09:54:14
Q. From 2007 to the present, your primary focus has not been on diesel fuel injection, correct? 09:54:18 09:54:22
A. Correct. 09:54:27

Q. How many arts do you consider yourself to be a person of ordinary skill in? 09:54:27 09:54:31

MR. CHOW: Objection; form. 09:54:33

THE WITNESS: I consider myself a jack of all trades. I don't know if I can make a count of how many, but if you would have, like, a specific topic to ask me on, I can try to say whether I think I am or not. 09:54:34 09:54:40 09:54:46 09:54:50 09:54:54

Q. (BY MR. PHILBIN) Explain to the jury what you mean by "jack of all trades." 09:54:55 09:54:57

A. I like learning things in lots of different fields. 09:55:00 09:55:05

Q. So if I retained you as an expert as a jack of all trades, you could educate yourself on basically any technology and testify about it, correct? 09:55:07 09:55:13 09:55:17 09:55:20

A. No. I would need a specific thing that I was tasked to make sure that I understood. 09:55:20 09:55:24

Q. Would it be fair to say that your opinions on claim construction have been shifting? 09:55:27 09:55:31

A. No. I would not say that. 09:55:34

Q. Would it be fair to say that your opinions on claim construction have been changing? 09:55:38 09:55:41

A. I don't believe that that's the case. 09:55:43

Q. Would it be fair to say that your opinions 09:55:46

on claim construction are malleable? 09:55:52

A. I mean, given new evidence, surely, I would take that into account and help use that in forming my opinion. 09:55:58 09:56:01 09:56:04

Q. From 2022 to the present, have you been provided new evidence as to what the state of the art was in October of 1999? 09:56:05 09:56:08 09:56:11

A. I can't tell you when I received each document, but I believe that I am making sure that my opinion represents the evidence that I have seen. 09:56:14 09:56:18 09:56:28

Q. Are you reserving the right that if you were provided new evidence today about the state of the art in October of 1999, that your opinions could change? 09:56:33 09:56:41 09:56:45 09:56:49

A. I do. Right. Given new evidence, we would take that -- I would make a new analysis of it and I would see where my opinion is the same and where my opinion would be different. 09:56:49 09:56:54 09:56:58 09:57:02

Q. So, as you sit here today, you don't have enough evidence about the state of the art in October of 1999 to formulate a rigid opinion, correct? 09:57:03 09:57:06 09:57:08

A. I don't think that there's ever such thing as enough evidence to form a rigid opinion. 09:57:14 09:57:17

Q. And as your opinions on claim construction in these related cases have changed, that's been 09:57:21 09:57:25

based on new materials that you received from your lawyers, correct? 09:57:28 09:57:31

MR. CHOW: Objection; form. 09:57:32

THE WITNESS: I don't think my opinions have changed. There's a compound question there, I believe, so if you would like to ask that again, I would be happy to answer it. 09:57:33 09:57:36 09:57:43 09:57:45

Q. (BY MR. PHILBIN) Okay. From December the 2nd, 2022, to the present, have your opinions on claim construction changed? 09:57:46 09:57:49 09:57:52

A. I mean, my view on the asserted patents and what that means in terms of the claim construction surely have evolved from the first day I started working on this case, because I didn't have all the evidence and I hadn't done my analysis. 09:57:53 09:58:01 09:58:05 09:58:08 09:58:11

I do careful analysis, and that takes time. 09:58:14 09:58:17

And so as I had those documents and I continued to do that analysis, that's what has helped me form my opinions in this case. 09:58:17 09:58:20 09:58:23

Q. So from December the 2nd, 2022, to the present, have your opinions on claim construction changed? 09:58:26 09:58:29 09:58:32

A. My opinion has not changed on what -- you know, the claim construction, I would say. Maybe my 09:58:33 09:58:38

wording has changed to make things more clear. 09:58:43

Q. Has your -- well, strike that. 09:58:47

In the GM case, on December 2, 2022, you 09:58:54
submitted a declaration that contained one set of 09:58:58
claim constructions, correct? 09:59:01

A. We submitted a declaration with GM. 09:59:05

Q. And that contained your opinions on claim 09:59:08
construction, correct? 09:59:12

A. Correct. On the -- yeah. The terms that I 09:59:12
was asked to construe. 09:59:18

Q. Okay. And you didn't pick the terms for 09:59:19
construction; you were told those by the lawyers, 09:59:22
correct? 09:59:24

A. Correct. 09:59:24

Q. In your review of the patents-in-suit, you 09:59:25
didn't identify any new terms that you thought, in 09:59:30
your opinion, needed to be construed; you just relied 09:59:34
on the terms your lawyers told you, correct? 09:59:37

A. I mean, I always have discussions with the 09:59:40
legal team, whether who came up with what, I can't 09:59:43
tell you. 09:59:50

Q. Can you identify a single claim term that 09:59:52
you said needed to be construed that you weren't told 09:59:55
to construe by the lawyers? 09:59:59

A. No. I was asked to construe terms, and I 10:00:01

did.
Q. One week after your December 2, 2022, declaration, you submitted -- in a different forum involving the same patents, you opined that no claim construction is required and the terms can be afforded their plain and ordinary meaning, correct? 10:00:03 10:00:03 10:00:07 10:00:12 10:00:15 10:00:20
A. I still believe that to be true. Most of the terms that we're doing, we're asserting the plain and ordinary meaning of them. 10:00:21 10:00:24 10:00:27
Q. Most of the terms. Which terms are not the plain and ordinary meaning? 10:00:29 10:00:31
A. Well, we have asserted that lift is the explicit definition given by the authors. 10:00:33 10:00:36
Q. Anything else? 10:00:39
A. No. I believe they were giving everything else the plain and ordinary meaning. 10:00:40 10:00:43
Q. So in this case, the Bosch case, over a year after your GM and plain and ordinary meaning declarations, you submitted a declaration with a new set of constructions, correct? 10:00:45 10:00:49 10:00:55 10:00:58
MR. CHOW: Objection; form. 10:01:00
THE WITNESS: Yes. We submitted a declaration with -- or I submitted a declaration with a new claim or with claim terms that we construed -- that I construed. 10:01:00 10:01:04 10:01:07 10:01:12

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Q. (BY MR. PHILBIN) In using your three different opinions on December the 2nd, 2022, December the 9th, 2022, and in this case, in some cases you've opined that a term needs construing that abandoned that construction, correct? 10:01:14 10:01:18 10:01:21 10:01:26 10:01:31

A. I would have to see what explicitly you're talking about so I can discuss it in more detail. But I would be happy to do that. 10:01:33 10:01:38 10:01:40

Q. Okay. But as you sit here today, based on the eight hours of prep that you did for this deposition, you don't know whether or not you abandoned the claim construction position? 10:01:42 10:01:45 10:01:46 10:01:48

A. We had -- I was asked to -- for example, it seems like one of the terms wasn't an issue anymore, so it was not included in this latest declaration, for example. 10:01:51 10:01:56 10:02:00 10:02:03

Q. In some cases, you have changed your mind the other way and said, no construction was required on December the 2nd, 2022, and December the 9th, 2022. Only to later opine that a construction was necessary on February the 1st, 2024, correct? 10:02:03 10:02:07 10:02:09 10:02:13 10:02:16

MR. CHOW: Objection; form. 10:02:19

THE WITNESS: Again, I would like to see exactly what we're talking about. But there are terms that we said -- I believe that we said we 10:02:20 10:02:24 10:02:26

could give the plain and ordinary meaning to, and then now we're just being explicit with what that plain and ordinary meaning is. 10:02:32 10:02:35 10:02:39

MR. CHOW: If you're going to go to another exhibit, is it a good time to take a break? 10:02:46 10:02:48

MR. PHILBIN: Sure. We can take a break. 10:02:50

THE VIDEOGRAPHER: We are going off the record. The time is 10:02 a.m. 10:02:52 10:02:54

(Whereupon, a recess was taken at 10:02 a.m.) 10:02:54 10:02:54

(Whereupon, the proceedings resumed at 10:10 a.m.) 10:02:54 10:10:51

THE VIDEOGRAPHER: We are back on the record. The time is 10:10 a.m. 10:10:51 10:10:56

(Exhibit Number 2 was marked for identification.) 10:10:56 10:10:59

Q. (BY MR. PHILBIN) Dr. Quinlan, I hand you what has been marked as Exhibit Number 2 to your deposition. And I will represent to you, sir, that is a chart that we prepared based on your three declarations related to these patents in this case. 10:10:59 10:11:02 10:11:07 10:11:09 10:11:13

I have those declarations with me today, if you would like to review them to confirm with me that that chart is in fact a fair summary of your opinions. 10:11:16 10:11:18 10:11:22 10:11:25

A. I believe that would be useful. 10:11:25
Q. Okay. Let me hand you what's been marked as Exhibit Number 3 to your declaration, I believe your PR4-3 declaration in the Bosch v. Westport case in Marshall. 10:11:28 10:11:33 10:11:37 10:11:47
And I'm not going to mark the GM declaration as an exhibit, but I've got a copy if you'd like to use it to confirm. 10:11:55 10:11:57 10:12:04
A. Okay. 10:12:06
Q. And I also have a copy of your December the 9th, 2022, declaration that I'm not going to mark as an exhibit. But I've got it if you'd like to confirm that we fairly summarized your opinions on Exhibit 2. 10:12:07 10:12:17 10:12:19 10:12:23 10:12:26
A. Okay. 10:12:27
MR. CHOW: Yeah, please. 10:12:28
Q. (BY MR. PHILBIN) Sir, take as much time as you need, and let me know if Exhibit 2 is a fair summary of your opinions that you've submitted related to your patents-in-suit in this case. 10:12:29 10:12:56 10:13:00 10:13:05
MR. CHOW: Just so I'm straight on the exhibits. The summary that you had prepared is Exhibit Number 2? 10:13:08 10:13:10 10:13:15
MR. PHILBIN: Correct. 10:13:17
(Exhibit Number 3 was marked for 10:13:17

identification.) 10:13:18
MR. CHOW: And then his declaration in 10:13:18
the Bosch Westport case is Exhibit Number 3? 10:13:20
MR. PHILBIN: Correct. 10:13:25
MR. CHOW: And you're not currently 10:13:25
marking his declaration in the GM case or his 10:13:27
declaration in the IPR as exhibits? 10:13:29
MR. PHILBIN: Correct. If you'd like me 10:13:32
to, I can. 10:13:33
MR. CHOW: Up to you. 10:13:35
MR. PHILBIN: Well -- 10:13:38
MR. CHOW: I guess, if you're going to be 10:13:59
asking questions about those declarations 10:14:01
specifically, then we would probably need to, 10:14:02
but... 10:14:06
Q. (BY MR. PHILBIN) I will tell you what, 10:14:24
Dr. Quinlan. I got a red pen. If you find any 10:14:27
mistakes on Exhibit Number 2, feel free to correct 10:14:31
it. 10:14:35
A. Yeah, hopefully, there are no mistakes. 10:14:36
Okay. Other than the capitalization, it appears to 10:15:17
be correct. 10:16:43
Q. You've had several minutes to look at all 10:16:44
the source materials for Exhibit Number 2, correct? 10:16:47
A. Yes. I think it looks like the current 10:16:51

declaration is complete. The previous declaration looks like it's here except for the -- all -- some of the exhibits. 10:16:59 10:17:03 10:17:06

Q. Okay. And your opinions are expressed in the report, not in exhibits, correct? 10:17:07 10:17:10

A. Yep. 10:17:11

Q. So I've given you everything you need to confirm that Exhibit Number 2 is a fair summary of your opinions related to the patents-in-suit, correct? 10:17:12 10:17:14 10:17:19 10:17:21

A. It appears that you have pulled these from the documents correctly, as I said, other than the capitalization. 10:17:21 10:17:25 10:17:28

Q. It says, for the term "interior chamber," on December the 2nd, 2022, your opinion was that no construction is necessary, correct? 10:17:30 10:17:47 10:17:51

A. Yeah. We believe that it could take its plain and ordinary meaning. 10:17:52 10:17:55

Q. And one week later, you had the same belief that it was plain and ordinary meaning; no construction offered, correct? 10:17:57 10:17:59 10:18:03

A. It appears to be correct. 10:18:04

Q. And 14 months later, you come up with a new opinion with a construction on February 1, 2024, correct? 10:18:05 10:18:09 10:18:12

A. I believe that it's not a new opinion. I think that it's consistent with us believing that it's the plain and ordinary meaning. And we wanted -- you know, I want to be very explicit here about what that plain and ordinary meaning is. 10:18:12 10:18:17 10:18:20 10:18:24 10:18:28

Q. But you didn't feel the need to be explicit about the plain and ordinary meaning of "interior chamber" on December the 2nd, 2022, or December the 9th, 2022, correct? 10:18:30 10:18:34 10:18:37 10:18:40

A. At that time, I thought it was clear what that meant, but through the preceding cases, it seemed like it needed to be construed. 10:18:42 10:18:47 10:18:53

Q. And for passive hydraulic link, you had an opinion on December the 2nd, 2020, but then decided no construction was necessary one week later and maintained that no construction necessary 14 months later, on February 1, 2024, correct? 10:18:55 10:19:00 10:19:03 10:19:05 10:19:08

MR. CHOW: Objection; form. 10:19:11

THE WITNESS: It appears that this term isn't one of the main terms that's at dispute here between the two parties. And so it didn't seem like it needed to be included here. 10:19:12 10:19:16 10:19:22 10:19:26

Q. (BY MR. PHILBIN) How did you formulate your opinion as to which terms were at dispute between the parties? 10:19:28 10:19:30 10:19:32

A. This was -- I was asked to construe? For example, in the 12/2/22 case, you know, GM and the law firm asked me to construe terms. 10:19:36 10:19:39 10:19:45

Q. Is that a longwinded way of saying you learned from the lawyers? 10:19:50 10:19:52

A. It's a way of saying that I was asked to construe specific terms, and I did. 10:19:53 10:19:55

Q. By the lawyers? 10:19:58

A. Yes. 10:19:59

Q. By no one else? 10:20:00

A. Not that I'm aware of. 10:20:01

Q. Are there any other terms that are in dispute, other than the ones contained on Exhibit 2? 10:20:03 10:20:06

A. I don't think I would have any -- you know, I wouldn't know in the bigger case if there's a dispute between the two parties. 10:20:10 10:20:17 10:20:22

Q. As you sit here today, the only disputed terms that you're aware of between the parties are contained on Exhibit Number 2; is that correct? 10:20:23 10:20:26 10:20:29

A. Let me look at -- as far as I'm aware, that's the case. 10:20:32 10:21:07

Q. Okay. For the term "valve needle," you had one construction on December the 2nd, 2022, then no construction one week later, and then a different construction on February 1, 2024, correct? 10:21:08 10:21:16 10:21:21 10:21:23

A. Correct.
Q. And for the term "valve member," you had one construction on December 2, 2022, no construction on December 9, 2022, and a new and different construction on February 1, 2024, correct?
A. I mean, I wouldn't say that there -- it's a new construction. It's maybe new wording, but my opinion is the same in all three cases.
Q. Okay. And same for "fluid passage"; you had one construction on December 2, 2022, no construction one week later, and a different construction 14 months later, correct?
A. Again, I believe that those are all --
MR. CHOW: Objection; form.
THE WITNESS: -- the plain and ordinary meaning. And if a word has changed or something between two of the declarations, that was to make it more clear in the more recent cases.
Q. (BY MR. PHILBIN) Would you agree with me that a person's -- of ordinary skill's understanding of the art at the time of the invention is fixed?
A. I think that it's different for each person. You know, every person that was skilled in the art would have a different experience in 1999. And so I don't think there's any such thing as one

way to see that view.
But, you know, the date was the date. Whatever people had at that date was what it was.
Q. So let me see if I can expand on what you just testified to.
If we had five persons of ordinary skill in the art in the room, it's your opinion they might have five different understandings of a particular claim term.
A. I mean, their opinions, so they surely could.
Q. And their opinions of what someone of ordinary skill in the art would depend on what knowledge they had at the time of invention, in this case in 1999, correct?
A. Correct. And we're assuming that they have a degree in mechanical engineering, and they have experience in the field, two years or more, or kind of equivalent. But, for each person, that would be different.
Q. In your opinion, does a person of ordinary skill in the art's understanding of the invention, at the time of the invention -- is that fixed or shifting?
A. I mean, it's -- the -- so the true

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10:23:32
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10:23:38
10:23:41
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10:23:55
10:23:56
10:23:59
10:24:04
10:24:07
10:24:09

understanding of a person skilled in the art at that date in 1999 is what it is. It is what it was on that date. 10:24:24 10:24:29 10:24:36

And, yes, if you get ten of them together, they're each going to have their own experience, which is different. 10:24:37 10:24:39 10:24:42

So it's fixed in a sense of that on that day, their experience was what it was. But that doesn't mean that different people won't come to a different conclusion based on their personal experience. 10:24:44 10:24:48 10:24:52 10:24:55 10:25:00

Q. Let me ask it this way. Are you here to opine what every person of ordinary skill in the art could have understood these claim terms to mean as of October of 1999? 10:25:00 10:25:03 10:25:07 10:25:11

A. I'm trying to represent what the average person would have. 10:25:12 10:25:15

Q. Okay. 10:25:17

A. As far as experience. 10:25:18

Q. And you considered yourself above average as of October of 1999; is that correct? 10:25:19 10:25:22

A. As of October of 1999? 10:25:24

Q. Yes. 10:25:28

A. I was an undergraduate in October of 1999, so I don't know if I would be above average then, 10:25:28 10:25:34

right? That's pretty hard. I didn't have a degree. I didn't have much work experience. 10:25:38 10:25:41

Q. Should an expert's opinion vary depending on what court they're in? 10:25:44 10:25:57

A. I think the expert's opinion is what it is. I don't think that it depends on whether you're in court or not. 10:25:59 10:26:03 10:26:06

Q. So we see in Exhibit 2, when you submitted your declarations on October the 9th, 2022, you didn't propose any claim constructions, yet, in the other two venues, you did propose claim constructions, correct? 10:26:09 10:26:14 10:26:18 10:26:22 10:26:26

A. Again, we're -- I'm proposing that the terms take their plain and ordinary meaning, unless, you know, expressly put in the document what the definition is. So... 10:26:27 10:26:32 10:26:39 10:26:43

Q. Okay. Let -- 10:26:45

A. Whether that was enough to make it clear to all the parties involved, maybe that has -- is different. And so I'm trying to make sure that it's clear what the plain and ordinary meaning is. 10:26:46 10:26:51 10:26:55 10:26:58

Q. Okay. Let's take the first term on Exhibit Number 2. In this case, you've opined that "lift" means displacement of the valve/member away from its closed/seated position to its open position, correct? 10:27:02 10:27:05 10:27:08 10:27:14

A. That looks correct. 10:27:19
Q. That's different than what you submitted on 10:27:21
December the 9th, 2022, correct? 10:27:23
A. Those are maybe different words, but I 10:27:26
believe that the opinion is consistent. 10:27:29
Q. So do you believe that your definition of 10:27:31
"lift" is plain and ordinary meaning? 10:27:33
A. I think it was consistent with the plain 10:27:36
and ordinary meaning. But -- let me look at the 10:27:43
document for a second here. Okay. 10:27:49
So in Patent 829 -- so I'm looking at the 10:28:04
declaration on page 48, paragraph 127 -- the 10:28:27
specification states that the "Lift in the context of 10:28:31
the needle valve is defined herein as the 10:28:36
displacement of the valve needle away from its 10:28:40
closed/seated position to its open position." 10:28:44
And then the 8 -- 138 patent has language 10:28:48
also that uses the -- is defined herein with 10:28:56
essentially, I think, exactly the same wording. And 10:29:00
so I think that it is the expressed definition of the 10:29:05
authors since they have said that it's the 10:29:11
definition. And so we should take that as the term. 10:29:14
But that is also consistent, I believe, 10:29:20
with what someone would -- in the skill in the art 10:29:24
would think the plain and ordinary meaning to be. 10:29:29

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Q. And you didn't make the argument on December the 9th, 2022, that the patent contained a specific definition, correct? Of "lift"? 10:29:35 10:29:38 10:29:41

A. It's on the December 2nd. 10:29:45

Q. December 9, the one on the right? 10:29:47

A. December 9. So, again, I don't think that we necessarily thought it -- I didn't think it was necessary to put in there because it seems like it's the plain and ordinary meaning. 10:29:50 10:29:57 10:30:04 10:30:12

Q. Okay. So it's your opinion that someone could take any of the definitions on Exhibit 2 and argue them to a different forum as plain and ordinary meaning, correct? 10:30:13 10:30:16 10:30:20 10:30:24

MR. CHOW: Objection; form. 10:30:26

THE WITNESS: Yeah. I don't think I understand your question. 10:30:27 10:30:28

Q. (BY MR. PHILBIN) All of your opinions on Exhibit 2 are plain and ordinary meaning, correct? 10:30:29 10:30:31

A. So "lift" is that, and also it has been explicitly given. So the patent author acted to explicitly define "lift." 10:30:35 10:30:42 10:30:49

Q. Would you agree with me that your construction of "valve needle" is different on December 2, 2022, and February 1, 2024? 10:30:51 10:30:54 10:30:59

A. The wording is different between the two, 10:31:01

yes, but the opinion is the same. 10:31:05

Q. Let's just break that down for a minute. 10:31:06

What's your plain and ordinary meaning understanding of "valve"? 10:31:08 10:31:10

A. Well, I haven't done the analysis on that term exactly. So, you know, I'm not sure I can give you a nice buttoned-up version of it, but... 10:31:14 10:31:18 10:31:25

Q. So, as you sit here today, you can't give me the plain and ordinary meaning of the term "valve," correct? 10:31:29 10:31:32 10:31:35

MR. CHOW: Objection; form. 10:31:36

I didn't think he finished his answer yet, Counsel. 10:31:38 10:31:38

Q. (BY MR. PHILBIN) Yes or no? Can you give me a plain and ordinary meaning of the term "valve"? 10:31:40 10:31:42

A. Whether I would give one that had the depth of analysis behind it that I would want for it to be my opinion, I would say no, not right now. 10:31:47 10:31:50 10:31:53

Q. Okay. 10:31:58

A. But I surely can discuss valves. I've been working on valves for 25 years. So I know a lot about valves. 10:31:58 10:32:04 10:32:08

Q. How many different types of valves are you aware of as you sit here today? 10:32:09 10:32:12

A. It would take a long time to count, I would 10:32:14

say. 10:32:19

Q. Hundreds? 10:32:19

A. I don't know. I mean, you know, I think it would be hard to classify exactly what you're asking in terms of how are we saying this versus that, but, you know, this is -- this was one of our primary focuses when I was in industry, was valve technology. 10:32:20 10:32:27 10:32:31 10:32:38 10:32:42

Q. Sir, my question was: How many? 10:32:46

Can you answer that question? 10:32:48

A. I can't give you a specific number. 10:32:49

Q. Okay. This deposition will go much smoother if you just refine your answer to my question. So when I ask "How many," I'm looking for a number. And if you don't know, simply say, "I don't know." I don't need an editorial comment. 10:32:51 10:32:55 10:32:58 10:33:00 10:33:02

Fair? 10:33:04

MR. CHOW: Counsel, I don't think that's an inappropriate instruction. His answer is going to be his answer. 10:33:04 10:33:06 10:33:08

Q. (BY MR. PHILBIN) How many valves are you aware of as you sit here today? 10:33:08 10:33:10

A. I would have to count if you want a number. I mean, that would not be a reasonable thing to do right now. Many. 10:33:13 10:33:16 10:33:19

Q. As you sit here today, can you testify as 10:33:20

to the plain and ordinary meaning of the term "valve" to a person of ordinary skill in the art as of October 1999? 10:33:23 10:33:26 10:33:30

A. I have not done the in-depth analysis of that term, but I believe that I, you know, understand that term very, very well. 10:33:31 10:33:34 10:33:38

Q. As you sit here today, can you testify about the plain and ordinary meaning of the term "needle"? 10:33:40 10:33:43 10:33:47

A. Again, I haven't maybe, specifically, looked at just that term. We're not looking at these terms in a vacuum. That wasn't what I was asked to do. 10:33:47 10:33:51 10:33:55 10:33:59

Q. Okay. In the context of the patents-in-suit, as of October of 1999, what was the plain and ordinary meaning of the term "valve" to a person of ordinary skill in the art? 10:33:59 10:34:02 10:34:07 10:34:09

A. Again, I haven't done the analysis on that. I can give you a more quick opinion. I mean, something less than an opinion. 10:34:10 10:34:13 10:34:17

Q. So, as you sit here today, you don't have an opinion? 10:34:20 10:34:23

A. I haven't formed a careful opinion with that. That wasn't what I was asked to do. 10:34:23 10:34:28

Q. In the context of the patents-in-suit, as 10:34:31

of October 1999, what was the plain and ordinary meaning of the term "needle" to a person of ordinary skill in the art? 10:34:34 10:34:37 10:34:42

A. Again, I don't -- I wouldn't say that that is what -- the term that I was asked to construe. So I haven't formed a formal opinion of that, perhaps. 10:34:44 10:34:48 10:34:53

Q. In the context of the patents-in-suit, as of October 1999, what was the plain and ordinary meaning of the term "member" to a person of ordinary skill in the art? 10:34:58 10:35:03 10:35:06 10:35:11

A. Again, I think this is a hypothetical. I can't take that out of context and just think of what a member is. So I have not formed an opinion on the term "member." 10:35:12 10:35:16 10:35:19 10:35:24

I think that people in the -- skills in the art would take that very many different ways, depending on the context. 10:35:26 10:35:28 10:35:32

Q. In the context of the patents-in-suit, as of October 1999, what was the plain and ordinary meaning of the term "interior" to a person of ordinary skill in the art? 10:35:34 10:35:37 10:35:40 10:35:43

A. Again, I don't think I have done the analysis on the term "interior," and so I can't provide a specific one. I surely can offer opinions on interior chamber if you like. 10:35:45 10:35:48 10:35:53 10:36:00

Q. Okay. I'm going to ask you a series of terms. And my question is: In the context of the patents-in-suit, as of October the 1st, 1999, do you have an opinion as to the plain and ordinary meaning of that term to a person of ordinary skill in the art direct? 10:36:04 10:36:08 10:36:11 10:36:16 10:36:18 10:36:23

A. I believe that this is an ambiguous question. 10:36:24 10:36:29

Q. Indirect? 10:36:30

A. Again, I believe this is ambiguous. 10:36:31

Q. Sealed? 10:36:34

A. Again, without context, I don't think that I can do that. 10:36:36 10:36:43

Q. Passive? 10:36:43

A. The same answer. 10:36:44

Q. Active? 10:36:46

A. The same answer. 10:36:47

Q. Link? 10:36:49

A. Again, I think without context, talking about specifically what we're talking about, I can't provide you that answer. 10:36:52 10:36:56 10:36:59

Q. Passage? 10:37:01

A. Same answer. 10:37:02

Q. Chamber? 10:37:04

A. Again, I think without context, I don't see 10:37:05

that I have a carefully worded construction for those terms. 10:37:16 10:37:21

Q. Hydraulic? 10:37:22

A. The same answer. 10:37:24

Q. Unsealed? 10:37:26

A. Again, I am -- know all of these terms. It's not that I have done the careful analysis to come up with a formal opinion on what the formal definition is of those. 10:37:29 10:37:41 10:37:43 10:37:47

Q. Injection? 10:37:48

A. The same answer. 10:37:53

Q. Port? 10:37:54

A. The same answer. 10:37:55

Q. Struck? 10:37:56

A. The same answer. 10:37:57

Q. Pintle fuel injector? 10:37:59

A. The same thing. 10:38:02

Q. So in formulating your opinions in this case, you did not form an opinion to any of the terms as to the plain and ordinary meaning to a person of ordinary skill in the art in October of 1999 for "valve," "needle," "member," "interior," "direct," "indirect," "sealed," "passive," "active," "link," "passage," "chamber," "hydraulic," "unsealed," "injection," "port," "stroke," or "pintle fuel 10:38:06 10:38:09 10:38:16 10:38:19 10:38:23 10:38:26 10:38:30 10:38:33

injector," correct? 10:38:37
MR. CHOW: Objection; form. 10:38:37
THE WITNESS: I made sure that I 10:38:39
understood everything that was in the patent and 10:38:46
the evidence that's involved with that. 10:38:48
Did I form a formal opinion of those 10:38:52
terms? No, because that wasn't what we were tasked 10:38:57
to do. 10:39:01
I formed the formal opinions on the 10:39:01
words, the phrases that I was asked to construe. 10:39:05
And the other terms I afforded the plain and 10:39:08
ordinary meaning as I understand them in 1999 in 10:39:12
October. 10:39:16
Q. (BY MR. PHILBIN) Is the plain and ordinary 10:39:17
meaning of interior the opposite of exterior? 10:39:19
MR. CHOW: Objection; form. 10:39:22
THE WITNESS: I think it depends on the 10:39:23
context we have to look at. 10:39:25
Q. (BY MR. PHILBIN) Give me an example of 10:39:28
context where interior is not the opposite of 10:39:30
exterior. 10:39:34
A. I surely haven't considered every possible 10:39:35
configuration for any hypothetical situation, so... 10:39:38
Q. But you're not comfortable testifying that 10:39:45
exterior is the opposite of interior to a person of 10:39:49

ordinary skill in the art in October 1999; is that correct? 10:39:53 10:39:57

A. Again, without being specific and looking at what we're talking about, it is, I think -- I can't form an opinion on that. 10:39:57 10:40:00 10:40:04

Q. Okay. For a fuel injector, can you give me an example of an exterior chamber? 10:40:06 10:40:15

MR. CHOW: Objection; form. 10:40:21

THE WITNESS: So the -- again, this seems quite hypothetical to think about what this is, but, okay. 10:40:23 10:40:32 10:40:35

Is it exterior to the engine? Is it exterior to the injector. 10:40:37 10:40:41

For example, if it was exterior to the injector, then maybe the combustion chamber is exterior chamber to that. 10:40:43 10:40:46 10:40:52

Q. (BY MR. PHILBIN) If I took the example of this hotel, would you agree with me that the floor that we're sitting on is an interior chamber? 10:40:56 10:40:58 10:41:00

MR. CHOW: Objection; form. 10:41:05

THE WITNESS: It is inside the building, and it's a room -- is a room of a chamber. We'd have to be careful on how we define that. 10:41:06 10:41:10 10:41:14

Q. (BY MR. PHILBIN) Okay. So you can't opine that the floor of the hotel is an interior chamber to 10:41:16 10:41:18

the hotel; is that your testimony? 10:41:22
A. I have not considered this hypothetical, so 10:41:23
I would have to consider it to give a formal 10:41:26
definition of whether it is or whether it's not. 10:41:29
Q. Okay. Is every room in the hotel an 10:41:31
interior chamber to the hotel? 10:41:34
A. Again, I can't form a formal opinion on 10:41:37
that without considering the hypothetical and really 10:41:41
looking at the specifics. 10:41:44
Q. Are the drawers in that cabinet an interior 10:41:45
chamber to the cabinet? 10:41:53
A. I think it, again, takes performing the 10:41:55
careful analysis to know. 10:41:57
Q. Okay. Can you identify, as you sit here 10:41:58
today, an interior chamber to this hotel? 10:42:01
A. I have not considered it, but -- so I 10:42:05
haven't given it any thought. 10:42:09
Q. Do you have an opinion that interior 10:42:11
chamber is something different than every chamber 10:42:13
that's on the interior? 10:42:18
MR. CHOW: Objection; form. 10:42:20
THE WITNESS: You're asking if the 10:42:21
interior chamber? 10:42:22
MR. PHILBIN: No. No. I'm not saying 10:42:24
"the." An interior chamber -- is every chamber 10:42:26

interior to whatever the device is that of an interior chamber? 10:42:31 10:42:36

MR. CHOW: Same objection. 10:42:37

THE WITNESS: Ask the question one more time. I'm making sure I'm being very careful with your wording. 10:42:42 10:42:43 10:42:47

Q. (BY MR. PHILBIN) Is every chamber on the inside of the device an interior chamber? 10:42:49 10:42:50

A. So again, that's a hypothetical. I think that you could call an interior chamber a room and not an interior chamber. And so if that's how you defined it, then surely then it would be a room. 10:42:53 10:42:55 10:43:02 10:43:06

Q. (BY MR. PHILBIN) Do you have an understanding of the plain and ordinary meaning of the term "stroke transmission"? 10:43:11 10:43:15 10:43:18

A. I have not construed that term, so I do not have a formal definition of that. 10:43:21 10:43:24

Q. Okay. Do you have an understanding of the plain and ordinary meaning of "stroke translation"? 10:43:24 10:43:27

A. Again, I understand what the term means. Do I have a formal definition of it? I would not say so. I've not done the analysis of that term. 10:43:29 10:43:33 10:43:37

Q. Is a pintle fuel injector a type of fuel injector used in rocket engines? 10:43:40 10:43:44

A. It is. 10:43:46

Q. Is a pintle fuel injector a type of fuel injector used in a bipropellant rocket engine? 10:43:47 10:43:51

A. It can be. 10:43:55

Q. As a starting place, do you agree or disagree that the plain and ordinary meaning can only have one meaning? 10:43:58 10:44:00 10:44:03

A. The plain and ordinary meaning I believe is an opinion, and so my opinion of it and someone else's opinion of it may be different. 10:44:04 10:44:16 10:44:21

Q. So based on that, you believe that the plain and ordinary meaning can have multiple meanings, correct? 10:44:23 10:44:26 10:44:28

A. Whether it's -- again, I believe it's an opinion, and so people's opinions surely can be different. 10:44:31 10:44:36 10:44:41

Q. Does that mean multiple? 10:44:41

A. It's more than one. 10:44:43

Q. Okay. What's your understanding of what multiple is? 10:44:44 10:44:48

A. More than one. Sure. 10:44:49

Q. Okay. So you would agree with me that your opinion is that you can have multiple plain and ordinary meanings for any given term, correct? 10:44:50 10:44:52 10:44:56

A. I'm saying that if you have a group of people of the ordinary skill in the art at a given 10:44:58 10:45:01

time and you ask them what the plain and ordinary meaning is, that you will not get, necessarily, the same answer from each one. 10:45:05 10:45:08 10:45:10

Q. In your opinion, does the plain and ordinary meaning vary over time? 10:45:12 10:45:15

A. I would assume -- 10:45:16

MR. CHOW: Objection; form. 10:45:19

THE WITNESS: -- that as someone gains more experience or has new evidence or makes new scientific discoveries, that their opinion of what the term means would change or could change. 10:45:20 10:45:25 10:45:30 10:45:36

Q. (BY MR. PHILBIN) So could you answer yes or no? Does the plain and ordinary meaning vary over time? 10:45:40 10:45:42 10:45:45

A. Whether yes or no, I think it could. 10:45:45

Q. Okay. In your opinion, does the plain and ordinary meaning of a term vary by location? 10:45:49 10:45:53

A. If by "location" you mean, from the same people at different locations, or different people in different locations? 10:45:55 10:46:07 10:46:11

Q. So you can't testify that the plain and ordinary meaning is consistent no matter what location in the United States, correct? 10:46:13 10:46:19 10:46:21

MR. CHOW: Objection; form. 10:46:24

THE WITNESS: Again, I think that it's 10:46:25

based on the person of the ordinary skill's opinion, and if they have different work experience. For example, working at two different companies at two different locations, then their opinion may be different. 10:46:27 10:46:32 10:46:35 10:46:39 10:46:42

Q. (BY MR. PHILBIN) Do you recall your testimony where you said different fuels were similar? 10:46:43 10:46:51 10:46:54

A. Yes. 10:46:54

Q. If I put diesel fuel in a commercial airliner, what would happen? 10:46:56 10:47:00

MR. CHOW: Objection; form. 10:47:02

THE WITNESS: So, for example, if the engine was supposed to run on jet fuel as you're asking? 10:47:03 10:47:06 10:47:11

Q. (BY MR. PHILBIN) Let's say supposed to run on Jet-A, and you put diesel fuel in, what happens? 10:47:11 10:47:13

A. It would probably perform very similar to -- with jet fuel. 10:47:17 10:47:20

Q. Would you take off in a plane loaded with diesel fuel instead of Jet-A fuel? 10:47:23 10:47:28

A. That's a strange hypothetical. Would I run it in a stand where personal safety was not involved? Sure. 10:47:30 10:47:33 10:47:37

Q. Is there a difference in the way you store 10:47:38

jet fuel and diesel fuel? 10:47:41
A. I'm not really familiar with mass storage 10:47:43
of these things. But they should be stored, I would 10:47:48
say, fairly similar. I'm not sure. 10:47:52
Q. And if you put diesel fuel in a rocket, 10:47:55
would it launch? 10:47:59
A. It depends on the rocket. 10:48:00
Q. Can you identify any rockets that would 10:48:03
launch with diesel fuel in them? 10:48:07
A. If the rocket was designed to run with RP1, 10:48:09
and you replaced it with diesel, I believe that it 10:48:12
would work, you know, fairly well. 10:48:16
There's certain things -- maybe things 10:48:21
could get clogged in things, maybe because, 10:48:24
essentially, you're -- have more careful control 10:48:27
over one fuel than the other. But, you know, as 10:48:30
far as overall function, they should be similar. 10:48:37
Q. Are you aware of any changes in the diesel 10:48:40
fuel industry that happened between 1997 and 2003? 10:48:51
A. I don't recall the year that Tier 1 10:48:56
emissions came in, but it was kind of in that range. 10:49:04
I believe that's what it was called, which was a big 10:49:07
change to the industry. 10:49:11
Q. Anything else? 10:49:12
A. I don't remember the exact years, but that 10:49:13

was also around when the, you know, light pickup systems were changing, you know, from older-style injectors to more, like, common rail-style injectors. 10:49:23 10:49:28 10:49:33

Q. Do you know what year that happened? 10:49:37

A. I do not. 10:49:38

Q. Do you know what year Tier 1 emissions happened? 10:49:40 10:49:41

A. I do not. 10:49:41

Q. Can you get within five years? 10:49:42

A. It would be a guess. I don't remember the -- 10:49:44 10:49:46

Q. Can you get within five years of the light pickup systems changing from the older-style injector to the newer-style injector? 10:49:51 10:49:54 10:49:57

A. Again, I believe it was in that period, but I'm not 100 percent sure. 10:50:00 10:50:03

Q. In October of 1999, who were the top five manufacturers of diesel fuel injectors? 10:50:05 10:50:15

A. I surely don't know. I don't have stats off the top of my head from 1999. 10:50:20 10:50:24

Q. Which fuel injector manufacturers can you identify that sold fuel injectors -- or made fuel injectors in October of 1999? 10:50:27 10:50:32 10:50:34

A. So Bosch, Siemens, Denzo, probably Stanadyne, Caterpillar, Sturman was making them then, 10:50:36 10:50:42

so international. Those are the ones I can think of off the top of my head. 10:50:51 10:51:14

Q. Okay. When did diesel engines first start including fuel injectors? 10:51:16 10:51:19

A. I surely don't know a date for any of the early development of diesels. 10:51:23 10:51:28

Q. Are you finished? 10:51:34

A. I don't think I'm totally understanding. I mean, like -- 10:51:36 10:51:40

Q. The question is, When did diesel engines first start including fuel injectors? 10:51:41 10:51:44

A. So, I mean, somewhere around the creation of the diesel engine, I assume. I'm not sure. 10:51:48 10:51:52

Q. What percentage of light-duty trucks used diesel fuel injectors in 1999? 10:51:57 10:52:00

A. What percentage of -- say that again. 10:52:04

Q. Light-duty trucks used diesel fuel injectors in 1999? 10:52:06 10:52:10

A. I do not have any idea. I don't know statics off the top of my head for that. 10:52:12 10:52:15

Q. What percentage of fuel injectors in 1999 were direct versus indirect? 10:52:19 10:52:21

MR. CHOW: Objection; form. 10:52:24

THE WITNESS: By "direct" or "indirect," what do you mean? 10:52:25 10:52:27

Q. (BY MR. PHILBIN) You don't understand those terms? 10:52:28 10:52:30

A. There are multiple ways that can be construed. 10:52:30 10:52:33

Q. Okay. So you can't answer the question, What percentage of fuel injectors in 1999 were direct versus indirect; is that right? 10:52:34 10:52:36 10:52:42

MR. CHOW: Objection; form. 10:52:43

THE WITNESS: It's an ambiguous question. I would need more information. 10:52:44 10:52:48

Q. (BY MR. PHILBIN) What percentage of fuel injectors in 199 -- strike that. 10:52:50 10:52:51

What percentage of diesel fuel injectors in 1999 were direct? 10:52:53 10:52:56

A. Again, that's an ambiguous question, so I don't know. 10:52:58 10:53:03

Q. Who was Bosch's biggest competitor for diesel fuel injector sales in 1999? 10:53:03 10:53:07

MR. CHOW: Objection; form. 10:53:12

THE WITNESS: I do not know. 10:53:13

Q. (BY MR. PHILBIN) You were deposed on January 12, 2023, in a related case involving the same patents, correct? 10:53:15 10:53:26 10:53:30

A. I do not remember the specific date, but it sounds right. 10:53:31 10:53:35

Q. You recall being deposed, correct? 10:53:35
A. I do. 10:53:38
Q. You testified truthfully in that prior deposition, correct? 10:53:39
A. I did. 10:53:42
Q. You were provided a copy of the transcript of your prior deposition, correct? 10:53:43
A. I was. 10:53:45
Q. You had the opportunity to review the transcript of your prior deposition, correct? 10:53:47
A. Correct. 10:53:49
Q. You had the opportunity to correct any mistakes in your prior deposition, correct? 10:53:51
A. Correct. 10:53:52
Q. You did not make any corrections, right? 10:53:54
A. Correct. 10:53:57
Q. You stand by your prior testimony as you sit here today? 10:53:57
A. I do. You know, it's hard to say that you're 100 percent accurate when you're asked many, many questions, but as far as I know, yes. 10:54:00
Q. Well, if you want to change anything, now is the time. Let me know. 10:54:00
A. As far as I know, there's nothing to change. 10:54:04
10:54:05
10:54:09
10:54:12
10:54:16
10:54:18
10:54:20
10:54:23

Q. All right. Would you look at Exhibit 3, sir? 10:54:23 10:54:34

A. (The witness complied.) 10:54:38

Q. I believe that's your -- your declaration, correct? 10:54:39 10:54:44

A. Correct. 10:54:44

Q. I want you to take as long as you need, but I want to know if you prepared Exhibit 3? 10:54:44 10:54:50

A. I did. 10:54:53

Q. And is Exhibit 3 complete? 10:54:54

A. As far as I can tell. 10:54:58

Q. You were truthful, honest, and forthright in what you wrote in Exhibit 3, correct? 10:55:34 10:55:38

A. I was. 10:55:41

Q. You had plenty of time to consider your opinions and correct any mistakes before you signed and submitted your declaration, Exhibit Number 3, correct? 10:55:42 10:55:45 10:55:48 10:55:51

A. Correct. 10:55:51

Q. As you sit here today, is there any part of your declaration you need to change or correct? 10:55:52 10:56:01

A. Not that I'm aware. 10:56:03

Q. Are there any false or misleading statements in Exhibit Number 3? 10:56:04 10:56:06

A. Not that I'm aware of. 10:56:08

Q. What portions of Exhibit Number 3 were you providing for lawyers? 10:56:09 10:56:14

A. The entire document, I would say, is my work product. I have worked with my legal team on developing it. 10:56:15 10:56:23 10:56:28

Q. When you testified to your "legal team," how many lawyers were on your legal team? 10:56:31 10:56:34

A. I can't say a specific number. I work close with Michael and Bosch. 10:56:37 10:56:42

Q. So at least two? 10:56:44

A. Correct. 10:56:46

Q. Plus three in-house lawyers at Bosch, correct? 10:56:47 10:56:53

A. That's -- I don't know 100 percent, but that's what it seems like. 10:56:53 10:56:56

Q. Okay. Did you review Rule 4-3B of the eastern district of Texas local patent rules before submitting your declaration? 10:56:57 10:57:02 10:57:07

A. I relied on my legal counsel for developing the -- what do you call it? The legal standards by which to use in this case. 10:57:08 10:57:11 10:57:18

Q. Okay. Let's turn to page 1, Section 1, Qualifications, in Exhibit Number 3. 10:57:19 10:57:25

Did you prepare all of Section 1, Qualifications? 10:57:27 10:57:31

A. I believe I prepared -- yes. All of this. 10:57:32
Q. What criteria did you use to decide what qualifications to list in Section 1 qualifications in Exhibit 3? 10:58:01 10:58:04 10:58:09
A. I was trying to provide a concise, yet relatively complete background of my experience in this field and related fields. 10:58:09 10:58:18 10:58:24
Q. In your opinion, does Section 1 of Exhibit 3 fairly and accurately list all of your qualifications relevant to this case? 10:58:27 10:58:30 10:58:37
A. No. 10:58:39
Q. No? Why didn't you include relevant qualifications in Section 1 of Exhibit 3 when you prepared it? 10:58:40 10:58:44 10:58:47
A. Well, you asked if I had all of them. I can't possibly find, you know, all of them. So that's what my CV is for and -- 10:58:48 10:58:52 10:58:57
Q. Were you given a page limit? 10:59:02
A. I was not. 10:59:04
Q. So you could have listed as many qualifications in Section 1 as you wanted, correct? 10:59:05 10:59:08
A. I put what I felt was the correct amount of qualifications to tell the reader that I was experienced in this field and other fields. 10:59:11 10:59:17 10:59:21
Q. And you listed enough qualifications in 10:59:24

Section 1 of Exhibit 3 to establish yourself as a person of ordinary skill in the art, in your opinion, correct? 10:59:27 10:59:32 10:59:37

A. Taken with my CV, which is obviously an exhibit in this document. I mean, that was the idea, is that this is the summary. 10:59:37 10:59:43 10:59:47

Q. Do you understand the purpose of Exhibit 3 is to give fair notice of your opinions to other parties? 10:59:51 10:59:54 10:59:57

A. That sounds consistent with my understanding. 10:59:58 11:00:03

Q. Do you believe Exhibit 3 does give fair notice of your qualifications, your opinions? 11:00:03 11:00:06

A. As far as I'm aware, yes. 11:00:09

Q. Okay. The first degree you obtained was in May of 2001, correct? 11:00:11 11:00:24

A. Correct. 11:00:26

Q. Your first relevant professional work experience started in May 2001, correct? 11:00:27 11:00:31

A. Sure, yes. I think so. I mean, I had -- again, I have experiences before that, like in undergraduate engineering, but that's the first time I was employed as a fuel system engineer. 11:00:34 11:00:48 11:00:52 11:00:54

Q. Nowhere in your qualifications do you talk about your undergraduate engineering work, correct? 11:00:56 11:00:59

A. But it's part of, you know, what we think of as a person of the ordinary skill in the art. We required that, right? 11:01:02 11:01:08 11:01:12

MR. PHILBIN: Objection; nonresponsive. 11:01:12

Q. (BY MR. PHILBIN) Can you answer my question? 11:01:14 11:01:15

A. So ask your question again. 11:01:16

Q. Nowhere in the Qualification Section of Exhibit 3 that you prepared do you list any undergraduate engineering experience, other than paragraph 6 that says you received a BS in mechanical engineering from Colorado State University in 2001, correct? 11:01:18 11:01:20 11:01:24 11:01:28 11:01:32 11:01:35

A. Again, I think that that was -- what I felt was the relevant overarching component of that time. That doesn't mean that that's all of my experience. 11:01:35 11:01:37 11:01:44

Q. Your first patent application on a fuel injection was filed on December 21, 2004, correct? 11:01:47 11:01:50

A. I would have to check, but it sounds like in the correct range of time. 11:01:55 11:01:57

Q. Are you aware of a patent application on a fuel injector on which you were a named inventor that was filed prior to 2004? 11:01:58 11:02:01 11:02:05

A. I do not recall the timing of our efforts in that. So I would not know. 11:02:07 11:02:10

Q. Looking at paragraph 13 of Exhibit Number 3, you contend that the patents you list in paragraph 13 of your declaration are in the same area of art as the patents-in-suit, correct? 11:02:13 11:02:20 11:02:23 11:02:26

A. The three are very close, and one in a similar vein, yes. 11:02:30 11:02:34

Q. So very close art or same art? 11:02:35

A. Well, I think three are in the same art, and one is in a closely-related field. 11:02:38 11:02:40

Q. Okay. Can you identify which patent number is in a closely-related field? 11:02:45 11:02:47

A. So the one that is not listed on here, but on my CV, is the one that I would say is a closely-related field, but not, you know, the same art. 11:02:49 11:02:52 11:02:56 11:03:00

It's for a hydraulic hybrid transmission instead of a injector. But lots of valves and hydraulics. 11:03:01 11:03:06 11:03:12

I'll give you the number here -- 11:03:14

Q. Sorry. 11:03:16

A. -- if you'd like. 11:03:16

Q. Sure. 11:03:17

A. It's Patent 8622859. 11:03:30

Q. Okay. Are you finished? 11:03:34

A. Yes. 11:03:37

Q. Okay. For the three patents that you testified were in the same art as the patents-in-suit, what possible explanation do you have for not disclosing the patents-in-suit to the patent office when you filed for your patent? 11:03:38 11:03:40 11:03:43 11:03:49 11:03:52

MR. CHOW: Objection; form. 11:03:56

THE WITNESS: Again, what patents were disclosed on the patent applications was part of, I would, you know -- I actually don't know. But it seems like it would have been made in conjunction with the legal team. 11:03:57 11:04:04 11:04:09 11:04:15 11:04:18

Q. (BY MR. PHILBIN) Could the reason you didn't disclose the patents-in-suit when you applied for patents in 2004 is that you were not aware of prior patents that predated your application? 11:04:19 11:04:21 11:04:26 11:04:30

MR. CHOW: Objection; form. 11:04:33

THE WITNESS: I can't possibly have known all of the patents prior to that date, you know, 6 million or 7 million of them. 11:04:34 11:04:38 11:04:44

Q. (BY MR. PHILBIN) As you sit here today, you can't testify whether you knew about the patents-in-suit prior to 2004, correct? 11:04:46 11:04:48 11:04:50

A. I do not recall the patents that I reviewed 20-something years ago. 11:04:54 11:04:57

Q. And you assert that you're a person of more 11:05:06

than ordinary skill in the art of the asserted patents, correct? 11:05:09 11:05:12

A. Yes. 11:05:13

Q. And you assert that you were a person of more than ordinary skill in the art as of October of 1999, correct? 11:05:14 11:05:16 11:05:20

MR. CHOW: Objection; form. 11:05:23

THE WITNESS: Again, on that date, I was not, but I believe that I have a good understanding of what someone -- a person of the ordinary skill in the art would have understood on that date. 11:05:23 11:05:30 11:05:32 11:05:35

Q. (BY MR. PHILBIN) Let me make sure I understand your testimony. Is it your testimony that you were not a person of ordinary skill in the art as of October of 1999? 11:05:39 11:05:42 11:05:44 11:05:48

A. So on that date, was I? 11:05:50

Q. Yes. 11:05:52

A. I was not. I was an undergraduate. I did not have the relevant experience needed on that specific date. 11:05:53 11:05:58 11:06:00

Q. So you would agree with me that on October -- in October of 1999, you were neither a person of ordinary skill in the art or a person of more than ordinary skill in the art in the asserted patents, correct? 11:06:01 11:06:02 11:06:06 11:06:10 11:06:14

A. On the date in October '99, I was not. But that doesn't mean that I am not now, and that I understand what a person of the ordinary skill in the art as of 1999 would understand. 11:06:15 11:06:19 11:06:24 11:06:29

Q. And the education that you've done, to go back in time, is in connection with your work on this case, correct? 11:06:33 11:06:36 11:06:40

A. Correct. 11:06:41

Q. And the way you educated yourself to go back in time is to first look at the patents, and second, look at materials sent to you by lawyers for Bosch, correct? 11:06:42 11:06:46 11:06:49 11:06:52

A. It's the patents, the history, the prior art, and my analysis of those contemporary documents. 11:06:53 11:06:57

Q. Okay. So you looked at the patents and materials sent from lawyers from Bosch. 11:07:01 11:07:04

Any other independent research that you did for materials that you consider? 11:07:07 11:07:09

A. Again, I looked through the history. And if there wasn't -- you know, for example, I would look up patents that related to the history. 11:07:13 11:07:15 11:07:19

I don't think I quite understand your question here, so... 11:07:23 11:07:26

Q. Okay. When you testify about history, are you testifying about prosecution history? 11:07:27 11:07:30

A. Yes. 11:07:32
Q. Can you identify a single document that you used to attempt to reconstruct knowledge of a person of ordinary skill in the art, in October of 1999. That was not provided to you by lawyers? 11:07:33 11:07:35 11:07:38 11:07:41
A. I can't pick out a specific example, but I surely was checking many patents. 11:07:45 11:07:50
Q. Why don't you turn to "materials reviewed" in Exhibit 3 that you prepared. That's Section 2 on pages 3 and 4. Identify for me any materials that you identified that you reviewed that were not sent to you by lawyers. 11:07:52 11:07:54 11:07:58 11:08:01 11:08:05
A. So let me check here -- well, so, I mean, the materials -- for example, it seems like F, G, and H are my work. So they were not provided to me. That's my work. 11:08:06 11:08:19 11:08:28 11:08:33
Q. F, G, and H? 11:08:36
A. Right. Is that -- F is the -- 11:08:39
Q. Responsive claim construction brief. 11:08:45
You prepared the responsive claim construction brief? 11:08:48 11:08:51
A. No. I think I'm off on which one's which. 11:08:51
MR. CHOW: I think he meant Exhibit F. 11:08:55
THE WITNESS: No. Sorry. 11:08:59
Q. (BY MR. PHILBIN) Sir, I'm asking you about 11:09:02

pages 3 and 4 of your declaration. 11:09:04

A. Yes. And I'm looking at the materials that are associated with them. 11:09:07 11:09:09

Q. Okay. 11:09:10

A. So -- okay. I was mistaken on that. Let's see. Let's see. Not that one. 11:09:12 11:09:16

Okay. So... 11:09:58

Q. I'm happy to go slow. Let's look on Exhibit 3, Section 2, the asserted patents. 11:10:43 11:10:47

Were those provided to you by the lawyers? 11:10:50 11:10:52

A. Yes. I think it seems like that, you know, the patents and the history are what we have here. 11:10:52 11:11:00

Q. Okay. 11:11:07

A. All right. Patents that we used -- that I used in forming my opinion. 11:11:07 11:11:12

Q. Okay. You prepared Exhibit 3, correct? 11:11:13

A. Yes. 11:11:17

Q. You prepared Section 2, Materials Reviewed of Exhibit 3, correct? 11:11:18 11:11:22

A. It is my work product, yes. 11:11:23

Q. Okay. Identify in Section 2, Materials Reviewed, of Exhibit 3 just by letter, under paragraph 16, all materials that were not provided to you by lawyers. 11:11:26 11:11:31 11:11:37 11:11:39

MR. CHOW: Sorry, Counsel. Just to clarify. Are you talking about the letters in paragraph 16? 11:11:42 11:11:45 11:11:46

MR. PHILBIN: Yes. The letters in paragraph 16, just like my question stated. 11:11:47 11:11:49

MR. CHOW: Okay. 11:11:51

MR. PHILBIN: Do you understand the question? 11:11:52 11:11:54

THE WITNESS: I believe so. 11:11:54

Q. (BY MR. PHILBIN) Okay. So paragraph 16 that you prepared has letters A through M. Tell me which of those letters did not come from the lawyers. 11:11:55 11:11:56 11:12:01

A. Again, I don't know, specifically. We worked on things like dictionary definitions back and forth, but -- so I couldn't tell you specifically on those. But the other ones, I believe, came from the lawyers. So I would have to go back and look on I, J, K, L, and M. 11:12:04 11:12:07 11:12:13 11:12:18 11:12:24 11:12:31

Q. So the five dictionaries, you think, may have come from a source other than the lawyers? 11:12:33 11:12:42

A. They may have come from my looking at the dictionaries. 11:12:44 11:12:48

Q. Okay. While we're on the topic of dictionaries, why didn't you consult the Dictionary of Automobile Engineering? 11:12:49 11:12:57 11:13:03

A. I used the resources that I had, and I thought that it gave a consistent take on it. And that was what I needed to form my opinion. 11:13:03 11:13:07 11:13:13

Q. When you formulated your opinions, were you aware of the Dictionary of Automobile Engineering? 11:13:15 11:13:18

A. I have not used that document. 11:13:21

Q. Have you ever known a Dictionary of Automobile Engineering to exist? 11:13:22 11:13:27

A. I have not. 11:13:28

Q. Okay. Have you ever looked? 11:13:29

A. I have not. 11:13:32

Q. Is the design of a diesel fuel injector valve closer to automotive engineering or mechanical engineering? 11:13:33 11:13:40 11:13:44

A. I don't really put a distinction between the two. I think of automotive engineering as a field within mechanic engineering, personally. 11:13:44 11:13:52 11:13:55

Q. You don't have a automotive engineering degree, correct? 11:13:56 11:14:01

A. No. But I have a mechanical engineering degree where -- that was many things were applicable to automotive engineering. 11:14:01 11:14:04 11:14:07

MR. PHILBIN: Sir, objection; nonresponsive. 11:14:10 11:14:10

Q. (BY MR. PHILBIN) My question was: You 11:14:12

don't have an automotive engineering degree, correct? 11:14:13
A. I do not have an automotive engineering 11:14:16
degree. 11:14:19
Q. Okay. You don't work as an automotive 11:14:19
engineer, do you? 11:14:22
A. Not currently, except for in consulting and 11:14:22
witnessing. 11:14:27
Q. And you haven't worked as an automotive 11:14:28
engineer since 2007; is that correct? 11:14:32
A. I have worked in automotive engineering 11:14:34
projects since then, but I have not been a full-time 11:14:38
employee at an automotive engineering firm since 11:14:42
then. 11:14:47
Q. And despite all your work in automotive 11:14:47
engineering, you weren't even aware that the 11:14:51
dictionary of automotive engineering exists, correct? 11:14:53
A. I haven't had a need to use it. 11:14:55
Q. Were there other technical or engineering 11:14:58
dictionaries that you were aware of that you didn't 11:15:03
cite in your declaration in this case? 11:15:05
A. I have a number of technical dictionaries 11:15:08
that I may have looked at. Whether -- they didn't 11:15:13
seem like maybe they were what I needed to form my 11:15:17
opinion, and so I did not include them. 11:15:19
Q. How many other technical dictionaries did 11:15:21

you look at and not include in your opinion? 11:15:25

A. I don't know. I have -- like I said, I 11:15:28

probably have four technical dictionaries. I can't 11:15:30

name the ones off the top of my head, but the ones 11:15:36

that I needed for the documents we included. And 11:15:42

that's what I needed to form my opinion in this case. 11:15:47

Q. Would it be fair to say that you looked at 11:15:50

other dictionaries but didn't rely on them? 11:15:53

A. I would say that is fair. 11:15:56

Q. And would you say that looking at a 11:15:58

dictionary is the same as reviewing a dictionary? 11:16:00

A. I'm not clear on what the legal definition 11:16:03

of "review" is. You know, I definitely could read 11:16:07

something and not review it in a sense of taking a 11:16:12

deep dive into it and really doing a thorough 11:16:16

analysis on it. 11:16:20

Q. Okay. So what's your explanation for 11:16:21

excluding the dictionaries that you looked at from 11:16:23

Section 2, the materials you reviewed? 11:16:27

A. Again, it would have been -- I looked at 11:16:30

it, read it. It didn't seem like it was necessarily 11:16:34

pertinent, and they didn't even have the term in 11:16:38

there, for example. And, so I didn't need it for 11:16:43

forming my opinion. 11:16:47

Q. Did you look at any SAE materials in -- 11:16:48

sorry. Strike that. 11:16:51

Did you review any SAE materials in 11:16:52

connection with forming your opinions? 11:16:55

A. As far as I know, no. 11:16:57

Q. Why not? 11:17:00

A. It didn't feel like that's what I needed to 11:17:01

form my opinion. 11:17:07

Q. Do you recall the titles of any of the four 11:17:08

dictionaries that you considered and didn't list in 11:17:11

Section 2 of Exhibit 3? 11:17:15

A. I do not. 11:17:16

Q. Would we have to come to your office to 11:17:17

find out? 11:17:22

A. Sure. 11:17:22

Q. You could understand someone coming to the 11:17:27

conclusion that you looked at eight dictionaries and 11:17:39

only cited four because you only liked the 11:17:43

definitions in the four you cited? 11:17:46

MR. CHOW: Objection; form. 11:17:49

THE WITNESS: I would think that someone 11:17:50

would understand that in looking at the definitions 11:17:53

that we're presenting a fair understanding of what, 11:17:59

you know, the terms mean. That's the point. 11:18:05

Q. (BY MR. PHILBIN) And you think it's fair 11:18:09

for materials reviewed to not include materials 11:18:10

looked at, correct? 11:18:13
A. I couldn't include every patent -- I can't 11:18:14
imagine every experience I had, every patent I ever 11:18:19
read, every article I had ever read about a diesel 11:18:25
fuel injector or such to go as material that is 11:18:29
informing my former opinion through this analysis. 11:18:34
It surely speaks to my experience as a whole, though. 11:18:39
Q. You looked at the four dictionaries 11:18:43
specifically in connection with this case, correct? 11:18:45
A. I looked through them for this case, yes, I 11:18:48
believe so. 11:18:52
Q. Okay. So we can agree there are four 11:18:52
technical dictionaries that are in your office that 11:18:55
you looked at for this case and didn't list in 11:18:58
Exhibit 3, Section 2, correct? 11:19:01
MR. CHOW: Objection; form. 11:19:03
THE WITNESS: Again, I maybe looked at 11:19:04
them. Whether I used them for forming my opinion, 11:19:06
I believe, no. 11:19:10
Q. (BY MR. PHILBIN) Okay. Can you answer my 11:19:10
question? 11:19:10
We can agree there are four technical 11:19:11
dictionaries that are in your office; you can't 11:19:14
recall the name of them; you looked at them in 11:19:17
connection with this case, and you didn't list them 11:19:19

in Exhibit 3, Section 2, correct? 11:19:22

MR. CHOW: Objection; form. 11:19:24

THE WITNESS: I would say that I looked through them, yes. Whether they're included or not, I don't remember which one's which here. 11:19:25 11:19:26 11:19:31

So, for example, I think it's -- Exhibit N, I believe, is probably one of the dictionaries that's sitting on my desk or on my shelf. It's the Dictionary of Mechanical Engineering by Oxford University Press. 11:19:34 11:19:57 11:20:05 11:20:10 11:20:15

Q. So you believe that's one of the four? 11:20:15

A. I do. 11:20:17

Q. So you can't identify the other three? 11:20:17

A. I do not. But they seemed like they weren't necessarily relevant to this, and so I didn't include them. 11:20:19 11:20:23 11:20:26

MR. PHILBIN: Let's take a short break. 11:20:34

THE VIDEOGRAPHER: We're going off the record. The time is 11:20 a.m. 11:20:36 11:20:37

(Whereupon, a recess was taken at 11:20 a.m.) 11:20:43 11:20:43

(Whereupon, the proceedings resumed at 11:32 a.m.) 11:20:43 11:32:26

THE VIDEOGRAPHER: We are back on the record. The time is 11:32 a.m. 11:32:26 11:32:32

Q. (BY MR. PHILBIN) Dr. Quinlan, are you ready to proceed? 11:32:35 11:32:40

A. I am. 11:32:41

Q. The highest level of academic promotion you have received was assistant professor, correct? 11:32:42 11:32:45

A. Correct. 11:32:47

Q. The first technical paper you wrote related to fuel injectors was in 2004, correct? 11:32:48 11:32:48

A. Correct. 11:32:51

Q. You came up with the definition of "person of ordinary skill in the art" in paragraph 26 of your declaration, Exhibit 3, correct? 11:32:51 11:32:54 11:32:58

A. I was -- we talked about it with the whole team of what we thought that a person of ordinary skill in the art would be, and that's what we selected. 11:33:01 11:33:11 11:33:15 11:33:17

Q. Okay. And who all is included in "we," who we selected? 11:33:18 11:33:21

A. Well, I can't remember exactly, but, for example, Michael and Bosch. 11:33:22 11:33:24

Q. Okay. So two lawyers and you -- 11:33:27

A. Yeah. 11:33:29

Q. -- came up with the definition of "a person of ordinary skill in the art" in paragraph 26 of your declaration; is that correct? 11:33:30 11:33:31 11:33:34

A. As far as I can remember, I think that seems right. 11:33:35 11:33:39

Q. Okay. And you chose to select a degree in mechanical engineering rather than automotive engineering, correct? 11:33:39 11:33:47 11:33:50

A. Again, I don't necessarily think that those are separate things. Most universities don't have an automotive engineering program, I would say. It's not as common. And so automotive engineering-type projects are done, typically, within the mechanical engineering department very many times. 11:33:50 11:33:53 11:33:57 11:34:00 11:34:04 11:34:07

Q. You've been to South Carolina? 11:34:11

A. I've been there and stayed there. That's about it. 11:34:13 11:34:16

Q. I will just tell you I have got two boys studying engineering in South Carolina, and you drive down the highway, there's an automobile plant on the left and on the right. 11:34:16 11:34:20 11:34:22 11:34:24

A. Yeah. They all moved out of Detroit. 11:34:26

Q. And the universities there are specialized in automotive engineering, not mechanical engineering. It's a separate discipline. 11:34:28 11:34:30 11:34:33

Did you know that? 11:34:35

A. Again, I don't know if I consider it a separate discipline. Surely, you can start a 11:34:35 11:34:38

department that has that name, and great. I think what you cover is very much the same. 11:34:41 11:34:44

Q. As you sit here today, do you have an understanding as to what the term "fuel passage" means? 11:34:47 11:34:49 11:34:52

A. I believe I understand what a fuel passage is in the context of the specific patents that we're looking at. 11:34:53 11:34:56 11:35:00

Q. Okay. If I drive my car to the Costco to get gas, and I put the nozzle in the hole, would you agree with me that it's a fuel passage all the way from where the nozzle goes in the hole until it explodes in the engine? 11:35:01 11:35:07 11:35:12 11:35:17 11:35:19

MR. CHOW: Objection; form. 11:35:22

THE WITNESS: In the hypothetical that we are not looking at the patents at issue here, I mean, it is a fuel passage. Whether it's the fuel passage that -- you know, again, that we would be talking about specifically in this case, I don't think it is. 11:35:23 11:35:25 11:35:31 11:35:36 11:35:39 11:35:42

Q. (BY MR. PHILBIN) You're saying that the gas I put in my car that ends up running the engine doesn't go through a fuel passage to get from the nozzle to the engine? 11:35:43 11:35:47 11:35:51 11:35:55

A. It goes through, I would say, many fuel 11:35:57

passages, more likely, than just one. But this is in the hypothetical case if we're just looking at a general thing, not a specific thing with the patent. 11:36:00 11:36:06 11:36:10

Q. So you would not say the trail the fuel travels from when it goes to the nozzle to the engine, you wouldn't agree that's a fuel passage? 11:36:13 11:36:18 11:36:22

A. Well, again, I think it's multiple fuel passages, at least. 11:36:25 11:36:30

Q. Why can it not be just one? 11:36:31

A. Well, it goes through valves and pumps and filters and orifices and all kinds of things. So I don't know if it's one passage. 11:36:33 11:36:36 11:36:40

Q. Do you disagree that a fluid passage is the way fluid passes from one point to another? 11:36:48 11:36:52

MR. CHOW: Objection; form. 11:36:56

THE WITNESS: I think that there is a structure involved with a fuel passage that goes beyond going from Point A to Point B. 11:36:57 11:37:00 11:37:05

Q. (BY MR. PHILBIN) So it's your testimony that a person of ordinary skill in the art would not understand the trail from the gasoline nozzle to the engine to be a fuel passage? Is that your testimony? 11:37:09 11:37:10 11:37:14 11:37:17

MR. CHOW: Objection; form. 11:37:21

THE WITNESS: I would contend they understood that how the fuel got from the nozzle to 11:37:22 11:37:24

the combustion chamber. Whether they would consider it a passage, I don't think that's the case. 11:37:28 11:37:32 11:37:39

Q. (BY MR. PHILBIN) Would you agree that a needle valve is a type of valve? 11:37:39 11:37:44

A. A needle valve is a type of valve, yes. 11:37:46

Q. Is it true that a valve needle is a component of a needle valve? 11:37:50 11:37:56

A. A valve needle can be a component of a needle valve. 11:38:02 11:38:07

Q. Can a needle valve be a needle valve without having a valve needle? 11:38:09 11:38:15

A. Can a needle valve be a needle valve without having a needle? 11:38:18 11:38:24

Q. Without having a valve needle. 11:38:26

A. A valve needle. It's hard with the round and round, but it seems like for there to be a needle valve, we generally would think it includes a valve needle. 11:38:29 11:38:32 11:38:40 11:38:44

Q. So when I ask you, "Is it true that a valve needle is a component of a needle valve," the answer to that would just be "yes," right? 11:38:44 11:38:47 11:38:51

MR. CHOW: Object to the form. 11:38:53

THE WITNESS: I think it's the necessary and sufficient conditions. 11:38:55 11:38:58

Could another valve have something that is a needle, but a valve needle that we don't call it a needle valve? Maybe. I'm not sure. 11:39:01 11:39:03 11:39:08

Q. (BY MR. PHILBIN) Okay. Does every needle valve have a valve needle? 11:39:12 11:39:16

A. I surely -- that seems consistent with how I would understand it, is that a valve -- a needle valve would have a valve needle. 11:39:19 11:39:21 11:39:28

Q. Can a valve needle be a component of other types of valves that are not needle valves? 11:39:31 11:39:36

A. In hypothetical, it's hard to tell. I would say that we would have to look at a specific case and see what it is. 11:39:39 11:39:44 11:39:46

Q. Does a control valve have a valve needle? 11:39:50

A. Depends on the type of control valve, I would suppose, right. You could use a needle valve as a control valve, or a control valve could be some totally different valve. 11:39:54 11:39:58 11:40:01 11:40:05

Q. Can you look at a fuel injector diagram and find the valve needle? 11:40:05 11:40:09

A. I would hope so, yes. 11:40:11

Q. Could you look at a fuel injector diagram and find the needle valve? 11:40:12 11:40:15

A. I would hope so, yes. 11:40:18

Q. Does a spool valve have a valve needle? 11:40:20

A. Again, I think we would have to look at the specific spool valve and see whether or not it fits with the criteria that we come up with for what a needle is or a valve needle is. 11:40:24 11:40:28 11:40:34 11:40:38

Q. I noticed you just got those two terms confused? 11:40:43 11:40:46

A. I didn't get them confused, I misspoke. 11:40:47

Q. Would it be a true statement that, quote, "the terms 'valve needle' and 'needle valve' are interchangeable"? 11:40:50 11:40:53 11:40:56

A. No. 11:40:57

Q. Have you ever made the statement "the terms 'valve needles' and 'needle valve' are interchangeable"? 11:40:58 11:41:02 11:41:04

A. Not that I can recall, but you tell me. 11:41:05

Q. Would you agree that the statement, the terms 'valve needle' and 'needle valve' are interchangeable is false and misleading"? 11:41:10 11:41:13 11:41:15

A. I don't think it's false and misleading. Again, it would be easy to misspeak and be talking about one and mean the other. 11:41:18 11:41:25 11:41:32

You know, and I think, in general, thinking of the difference between the valve and the components of the valves are often kind of used interchangeably. 11:41:36 11:41:38 11:41:42 11:41:46

Q. Would a person of ordinary skill in the art understand, quote, "the terms 'valve needle' and 'needle valve' are interchangeable at the time of the invention in this case"? 11:41:48 11:41:51 11:41:55 11:41:58

A. No. I don't think that they're interchangeable in that sense. 11:41:59 11:42:01

Q. Okay. Would you look back at Exhibit 2. 11:42:04

So for the term "valve needle" on December 2, 2022, you had a construction that included a slender elongated pointed rod, correct? 11:42:13 11:42:16 11:42:24

A. Correct. 11:42:29

Q. And in your new construction on February 1, 2024, it does not include a pointed rod, correct? 11:42:30 11:42:34

A. Correct. 11:42:38

Q. Would you agree that the pointed rod is no longer required for a valve needle? 11:42:38 11:42:44

A. I think it doesn't get at the heart of the dispute. And so while I would say most are pointed, it doesn't seem like it helps the function whether the exact tip comes to a point or not. As we continue to look at it, I think that the opinion is the same. I'm trying to get across the same message, but I'm trying to do it in a more clear way that gets the message across in simpler language, I would say. 11:42:47 11:42:55 11:43:01 11:43:06 11:43:11 11:43:15 11:43:19 11:43:23

Q. Are you finished? 11:43:29

A. Yes.
MR. PHILBIN: Objection; nonresponsive.
Q. (BY MR. PHILBIN) Would you agree that the pointed rod that is no longer required for a valve needle using your February 1, 2024, construction of valve needle?
A. The component, depending on the situation, may or may not be pointed, it seems like. And it didn't, again, have to do with the function.
So to simplify the construction, to make it clearer, I thought it wasn't a necessary term at this point.
Q. So we can agree that in December of 2022, you had the specific requirement that the rod being pointed, and you have taken that specific requirement out in February of 2024 for the term "valve needle," correct?
A. The words in the -- have changed, but the idea that I'm trying to get across is the same.
Q. Is the valve component and a valve the same thing?
A. Again, I think sometimes we think of them as, you know, oh, hey, you know, point at the needle, and you might point at the needle valve, that it's somehow related in a looser term.

So to clear that up, we made sure that I think that it's more consistent to talk about a valve component here, and so we have changed words. I have changed the words, but again, the overall idea is the same. 11:44:55 11:44:59 11:45:02 11:45:06 11:45:09

MR. PHILBIN: Objection; nonresponsive. 11:45:11

Q. (BY MR. PHILBIN) Is a valve component the same thing as a valve? 11:45:14 11:45:16

A. Again, I think that at least in a less formal way, we might use them more interchangeably. I think here what we have done is I have changed the words so that it's more clear that we're talking about the component, specifically. 11:45:19 11:45:21 11:45:25 11:45:28 11:45:31

Q. Do you agree that a valve component is part of a valve? 11:45:33 11:45:38

MR. CHOW: Form. 11:45:38

THE WITNESS: I think a valve component must be a part of the valve; otherwise, it could be a valve component. 11:45:39 11:45:41 11:45:43

Q. (BY MR. PHILBIN) But the valve component is not necessarily the whole valve, correct? 11:45:43 11:45:47

A. Correct. 11:45:49

Q. So a valve component is different than a valve, correct? 11:45:50 11:45:54

A. Again, the idea is the same. The wording I 11:45:54

have tried to improve to make it clear what we're talking about. 11:45:59 11:46:01

Q. From December of 2022 to February of 2024, you added the requirement of unsealing the interior chamber from the combustion chamber, correct? 11:46:01 11:46:05 11:46:08

A. That it -- yes. 11:46:12

Q. So in December, you didn't think unsealing -- in December '22, you didn't think unsealing was required, but 14 months later, you thought it was required, correct? 11:46:20 11:46:23 11:46:26 11:46:29

A. Again, I think that the idea is -- well, if it seals, then presumably, it unseals. But why not be explicit and so that the wording is very clear to the reader what we mean? 11:46:30 11:46:34 11:46:39 11:46:44

Q. What criteria do you use to determine if a rod is slender? 11:46:45 11:46:49

A. Slender, I would say speaks to, its relative thinness to maybe your reference, whatever that is. So there's no hard-and-fast rule, I would say. 11:46:50 11:46:55 11:47:00 11:47:09

Q. To determine whether or not a rod is slender as you have used that term in your definition of "valve needle," what criteria would you need to know to determine the slender? 11:47:09 11:47:14 11:47:16 11:47:20

A. We would have to do an analysis of the 11:47:23

geometry. We would have to look at the geometry and see whether or not I would look at it and say, Okay, would a person of ordinary skill in the art, in October of 1999, consider this valve to be slender? And it would be -- it is a subjective term. 11:47:26 11:47:30 11:47:33 11:47:37 11:47:41

Q. You said it was relative to something. Relative to what? 11:47:46 11:47:49

A. Without talking about a specific valve or something like that, I don't know what that dimension is. 11:47:50 11:47:55 11:47:58

Q. So is it your testimony your definition of "slender" as used in your definition of "valve needle" changes by the valve? 11:47:58 11:48:02 11:48:04

MR. CHOW: Objection; form. 11:48:06

THE WITNESS: The term that I'm construing here is based on the patent -- the two patents at issue and their claims and their specifications, their history, and the prior art. 11:48:14 11:48:17 11:48:21 11:48:25

So in that light, there's something. Like, we can talk about it. In a very general case, I don't know. 11:48:32 11:48:37 11:48:40

Q. (BY MR. PHILBIN) What criteria would a person of ordinary skill in the art use to determine if a valve component is slender? 11:48:41 11:48:53 11:48:57

A. Again, I don't think that there's a 11:49:02

quantitative measure of slenderness, necessarily. It's more of a subjective feel if I'm looking at the part versus the whole injector design, if we're talking about injectors, to determine whether the valve is slender or not. 11:49:04 11:49:12 11:49:16 11:49:18 11:49:21

Q. And whose subjective feel are we looking to determine whether or not a valve component is slender? 11:49:23 11:49:28 11:49:32

A. Well, we're trying to think about what the person of ordinary skill in the art would think. From their personal experience, through getting their mechanical or automotive engineering degree and then their experience working in the field, dealing with valves and other components, they would have a feel for what "slender" means. 11:49:32 11:49:35 11:49:41 11:49:43 11:49:49 11:49:53 11:49:57

Q. What other terms have you used that require a feel to interpret what you mean? 11:49:59 11:50:03

A. I mean, I would say that "elongated" is a relative term as well. 11:50:07 11:50:14

Q. Relative to what? 11:50:16

A. To determine whether a valve is elongated, I would say you have to -- a valve component is elongated, you would have to look at its, say, axial length versus its transverse dimension -- so, commonly, maybe the length over the distance -- and 11:50:18 11:50:22 11:50:27 11:50:31 11:50:34

determine what that ratio is. 11:50:38

Q. If I took just an average juror off the street, do you believe they would know what "slender and elongated" mean as you've used those in your definition? 11:50:40 11:50:44 11:50:47 11:50:50

MR. CHOW: Objection; form. 11:50:51

THE WITNESS: I believe that they have a relatively straightforward common ordinary meaning that a layperson would understand. 11:50:53 11:50:55 11:51:02

Q. (BY MR. PHILBIN) How long does a rod have to be in order to be elongated? 11:51:06 11:51:09

A. It would depend on its diameter. 11:51:11

Q. How long does a needle have to be to be elongated? 11:51:15 11:51:18

A. It would depend on its diameter. 11:51:18

Q. How slender does a needle have to be to be slender? 11:51:18 11:51:22

A. It would depend on how thin it was. 11:51:22

Q. Give me the measurements for slender that a valve needle would be slender. 11:51:25 11:51:30

A. I can't do that. 11:51:31

Q. Why not? 11:51:32

A. I need a specific valve to look at. 11:51:33

Q. What does "cooperates with a valve seat" mean? 11:51:35 11:51:41

A. So in this case, if we're saying that the valve needle must contact, it must have a -- essentially, a part of the seat and the valve housing must have a part of the seat, and they must touch each other and seal in order to keep fuel from going from the inside of the injector into the combustion chamber. 11:51:41 11:51:48 11:51:52 11:51:57 11:52:00 11:52:04 11:52:09

Q. And that's your definition of "cooperate"? 11:52:09

A. Whether that's my formal definition of "cooperate," that's my plain meaning of it in this sense. 11:52:12 11:52:15 11:52:18

Q. Does your February 2024 proposed construction of valve needle require a rod? 11:52:19 11:52:27

A. So it requires a component, and it requires that it be slender and elongated, okay. So whether that's a rod or not, we can argue. 11:52:29 11:52:39 11:52:44

But again, I'm trying to make it clear that maybe the "rod" word didn't seem to be at the material difference between the parties. And so I tried to clarify the language to distill that down. 11:52:47 11:52:51 11:52:57 11:53:02

And so, for example, right, if we're talking about a valve component, great, let's talk about a valve component. Whether it's a rod or not, that's fine. 11:53:06 11:53:09 11:53:13 11:53:17

MR. PHILBIN: Objection; nonresponsive. 11:53:21

Q. (BY MR. PHILBIN) Does your February 2024 proposed construction of valve needle require a rod? 11:53:23 11:53:26

A. It doesn't require it, while it might -- you know, that might be a realization of how it works. 11:53:29 11:53:31 11:53:34

Q. Does your February 2024 proposed construction of valve needle require anything pointed? 11:53:34 11:53:37 11:53:40

A. No. But again, may be very common that it is. 11:53:41 11:53:46

Q. Would you agree with me that you have taken out "directly prior to seals" in your February 2024 construction as opposed to your December 2022 construction? 11:53:46 11:53:59 11:54:06 11:54:09

A. The word "directly" was removed, but we included language to make it explicit that how the sealing is done and where the sealing is done. 11:54:09 11:54:14 11:54:21

So, "directly," it could maybe be more ambiguous here. And so, again, I have tried to be more explicit. 11:54:23 11:54:26 11:54:29

Q. What does "direct sealing" mean? 11:54:31

A. Well, in this sense, how I would take it is that it must be immediately adjacent to the two things that it's sealing. So if it's sealing A from B, and it's right in between, you know, that they're 11:54:34 11:54:42 11:54:46 11:54:50

basically right in the vicinity of each other, then that's directly sealing one from the other. 11:54:54 11:54:57

Q. And you'll agree with me you removed the requirement of directly sealing from your February 2024 construction, correct? 11:54:59 11:55:02 11:55:04

A. I have removed that word, but if you want to put it back in, I can. 11:55:06 11:55:09

Q. Do you feel like you need to? 11:55:11

A. I do not. 11:55:12

Q. Okay. You would agree with me that the meaning of "valve needle" as understood by a person of ordinary skill in the art in 1999 did not change in the 14 months from December '22 to February 2024, correct? 11:55:13 11:55:37 11:55:40 11:55:44 11:55:49

A. Correct. 11:55:49

Q. What new information did you review that changed your opinion in the 14 months between your two declarations in December '22 and February 2024? 11:55:50 11:55:55 11:55:59

MR. CHOW: Objection to form. 11:56:04

THE WITNESS: I did not change my opinion. 11:56:05 11:56:07

Q. (BY MR. PHILBIN) So your testimony is that your definition of "valve needle" is the same on December 2, 2022, and February 1, 2024. Is that your testimony? 11:56:07 11:56:14 11:56:17 11:56:23

A. The words have been changed to clarify both the meaning and maybe distill it down to the main, you know, differences between the parties so we can come at an agreement for what the construction should be. 11:56:23 11:56:27 11:56:32 11:56:34 11:56:38

Q. If you didn't review any new material in the 14 months between your two declarations, what changed? 11:56:39 11:56:44 11:56:47

A. For one, there was a deposition, right? So I got to understand Westport's view maybe better, you know, and what the important parts were, what was in contention and what wasn't. And so what parts were maybe not understood as well as others. And so I've adjusted the language as such. 11:56:48 11:56:55 11:57:01 11:57:04 11:57:09 11:57:13

Q. So your definition of "valve needle" from December '22 to February 2024, to the extent there's a change, is only based on conversations with lawyers in your deposition, correct? 11:57:16 11:57:20 11:57:24 11:57:27

MR. CHOW: Objection; form. 11:57:29

THE WITNESS: I surely reread the patents, looked at the prosecution history again. I took all of the evidence in the case when forming my opinion from the start. 11:57:31 11:57:33 11:57:41 11:57:46

Again, I don't think that my opinion has really changed on what a valve needle is, but I've 11:57:47 11:57:50

tried to make it more clear, whether for the reader, what the meaning is and what the differences could potentially be between constructions and so that it's very clear what -- how we believe -- you know, what I believe is the case. 11:57:54 11:57:58 11:58:04 11:58:08 11:58:12 11:58:16

Q. (BY MR. PHILBIN) If you came to Texas and looked a Texas jury in the eye, and I asked you, "What is an interior chamber," what would you tell me? 11:58:16 11:58:18 11:58:21 11:58:25

A. I would say, "I would need more context than that to know what an interior chamber is." 11:58:25 11:58:27

Q. So you would tell a Texas jury, "I don't know what the terms "interior chamber" by themselves means," correct? 11:58:30 11:58:32 11:58:36

A. I know what it means in day-to-day life. What it means in terms of patent law might be another thing, and then what it means in a very specific case looking at a specific claim. 11:58:36 11:58:39 11:58:44 11:58:47

I would say, you know, "Here's what it means. It means, a volume from which high-pressure fuel is injected into the combustion chamber when the valve is actuated." 11:58:49 11:58:52 11:58:57 11:58:59

Q. And you didn't think a definition of interior chamber was needed in December of 2022, 11:59:01 11:59:04

correct? 11:59:08
A. I was not asked to provide a definition in 11:59:08
that case. 11:59:11
It's my opinion that, you know, 11:59:12
essentially, that's the plain and ordinary meaning 11:59:14
of the term. And that's what I've presented now as 11:59:19
well. 11:59:23
Q. Okay. And a week later, on December 11:59:23
the 9th, 2022, no construction was necessary then 11:59:28
either, right? 11:59:31
A. Correct. I believe that the plain and 11:59:31
ordinary meaning is how we should take it. 11:59:36
Q. Okay. So does the requirement of 11:59:38
high-pressure fuel, does that come from interior or 11:59:40
chamber? 11:59:44
A. It comes from the claims and specifications 11:59:44
within the patents. 11:59:50
Q. You would agree with me that high-pressure 11:59:52
fuel is not defined by interior or chamber, correct? 11:59:55
A. Whether it's interior or not doesn't 12:00:00
determine whether it's high pressure, okay? And 12:00:05
whether it's a chamber or not doesn't determine 12:00:08
whether it's high pressure. 12:00:11
When we're looking at the specific interior 12:00:12
chamber as used in this patent, then I believe that 12:00:16

it requires that the interior chamber be at high pressure. 12:00:20 12:00:25

Q. So you think it's necessary here to add that limitation to the definition of "interior chamber"; is that correct? 12:00:25 12:00:27 12:00:30

A. I am taking all of the evidence and -- in forming that opinion. 12:00:32 12:00:40

So if we look at the current document -- sorry -- what is this? This is Exhibit 3, paragraph 102. 12:00:41 12:01:38 12:01:42

For instance, Claim 1 in the 829 Patent cites that the interior chamber is fluidly connected to said fuel inlet port. This injector is for injecting fuel at high pressure. 12:01:49 12:01:54 12:01:58 12:02:03

And so the fuel inlet port must have high-pressure fuel. And since they're fluidly connected, the interior chamber must be at high pressure. 12:02:06 12:02:10 12:02:15 12:02:19

Q. Would you agree you're taking something in the specification and inserting it into the claim in the definition of "interior chamber," specifically in the high-pressure fuel? 12:02:19 12:02:21 12:02:25 12:02:26

A. Well, so this, again, this comes from Claim 1. The -- it's hard to say that you're reading in the specification when -- let's look at -- do we have 12:02:29 12:02:32 12:02:38

a copy of the 829 Patent? 12:03:03

I can find it one other place, I know. 12:03:11

16. Page 16. No. Actually, it's in the patent. 12:03:22

Do you have a copy of the 829 Patent we 12:03:30

can look at? 12:03:33

Q. I do. 12:03:34

There you go. Oh, you got one. 12:03:35

MR. CHOW: We're not marking this as an 12:03:45

exhibit. 12:03:47

MR. PHILBIN: Unless he starts marking on 12:03:51

it, then we'll mark it. 12:03:56

THE WITNESS: I will try not to. 12:03:59

So from the 829 Patent, column one, 12:04:03

starting at column -- row 11, "the technical 12:04:06

field." It says, "The present invention relates 12:04:11

generally to high-pressure fuel injection valves or 12:04:15

injectors for internal combustion engines." 12:04:19

And so I don't think there were too much 12:04:26

of a stretch to see that this is for a 12:04:29

high-pressure fuel injector, since it's the 12:04:32

technical field in which this is filed. 12:04:35

Q. (BY MR. PHILBIN) Okay. I believe you 12:04:38

cited Claim 1 there in the 829 Patent that you've got 12:04:39

in front of you. 12:04:41

Do you see the words "high pressure" in 12:04:43

that claim anywhere? 12:04:46
A. Let's look. 12:04:47
So, not specifically in Claim 1. 12:05:12
Q. So the words "high pressure" are not in 12:05:14
Claim 1, but you want to add them, correct? 12:05:18
A. Again, taking the entire evidence -- so the 12:05:20
claims, the specifications, and the -- even the 12:05:24
technical field in which we're working in -- that -- 12:05:28
I think that that must be the case that this is a 12:05:33
high-pressure fuel injector. 12:05:37
Q. How much pressure is high pressure? 12:05:39
A. It's -- again, that's a relative term. So 12:05:41
it has to be high enough that you can overcome the 12:05:45
cylinder pressure inside the combustion chamber and 12:05:51
also atomize the spray into small enough droplets 12:05:56
that can evaporate quick enough and burn quick enough 12:06:03
for the time that you have to do the combustion 12:06:03
process. 12:06:08
Q. So all of those limitations that you just 12:06:08
listed you're adding into the definition of "high 12:06:11
pressure" that you're adding into the definition of 12:06:13
"interior chamber"? 12:06:16
A. No. I'm saying physically how it has to 12:06:17
work. 12:06:19
Q. Is 2,000 psi high pressure? 12:06:19

A. It depends on the definition. I mean, there's no hard-and-fast definition. 12:06:24 12:06:26

Is that high enough? Maybe; maybe not. It's where you -- yeah. Yeah. 12:06:29 12:06:36

Q. So you don't have an opinion one way or another if 2000 psi is high pressure? 12:06:38 12:06:42

A. It depends on what you're talking relative to. 12:06:45 12:06:47

Q. Is pressure a relative thing? 12:06:47

A. Pressure is an absolute number. But I mean, I can always say "this is the pressure." But whether it's high or not that is relative. 12:06:49 12:06:53 12:06:58

Q. What definition would you give the jury for what high pressure means in your definition of "interior chamber"? 12:07:01 12:07:06 12:07:10

MR. CHOW: Objection; form. 12:07:11

THE WITNESS: Again, I don't think I would give them a definition. If I needed to explain it to them, I would say that it has to be significantly higher than the pressure into which you're injecting, right? Flow goes from high pressure to low pressure, and so if you want to inject fuel into the combustion chamber, the pressure must be higher in the interior chamber. 12:07:12 12:07:14 12:07:17 12:07:20 12:07:23 12:07:26 12:07:28 12:07:32

Q. (BY MR. PHILBIN) And you can't tell the 12:07:35

jury whether 2000 psi is high pressure or not as you use that in your definition of "interior chamber," correct? 12:07:38 12:07:43 12:07:45

A. It depends on the pressure inside, say, the cylinder. 12:07:45 12:07:46

Q. What's your understanding of the doctrine of claim differentiation? 12:07:46 12:07:48

MR. CHOW: Objection; form. 12:07:51

Q. (BY MR. PHILBIN) If you have one. 12:07:54

A. So the legal term, maybe, I don't know exactly what you're talking about. 12:07:56 12:08:02

Can you maybe use less legalese and I can tell you whether I understand the concept? 12:08:04 12:08:08

Q. Do you apply the doctrine of claim differentiation in writing Exhibit 3? 12:08:10 12:08:13

MR. CHOW: Objection; form. 12:08:16

THE WITNESS: Are we speaking of the difference between one claim and another and how we read them? 12:08:17 12:08:22 12:08:26

Q. (BY MR. PHILBIN) Did you apply that concept in your declaration? 12:08:26 12:08:28

A. Surely. I understand that I should be taking this claim on its own and not be -- you know, if I have something, another claim that's dependent on it, then we have to take those in light with each 12:08:30 12:08:36 12:08:41 12:08:45

other. 12:08:49

Q. What's your understanding of the difference between a claimed embodiment and a preferred embodiment? 12:08:49 12:08:51 12:08:54

MR. CHOW: Objection; form. 12:08:56

THE WITNESS: The preferred embodiment is just a way of doing it that's potential. It's not the way or the only way. There's many different ways you can do that. So the claim is talking about all of the ways. 12:08:57 12:09:00 12:09:05 12:09:08 12:09:11

Q. (BY MR. PHILBIN) Does the specification of a patent contain the claimed embodiment or preferred embodiment? 12:09:12 12:09:17 12:09:23

MR. CHOW: Objection; form. 12:09:24

THE WITNESS: I believe it shows the preferred embodiments. 12:09:26 12:09:28

Q. (BY MR. PHILBIN) Did you distinguish between claimed embodiments and preferred embodiments in your work in this case? 12:09:29 12:09:31 12:09:31

A. I surely am aware of the difference and tried to take account to that, right, if I'm understanding what the claim means in terms of that and know that I can't read something in from the specifications into the claim. 12:09:33 12:09:38 12:09:40 12:09:43 12:09:47

Q. (BY MR. PHILBIN) Is it your understanding 12:09:48

that claim scope is limited to the embodiment shown in the patent? 12:09:50 12:09:55

A. I don't think that's correct, right? 12:09:55

Maybe ask your question again. 12:09:58

MR. PHILBIN: Let's take a break for lunch. 12:10:10 12:10:11

THE VIDEOGRAPHER: We are going off the record. The time is 12:09 p.m. 12:10:12 12:10:13

(Whereupon, a lunch recess was taken at 12:09 p.m.) 12:10:13 12:10:13

(Whereupon, the proceedings resumed at 1:04 p.m.) 12:10:13 13:05:15

THE VIDEOGRAPHER: We are back on the record. The time is 1:04 p.m. 13:05:15 13:05:19

Q. (BY MR. PHILBIN) Dr. Quinlan, did you get lunch? 13:05:23 13:05:27

A. I did. 13:05:28

Q. Are you ready to proceed? 13:05:28

A. Yes. 13:05:29

Q. Any of your testimony from this morning that was inaccurate or untrue? 13:05:30 13:05:31

A. Not that I'm aware of. 13:05:33

Q. Okay. You testified this morning that you had an understanding of the claim construction disputes that informed your changing of your claim 13:05:36 13:05:38 13:05:41

construction definitions. 13:05:46
Do you recall that testimony? 13:05:47
A. I do. 13:05:48
Q. What is your understanding of the claim 13:05:49
construction disputes between the parties? 13:05:51
A. I may not know, like, the overarching 13:05:54
points that, you know, is your-all's business, but 13:06:00
I've seen Westport's construction on terms and where 13:06:05
I felt that maybe the differences weren't the 13:06:13
important part or were essentially similar words for 13:06:22
the same structure that could be replaced without 13:06:25
issue. 13:06:30
I made some of those changes so that the 13:06:30
more important differences are the thing that come 13:06:33
into play. 13:06:37
Q. Are all the claim construction disputes 13:06:38
between the parties based on your understanding 13:06:42
contained in Exhibit 2? 13:06:45
A. I wouldn't know. 13:06:46
Q. Why not? 13:06:47
A. I'm not a lawyer, and I haven't been 13:06:51
involved in, you know, going back and forth between 13:06:56
you two. 13:06:59
Q. Okay. Perhaps you didn't hear all my 13:07:00
question. 13:07:03

Are all the claim construction disputes between the parties based on your understanding contained in Exhibit 2? 13:07:04 13:07:06 13:07:08

A. Based on my understanding? These are the terms that I have been dealing with, and I believe they're the terms that are at dispute. 13:07:09 13:07:23 13:07:27

Q. You're not aware of any disputed terms that are not in Exhibit 2, correct? 13:07:29 13:07:32

A. I -- not that I'm aware of. 13:07:35

Q. Okay. Your opinion changed from December 2022 to February 2024, based, in part, on what you read in Westport's filing; is that correct? 13:07:45 13:07:49 13:07:55

MR. CHOW: Object to form. 13:07:59

THE WITNESS: That is incorrect. I don't believe my opinions changed. How I worded some of the constructions may have changed to where we had common ground, you know, used that so that it doesn't look like a dispute and where it seemed like things were different or misunderstood. 13:08:00 13:08:03 13:08:10 13:08:12 13:08:17 13:08:21

For example, from the deposition and then seeing how the two sides interacted, I tried to make the wording more clear. 13:08:26 13:08:30 13:08:39

Q. (BY MR. PHILBIN) So if we take valve needle in Exhibit 2, you believe pointed rod is still a requirement as of February 1, 2024; is that 13:08:42 13:08:45 13:08:48

correct? 13:08:51
A. I think that it's relatively unimportant 13:08:51
whether it's pointed or not. The part that may come 13:08:55
into the pointedness is that there's -- a person of 13:09:01
the ordinary skill in the art would know that you 13:09:05
have to have a differential angle between this angle 13:09:09
and this angle so that you had a line contact and you 13:09:12
could seal. 13:09:15
But that really has been replaced. That 13:09:16
pointed part was with the cooperates with a valve 13:09:20
seal to seal and unseal -- the valve seat to seal and 13:09:26
unseal. 13:09:30
Q. So is it your testimony that "cooperates" 13:09:30
includes the concept of pointed rod? 13:09:33
A. No, not necessarily. It means that as long 13:09:36
as it can cooperate in a functional manner as the 13:09:42
person of ordinary skill in the art would see it, 13:09:47
then that seems like it fits the definition. 13:09:50
Q. If the Court adopted your claim 13:09:56
constructions in any of your declaration shown on 13:09:59
Exhibit 2, it's your position they all mean the same 13:10:02
thing, correct? 13:10:05
A. That "lift" means the same thing as "valve 13:10:07
needle"? 13:10:10
Q. No. Each one of the three columns means 13:10:10

the same thing for each term because they're all the same, based on your testimony, right? 13:10:13 13:10:16

A. I believe my opinion is consistent with each one of the cases, you know, maybe with the exception of "lift," where we're giving it the explicit definition. It could vary some from the plain and ordinary meaning, although I don't particularly think it does. 13:10:18 13:10:20 13:10:25 13:10:28 13:10:32 13:10:35

Q. So in your declaration, Exhibit 3, you disclose all the information you considered in forming your opinions in this case in Exhibit 3, correct? 13:10:38 13:10:51 13:10:55 13:10:57

A. I did. 13:10:57

Q. You did not list any interviews or conversations with anyone in the materials reviewed or considered, correct? 13:10:58 13:11:06 13:11:08

A. Correct. 13:11:09

Q. You did not have any interviews or conversations with anyone in connection with your work in this case, correct? 13:11:10 13:11:13 13:11:15

MR. CHOW: Objection; form. 13:11:19

THE WITNESS: I spoke with my lawyers, but beyond that, no. 13:11:21 13:11:25

Q. (BY MR. PHILBIN) Okay. So the only conversation -- well, strike that. 13:11:26 13:11:30

Did you rely on the conversations with the lawyers in forming your opinions? 13:11:31 13:11:33

MR. CHOW: Objection; form. 13:11:33

THE WITNESS: No. My opinions were formed based on looking at what a person of the ordinary skill in the art at the time, so October 1999, would see in the patent when they read the claims, the specification, looked through the prior art, the prosecution history, and made a complete assessment of all of that material. 13:11:36 13:11:38 13:11:43 13:11:46 13:11:50 13:11:56 13:12:03

Q. (BY MR. PHILBIN) So the only things that you relied upon in formulating your opinions in this case is paper and your experience, correct? 13:12:06 13:12:16 13:12:19

MR. CHOW: Objection; form. 13:12:24

THE WITNESS: If we, you know, relax the definition of "paper" to include digital paper, a computer screen or something, reading material on their printed-out copies of these things, the things that are listed in Section 16 -- or in Section 2, paragraph 16, I believe those are all the material that I used for forming my opinion. 13:12:26 13:12:36 13:12:42 13:12:45 13:12:51 13:12:54 13:12:57

Q. (BY MR. PHILBIN) Okay. And all of the knowledge that you had about the state of the art in October of 1999 is contained in Section 2 of Exhibit 3 of your report, correct? 13:12:59 13:13:01 13:13:04 13:13:09

A. No. I think that my understanding of what a person of the ordinary skill in the art, in October of '99, is through my own experience, through a similar time working in the industry, and looking at the intrinsic and extrinsic evidence that is in the case, and, you know, just my complete experience. 13:13:12 13:13:15 13:13:19 13:13:23 13:13:28 13:13:34

Q. Okay. Is the intrinsic and extrinsic evidence in the case contained in Exhibit 3? 13:13:38 13:13:43

A. In Exhibit 3. As far as I know, all of the -- let's see. So if 16-A is the asserted patents -- but that's not what's in Section A here. That's my CV. 13:13:46 13:13:50 13:13:57 13:14:05

So the patents themselves and the prosecution history are -- shouldn't -- so the asserted patents are -- have not been included as an exhibit here. 13:14:06 13:14:19 13:15:09 13:15:13

So, I mean, that's surely part of the intrinsic evidence, is the patents themselves. But it's listed as materials that I reviewed in making my opinion. 13:15:15 13:15:18 13:15:23 13:15:26

Q. Okay. So I'm asking you about materials reviewed in making your opinions, which is Section 2, paragraph 16, in the document that you prepared. 13:15:26 13:15:29 13:15:32

Do you understand that? 13:15:34

A. Okay. I thought you were asking if it's 13:15:35

actually included in the document. 13:15:36
Q. Nope. Nope. Nope. So listen to my 13:15:37
question. 13:15:41
"In paragraph 16, Section 2, of Exhibit 3 13:15:41
that you prepared, did you identify all the 13:15:46
materials that you reviewed to educate yourself 13:15:50
about the state of the art in October of 1999"? 13:15:54
A. I would say not necessarily. What I have 13:15:58
listed here is all of the pieces of material that I 13:16:01
used in forming my opinion of what a person of the 13:16:06
ordinary skill in the art in 1999 would see these 13:16:10
terms as. 13:16:16
Q. Okay. So to use your language, Section 2 13:16:17
of Exhibit 3 contains a listing of all pieces of 13:16:20
material that you used in forming your opinion of 13:16:24
what a person of ordinary skill in the art in October 13:16:27
of 1999 would think, correct? 13:16:31
A. In terms of understanding these, the claim 13:16:33
terms. 13:16:38
Q. Okay. And you cited certain dictionaries, 13:16:39
correct? 13:16:45
A. Yes. 13:16:45
Q. Did the -- in Sub I on page 4 of the 13:16:46
Exhibit 3, Merriam Webster's Collegiate Dictionary. 13:16:53
Did it have a definition of valve needle? 13:16:57

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A. Can you repeat the term that you would like? 13:17:01 13:17:26

Q. Certainly. "Valve needle." 13:17:26

A. So I have not included that here. And if I -- I'm not 100 percent sure, so I would have to look in the dictionary again and see if it's in there. 13:17:30 13:17:40 13:17:47 13:17:50

Q. Let's go to the next one, Oxford English Dictionary, Item J on page 4 of Exhibit 3. 13:17:50 13:17:55

Did the Oxford Dictionary contain a definition of "valve needle"? 13:17:58 13:18:00

A. Of "valve needle"? 13:18:02

Q. Yes, sir. And that's the online version. I think you got two of them. Item J and K are both Oxford English Dictionary. 13:18:05 13:18:15 13:18:20

A. Not that I see here and not that I recall. 13:18:58

Q. Do you recall that I asked you what your understanding of the term "valve" was, and you couldn't tell me? 13:19:00 13:19:11 13:19:13

A. I remembered you asked in -- essentially, in a vacuum what that meant. 13:19:14 13:19:19

Q. And you couldn't tell me, right? 13:19:21

A. Because I needed more information. 13:19:23

Q. Okay. And I asked you about -- the same question about "needle," and you couldn't tell me, 13:19:24 13:19:26

correct? 13:19:29

A. Again, in a vacuum, no. I don't think a person of the ordinary skill in the art can form an opinion yet without knowing what we're talking about. 13:19:29 13:19:33 13:19:36

Q. And the only opinion that you formed is the combination of those two words for the term "valve needle," correct? 13:19:39 13:19:42 13:19:46

A. I mean, that is -- so again, I think that a person of the ordinary skill in the art has some idea of what a valve is and what a needle is, and that informs, I think, the understanding of what the combined phrase means. 13:19:47 13:19:54 13:19:58 13:20:04 13:20:06

But it doesn't mean that I would form a full opinion on what any of those things mean in a vacuum. 13:20:10 13:20:12 13:20:16

Q. Would you confirm that none of the dictionaries that you cite contain a definition of "valve needle"? 13:20:16 13:20:19 13:20:23

A. None that I remember. 13:20:24

Q. Did any of the dictionaries that you looked at but didn't cite and didn't tell us about contain a definition of "valve needle"? 13:20:31 13:20:35 13:20:39

A. Not that I'm aware of. 13:20:40

Q. Is the term "elongated" -- does that come from valve or needle? 13:20:42 13:21:08

MR. CHOW: Objection; form. 13:21:12
THE WITNESS: Again, it comes to, 13:21:16
probably, taking the phrase as a whole in context 13:21:18
of the claims of the patents here. 13:21:22
But surely, if I think about what a 13:21:27
person of the ordinary skill in the art in 1999 13:21:31
or -- you know, and I look at if I ask them is a 13:21:35
needle elongated, I think that they may use 13:21:43
different words, but they're going to say that -- 13:21:49
ultimately, they're going to say that, yes, that is 13:21:52
elongated. 13:21:55
Q. (BY MR. PHILBIN) Did you find the word 13:21:56
"elongated" in any of the dictionaries that you 13:21:57
looked at and told us about? 13:22:02
A. I can't remember if I looked it up or not. 13:22:04
I think I looked it up in the OED. 13:22:07
Q. What's the OED? 13:22:10
A. Oxford English Dictionary. 13:22:15
Q. The online version? 13:22:18
A. Yes. 13:22:20
Q. What is a plunger? 13:22:20
A. You have to give me more context than that. 13:22:22
There's more than one plunger. 13:22:26
Q. Is a plunger slender? 13:22:28
A. You'll have to tell me what plunger we're 13:22:30

talking about first. 13:22:33
Q. Is a plunger elongated? 13:22:34
A. You'll have to be more specific on which 13:22:36
plunger we're talking about. 13:22:38
Q. Is a plunger a valve component? 13:22:44
A. Again, I would have to see what valve we're 13:22:54
talking about. 13:22:56
Q. Is a plunger a valve member? 13:22:57
A. I would have to know what valve we're 13:22:59
talking about. 13:23:01
Q. Do you agree that every word in a claim 13:23:02
construction is important? 13:23:06
MR. CHOW: Objection; form. 13:23:07
THE WITNESS: We do our best to be 13:23:07
concise and clear, and so we maybe -- you know, 13:23:17
sometimes we can write better or write it a 13:23:24
different way. 13:23:28
But the understanding of the claim 13:23:28
construction should be essentially the same for a 13:23:32
person of the ordinary skill in the art. 13:23:37
Q. (BY MR. PHILBIN) Do you agree or disagree 13:23:40
that every word in the claim construction is 13:23:41
important? 13:23:45
A. I think that when we look at the 13:23:45
construction, that we should put weight on each word. 13:23:48

Q. So you can't just flat out agree or disagree that every word in a claim construction is important; is that right? 13:23:53 13:23:57 13:24:00

MR. CHOW: Objection; form. 13:24:01

THE WITNESS: I would start by giving each word weight, but if I found a word was redundant, for example, then is that word important? No. It probably could have been deleted and retained the meaning of the claim construction. 13:24:02 13:24:04 13:24:10 13:24:13 13:24:15 13:24:20

Q. (BY MR. PHILBIN) Do you consider all the changes in your opinions in Exhibit 2 immaterial? 13:24:20 13:24:22

MR. CHOW: Object to form. 13:24:27

THE WITNESS: The opinion that I'm trying to express in them is consistent from the different versions. 13:24:29 13:24:33 13:24:39

Q. (BY MR. PHILBIN) That wasn't my question. 13:24:40

Do you consider your changes immaterial? 13:24:42

A. Whether someone considers them immaterial or not, that would be their opinion. I am presenting again, what I think is a consistent opinion. 13:24:45 13:24:48 13:24:52

Q. Okay. Let's try one more time. Listen to my question. I didn't ask about anybody else's consideration; I asked about yours. 13:24:55 13:24:57 13:25:00

Do you consider your changes as shown in 13:25:02

Exhibit 2 immaterial? 13:25:05

A. I don't know if I thought about what 13:25:07
"immaterial" means in this case. I think I'm 13:25:12
presenting a consistent opinion in the different 13:25:15
versions. 13:25:19

Q. Do you consider your changes in the three 13:25:19
different declarations reflected in Exhibit 2 13:25:22
irrelevant? 13:25:25

A. The same thing. Whether it's irrelevant or 13:25:26
not, I don't think that that's -- I don't think 13:25:29
that's correct. I think the changes are to make it 13:25:31
clearer and closer to what we can come on an 13:25:35
agreement between Bosch and Westport of what the 13:25:40
construction should be. 13:25:46

Q. Do you think your assignment is to reach an 13:25:47
agreement between Bosch and Westport on what a 13:25:50
construction should be? 13:25:53

A. No. I'm providing an opinion of what I 13:25:54
think that a person of the ordinary skill in the art, 13:25:57
at the time, would take these terms to mean. If 13:26:00
there's a small change between the two sides' 13:26:04
language that is less important or makes almost no 13:26:09
difference in the construction, then sometimes we 13:26:15
have thought Well, okay. They're similar so, is 13:26:21
there a difference between this word and that word. 13:26:25

Does it matter if it's this word or that word? 13:26:27
And where there wasn't a -- you know, a 13:26:30
difference that would not construe the term 13:26:35
accurately, sometimes we adopted those words. 13:26:43
Q. When you used the term "we" in your last 13:26:47
answer, you're referring to you plus your legal team? 13:26:55
A. It's an academic thing. I could write a 13:26:58
sole-author paper, and I would say that, where I did 13:27:02
all the work, and I would say, "We did this." 13:27:06
Q. So you refer to yourself in multiple? 13:27:08
A. It's a style of scientific writing and 13:27:13
presentation that we give credit to everyone, even 13:27:16
when you're the only one that did the work. 13:27:20
Q. Does your adding the term "high pressure" 13:27:21
eliminate a dispute or add a new dispute? 13:27:24
A. I don't think it changes the dispute. I 13:27:28
think it makes it more clear what the difference is. 13:27:31
Q. Have you spoken with anyone at Westport 13:27:33
about their claim construction position? 13:27:37
A. I have not. 13:27:38
Q. Have you spoken with anyone at Westport 13:27:39
about what they consider important on claim 13:27:41
construction? 13:27:43
A. I have not. 13:27:44
Q. You've talked to your lawyers about what 13:27:44

they think Westport thinks is important? 13:27:47
MR. CHOW: Objection; form. 13:27:49
I caution the witness not to reveal the 13:27:50
context of any attorney-client -- actually, of any 13:27:53
privileged communications. 13:27:54
MR. PHILBIN: We can address that later. 13:27:55
I think he's testified multiple times that he 13:27:57
relied upon the "we" conversation between him and 13:28:00
the legal team, but I'm not going to press the 13:28:02
issue on this one. 13:28:05
MR. CHOW: Okay. And I disagree with 13:28:06
you, but we can take that up later. 13:28:08
THE WITNESS: So state your question 13:28:10
again so I make sure -- 13:28:15
(Court reporter asked for clarification.) 13:28:15
Q. (BY MR. PHILBIN) The only information that 13:28:21
you've got about Westport's position on claim 13:28:22
construction is the information you received from 13:28:26
your legal team, correct? 13:28:27
A. I disagree. 13:28:29
Q. Where else did you get it? 13:28:30
A. So from interacting with the attorneys for 13:28:33
Westport in the last deposition. I think I 13:28:39
understood more their position by going through that 13:28:43
process. 13:28:46

I think that we received a brief, right, that's explaining Westport's position in terms of the claim construction. So I haven't spoken to anybody about it, but doesn't mean there's not information on what Westport thinks is important. Westport's claim constructions have informed us. 13:28:47 13:28:54 13:29:01 13:29:05 13:29:10 13:29:13

Q. You said, "we received the brief." 13:29:16

Did you receive the brief? 13:29:18

A. I did not. 13:29:19

Q. So in this instance, you're using "we" to include you and your legal team, correct? 13:29:19 13:29:22

A. Sure. 13:29:25

Q. That's right, right? 13:29:27

A. Yes. 13:29:30

Q. So sometimes you use the term "we" to include you and your legal team, and sometimes you use it as you individually, correct? 13:29:31 13:29:35 13:29:38

A. Yes. And if it's ever not clear, please ask. 13:29:40 13:29:43

Q. Let's talk about interior chamber. 13:29:43

A. Great. 13:29:48

Q. You didn't think a construction was necessary in December 2, 2022, correct? 13:29:49 13:29:51

A. I was not asked to construe that term. 13:29:53

Q. Wasn't my question, sir. 13:29:59

Did you think a construction was necessary on December 2, 2022? 13:30:01 13:30:02

MR. CHOW: Objection; form. 13:30:06

THE WITNESS: My personal opinion? 13:30:07

Q. (BY MR. PHILBIN) Yes, sir. 13:30:09

A. No. I think that it takes the plain and ordinary meaning as a person of the ordinary skill in the art would see it at that time. 13:30:11 13:30:14 13:30:18

Q. (BY MR. PHILBIN) And that was the same position you had on December 9, 2022, correct? 13:30:20 13:30:22

A. Correct. 13:30:24

Q. And then 14 months later, on February 1st, you proposed a definition for the first time, correct? 13:30:25 13:30:27 13:30:31

A. Correct. 13:30:31

Q. Could a fuel injector contain multiple interior chambers? 13:30:31 13:30:49

MR. CHOW: Objection; form. 13:30:50

THE WITNESS: A hypothetical injector, can it have multiple chambers that are inside of it? Maybe. But are we talking about the specific thing? 13:30:51 13:30:55 13:30:58 13:31:02

I mean, here the interior chamber is given -- is basically specified. 13:31:04 13:31:07

Q. (BY MR. PHILBIN) Can you answer my 13:31:12

question? 13:31:13
A. Ask it again and I'll make sure that I understand it. 13:31:13 13:31:17
Q. Can a fuel injector contain multiple interior chambers? 13:31:17 13:31:23
A. It comes down to your definition of what an interior chamber is and what the specific injector is. 13:31:24 13:31:28 13:31:31
Q. Can you identify any place in the patent specification where the patent team limited interior chamber to a single chamber? 13:31:32 13:31:32 13:31:35
A. So starting from paragraph 101, we have the Claim 1 of the 138 Patent recites -- 13:32:34 13:32:44
(Court reporter asked for clarification.) 13:32:44
THE WITNESS: 138 -- "an interior chamber fluidly connected to said fuel inlet port." It further recites "a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed," and "said valve member having one end diposed within said valve housing and an opposite and extendable from said valve seat toward the combustion chamber, wherein said valve member comprises a sealing surface that fluidly seals against said valve seat when said valve injector 13:32:53 13:32:55 13:33:01 13:33:04 13:33:09 13:33:13 13:33:16 13:33:22 13:33:26 13:33:30 13:33:33

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[sic] is closed and that is liftable away from said valve seat when said injector [sic] valve is open." 13:33:36 13:33:39

Okay. This is telling me that the interior chamber is connected to the fuel port, the fuel inlet port. But more importantly, that it is providing the sealing between the interior chamber and combustion chamber. So this really tells me where in this patent the interior chamber is. 13:33:43 13:33:48 13:33:52 13:33:58 13:34:04 13:34:07

It's right next to the seal. Can it be other places? Sure. I think that a person of ordinary skill in the art would say, Well, it sounds like it's likely up here by the inlet port, but it really must be here between -- next to the interior chamber and combustion chamber and is separated -- the interior chamber can be separated from that by the sealing surface of the seat. 13:34:12 13:34:15 13:34:19 13:34:23 13:34:26 13:34:32 13:34:36 13:34:38

Q. So do you agree or disagree that the patent specification limits interior chamber to a single chamber? 13:34:43 13:34:46 13:34:50

A. I think a person of the ordinary skill in the art would think that it's -- whether or not it's one chamber, we have to discuss what a chamber is, in a sense. But that it must be, you know, essentially, a free-flowing fluid connection with this part that must be -- the part that's separating -- you know, 13:34:51 13:34:55 13:34:59 13:35:02 13:35:09 13:35:16

where the seal is, where the interior chamber touches the combustion chamber right from the flame (ph). 13:35:19 13:35:23

Q. So that was a lot of words. 13:35:27

Does specification require the interior chamber to be a single chamber or not? 13:35:29 13:35:32

A. I -- does it require to be a single chamber? Again, I think that it depends on how the actual person -- how a person of the ordinary skill in the art would see it. 13:35:35 13:35:39 13:35:47 13:35:52

They would see it as long as it's fluidly connected and has a free-flowing path, then that could be part of the interior chamber. 13:35:54 13:35:57 13:36:01

Is that one chamber? I think that's probably one chamber. How I would personally view it. 13:36:04 13:36:06 13:36:11

Q. Is it your opinion that the patent embodiments show only one chamber within the valve body? 13:36:11 13:36:13 13:36:19

A. So I'm not taking the embodiments, whether that's one chamber or not. 13:36:19 13:36:26

Do you want to -- let's see -- look at -- let's find a good picture. 13:36:28 13:36:28

Let's look at in paragraph 87. We see Figure 1 from the 829 Patent, and here we have colored the part that I think must be the interior 13:36:38 13:36:43 13:36:50

chamber that's required by the claim -- the analyst at, essentially, is it 106 or -- let's see. I can't see where the leaders are on this. 13:36:58 13:37:04 13:37:13

But there's a slight orange in the analyst there. That orange color was saying, yeah, that must be part of the interior chamber, because of the claim. 13:37:17 13:37:19 13:37:22 13:37:25

Sure. One of the preferred embodiments is where the actuator itself is within the interior chamber. And so there's probably another analyst here that I could consider in the interior chamber. 13:37:25 13:37:31 13:37:37 13:37:40

Is it, you know, freely flowing and connected directly? Yeah, I think so. So would I consider that one chamber? Sure. 13:37:44 13:37:48 13:37:52

MR. PHILBIN: Objection; nonresponsive. 13:37:54

Q. (BY MR. PHILBIN) I think you tried to insert a word into my question. I didn't use the word "interior." 13:37:56 13:37:58 13:38:00

My question is, Is it your opinion that the patent embodiments show only one chamber within the valve body? 13:38:02 13:38:05 13:38:09

Can you answer that question? 13:38:10

A. I'm sorry. I misunderstood your question, then. 13:38:12 13:38:15

There can be multiple chambers within a 13:38:16

valve or an injector. 13:38:23

Q. Can you have a chamber within a chamber? 13:38:27

A. Probably, if there's a structure that divides those two chambers, you can have a chamber in a chamber in a hypothetical. 13:38:31 13:38:38 13:38:43

Q. Now I'm going to use the word "interior." Can you have an interior chamber within another interior chamber? 13:38:45 13:38:46 13:38:52

A. I have no idea what an interior chamber means in this hypothetical, so I don't think I can answer that. 13:38:52 13:38:55 13:38:57

Q. In the context of your opinion, in using your definition of "interior chamber," can you have an interior chamber within another interior chamber? 13:38:58 13:39:04 13:39:06

A. Okay. I'm -- I haven't thought about this for very long; you know, 15 seconds now. 13:39:09 13:39:31

I -- I can't think of an embodiment where I could have an interior chamber using this definition inside of another. But that doesn't mean that I couldn't come up with one. Maybe. I'm not sure. 13:39:47 13:39:52 13:39:55 13:39:58 13:40:01

Q. In your opinion, is every interior chamber connected to a combustion chamber? 13:40:02 13:40:06

MR. CHOW: Objection; form. 13:40:09

THE WITNESS: It depends on what interior 13:40:09

chamber we're talking about. 13:40:09

Q. (BY MR. PHILBIN) In the context of these patents, in your opinion? 13:40:13 13:40:15

A. Are we talking about the specific claim term? 13:40:16 13:40:19

Q. Yes, sir. 13:40:20

A. So within this patent, its claims and its specifications, its history, how a person of the ordinary skill in the art would see it, yes. I think an interior chamber would be immediately separated from the combustion chamber with a seal. 13:40:20 13:40:26 13:40:29 13:40:33 13:40:36

Q. How far away can the combustion chamber be from the interior chamber to satisfy your definition of "adjacent"? 13:40:44 13:40:52 13:41:02

A. Well -- so we see -- look here in paragraph 103. We have Claim 1 from the 829 Patent further recites "a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber" and "wherein a valve needle is movable between a closed position at which is 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 the valve seat whereby said interior chamber is 13:41:02 13:41:18 13:41:25 13:41:31 13:41:34 13:41:38 13:41:41 13:41:45 13:41:50 13:41:56 13:42:00

fluidly connected with said nozzle orifice." 13:42:04

So I think a person of the ordinary skill 13:42:11
in the art would know that the seat may not be the, 13:42:14
you know, immediate thing that is separating the 13:42:21
interior from the combustion chamber, because it 13:42:27
still has to go through a nozzle so that we can drop 13:42:30
the pressure from high pressure to low pressure and 13:42:33
turn the liquid into small droplets which can 13:42:37
evaporate and burn. 13:42:42

MR. PHILBIN: Objection; nonresponsive. 13:42:42

Q. (BY MR. PHILBIN) My question, sir, was 13:42:45
"how far?" 13:42:47

A. I can't tell you how far. I can tell you 13:42:48
that it has to be in the neighborhood and probably go 13:42:52
through the nozzle orifice if there's a nozzle 13:42:54
orifice in this case. 13:43:00

Q. Which word, "interior" or "chamber," 13:43:00
requires high-pressure fluid to be injected? 13:43:02

A. It doesn't have to do with interior 13:43:05
chamber, necessarily. It has to do with how a person 13:43:10
of the ordinary skill in the art would see the 13:43:12
injector operating. They would know that the 13:43:16
pressure on the inside of the injector had to be 13:43:18
significantly higher than the pressure within the 13:43:21
combustion chamber so that the injection can first be 13:43:24

flowing the right way, and, second, so that the liquid can be atomized into small droplets which evaporate and burn, evaporate, mix, and burn. 13:43:27 13:43:30 13:43:35

Q. So is the answer to my question "neither"? 13:43:40

A. Let's ask it again, then. 13:43:43

Q. Which word, "interior" or "chamber," requires high-pressure fuel to be injected? 13:43:45 13:43:49

A. I think it's not either word. It's the entire phrase taken in context with the patents. 13:43:52 13:43:54

Q. Okay. Which word, "interior" or "chamber," requires a valve to be actuated? 13:43:57 13:44:00

A. Again, I would say this is given right from the claim language, saying that these things are right next to each other. The interior chamber with the combustion chamber. 13:44:02 13:44:10 13:44:12 13:44:16

Q. Okay. Would you agree with me that what causes the valve to be actuated is the pressure differential? 13:44:18 13:44:20 13:44:24

MR. CHOW: Objection; form. 13:44:25

THE WITNESS: It depends on the injector. 13:44:25

Q. (BY MR. PHILBIN) The opening and closing of the valve is caused by high pressure on one side and low pressure on the other side, correct? 13:44:28 13:44:32 13:44:34

A. Again, it depends on the specific injector we're talking about. 13:44:37 13:44:41

Do you want to point to a specific injector that we can talk about? 13:44:42 13:44:44

Q. We're going to get to that. Yes, sir. 13:44:46

Let's talk about fluid passage. You know what fluid passage is, right? 13:44:48 13:44:49

A. So I have formed an opinion on what fluid passage from said interior chamber to said combustion chamber is. 13:44:51 13:44:59 13:45:03

Q. Is a hallway a passage? 13:45:04

MR. CHOW: Objection; form. 13:45:06

THE WITNESS: I think it would depend on your definition of a passage. 13:45:06 13:45:08

Q. (BY MR. PHILBIN) Is pipe a passage? 13:45:10

A. I would think it depends on what your definition of "passage" is. 13:45:12 13:45:16

Q. Is a pipe a fluid passage? 13:45:17

A. It again depends on the context and how the person of ordinary skill in the art is seeing it in that context. 13:45:20 13:45:26 13:45:29

Q. Is a hose a fluid passage? 13:45:30

A. It depends on the context. 13:45:32

Q. If I use a hose to fill my sink, is the hose a fluid passage? 13:45:34 13:45:37

A. In this hypothetical, I mean, you are filling the sink from your -- the spout to the sink. 13:45:39 13:45:44

You're saying then, is it a fluid passage? 13:45:53
In that case, it seems to be consistent 13:45:58
with how a person of the ordinary skill in the art 13:46:01
would see, at least in this context. 13:46:04
Q. If I use the same hose to drain my sink, is 13:46:07
the hose a fluid passage? 13:46:11
A. Again, we would have to think about it. 13:46:13
But if you're taking it from the sink to a drain, 13:46:16
then that hose is a fluid passage, likely. 13:46:23
Q. Is a straw a fluid passage? 13:46:28
A. If it -- you know, you're taking soda from 13:46:30
the cup to your mouth, then maybe it's a fluid 13:46:37
passage. 13:46:41
Q. Is your throat a fluid passage? 13:46:41
A. You know, I haven't thought of it. But, 13:46:44
you know, you could -- in this hypothetical, you 13:46:50
could consider that a fluid passage. 13:46:53
Q. Is a syringe a fluid passage? 13:46:54
A. I'm not sure. I'd have to think about 13:47:01
that. 13:47:01
Q. Is a gutter on a house a fluid passage? 13:47:01
A. Again, I think that looks like it would 13:47:04
depend on your definition. 13:47:08
Q. Would you agree that one purpose of a check 13:47:09
valve on a pipe is to control the direction of the 13:47:11

flow? 13:47:15
MR. CHOW: Objection; form. 13:47:16
THE WITNESS: A check valve, the idea is to have the flow at least predominantly in one direction. 13:47:17 13:47:24 13:47:29
Is that the only reason that you use it? Not necessarily. 13:47:30 13:47:34
Q. (BY MR. PHILBIN) Related to fluid passage, have you abandoned your December 22 opinion that fluid passage requires a particular direction of flow? 13:47:37 13:47:49 13:47:54 13:47:57
MR. CHOW: Objection; form. 13:48:00
THE WITNESS: So we're talking about the December 2, '22? 13:48:01 13:48:05
Q. (BY MR. PHILBIN) Yes, sir. 13:48:08
A. So in that construction, we say that it flows from the interior chamber to the combustion chamber. 13:48:09 13:48:14 13:48:20
In the current form, I have that fuel flows from the interior chamber to the combustion chamber. So as far as I see it, the directionality is the same. 13:48:21 13:48:28 13:48:31 13:48:37
Q. So does directionality, does that require from the word "passage" or "fluid"? 13:48:38 13:48:41
A. It's required from inside of the claim 13:48:43

term, but it says "from said injector" -- "interior chamber to said combustion chamber." 13:48:47 13:48:55

If they didn't want a direction, right, giving weight to each one of these words, I assume that the -- you know, the author would have used "between" if they didn't want a direction in there. And that's consistent with how a person of the ordinary skill in the art would see this injector operate. 13:48:58 13:49:02 13:49:05 13:49:10 13:49:13 13:49:16 13:49:19

Q. Would you agree with me there's a road that runs from this hotel to the airport? 13:49:19 13:49:22

A. So there -- sure. There is a road that runs from here to there. 13:49:29 13:49:34

Q. And just because I phrase "the road is running from the hotel to the airport" doesn't mean I can't drive on the road from the airport to the hotel, correct? 13:49:35 13:49:38 13:49:42 13:49:47

A. But if it was known to a person of the ordinary skill that it was a one-way road, then it would be. 13:49:48 13:49:50 13:49:53

Q. So where in the patent do you see the one-way-road limitation for fluid or passage? 13:49:54 13:49:56

A. I mean, it says it right there, "from interior chamber to combustion chamber." But again, that also is wholly consistent with how injectors 13:49:59 13:50:03 13:50:08

operate. The fluid goes from the interior chamber to the combustion chamber. 13:50:13 13:50:16

MR. PHILBIN: Would you mark this. 13:50:40

THE WITNESS: So I'm not sure if I'm done answering the question yet. 13:50:42 13:50:44

(Exhibit Number 4 was marked for identification.) 13:50:44 13:51:17

MR. CHOW: So is this Exhibit 5? 13:51:17

MR. PHILBIN: 4. 13:51:19

MR. CHOW: 4. 13:51:20

THE WITNESS: So, for example, the specifications from the 829 Patent -- so I'm looking at paragraph 118. I will just read part of it. It says -- the highlighted part here is that these -- essentially, I will paraphrase the first part. 13:51:48 13:51:52 13:51:58 13:52:02 13:52:08 13:52:12

The openings that go through the injector that provides the flow from the inlet port to the -- to the nozzle, this is what is required to permit free flow of the fuel from the inlet port through the -- to the nozzle/orifices, right? And this is when the injector is opened. 13:52:12 13:52:15 13:52:21 13:52:26 13:52:30 13:52:35

We have to have this free flow, again, from the inlet port to the nozzle. And that's the only direction that fuel is useful in an engine, is 13:52:38 13:52:40 13:52:44

when it gets inside a combustion chamber to burn. So this is how a person of the ordinary skill in the art would see the direction. 13:52:48 13:52:53 13:52:58

Q. Is it your opinion that the inventors disclaimed any other arrangement? 13:52:59 13:53:02

A. So I would say there's no disclosure I could think of of a case where the fluid is flowing in the opposite direction. 13:53:05 13:53:34 13:53:36

So, you know, I think that that is consistent with the directionality of a person of the ordinary skill. 13:53:41 13:53:44 13:53:50

MR. PHILBIN: Objection; nonresponsive. 13:53:50

Q. (BY MR. PHILBIN) Is it your opinion that the inventors disclaimed any other arrangement? 13:53:50 13:53:52

A. Again, as far as I can see, they don't disclose anything going the opposite direction. And that would go against what I would typically think as a person of the ordinary skill in the art would see. So I think that that directionality is important here. 13:53:55 13:53:58 13:54:01 13:54:04 13:54:08 13:54:11

Q. Okay. Would you take a look at Exhibit 4. 13:54:11

A. (The witness complied.) 13:54:14

Q. Let me just hand you a highlighter. 13:54:15

Would you highlight the valve needle in Exhibit 4? 13:54:18 13:54:21

MR. CHOW: Objection; form. 13:54:24
THE WITNESS: So let's -- 13:54:25
MR. CHOW: Counsel, can you provide some context for this exhibit? 13:54:31
MR. PHILBIN: Nope. 13:54:35
MR. CHOW: So you're not going to inform Dr. Quinlan where this exhibit came from? 13:54:36
THE WITNESS: I know where it came from. 13:54:39
MR. PHILBIN: I asked him before the break if he can identify just based on a figure, and he said yes. 13:54:41
THE WITNESS: Is it in this figure? That's the question, right? This is only a portion of the injector. 13:54:43
Q. (BY MR. PHILBIN) That wasn't my question, sir. 13:54:45
My question is, Is there a valve needle on Exhibit 4? 13:54:48
A. I don't think that was your question. I can read it. 13:54:49
Q. Okay. Strike. 13:54:51
This is my question now: Identify the valve needle in Exhibit 4. 13:54:53
MR. CHOW: Objection; form. 13:54:55
And I'm going to state for the record 13:54:56

that I'm objecting to this exhibit as being incomplete. 13:55:12 13:55:15

THE WITNESS: I would have to agree, this is incomplete. 13:55:17 13:55:18

I don't know if I see the needle in this drawing. 13:55:20 13:55:23

Q. (BY MR. PHILBIN) So is it your testimony you cannot see a valve needle in Exhibit 4? 13:55:24 13:55:25

A. I am testifying that I would need to look at this more carefully in the context -- in seeing the broader context again, not just handing me something that happened 20 years ago. 13:55:30 13:55:31 13:55:36 13:55:40

Q. Okay. 13:55:42

MR. PHILBIN: Mark this as 5, please. 13:55:50

(Exhibit Number 5 was marked for identification.) 13:55:50 13:56:13

Q. (BY MR. PHILBIN) Can you identify the valve needle in Exhibit 5? 13:56:13 13:56:16

MR. CHOW: Objection; form. 13:56:18

Counsel, you're also not going to provide Dr. Quinlan an identification of where this came from or any additional information put into context? 13:56:18 13:56:21 13:56:24 13:56:25

MR. PHILBIN: I'm asking him just about what's contained in Exhibit 5. 13:56:25 13:56:27

MR. CHOW: Okay. And you're not going to provide any more context; is that right? 13:56:29 13:56:30

MR. PHILBIN: I am not. 13:56:33

THE WITNESS: Part of the injector is cut off here. But I would say that, you know, whether or not this is the exact language in that claim, because -- or patent, because again, that was 20 years ago. 13:56:34 13:56:37 13:56:42 13:56:45 13:56:49

You know, the valve needle is right there (indicated.) 13:56:50 13:56:50

Q. (BY MR. PHILBIN) Have you highlighted the item numbered as 35? 13:56:59 13:57:01

A. I have. 13:57:03

Q. Do you need any more information to determine whether or not 35 is the valve needle? 13:57:04 13:57:09

A. Again, I don't know what it was called in that patent. The words could be different, but my opinion is that that is a valve needle. 13:57:13 13:57:16 13:57:21

Q. Do you recognize Exhibit 5? 13:57:24

A. Again, these are from Sturman injectors. 13:57:26

MR. CHOW: Object to this line of questioning as being beyond Dr. Quinlan's declaration. 13:57:30 13:57:31 13:57:34

MR. PHILBIN: Would you mark this as Exhibit 6, please. 13:57:38 13:57:39

(Exhibit Number 6 was marked for identification.) 13:57:39 13:57:58

MR. CHOW: Same objections to this Exhibit Number 6 as I had for 4 and 5. 13:57:58 13:58:01

And I'd like Counsel to confirm that you're not going to provide Dr. Quinlan with any additional context with respect to this exhibit? 13:58:06 13:58:08 13:58:12

MR. PHILBIN: Exhibit 6 is a standalone exhibit. That's what I'm going to show him. 13:58:13 13:58:15

Q. (BY MR. PHILBIN) Where's the valve needle in Exhibit Number 6, sir? 13:58:13 13:58:19

A. As far as I can see, I wouldn't consider any of those a valve needle. 13:58:21 13:58:25

MR. PHILBIN: Let's take a break. 13:58:34

THE VIDEOGRAPHER: We're going off the record. The time is 1:58 p.m. 13:58:36 13:58:38

(Whereupon, a recess was taken at 1:58 p.m.) 13:58:38 13:58:38

(Whereupon, the proceedings resumed at 2:05 p.m.) 13:58:38 14:05:39

THE VIDEOGRAPHER: We are back on the record. The time is 2:05 p.m. 14:05:39 14:05:44

MR. PHILBIN: Pass the witness. 14:05:48

EXAMINATION 14:05:48

BY MR. CHOW: 14:05:48

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Q. Dr. Quinlan, I just have a couple quick questions for you. 14:05:57 14:05:59

Taking a look at Exhibit 3, is the entirety of Exhibit 3 your opinion? 14:06:01 14:06:04

A. Yes. 14:06:06

Q. Okay. Did you rely on conversations with counsel in order to form your opinion? 14:06:07 14:06:10

A. I was provided documents to review and claims to construe, but the opinions are wholly mine. 14:06:11 14:06:16

Q. Okay. Did you rely on the conversations with counsel in order to form your opinions? 14:06:20 14:06:21

A. No. 14:06:23

MR. CHOW: No further questions. 14:06:25

MR. PHILBIN: Thank you very much, sir. Appreciate your time. 14:06:26 14:06:28

THE WITNESS: Have a great one. 14:06:29

THE VIDEOGRAPHER: This ends the video deposition of Dr. Matthew Quinlan. We are going off the record. The time is 2:06 p.m. 14:06:31 14:06:32 14:06:35

MR. CHOW: E-Tran, rough. 14:06:40

MR. PHILBIN: I don't need a rough, final Friday. 14:07:02 14:07:18

MR. CHOW: Same time frame is fine. 14:07:36

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WHEREUPON, the within proceedings were concluded at the approximate hour of 2:06 p.m. on the 1st day of March, 2024.

* * * * * *

J. MATTHEW QUINLAN
March 1, 2024

ERRATA SHEET

In Re: Robert Bosch, LLC V. Westport Fuel Systems Canada, Inc.

I have read the foregoing 161 pages of the transcript and wish to make the following changes:

PAGE(S)	LINE(S)	REASON(S)
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CERTIFICATION OF DEPONENT

I, J. MATTHEW QUINLAN, do hereby certify that I have read the above and foregoing deposition and that the same is a true and accurate transcription of my testimony, except for attached amendments, if any.

Amendments attached ( ) Yes ( ) No

_____
J. MATTHEW QUINLAN

The signature above of J. MATTHEW QUINLAN, was subscribed and sworn to before me in the county of _____, state of _____, this _____day of _____, 2024.

_____
Notary Public

My commission expires

Robert Bosch, LLC V. Westport Fuel Systems Canada, Inc., 02/29/2024, (tlm)

REPORTER'S CERTIFICATE

STATE OF COLORADO)
) ss.
CITY AND COUNTY OF DENVER)

I, THERESA L. MENDEZ, Registered Professional Reporter and Notary Public, State of Colorado, do hereby certify that previous to the commencement of the examination, the said J. MATTHEW QUINLAN was duly sworn by me to testify to the truth in relation to the matters in controversy between the parties hereto;

That the said deposition was taken in machine shorthand by me at the time and place aforesaid and was thereafter reduced to typewritten form, consisting of 161 pages herein; that the foregoing is a true transcript of the questions asked, testimony given, and proceedings had.

I further certify that I am not employed by, related to, nor of counsel for any of the parties herein, nor otherwise interested in the outcome of this litigation.

IN WITNESS I, WHEREOF have affixed my signature and seal this 8th day of March, 2024.

My commission expires September 21, 2025.

Theresa Mendez

Theresa L. Mendez, Registered Professional Reporter and Notary Public

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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 rolled out to users and currently being used by numerous on- and off-campus researchers
- 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

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- 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

- Patel, S. C., Griffin, J., Schmidt, E. M., Runnels, B., and **Quinlan, J. M.**, "A Diffuse Interface Approach to Modeling Acoustic Wave-Droplet Interactions," *AIAA Science and Technologies Forum and Exposition.* Vol. AIAA-2024-1659, Orlando, Florida, 2024.
- Schmidt, E. M., Meier, M., **Quinlan, J. M.**, and Runnels, B., "A Diffuse Interface Model for Viscous Compressible Flow in Eroding Porous Media," *AIAA Science and Technologies Forum and Exposition.* Vol. AIAA-2024-2721, Orlando, Florida, 2024.
- Meier, M., Runnels, B. **Quinlan, J. M.**, and Schmidt, E. M., "Anisotropy of burn rates in solid composite propellants with phase field modeling," *AIAA Science and Technologies Forum and Exposition.* Vol. AIAA-2024-0214, Orlando, Florida, 2024.
- Day, J., **Quinlan, J. M.** "Modeling Nonlinear Acoustic Damping Due to Flow Separation Over a Baffle Blade," *184th Meeting of the Acoustical Society of America.* Vol. 3pSA, Chicago, Illinois, 2023 (Invited).

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- 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 Solid/Fluid Boundaries with AMR," *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 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.** "Rocket Science: Combustion Instabilities and High-speed Laser Diagnostics," *Invited talk—Science on Tap, Cool Science*, Colorado Springs, Colorado, April 2023.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, March 2023.

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- **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.
- **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.

EXPERT WITNESS EXPERIENCE

Deposed: January 12, 2023

US District Court for the Eastern District of Texas Marshal Division
Westport Fuel systems Canada Inc. v. General Motors, LLC: Case No. 2:21-cv-00456[JRG/RSP]

Gave deposition on claim construction at the request of General Motors

HONORS

Award: Abe M. Zarem Educator Award in Astronautics 2022
AIAA

Mentorship award received with student Joseph Day for his research on nonlinear acoustic damping due to flow separation: "Tip Shape, Height, and Thickness Influence on Nonlinear Acoustic Damping from Baffle Blades". As part of this award, Joseph was invited to present his work at the International Astronautical Congress (IAC) 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

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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 mono-propellant, 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

Compressible Flow (full responsibility for course—Grad) Spring 2024
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Spring 2024
University of Colorado—Colorado Springs, Colorado Springs, CO

Rocket Propulsion (full responsibility for course—Grad) Fall 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Incompressible Flow (full responsibility for course—Grad) Spring 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

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

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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

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

Co-advisor Expected 2024
Emma Schmidt—Doctor of Philosophy in Mechanical Engineering
"Self-similar Diffuse Boundary Method for Phase Boundary Driven Flow of an Inviscid Gas"
University of Colorado—Colorado Springs, Colorado Springs, CO

Co-advisor Expected 2024
Maycon Meier—Doctor of Philosophy in Mechanical Engineering
"Full-feedback Diffuse Interface Model of Solid Composite Propellant Deflagration"
University of Colorado—Colorado Springs, Colorado Springs, CO

Advisor/chair 2023
Joseph Day—Masters of Science in Mechanical Engineering
"Modeling Nonlinear Acoustic Damping Due to Flow Separation Over a Baffle Blade"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2023
Daniel Bugas—Doctor of Philosophy in Mechanical Engineering
"Network Plasticity for Multiscale Modeling of Deformation-Driven Microstructure Evolution"

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University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2023
Jared Strutton—Doctor of Philosophy in Mechanical Engineering
"Resolving Early Cure Kinetics and Viscoelasticity in Polyurethane Binders and Composites with Coupled Rheology and Spectroscopy"
University of Colorado—Colorado Springs, Colorado Springs, CO

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 2015–2024
  - 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 2020–2024
- 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)

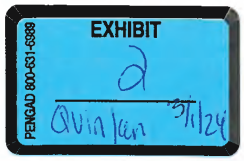
Avid Photographer

- 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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Proposed Claim Constructions from Dr. Quinlan's Declarations

Term	GM Case Declaration (dated 12/02/2022)	Bosch Case Declaration (dated 02/01/2024)	IPR2022-00292 / IPR2022-00293 Declarations (dated 12/09/2022)
"lift"	No opinion offered.	"The displacement of the valve [needle ('829 patent) / member ('138 patent)] away from its closed / seated position to its open position"	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."
"valve needle"	"Valve consisting of a slender elongated pointed rod that directly seals interior chamber from combustion chamber"	"A slender elongated valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber"	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."
"valve member"	"Member that directly seals interior chamber from combustion chamber"	"Valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber"	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."
"fluid passage from said interior chamber to said combustion chamber"	"Passage for fuel to flow from the interior chamber to the combustion chamber"	"Passage for fuel to flow from the interior chamber to the combustion chamber."	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."
"interior chamber"	No opinion offered.	"Volume from which high pressure fuel is injected into the combustion chamber when the valve is actuated"	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."
"passive hydraulic link"	"Sealed hydraulic fluid transmitting actuating forces but not employed to generate an actuating force"	No opinion offered.	No construction of any term proposed. All terms can be "afforded their plain and ordinary meaning."



UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

ROBERT BOSCH LLC, *Plaintiff,* v. WESTPORT FUEL SYSTEMS CANADA, INC., *Defendant.*	Case No. 2:23-cv-00038-JRG-RSP **JURY TRIAL DEMANDED**

P.R. 4-3 DECLARATION OF DR. J. MATHEW QUINLAN IN SUPPORT OF PLAINTIFF ROBERT BOSCH LLC'S CLAIM CONSTRUCTION POSITIONS



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I, Dr. J. Matt Quinlan, do hereby declare:

1. I am making this declaration at the request of Plaintiff and Counter-Defendant Robert Bosch LLC ("Bosch") in the above-captioned case and have been asked to provide testimony and opinions regarding certain aspects of U.S. Patent Nos. 6,298,829 B1 ("'829 Patent") and 6,575,138 B2 ("'138 Patent") (collectively, the "Asserted Patents"). Specifically, I was asked to provide my opinion about what the meaning is of certain claim terms to one of ordinary skill in the art. This declaration is submitted in accordance with Eastern District of Texas Local Patent Rule 4-3(b).

2. This declaration, including the exhibits hereto and cited materials, identifies my opinions to date, although I may provide further testimony and opinions if asked to testify in court or at a deposition. I also reserve the right to supplement or amend my opinions, as well as the bases for those opinions, if I receive additional relevant information or to respond to opinions offered by other experts in this case. I may rely on demonstrative exhibits, including pictures, figures, and drawings that appear in this report and the referenced exhibits and materials.

3. In preparing this declaration, I have reviewed the Asserted Patents and their prosecution histories, as well as the documents mentioned in this declaration. This declaration provides background information regarding fuel injectors and my expert opinions regarding the Asserted Patents, including opinions relating to the proper construction of certain claim terms and the bases for my opinions. In forming my opinions, I relied on my education, knowledge, and experience and I considered the level of ordinary skill in the art as discussed below.

I. QUALIFICATIONS

4. My curriculum vitae ("CV") is attached hereto as Exhibit A and provides an accurate identification of my background and experience.

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5. 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.

6. I received a B.S. in mechanical engineering from Colorado State University in 2001.

7. 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.

8. Starting in 2006, I returned to Colorado State University to continue my studies. I received a M.S. in mechanical engineering in 2009.

9. 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.

10. I received a Ph.D. in aerospace engineering from the Georgia Institute of Technology in 2015.

11. 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.

12. I joined the faculty at UCCS in 2018 as a visiting assistant professor and permanently in 2019 as an assistant professor.

13. 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

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"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").

14. 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).

15. A complete list of my patents and publications is included as part of my attached CV.

II. MATERIALS REVIEWED

16. In preparing this declaration, I have reviewed the following materials:

a. The Asserted Patents;

b. The file histories of the Asserted Patents and patents cited therein (Exhibits B-G);

c. The parties' proposed constructions of claim terms for the Asserted Patents;

d. Plaintiff Westport Fuel Systems Canada Inc.'s ("Westport") Disclosure of Asserted Claims and Infringement Contentions in this action;

e. Westport's Opening Claim Construction Brief in *Westport Fuel Systems Canada Inc. v. Nissan North America, Inc.*, No. 2:21-cv-00455-JRG-RSP (Lead Case);

f. Defendant General Motors LLC's Responsive Claim Construction Brief in *Westport Fuel Systems Canada Inc. v. Nissan North America, Inc.*, No. 2:21-cv-00455-JRG-RSP (Lead Case);

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g. Materials from Robert Bosch LLC and Mercedes-Benz USA, LLC's Petition for *Inter Partes* Review of U.S. Patent No. 6,298,829, Case No. IPR2023-00292;

h. Materials from Robert Bosch LLC and Mercedes-Benz USA, LLC's Petition for *Inter Partes* Review of U.S. Patent No. 6,575,138, Case No. IPR2023-00293;

i. Merriam-Webster's Collegiate Dictionary Excerpt (10th ed. 1997) (Exhibit H);

j. Oxford English Dictionary Excerpt, available at: https://www.oed.com/dictionary/needle_n?tl=true (Exhibit I);

k. Oxford English Dictionary Excerpt (2nd ed. 1989), available at https://www.oed.com/oedv2/00156466 (Exhibit J);

l. American Heritage Dictionary Excerpts (3d ed. 1996) (Exhibits K, M); and

m. Oxford Dictionary of Mechanical Engineering (2d ed. 2019) (Exhibits L, N).

III. LEGAL STANDARDS

17. I am not an attorney but have been instructed in and applied the law as described in this section.

A. Claim Construction

18. I have been informed and understand that the words of a patent claim are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention, i.e., as of the effective filing date of the patent application. The person of ordinary skill in the art is deemed to read the claim term or claim limitation not only in the context of the particular claim in which the disputed

term appears, but in the context of the entire patent, including the specification. I understand that claim construction may deviate from the ordinary and customary meaning of a disputed term only if (1) a patentee sets out a definition and acts as his or her own lexicographer, or (2) the patentee disavows the full scope of a claim term either in the specification or during prosecution.

19. I have been informed and understand that the first step in claim construction is to look to the language of the claims themselves. I understand it is a bedrock principle of patent law that the claims of a patent define the invention to which the patentee may exclude others from using.

20. I have been informed and understand that claims should also be read in view of other claims of the patent, both asserted and unasserted. I understand that claim terms are normally used consistently throughout the patent, and therefore the usage of a term in one claim can often help in understanding the meaning of the same term in other claims. Further, I understand that differences among claims can also be a useful guide in understanding the meaning of particular claim terms. As a specific example, I understand that the presence of a dependent claim with a particular limitation gives rise to a presumption that this limitation is not present in the independent claim from which it depends.

21. I have been informed and understand that claims must be read in view of the specification, of which they are a part. But while claim terms are understood in light of the specification, a claim construction must not import limitations from the specification into the claims. Absent limiting circumstances, a patentee is entitled to the full breadth of claim scope supported by the claims and specification.

22. I have been informed and understand that a court may rely on extrinsic evidence to shed useful light on the relevant art. Though extrinsic evidence is generally less significant and

less reliable than intrinsic evidence, the court may rely on extrinsic evidence at least to (1) help educate the court regarding the field of the invention, and (2) determine what a person of ordinary skill in the art would understand the claim terms to mean.

23. I have been asked to review the claims and provide my opinion regarding the meaning of the claims from the perspective of one of ordinary skill in the art. My opinions on claim construction expressed in this Declaration are from the perspective of, and based upon the knowledge of, a person of ordinary skill in the art at the time of the invention, and are consistent with my understanding as stated above.

B. Person of Ordinary Skill in the Art

24. 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 person of ordinary skill in the art ("POSITA") may have for combining references.

25. 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.

26. A POSITA in the technology field of the Asserted Patents 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 of fuel injection systems for internal combustion engines or an equivalent level of skill, knowledge, and experience.

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27. 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.

28. 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, as set forth below.

29. 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, as set forth below.

30. 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 Asserted Patents. 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.

IV. THE ASSERTED PATENTS

A. The '829 Patent

1. Effective Filing Date

31. I understand that the application leading to the '829 Patent was filed on March 9, 2000.

32. Based on my review of the '829 Patent, I note that it also references an October 15, 1999 provisional application filing on its face.

33. I have not formed an opinion as to what the effective filing date of the '829 Patent is. 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

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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 if the '829 Patent is determined to have a later March 9, 2000 effective filing date.

2. Overview

34. The '829 Patent begins by discussing prior art fuel injectors and 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[.]" ('829 Patent, 1:21-29.) The '829 Patent explains that this type of injection—in contrast to port injection into the manifold or port, outside of the combustion chamber—is "desirable" because direct injection improves engine performance and reduces emissions. (*Id.*) Direct or port injection options should not be confused with directly or indirectly actuated injectors. A directly actuated injector refers to an injector in which the injection valve member/needle lift is directly controlled by the injector's actuator, as opposed to an indirectly actuated injector that refers to an injector in which the injection valve member/needle is opened and closed hydraulically by a control/pilot valve, which in turn is controlled by the injector's actuator. The '829 Patent teaches a "directly actuated injection valve," (*see, e.g.*, the '829 Patent's title) and states that "[a] problem with employing a piezoelectric or magnetostrictive actuator …" or really any actuator in this arrangement, "… to operate a control valve, which in turn controls the flow of a hydraulic fluid to operate an injection valve, is that this arrangement requires the intermediate action of a hydraulic fluid. Any delays caused by the displacement of the hydraulic fluid causes delays in the actuation of the injector." (*Id.*, 3:39-45).

35. More specifically, the '829 Patent relates to "high pressure fuel injection valves or injectors for internal combustion engines" that are "directly controllable by" a "piezoelectric or

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magnetostrictive" activator. ('829 Patent, 1:12-16.) According to the '829 Patent, the injector also includes a "passive hydraulic link." (*Id.*, 1:17.)

36. The '829 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.*, '829 Patent, 1:56-57, 2:24-27, 2:62-65.)

37. The '829 Patent goes on, however, to identify certain purported problems with these known systems. For instance, according to the '829 Patent, prior art 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." ('829 Patent, 1:67-23.)

38. The '829 Patent states that solenoid actuators are "not suitable for applications that require a combination of fast response times and high actuating forces, such as, for example, injectors used for high pressure fuels." ('829 Patent, 2:45-48.)

39. The '829 Patent recognizes that some of the purported problems with the prior art injectors had been solved before its alleged invention. For example, the patent acknowledges that prior art injectors could also use piezoelectric and magnetostrictive actuators, rather than solenoids. But the patent claims that these 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. ('829 Patent, 3:39-50.) From this, a POSITA would understand that the purported invention of the '829 Patent includes using a piezoelectric or magnetostrictive actuators to directly open and close the injector valve, rather than control an intermediate valve. For example, after discussing these admittedly prior art 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.)

40. The '829 Patent contrasts a "passive hydraulic link" from an "active hydraulically operated systems," explaining: "[a]nother disadvantage of active hydraulically operated systems is that hydraulic fluid needs to be supplied and drained from a hydraulic cylinder." ('829 Patent, 3:48-50.) From the '829 Patent, a POSITA would understand that the alleged invention is an injector that includes a "passive hydraulic link." (*Id.*, 4:20, 7:10-20.) A POSITA would understand that a passive hydraulic link includes a hydraulic fluid layer that acts substantially as a solid to transmit opening and closing forces rather. For example, the patent explains 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.* at 7:10-22.)

41. According to the'829 Patent, its "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." ('829 Patent, 7:43-46.) 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.)

42. The below annotated versions of Figures 1-3 of the '829 Patent provide an example of a "directly actuated fuel injection valve 100." ('829 Patent, 8:39-41.)

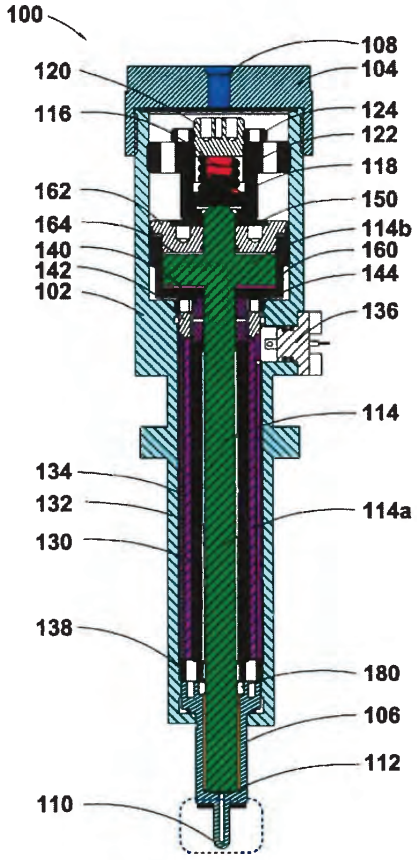


Figure 1

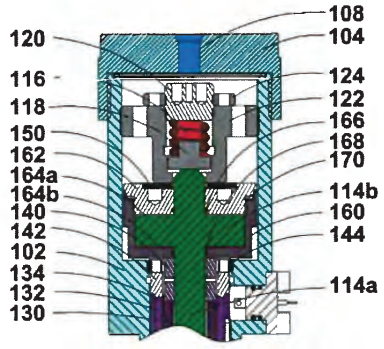


Figure 2

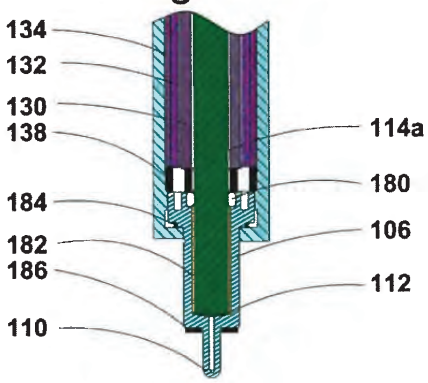


Figure 3

(*Id.*, Figs. 1-3 (annotated).)

43. The elements of this injector have been annotated as follows:

- **Teal**: A "valve housing 102," "cap 104," and "tip 106" that "provide a fluidly sealed valve body." ('829 Patent, 8:41-43.)
- **Blue**: An "inlet port 108" (blue) allows high-pressure fuel to enter the injector. (*Id.*, 1:32-37, 8:45-46.)

- **Orange**: "interior chamber" within the injector is adjacent to and sealed via the valve needle 114 from the nozzle orifice 100, which receives the high-pressure fuel from the inlet port 108. (*Id.*, 1:32-37,). The high-pressure fuel is injected from the interior chamber into the combustion chamber via the nozzle orifice. Based on the description of the claim, the interior chamber—which is sealed from the combustion chamber when the valve is closed—necessarily includes annular space 182 around the green-colored valve needle 114, as more clearly shown in Figure 3. The annular space 182 fulfills the criteria of claim 1, which requires that the interior chamber be sealed by the valve needle from the nozzle orifice.
- **Dashed blue outline**: A "valve tip 106" with a "nozzle orifice 110" "through which fuel exits" the injector. (*Id.*, 8:46-48.)
- **Green**: A "[v]alve 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.)
- **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.)
- **Purple**: A "magnetostrictive actuator" including a member 130, coil 132, and flux tube 134 located within the housing. (*Id.*, 9:45-49.)
- **Pink**: "[H]ydraulic fluid 164b" of "a hydraulic link assembly." (*Id.*, 10:62-64; 12:46-51.) The pink may be difficult to see in Figures 1 and 2 because of the size of the drawing.

44. The '829 Patent also explains to a POSITA how the allegedly novel 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." ('829 Patent, 9:51-10:8.) "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.) When valve needle 114 moves up away from the valve seat 112, a POSITA would understand that the fuel from the interior chamber exits and is injected into the combustion chamber. A POSTIA would understand that, in the purported invention, since the interior chamber is fluidly connected to the fuel inlet port, the fuel in the interior chamber is at the same pressure as the fuel inlet, which is a higher pressure than the combustion chamber. The '829 Patent's injection valve relies on this pressure difference to inject fuel into the combustion chamber.

45. The injection valve must be biased closed and contains "a needle spring [that] biases the valve needle in the closed position." ('829 Patent, Abstract.)

46. Since, an "actuator assembly may be activated to provide an opening force that is opposite and greater than the closing force provided by the spring assembly," when the actuator is deactivated, the biasing force causes the nozzle valve to close. ('829 Patent, 9:36-38.)

47. For instance, "[t]o close injection valve 100, at the end of the injection event, electric coil 132 is de-energized, causing magnetostrictive member 130 to contract. When valve needle 114 is moving from the open position to the closed position, the closing force originates from needle spring". ('829 Patent, 13:32-36.)

48. Alternatively, the "[v]alve closure may be optionally accelerated by initially reversing the current to negative current I_4." ('829 Patent, 14:34-35.)

49. Typically, a fast nozzle valve closing is desirable, but "[w]hen the fuel is gaseous, there is a greater need to slow down the valve needle upon closing because there is no liquid fuel to dampen the impact of the valve member on the valve seat." ('829 Patent, 16:53-56.)

50. "To reduce the impact and consequent wear of the valve needle when it makes contact with the valve seat, ... the current may be momentarily increased to positive current I_5 to slow down the valve closing action" in order to reduce seat wear. ('829 Patent, 14:35-39.)

51. The '829 Patent also explains that its 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." ('829 Patent, 12:57-60.) 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.*, 12:57-62.) 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.) The '829 Patent describes that in this way the injector can account for wear and differences in thermal expansion by automatically adjusting the thickness of the hydraulic link layer.

3. Prosecution History of the '829 Patent

52. As noted above, I have reviewed the '829 Patent's prosecution history. Originally filed claims 1–20 were rejected in a March 2001 office action as anticipated by or obvious over U.S. Patent No. 3,598,506 to O'Neill (Ex. B, "O'Neill") (Ex. C (March 21, 2001 Office Action).) Claims 21-30, however, which either required a particular "magnetostrictive member" structure or were directed to a method, were allowed. (*Id.*, pp. 1, 4.)

53. In rejecting claims 1-20, the Examiner pointed to Fig. 4 of O'Neill as pertinent, which I have reproduced below for reference: (Ex. C (March 21, 2001 Office Action), pp. 2-3.)

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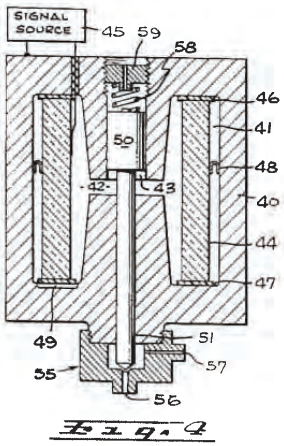


Fig. 4

(O'Neill, Fig. 4.) The Examiner explained that chambers 42 and 43 shown in this figure correspond to the "hydraulic link assembly" required by the pending claims. (Ex. C (March 21, 2001 Office Action), p. 3.)

54. 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 in "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. (O'Neill, 4:10-49.)

55. 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. D (June 22, 2001 Amendment and Request for Reconsideration), p. 4.) 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. 5.) 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.*, pp. 5, 7.) 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. 5.)

56. The claims were allowed after this response.

4. The '829 Patent's Claims

57. For reference, the asserted claims of the '829 Patent (1-3, 6, 11-12, 14-15, and 18-20) 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:
>
> 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 needle stronger than said closing

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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.

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.

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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.

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.

B. The '138 Patent

1. Effective Filing Date

58. I understand that the application leading to the '138 Patent was filed on May 23, 2001.

59. 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.

60. I have not formed an opinion as to what the effective filing date of the '138 Patent is. 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 if the '138 Patent is determined to have a later March 9, 2000 or a May 23, 2001 effective filing date.

2. Overview

61. The '138 Patent is a continuation-in-part of the '829 Patent, and, thus, includes a similar specification to the '829 Patent, with some differences as noted below.

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62. One difference between the '829 and '138 Patents is the type of valve. As noted above, the '138 Patent describes an injector with a "valve member." Based on the description in the patent, a POSITA would understand, in this patent, that to be an outwardly opening valve that opens and closes to separate the interior chamber from the combustion chamber. In contrast, the '829 Patent describes an injector with a "valve needle." Based on the description in the patent, a POSITA would understand that the '829 Patent's "valve needle" is different than the '138 Patent's "valve member." I address this more fully below, but the different terms and the teachings of the patents would inform a POSITA that a "valve needle" has a particular (needle-like) shape while a "valve member" could be of various shapes. And while the '138 Patent's valve member is outwardly opening, the '829 Patent's valve needle is inwardly opening. 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." ('138 Patent, 8:61-63.)

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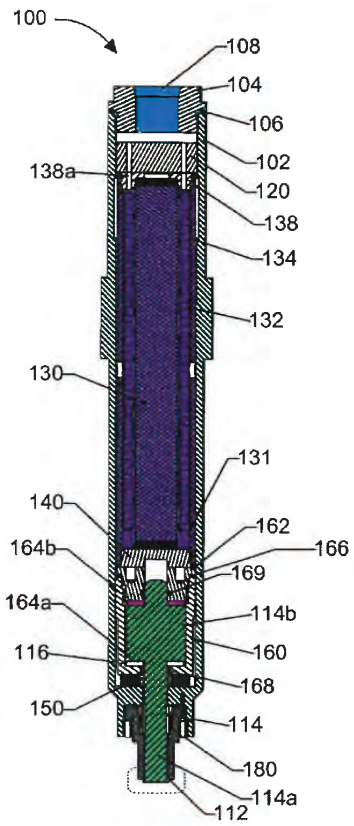


FIG. 1

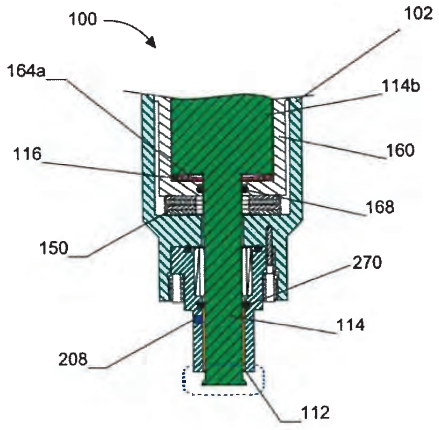


FIG. 2

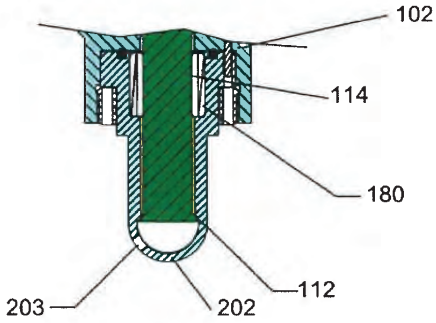


FIG. 2a

(*Id.*, Figs. 1, 2, 2(a) (annotated).)

63. The elements of this injector have been annotated as follows:

- **Teal**: A "valve housing 102" and "[v]alve cap 104" that "provide a fluidly sealed valve body." ('138 Patent, 9:4-6.)
- **Blue**: A "fuel inlet 208," as shown in Figure 2. (*Id.*, 13:34.)

- **Orange**: "interior chamber" of the injector is adjacent to and sealed from the combustion chamber by the valve member, whereby the interior chamber receives high-pressure fuel from the inlet port. The high-pressure fuel is injected from the interior chamber into the combustion chamber. (*Id.*, 1:32-37, 9:4-9.) Based on the description of the claim, the interior chamber—which is sealed from the combustion chamber when the valve is closed—necessarily includes the annular opening around the green-colored valve stem 114a, as more clearly shown in Figure 2 and 2a, to allow fuel to flow from the fuel inlet port through to the valve tip to be injected into the combustion chamber when the injector is actuated. (*See, e.g. id.*, 4:9-11, 10:1-6.) The annular opening fulfills the criteria of claim 1 of the '138 Patent, which requires that the interior chamber be sealed by the valve member from the combustion chamber.
- **Green**: A "valve member 114" located within the injector. (*Id.*, 9:23-27.)
- **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, 9:59-64.)
- **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.)
- **Purple**: A "magnetostrictive actuator" including a member 130, bobbin 131, coil 132, and flux tube 134 located within the housing. (*Id.*, 10:41-46.)
- **Pink**: "[H]ydraulic fluid 164b" of "a hydraulic link assembly." (*Id.*, 11:65-67; 14:16-22.)

64. The '138 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.)

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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.) "The opening force generated by the actuator assembly is transmitted to valve member 114 through" "hydraulic fluid 164b" of the "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.)

65. The biasing, closing force are in opposite directions for the inwardly ('829 Patent, 4:11-14) and outwardly ('138 Patent, 3:30-33) opening nozzle valves. For the needle valve explained in the '829 Patent, the biasing force (often from a mechanical spring ('829 Patent, Claim 1(c)) forces the needle valve against the nozzle seat to "seal" the fuel from the combustion chamber. In other words, the nozzle valve must be "strongly seated to avoid leakage of the fuel into the combustion chamber between injection events." (*Id.*, 1:42-43.) The direction of the biasing, closing force in this case is toward the combustion chamber (*see, e.g., id.*, Figs. 1, 2). Similarly, the outward opening injector described in the '138 Patent must completely seal the fuel from the combustion chamber when not actuated. ('138 Patent, 1:42-47.) But, in this case, to seal against the seat, the closing force must be in the direction away from the combustion chamber (*see, e.g., id.*, Fig. 2).

66. Like the '829 Patent, the '138 Patent explains that its injector allows for "[a]uto-adjustments" via "the migration of hydraulic fluid from chamber 164b on one side of the hydraulic piston 114b to chamber 164a" (light pink) "on the other side" of the piston. ('138 Patent, 15:14-25.)

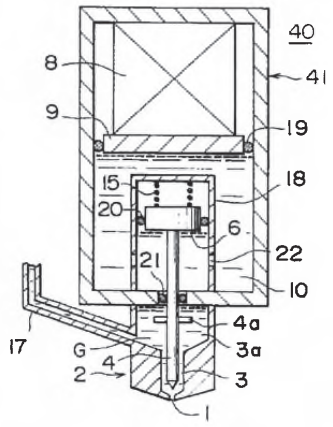
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3. Prosecution History of the '138 Patent

67. As noted above, I have reviewed the '138 Patent's prosecution history. The originally filed claims were rejected in a November 2002 office action as obvious over U.S. Patent No. 5,630,550 to Kurishige ("Kurishige," Ex. E). (Ex. F (Nov. 14 2002 Office Action).)

68. I have reviewed the Kurishige reference. Fig. 1 of Kurishige is reproduced below:

FIG. 1



(Kurishige, Fig. 1.) 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 amplified distance. Needle 4, which is connected to the piston 6, then lifts and valve 1 opens. (*Id.*, 5:46-67.)

69. 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. G (Feb. 21. 2003 Amendment and Request for Reconsideration), p. 7.) 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.*) The claims were allowed after this response.

4. The '138 Patent's Claims

70. For reference, the asserted claims of the '138 Patent (1-3, 6, 13-14, 17-21, and 26-28) 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:
>
> 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

(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.

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.

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21. The injection valve of claim **1** wherein said biasing mechanism comprises a spring.

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.

V. DISPUTED TERMS OF THE ASSERTED PATENTS

A. "valve member"

Claim	Term, Phrase, or Clause	Meaning To One Of Ordinary Skill In The Art	Westport's Construction
'138 Patent, Cls. 1, 19, 28	"valve member"	valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber	Defined by the claim itself: a valve component having "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"

71. Claims 1, 19, and 28 of the '138 Patent each recite a "valve member." The meaning of this term to a person having skill in the art when read in the context of the asserted claims of the '138 Patent and the specification of the '138 Patent is: valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber." The intrinsic record is consistent with, and supports, this understanding of the term "valve member," as set forth below.

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72. The broader context of the term in claim 1 is "(a) a valve housing, comprising:…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."

73. Thus, according to the language of the claim itself, claim 1 requires a "valve member"—which is a component of the valve—that has the function of "cooperating with" a "valve seat" "to seal" an "interior chamber from [the] combustion chamber." ('138 Patent, claim 1.) This would further confirm to a POSITA that it is the component itself, and not some other structure, that operates to open and close/seal the fluid passage from the injector's "interior chamber" to the "combustion chamber."

74. 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." A POSITA would understand this to mean 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.

75. Furthermore, a POSITA would understand the claimed "valve member" to be part of an outwardly opening valve because the valve member opens the nozzle—connecting the injector's 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—where the entire valve is located on one side of the valve seat that seals the interior of the injector from the combustion chamber.

76. The valve member is identified as reference numeral 114 in the specification of the '138 Patent and is shown in **green** below:

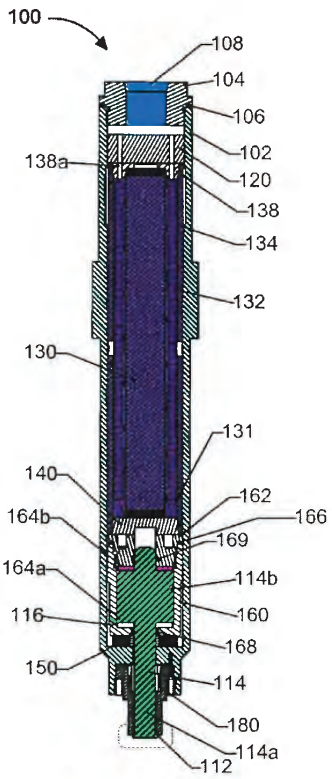


FIG. 1

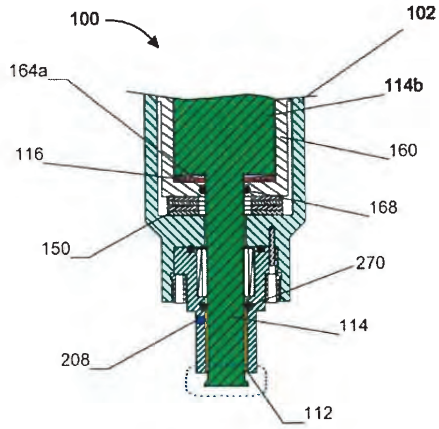


FIG. 2

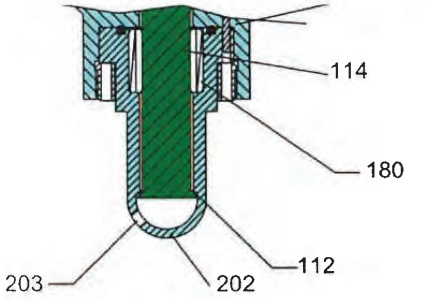


FIG. 2a

('138 Patent, Figs. 1, 2, 2(a) (annotated).)

77. As shown in Figures 1-2(a) above, and as described in the specification, the "valve member 114 is disposed within the interior of valve housing 102 and extends through an opening in the tip of valve housing 102. The sealing surface of valve member 114 contacts valve seat 112

to close injection valve 100 by preventing fuel from passing beyond valve seat 112 and into the combustion chamber." ('138 Patent, 9:59-64.)

78. In my opinion, a POSITA would have understood the term "valve member" within the '138 Patent to refer to an injection valve component that separates and seals the injector's interior chamber from the combustion chamber. As set forth above, the meaning of the claim language and surrounding context makes it clear that the valve member opens to the combustion chamber and not any other chamber. The specification is fully consistent with, and supports, this understanding of the term; all disclosed embodiments describe the valve member opening to the combustion chamber and all figures show the same.

79. Notably, the '138 Patent's recitation of the term "valve member" is contrasted with the '829 Patent's recitation of the term "valve needle" (described more fully, below). Both valve components are described as performing similar functions, i.e., sealing the interior chamber from the combustion chamber, but it is clear from the specification and figures of the '138 Patent that the valve member cannot be a valve needle because the specification of the '138 Patent distinguishes an outward opening injection valve using a valve member from an inwardly opening needle valve using a valve needle: "Opposed to a needle valve, which employs a needle that is retracted into the valve body to open the valve, an outward opening injection valve extends a valve member outward and away from the valve body to open the valve. To open an outward opening fuel injection valve for injecting fuel into an engine, a valve member is moved away from a valve seat and towards the combustion chamber." ('138 Patent, 8:63-9:3.) Also: "Another advantage of an outward opening injection valve is that when the valve is closed, there is less concern about combustion products fouling or clogging the injection valve because unlike a needle valve there are no exposed nozzle holes." (*Id.*, 9:32-36.)

80. To the extent Westport's construction is meant to broaden the term to include a valve member that does not seal the interior chamber from the combustion chamber that is incorrect and not how a POSITA would understand the term, because it would read out the requirement in the claim language that the valve member cooperate with a valve seat "to seal said interior chamber from said combustion chamber." ('138 Patent, Claim 1.) The only embodiments in the '138 Patent disclose a directly actuated injection valve where the "valve member" operates to seal the interior chamber of the device from the engine's combustion chamber without using intermediate/pilot control valves.

81. The above evidence from the '138 Patent supports my opinion that a POSITA would understand the invention described and claimed in the '138 Patent be a directly actuated injector with an outwardly-opening valve member—a component of the valve—that *seals the interior chamber from the combustion chamber*, which is the meaning of this term in the context of the claims and specification.

82. Thus, for all the reasons above, in my opinion, a POSITA would understand the term "valve member" to mean "valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber."

B. "valve needle"

Claim	Term, Phrase, or Clause	Meaning To One Of Ordinary Skill In The Art	Westport's Construction
'829 Patent, Cls. 1, 14, 20	"valve needle"	a slender elongated valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber	"a valve component having a cylindrical portion with a sealing end"

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83. Claims 1, 14, and 20 of the '829 Patent each recite a "valve needle." The plain and ordinary meaning of this term in the context of claims 1, 14, and 20 to a person having ordinary skill in the art when reading the '829 Patent is: "a slender elongated valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber." The intrinsic record is consistent with, and supports, this plain meaning understanding of the term "valve needle," as set forth below.

84. The context of the term in claim 1 is "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."

85. There are two key differences between my construction for this term and Westport's proposed construction, which, in my view, is incomplete and not the plain and ordinary meaning of this term. First, Westport's construction does not account for the valve needle's function in directly sealing the interior chamber from the combustion chamber, as required by claim 1. Second, Westport impermissibly broadens the structure recited, interpreting valve needle to be a generic "valve component having a cylindrical portion" without giving meaning to the term "needle," which a POSITA would understand provides the shape of the "valve needle." I address each issue in turn below.

86. ***First***, according to the plain meaning of the language of claim 1 quoted directly above, the valve needle must function to open and close (*i.e.*, "seal") the fluid passage from the "interior chamber" to the "nozzle orifice" and subsequently the "combustion chamber."

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87. The valve needle is identified as reference numeral 114 in the specification of the '829 Patent and is shown in **green** below:

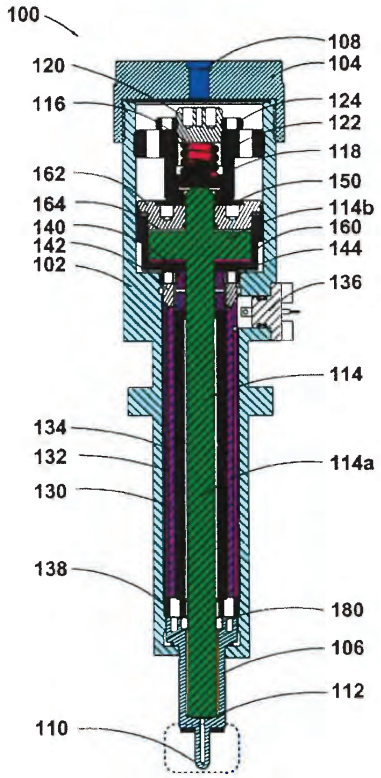


Figure 1

('829 Patent, Fig. 1 (annotated).)

88. As shown in Figure 1 above, and as described in the specification, the "[v]alve needle 114 is disposed within the interior of the valve body and contacts valve seat 112 to close injection valve 100 by preventing fuel from passing beyond valve seat 112 to nozzle orifice 110." ('829 Patent, 8:59-62.)

89. The "valve needle" as claimed, described in the specification, and shown in the figures of the '829 Patent pertains to a directly actuated injector.

90. To the extent Westport's construction, however, broadens the term—by reading out the requirement of claim 1 of the '829 Patent that the "valve needle" must seal or unseal the interior chamber from the combustion chamber—to cover this very different arrangement of an injection valve, which is not how a POSITA would have understood this term. In my opinion, the term "valve needle" within the '829 patent must therefore refer to an injection valve needle that separates the injector's interior chamber from the combustion chamber.

91. As set forth above, the meaning of the claim language and surrounding context makes it clear that the valve needle opens the interior chamber to the combustion chamber. The specification is fully consistent with, and supports, this understanding of the term; all disclosed embodiments describe the valve needle opening the fuel passage to the combustion chamber and all figures show the same. Thus, a POSITA would understand the term "valve needle" as used in claim 1 of the '829 Patent to require that it cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber.

92. ***Second***, Westport's construction attempts to broaden the term "valve needle" to be a "valve component having a cylindrical portion." In my opinion, however, a POSITA would understand from the use of the term "needle" that there is a specific structure or shape ascribed to this component of the valve such that it is not simply a valve component "having a cylindrical portion."

93. A valve can be any variety of mechanical structure. A valve *needle*, however, is a specific type of structure. For instance, every figure of the '829 Patent shows the valve needle 114 as a slender elongated valve component, which is exactly how one of skill in the art would understand the term. (*See*, *e.g.*, '829 Patent, Figs. 1-3.) Further, the specification describes the "differential *angle* between the end surface of valve needle 1[1]4 and valve seat 112," indicating

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that the valve needle includes an angled tip, *i.e.*, is a slender elongated valve component. (*Id.* at 8:50-57.)

94. This interpretation is further supported by the dictionary definitions of "needle" both at the time of the filing of the '829 Patent and in more current dictionaries: (1) "a slender pointed rod controlling a fine inlet or outlet (as in a valve)" (Ex. H (Merriam-Webster's Collegiate Dictionary 10th Ed.) at BOSCH_WP_0072360); and (2) "[a] thin pointed or tapering rod used to provide fine adjustment in closing an aperture, as in a valve" (Ex. I (Oxford English Dictionary, available at: https://www.oed.com/dictionary/needle_n?tl=true) at BOSCH_WP_0072376; *see also* Ex. J (Oxford English Dictionary 2nd Ed. (1989), available at https://www.oed.com/oedv2/00156466) at BOSCH_WP_0072416). Similarly, the definition of "needle valve" around this timeframe was "[a] valve having a slender point fitting into a conical seat, used to regulate accurately the flow of a liquid or gas." (Ex. K (The American Heritage Dictionary of the English Language Third Ed.) at BOSCH_WP_0072370). Current dictionaries also define "needle valve" as "[a] regulating valve with a relatively small outlet, a long tapered seat, and a needle-shaped plunger moved axially by a fine-threaded screw." (Ex. L (Oxford Dictionary of Mechanical Engineering (2d Ed. 2019)) at BOSCH_WP_0072437). A POSITA would understand the term "valve needle" to be a component of a "needle valve.". (*See, e.g.*, '829 Patent at 2:21-23 (describing the "valve needle" as a component in a "needle valve").)

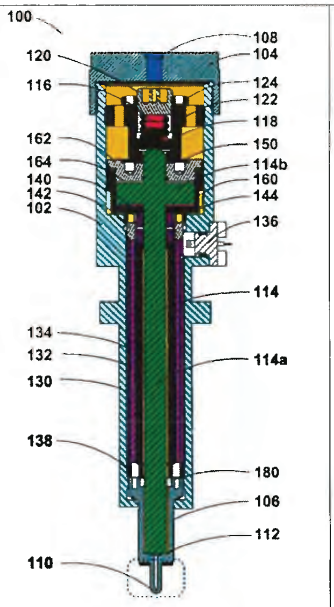
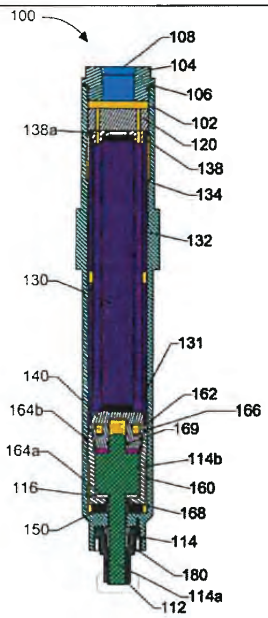
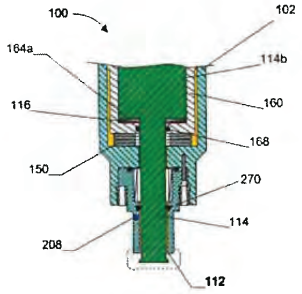
95. Additionally, the dictionary distinguishes between a "valve" and a "needle valve," indicating that a "valve needle" is more specific than just a generic cylindrical structure. (*See* Ex. M (The American Heritage Dictionary of the English Language 3rd Ed.) at BOSCH_WP_0072363 (defining valve as "[a]ny various devices that regulated the flow of gases, liquids, or loose materials through piping or through apertures by opening, closing, or obstructing ports or

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passageways"); *see also* Ex. N (Oxford Dictionary of Mechanical Engineering (2d Ed. 2019)) at BOSCH_WP_0072428 (providing a similar definition for valve).)

96. By contrast, the '138 Patent discloses a different valve shape, which uses a valve that is not a needle because it is not slender and elongated. For example, Figure 1 of the '829 Patent shows a slender elongated valve needle 114, which runs nearly the entire length of the injection valve. ('829 Patent, 8:59-65.) In contrast, Figures 1 and 3 of the '138 Patent show the valve member 114 as much shorter than the valve needle and a portion of the valve member (114b) much wider than the valve needle. ('138 Patent, 9:59-10:9.) Additionally, on the end of the valve member 114 that extends into the combustion chamber when the valve is actuated, the diameter of the valve member is larger than the diameter of the guide (as shown in Figure 2 of the '138 Patent below). This is necessary to seal the interior chamber from the combustion chamber when the valve is in the closed position. A needle shaped valve would not be able to form such a seal against the valve seat because, as shown in Figure 1 below of the '829 Patent, a valve needle tip would be too small in diameter.

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 Figure 1	 FIG. 1	 FIG. 2
'829 Patent, Figure 1	'138 Patent, Figure 1	'138 Patent, Figure 2

97. A POSITA would understand that while a "valve needle" and a "valve member" would have similar functions (*i.e.*, to seal the interior chamber from the combustion chamber), a "valve needle" must have a specific structure or shape. For example, a POSITA would understand, in light of the teaching of the specification, that a needle valve (which uses a "valve needle") is inwardly opening and a "valve member" is outwardly opening. This is because the '138 Patent distinguishes a "valve member" from a valve needle: "Opposed to a needle valve, which employs a needle that is retracted into the valve body to open the valve, an outward opening injection valve extends a valve member outward and away from the valve body to open the valve. To open an outward opening fuel injection valve for injecting fuel into an engine, a valve member is moved away from a valve seat and towards the combustion chamber." ('138 Patent, 8:63-9:3.) Also: "Another advantage of an outward opening injection valve is that

when the valve is closed, there is less concern about combustion products fouling or clogging the injection valve because unlike a needle valve there are no exposed nozzle holes." (*Id.*, 9:32-37.)

98. Despite this, Westport construes "valve needle" in the '829 Patent and "valve member" in the '138 Patent the same, both as a generic "valve component." Simply adding "having a cylindrical portion," insufficiently distinguishes a "valve needle" from a "valve member," improperly equating the two and failing to recognize that a valve needle is a specific type of structure, and that a valve member would necessarily be broader.

99. Thus, for all the reasons above, in my opinion, a POSITA would understand the term "valve needle" to mean a "slender elongated valve component that cooperates with a valve seat to seal or unseal the interior chamber from the combustion chamber," which is the meaning of this term in the context of a directly actuated inwardly opening injector.

C. "interior chamber"

Claim	Term, Phrase, or Clause	Meaning To One Of Ordinary Skill In The Art	Westport's Construction
'829 Patent, Cl. 1; '138 Patent, Cl. 1	"interior chamber"	volume from which high pressure fuel is injected into the combustion chamber when the valve is actuated	Plain and ordinary meaning

100. Claim 1 of the '829 Patent recites "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," and "wherein a 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."

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101. Claim 1 of the '138 Patent recites "an interior chamber fluidly connected to said fuel inlet port." It further recites "a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed" and "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."

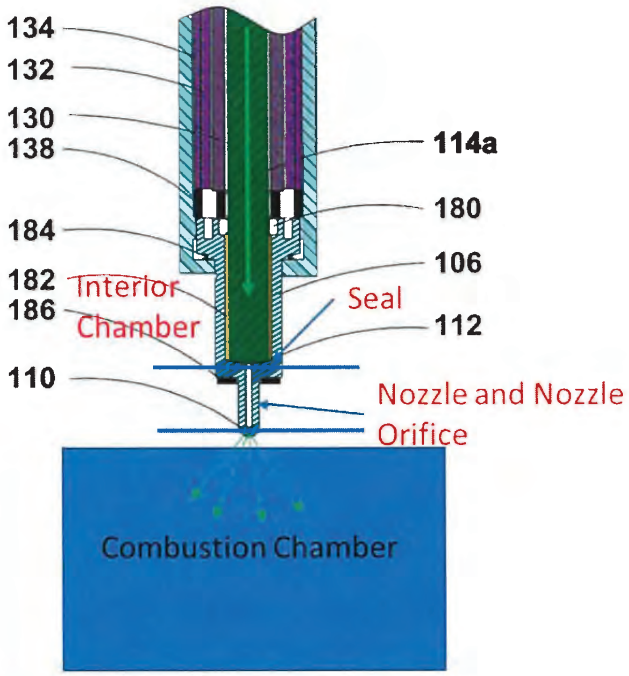
102. The intrinsic record, however, provides the context necessary to understand that the claimed "interior chamber" must be the "volume from which high-pressure fuel is injected into the combustion chamber when the valve is actuated." Claim 1 of the '829 Patent recites that the "interior chamber" is "fluidly connected to said fuel inlet port." A POSITA would understand the fuel inlet port is the port "through which fuel enters the valve body" and the "interior chamber" to be a space or volume within the injection valve receiving high-pressure fuel via the fuel inlet port. ('829 Patent, 1:32-37, 8:45-46.) Thus, the interior chamber contains high-pressure fuel.

103. Claim 1 of the '829 Patent further recites "a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber" and "wherein a 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." A POSITA would understand the nozzle orifice to be the orifice "through which fuel exits the valve body" and is directly injected into the combustion chamber. ('829 Patent. 8:47-48.) Because the interior chamber is fluidly sealed from the nozzle orifice (and therefore adjacent to the combustion chamber), the nozzle

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orifice provides a fluid passage ***from*** the interior chamber ***to*** the combustion chamber when the valve needle is in an open position. As a result, a POSITA would understand that the nozzle orifice would connect the interior chamber to the combustion chamber so that fuel is directly injected ***from*** the interior chamber ***to*** the combustion chamber when the valve is actuated. Thus, a POSITA would understand that the interior chamber must be a volume within the injection valve that holds fuel so that it can be directly injected from the interior chamber into the combustion chamber.

104. Annotated Figure 3 below shows what a POSITA would understand to be the relationship between the interior chamber, the seal between the valve needle and valve seat, and the combustion chamber, and how fuel would flow, as shown by the solid green arrows, based on the language in claim 1 of the '829 Patent.



('829 Patent, Fig. 3 (annotated).)

105. The embodiments disclosed in the specification are consistent with this understanding of the interior chamber. For example, Figure 1 of the '829 Patent discloses an embodiment of the invention wherein the actuator is disposed within the injection valve housing. In annotated Figure 1, below, the actuator is colored **purple**. ('829 Patent, 9:45-49.) The fuel inlet port is shown as 108 and the nozzle orifice as 110. (*Id.*, 8:45-48.)

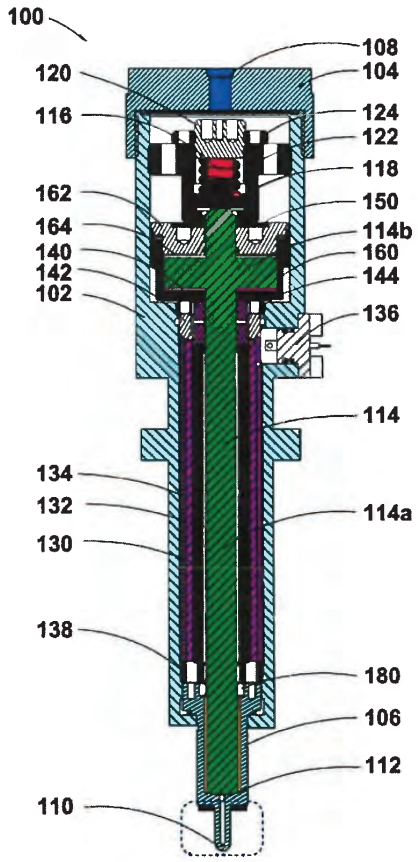


Figure 1

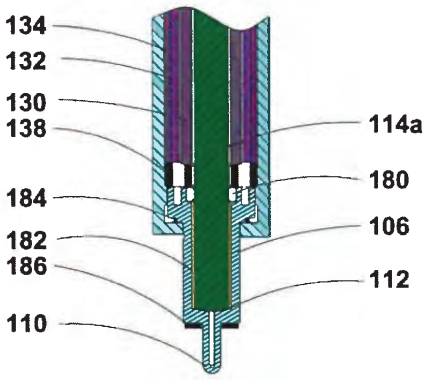


Figure 3

('829 Patent, Figs. 1, 3 (annotated).)

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106. The interior chamber, which is both fluidly connected to the fuel inlet port and sealed against the nozzle orifice, necessarily includes the annular space 182 (as shown in orange in Figure 3 above), which is disposed around the valve stem 114a and thereby adjacent to and sealed against the nozzle orifice according to the claim language. ('829 Patent, 13:6-14.) Any other gaps between valve components and openings provided in certain valve components, to allow fuel to free flow from the fuel inlet port through the nozzle orifice when the valve is open, as shown in Figure 3 above, may also be part of the interior chamber. (*Id.*)

107. The asserted claims and specification of the '138 Patent are also consistent with, and support, my proposed construction for "interior chamber." As in claim 1 of the '829 Patent, claim 1 of the '138 Patent recites that the "interior chamber" is "fluidly connected to said fuel inlet port." And a POSITA would similarly understand the fuel inlet port is the port "through which fuel enters the valve body" and the "interior chamber" to be a space or volume within the injection valve containing high-pressure fuel. ('138 Patent, 9:8-9, 1:36-40.)

108. Claim 1 of the '138 Patent further recites "a valve seat for cooperating with a valve member to seal said interior chamber from said combustion chamber when said injection valve is closed" and "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." A POSITA would understand the recited claim language to mean that the "valve member" fluidly seals the "interior chamber" such that fuel does not flow from the interior chamber into the combustion chamber when the injection valve is closed but allows fuel to pass from the interior chamber to the combustion chamber when the injection valve is open. Thus, a POSITA would

understand that the interior chamber must be a volume within the injection valve that holds fuel and is located adjacent to the combustion chamber so that it can be directly injected into the combustion chamber.

109. The embodiments disclosed in the specification are consistent with this understanding of the interior chamber. For example, Figure 1 of the '138 Patent discloses an embodiment of the invention wherein the actuator is disposed within the injection valve housing. In annotated Figures 1 and 2, below, the actuator is colored **purple**. ('138 Patent, 10:41-46.) The fuel inlet port is shown as 108, the valve seat as 112, and the valve member as 114. (*Id.*, 9:22-30.)

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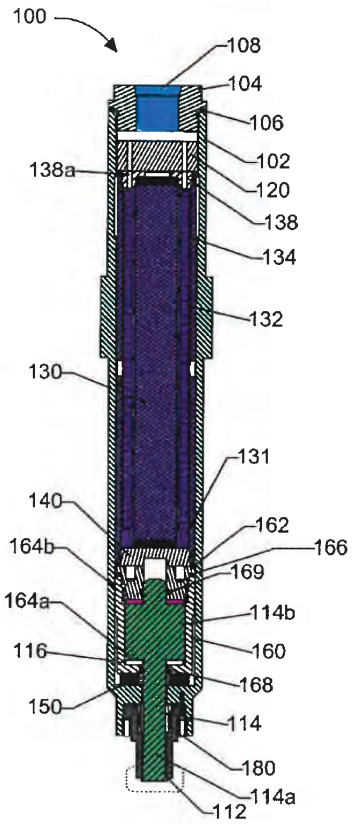


FIG. 1

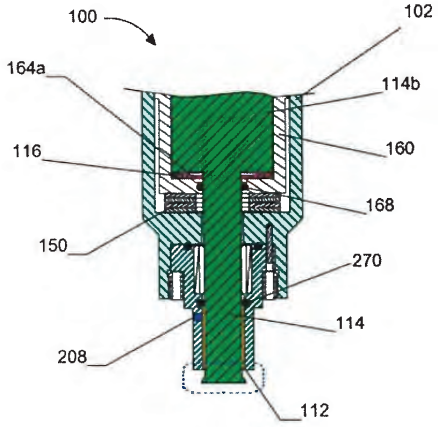


FIG. 2

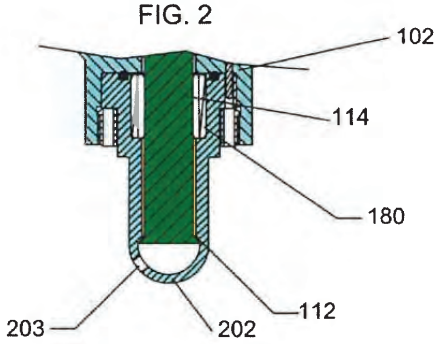


FIG. 2a

('138 Patent, Figs. 1, 2, 2a (annotated).)

110. The interior chamber, which is fluidly connected to the fuel inlet port and also sealed from the combustion chamber by the valve member 114, necessarily includes the annular space around the valve components (orange-colored portions of Figures 2 and 2(a) above) and may also include gaps that allow fuel to flow from the fuel inlet port to the nozzle seat. ('138 Patent 4:9-15, 9:40-47, 10:1-6, 14:48-59.)

111. Additionally, in another disclosed embodiment, the fuel inlet port is fluidly connected to the interior chamber near the valve tip such that the fuel does not come into contact

with the actuator assembly. ('138 Patent, 4:15-18, claim 16 ("The injection valve of claim 1 wherein said fuel inlet port is positioned near the valve tip such that the fuel flowing through said interior chamber does not contact said actuator assembly.")) In both embodiments, the interior chamber holds fuel so that it can be directly injected from the interior chamber into the combustion chamber.

112. Thus, a POSITA would understand that the interior chamber must be a volume within the injection valve that holds fuel so that it can be directly injected from the interior chamber into the combustion chamber.

113. A POSITA would also understand that for combustion to occur, the fuel must be injected into the combustion chamber at a sufficiently high pressure to turn the liquid fuel into a mist to evaporate and mix with the air in the combustion chamber. For instance, the requirement for the injection to occur at high pressure is recited in the Asserted Patents, which state "[t]he gaseous fuel needs to be injected at high pressure to overcome the combustion chamber pressure, which is high at the end of the compression stroke. Preferably, the injection pressure is high enough to promote good mixing between the injected fuel and the combustion chamber air." ('829 Patent, 1:32-37; '138 Patent, 1:36-40.)

114. Additionally, the specifications of both Asserted Patents state, "[t]he present invention relates generally to high pressure fuel injection valves or injectors for internal combustion engines…." ('829 Patent, 1:12-14; '138 Patent, 1:16-18.) In addition, when the injection valve is open, the interior chamber "…permit[s] the free flow of fuel from inlet port 108 through to nozzle orifice 110…." ('829 Patent, 13:8-13.) A POSITA would understand that in order to inject high pressure fuel through the nozzle orifice that the interior chamber must contain high-pressure fuel.

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115. Although Westport contends that "interior chamber" should be given its plain and ordinary meaning, I understand that Westport has not explained what it contends the plain and ordinary meaning to be. Accordingly, a POSITA would understand the claimed "interior chamber" in the asserted claims to be the "volume from which high pressure fuel is injected into the combustion chamber when the valve is actuated."

D. "fluid passage from said interior chamber to said combustion chamber"

Claim	Term, Phrase, or Clause	**Meaning To One Of Ordinary Skill In The Art**	**Westport's Construction**
'829 Patent, Cl. 1	"fluid passage from said interior chamber to said combustion chamber"	passage for fuel to flow from the interior chamber to the combustion chamber	"a pathway fluidly connecting the interior chamber and the combustion chamber"

116. Claim 1 of the '829 Patent recites "a fluid passage from said interior chamber to said combustion chamber." The plain and ordinary meaning of this phrase to a person having ordinary skill in the art when reading claim 1 and the '829 Patent is: "passage for fuel to flow from the interior chamber to the combustion chamber." The intrinsic record is consistent with, and supports, this plain meaning understanding of the claim phrase, as set forth below.

117. The context of the term in claim 1 is "a nozzle comprising a nozzle orifice providing a fluid passage from said interior chamber to said combustion chamber."

118. The specification of the '829 Patent describes this term as follows:

> The movement of valve needle 114 is guided near valve tip 106 by guide 180 (see FIG. 3). FIG. 3 shows annular space 182 disposed around valve stem 114 *a*. Between injection events, fuel remains in annular space 182. When injection valve 100 is open, fuel flows through annular space 182, other gaps between valve components, and openings provided in certain valve components, which all cooperate ***to permit the free flow of fuel from inlet port 108 through to nozzle orifice 110*** (which may be one of a plurality of

> nozzle orifices radially oriented from the nozzle throat). For example, FIGS. 1 through 3 show ***openings that provide fluid passages through components*** such as needle spring housing 122, lock nut 144, and pole 138. FIG. 3 also shows seal 184 between valve housing 102 and valve tip 106, and cylinder head face seal 186, which seals between injection valve 100 and the engine cylinder head (not shown).

('829 Patent, 13:5-20 (emphasis added).)

119. As set forth above, the plain and ordinary meaning of the claim language and surrounding context makes it clear that the fluid passage is a passage for fuel to flow from the interior chamber to the combustion chamber. First, a POSITA would understand a "fluid passage" to be a passage designed for fluid to flow and not just an opening where fluid could flow but does not. Second, a POSITA would understand that fuel flows from the inlet port, through the injector's interior chamber, and out of the injector to the combustion chamber. There are no embodiments or figures in the specification where a fluid passage is described as bidirectional. Instead, the specification is fully consistent with, and supports, my understanding of the term; all disclosed embodiments describe the fuel flowing from the interior chamber to the combustion chamber and all figures show the same.

120. As I discussed above, one of skill in the art reading the '829 Patent would understand that the "invention" is an improvement to a "directly actuated injection valve," not an indirectly actuated injection valve. The only embodiments in the '829 Patent disclose a directly actuated injection valve, where the fuel flows from the interior chamber to the combustion chamber. There is no disclosure of fuel flowing in the opposite direction (i.e., from the combustion chamber to the interior chamber). Fuel flowing from the combustion chamber to the interior chamber would make no sense to a POSITA.

121. Westport's construction is incorrect because the claimed injector is supposed to inject fuel into the combustion chamber. Thus, the fuel must flow ***from*** the interior chamber ***to***

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the combustion chamber. Westport's construction, which is not the plain and ordinary meaning of the term, reads out that directionality to encompass any passage including one where fuel flows away from the combustion chamber through the interior chamber. That is nonsensical and not how a POSITA would understand this term.

122. Westport appears to broaden the term to cover the very different arrangement of an injector that allows fuel to flow from the combustion chamber to the interior chamber. However, for similar reasons as set forth above in Section V.C., the "fluid passage from said interior chamber to said combustion chamber" as claimed, described in the specification, and shown in the figures of the '829 Patent pertains to a directly actuated injector where fuel flows ***from*** the interior chamber ***to*** the combustion chamber.

123. Westport's proposed construction is not how a POSITA would understand the term because it effectively reads out the direction of the fuel flow. Specifically, the claim recites a "fluid passage ***from*** said interior chamber ***to*** said combustion chamber." ('829 Patent, claim 1 (emphasis added).) In my opinion, based on the operation of directly actuated injectors, this language indicates a specific direction of the fuel flow ***from*** the interior chamber ***to*** the combustion chamber. Westport's proposal, however, simply recites a fluid connection between the interior chamber and the combustion chamber, seemingly allowing for fluid to flow in either direction. This improperly broadens the scope of the claim and reads out a necessary requirement.

124. Westport's proposed construction is also not how a POSITA would understand the term because it allows for an opening that is not designed for fluid to flow through to satisfy this claim language and, further, fails to indicate a direction for the fuel to flow, as required by the claim language.

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E. "lift"

Claim	Term, Phrase, or Clause	Meaning To One Of Ordinary Skill In The Art	Westport's Construction
'829 Patent, Cl. 1, 11, 12; '138 Patent, Cl. 1, 17, 18	"lift"	"the displacement of the valve [needle ('829 Patent)/member ('138 Patent)] away from its closed/seated position to its open position"	Defined by the claim itself: "the distance traveled by said sealing end away from said valve seat"

125. A POSITA would understand that the patent applicant gave an express definition for "lift" to mean "the displacement of the valve [needle ('829 Patent)/member ('138 Patent)] away from its closed/seated position to its open position."

126. I understand that patentees can expressly define terms to have a specific meaning. Here, the patentee expressly defined the meaning of "lift" in the context of needle valves and—more generally—injection valves. And the specifications of the Asserted Patents define the term "lift."

127. In the '829 Patent, the specification states: "'Lift' in the context of needle valves ***is defined herein*** as the displacement of the valve needle away from its closed/seated position to its open position." ('829 Patent, 2:21-23 (emphasis added).) In the '138 Patent, the specification states: "'Lift' in the context of injection valves ***is defined herein*** as the displacement of the valve needle or member away from its closed/seated position to its open position." ('138 Patent, 2:48-51 (emphasis added).)

128. Given these express definitions of "lift" in the context of needle valves and injection valves, a POSITA would understand the term "lift" in the asserted claims to mean: "the displacement of the valve [needle ('829 Patent)/member ('138 Patent)] away from its closed/seated position to its open position."

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129. Furthermore, the express definition of "lift" in the '829 specification is consistent with the language of claim 1 of the '829 Patent, which recites: "wherein valve needle lift equals the distance traveled by said sealing end away from said valve seat." A POSITA would understand that "[t]he ***distance*** traveled by said sealing end [of the valve needle] away from said valve seat" is the same as "the ***displacement*** of the valve needle away from its closed/seated position to its open position." However, my proposed construction—which is the express definition of the term "lift" from the specification—clarifies the specific component (and not just the "sealing end" of the component) that moves during actuation of the injector.

130. Additionally, it appears that Westport's proposed construction is based only on the language of claim 1 of the '829 Patent, however, Westport is proposing that its construction be applied to both the '829 Patent and the '138 Patent. I understand that it would not be proper to import claim limitations from one patent to another.

131. Given these points, a POSITA would understand that the patentee defined the term "lift" consistently in the specification of both of the Asserted Patents and would understand the term to mean: "the displacement of the valve [needle ('829 Patent)/member ('138 Patent)] away from its closed/seated position to its open position."

VI. CONCLUSION

132. I reserve the right to supplement, modify, or revise my opinions and constructions based on additional information that is provided to me in this litigation.

133. I hereby declare under penalty of perjury that the foregoing is true and correct; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: February 1, 2024



Dr. J. Matt Quinlan

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Exhibit A

John "Matt" Quinlan
(719) 351-9770
jquinlan@uccs.edu
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 rolled out to users and currently being used by numerous on- and off-campus researchers
- 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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Talks

- **Quinlan, J. M.** "Rocket Science: Combustion Instabilities and High-speed Laser Diagnostics," *Invited talk—Science on Tap, Cool Science*, Colorado Springs, Colorado, April 2023.
- **Quinlan, J. M.** "Combustion Instabilities and Nonlinear Acoustic Damping," *Invited talk—MAE Research Seminar, University of Colorado–Colorado Springs*, Colorado Spring, Colorado, March 2023.

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- **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.
- **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.

EXPERT WITNESS EXPERIENCE

Deposed: January 12, 2023

US District Court for the Eastern District of Texas Marshal Division
Westport Fuel systems Canada Inc. v. General Motors, LLC: Case No. 2:21-cv-00456[JRG/RSP]

Gave deposition on claim construction at the request of General Motors

HONORS

Award: Abe M. Zarem Educator Award in Astronautics 2022

AIAA

Mentorship award received with student Joseph Day for his research on nonlinear acoustic damping due to flow separation: "Tip Shape, Height, and Thickness Influence on Nonlinear Acoustic Damping from Baffle Blades". As part of this award, Joseph was invited to present his work at the International Astronautical Congress (IAC) 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 mono-propellant, 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

Compressible Flow (full responsibility for course—Grad) Spring 2024
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Spring 2024
University of Colorado—Colorado Springs, Colorado Springs, CO

Rocket Propulsion (full responsibility for course—Grad) Fall 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Control of Aero. and Mech. Systems (full responsibility for course) Fall 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Incompressible Flow (full responsibility for course—Grad) Spring 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

Engineering Thermodynamics II (full responsibility for course) Spring 2023
University of Colorado—Colorado Springs, Colorado Springs, CO

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

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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

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

Co-advisor Expected 2024
Emma Schmidt—Doctor of Philosophy in Mechanical Engineering
"Self-similar Diffuse Boundary Method for Phase Boundary Driven Flow of an Inviscid Gas"
University of Colorado—Colorado Springs, Colorado Springs, CO

Co-advisor Expected 2024
Maycon Meier—Doctor of Philosophy in Mechanical Engineering
"Full-feedback Diffuse Interface Model of Solid Composite Propellant Deflagration"
University of Colorado—Colorado Springs, Colorado Springs, CO

Advisor/chair 2023
Joseph Day—Masters of Science in Mechanical Engineering
"Modeling Nonlinear Acoustic Damping Due to Flow Separation Over a Baffle Blade"
University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2023
Daniel Bugas—Doctor of Philosophy in Mechanical Engineering
"Network Plasticity for Multiscale Modeling of Deformation-Driven Microstructure Evolution"

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University of Colorado—Colorado Springs, Colorado Springs, CO

Committee member 2023
Jared Strutton—Doctor of Philosophy in Mechanical Engineering
"Resolving Early Cure Kinetics and Viscoelasticity in Polyurethane Binders and Composites with Coupled Rheology and Spectroscopy"
University of Colorado—Colorado Springs, Colorado Springs, CO

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 2015–2024
  - 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 2020–2024
- 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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Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
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Exhibit B

United States Patent

[11] **3,598,506**

[72] Inventor **Cormac Garrett O'Neill**
Castro Valley, Calif.

[21] Appl. No. **818,678**
[22] Filed **Apr. 23, 1969**
[45] Patented **Aug. 10, 1971**
[73] Assignee **Physics International Company**
San Leandro, Calif.

[54] **ELECTROSTRICTIVE ACTUATOR**
15 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **417/383,** 310/8
[51] **Int. Cl.** **F04b 19/00,** H01v 7/00
[50] **Field of Search** ..... 103/1, 44, 440, 44 W; 230/1; 417/383; 310/8.1, 8; 340/11

[56] **References Cited**

UNITED STATES PATENTS

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2,555,613	6/1951	Soberg	103/44
3,150,592	9/1964	Stec	103/1
3,270,672	9/1966	Haines et al.	103/1
3,418,980	12/1968	Benson	103/1 X

Primary Examiner—Robert M. Walker
Attorney—Lindinberg, Freilich & Wasserman

ABSTRACT: Apparatus is disclosed for doing useful work with electroexpansive material which expands volumetrically in response to an electric field. The material is disposed in a chamber of a fixed volume slightly greater than the volume of the material at rest. The volume intermediate the material and the chamber is filled with a fluid having good insulation properties. When the material expands in response to an electrical signal, insulating fluid is forced out of a passage in a wall of the chamber and performs work by actuating a plunger or diaphragm. Means, such as an intermediate piston, may be employed to isolate the insulating fluid from the hydraulic fluid in a device being thus hydraulically driven, such as a pump valving means or fluid control valve.

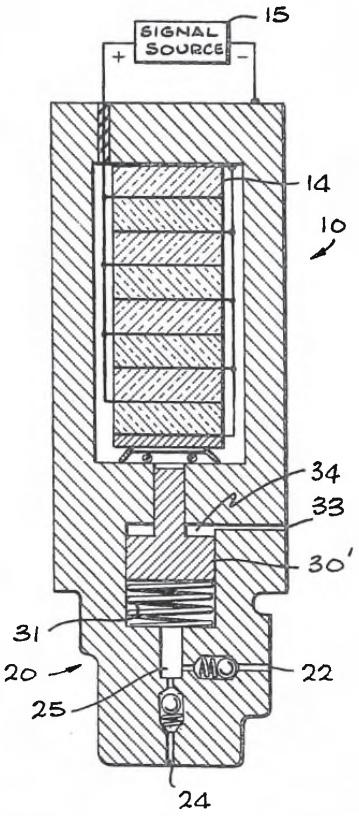


Fig. 1

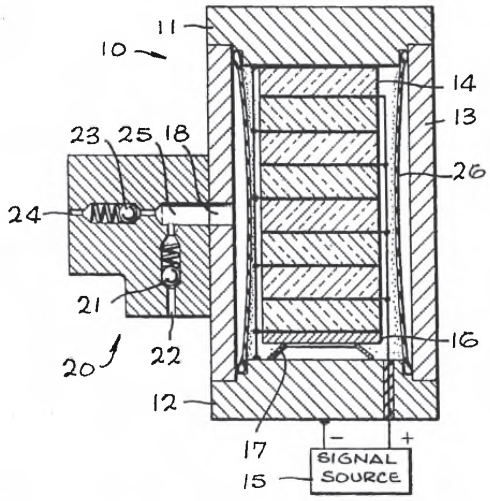


Fig. 2

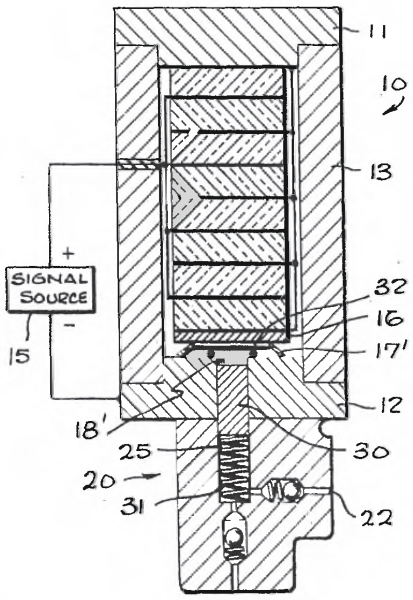
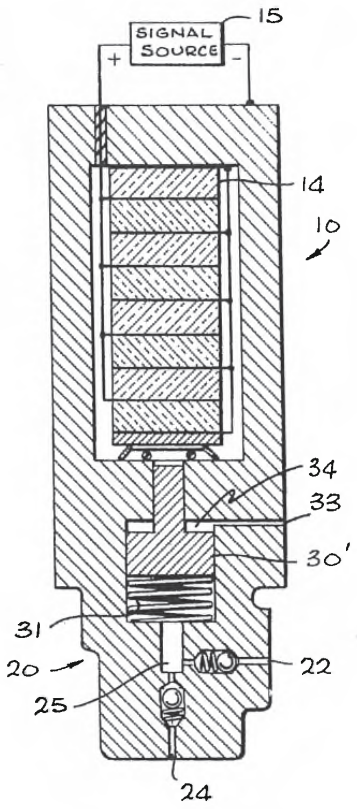


Fig. 3



CORMAC G. O'NEILL
INVENTOR.

BY Lindenberg & Freilich

ATTORNEYS

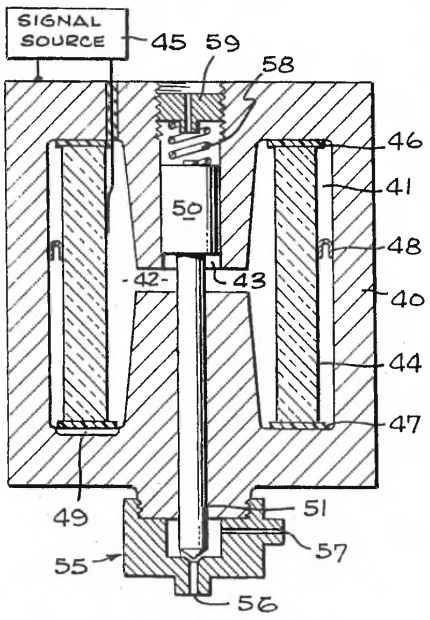


Fig. 4

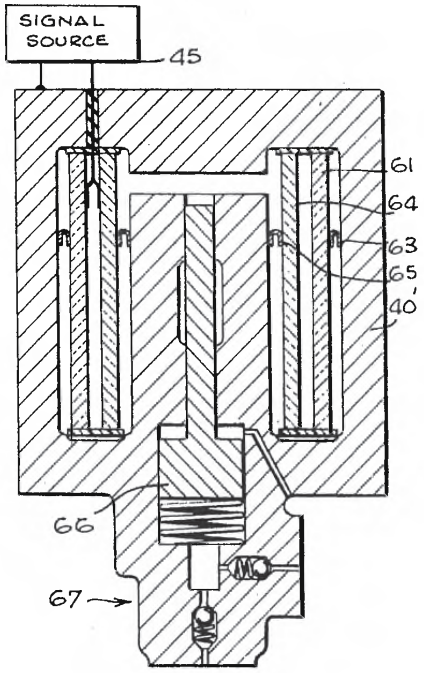


Fig. 6

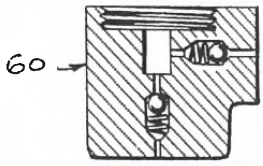


Fig. 5

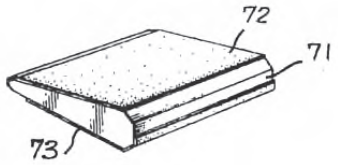


Fig. 8

CORMAC G. O'NEILL
INVENTOR.

BY Lindenberg & Freilich

ATTORNEYS

Fig. 7

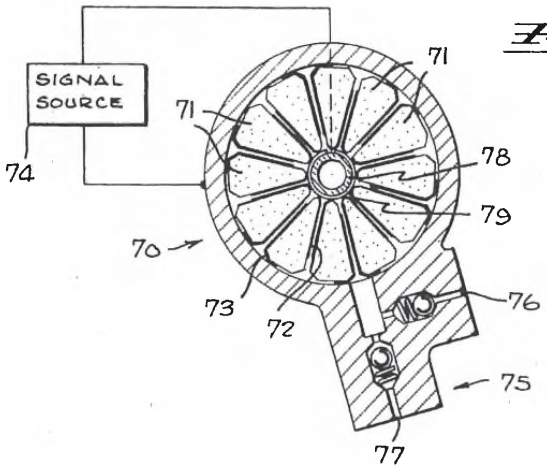


Fig. 9

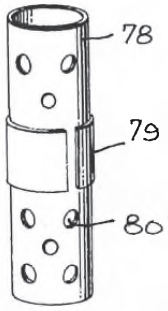
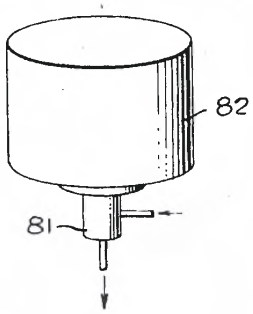


Fig. 10



CORMAC G. O'NEILL
INVENTOR.

BY Lindenberg & Freilich

ATTORNEYS

ELECTROSTRICTIVE ACTUATOR

BACKGROUND OF THE INVENTION

This invention relates to drivers for pumps, valves, actuators and the like, and more particularly to electroexpansively powered drivers.

Such devices as pumps and fuel injectors have been devised based upon the piezoelectric effect of certain materials. Upon application of an electric field across such material, the material expands or contracts along known axes, depending upon the polarity of the electric field. Therefore, in such piezoelectric devices the expanding and contracting material is generally so disposed in a housing that the mechanical load is transmitted directly by the material, thereby requiring a precise configuration and low compliance for the load surfaces Another disadvantage of directly driven devices is that the travel of the load surfaces is quite limited. To overcome that disadvantage, it has been common practice to so stack a plurality of piezoelectric elements that their cumulative piezoelectric expansion is more substantial. But that, of course, compounds the first problem since more precise load surfaces with low compliance are then required.

Some materials known as electrostrictive material exhibit the property of a positive dimension change in a direction parallel to the applied electric field regardless of the polarity of the applied field, with only a second order reduction in dimensions along two complementary (orthogonal) directions. In other words, given the direction of the applied electric field as the principle axis, the material will expand along that axis regardless of the polarity of an applied voltage with very little contraction along second and third mutually perpendicular axes. Consequently, upon application of a voltage of either polarity, the material increases in volume sufficiently to perform useful work.

The present invention concerns the performance of useful work through use of any material, referred to hereinafter as "volumetric electroexpansive material," that is known to exhibit an increase in volume in response to an electric field regardless of whether the increase in volume is due to the piezoelectric effect or the electrostrictive effect. The performance of work is best carried out hydraulically to avoid having mechanical loads transmitted through material interfaces.

An important advantage of a hydrostatically driven device using elements of volumetric electroexpansive material is that the elements may be easily produced, such as by casting, with loose tolerances in respect to surface finish, compliance of interfaces, and mechanical strength of the ceramic material, as well as dimensions. But of all the advantages of such a device, the most important is that displacement amplification may be readily achieved hydraulically even though that use of electroexpansive material would produce lower strains along a given axis for a certain voltage gradient than in directly driven devices.

SUMMARY OF THE INVENTION

According to the invention, an electroexpansively powered fluid driver is provided by a body having a chamber of a given volume and a passage in a wall thereof communicating with that chamber. Volumetric electroexpansive material is disposed in that chamber but not to its full capacity. The space intermediate the volumetric electroexpansive material and the chamber is filled with a fluid so that when an electric field is applied across the electroexpansive material, the material may undergo a total volume increase to perform work by forcing fluid from the chamber through the passage in its wall. Such a fluid driver may be employed to pump fluid, either directly or by means of a piston.

A plurality of electroexpansive elements may be used to increase the total change in volume, i.e., to increase the hydraulic displacement produced in response to an electrical signal.

The driver chamber may be of any suitable elongated configuration, such as a cylinder to accommodate a stack of elements. The driver chamber may also be annular and the electroexpansive elements tubular.

Another configuration for the electroexpansive elements for the use in a cylindrical chamber is a substantially segmental section. A plurality of segmental sections are disposed in the cylindrical chamber such that each makes electrical contact with a split tube spring at the center. The split tube spring urges each of the segmental sections against the cylindrical wall of the chamber where a second electrical contact is made to provide an electrical field in response to an electrical signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a longitudinal cross section of a first embodiment of the present invention. **2** illustrates a variant of the first embodiment shown in FIG. **1**.

FIG. **3** illustrates another variant of the first embodiment illustrated in FIG. **1**.

FIG. **4** shows a longitudinal cross section of a second embodiment of the present invention.

FIG. **5** shows a cross section of a pump valving means for use with the embodiment of FIG. **4** in place of a valve element shown.

FIG. **6** illustrates a variant of the second embodiment illustrated in FIG. **4**.

FIG. **7** shows a cross section of a third embodiment of the present invention.

FIG. **8** shows an isometric view of a segmental section of electroexpansive material employed in the embodiments of FIG. **7**.

Fig. **9** illustrates a central column of nonconductive material with holes throughout and a split ring of conductive spring material for use in the embodiment illustrated in FIG. **7** at the center of a plurality of segmental sections.

FIG. **10** illustrates in an isometric view a variant of the embodiment illustrated in FIG. **7**.

The novel features that are considered characteristic of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description with reference to the accompanying drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, there is shown an electroexpansive driver body **10** comprising end plates **11** and **12** and a cylindrical tube **13**. Disposed within the driver body are a plurality of stacked elements made of volumetric electroexpansive material, such as element **14**, each in the form of a disc. There are a number of different materials commercially available that exhibit a volumetric electroexpansive effect in response to an electrical signal. Some suitable ceramic materials are "Thin Loop" by Channel Industries of Santa Barbara, California, and "Skinny Loop" by Honeywell of Minneapolis, Minnesota.

A signal source **15** is connected across each of the stacked elements by, for example, soldering one terminal of the source **15** to the plate **12** and the other terminal of the source **15** to a thin metal electrode interposed between each of the opposing faces of adjacent discs as shown. Alternate pairs of opposing faces are connected to the positive and negative terminals of the source **15** in such a manner that each disc shares a positive electrode with one neighbor and a negative electrode with the other neighbor, the two electrodes at the stack extremities being of the same polarity as the terminal of the source source **15** connected to the end plate **12**. The plate **12** is made of suitable conductive material. The plate **11** is in direct contact with the top of the stacked elements while the plate **12** is in contact with the bottom of the stack through a metal disc **16** and a metal spring washer **17**. The metal spring **17** holds the elements of the stack in electrical contact with the thin metal electrodes interposed between adjacent discs. As electrical signals from the source **15** are applied, the stack continually

expands, thereby continually flexing the spring **17**. The disc **16** protects the stack of electroexpansive elements from damage due to forces against the spring **17**.

When an electrical signal is applied to the stack of electroexpansive elements from the source **15**, the total volume of the electroexpansive material disposed within the chamber of the body **10** increases. Fluid within the chamber of the body **10** is thereby forced to flow under pressure through a passage **18** in the tubular wall **13** of the chamber. As the electrical signal is removed, the total volume of the electroexpansive material descreases, thereby causing a reduction in pressure on the remaining fluid in the chamber of the body **10**.

In order to pump fluid continually in response to electrical pulses, pump valving means **20** is connected to the passage **18**. A one-way valve **21** at the fluid inlet port **22** prevents fluid being forced from the chamber of the body **10** from being returned to its source. A one-way valve **23** in the outlet port **24** similarly prevents fluid from flowing in the opposite direction.

If the fluid being pumped is an electrical conductor, fluid in the chamber of the body **10** would provide a short circuit across the electroexpansive elements. Accordingly, to pump conductive fluid, a sleeve **26** of flexible material is provided around the stack of electroexpansive elements, from the plate **11** to the plate **12**, to isolate the fluid (which has suitable insulation properties) in contact with the stack of elements from the fluid pumped. In either case, a predetermined minimum feed pressure at the inlet **22** would be required to insure filling a pumping chamber **25**.

FIG. **2** illustrates a variant of the first embodiment illustrated in FIG. **1**. The variation is substitution of a piston **30** for the flexible sleeve **26** in the first embodiment of FIG. **1** to isolate the fluid being pumped through the pump valving means **20** from fluid in the drive chamber of the body **10**. The volumetric electroexpansive elements, such as the elements **14**, are connected to a signal source **15** as before.

As the electroexpansive material increases in volume, fluid is driven from the chamber of the body **10** through a passage **18'** against the piston **30**, thereby forcing fluid from the pumping chamber **25** through the outlet port **24** of the pump valving means **20**. As the electrical signal is removed, the volume of the electroexpansive material decreases thereby allowing fluid to reenter the chamber of the body **10** as the piston **30** is driven upwardly under the feed pressure of fluid at the inlet port **22**. To minimize the feed pressure that would be required to insure filling the pump chamber **25** to its maximum, a return spring **31** is provided for the piston in the pumping chamber **25**. Since fluid to and from the passage **18'** must pass by the spring washer **17'**, holes (such as hole **32**) may be provided in the washer **17'**. Alternatively, notches may be provided along the inner and outer edges of the washer **17'**, or radial bypass slots may be provided in the plate **12** or the disc **16**.

Still another variant of the first embodiment of the present invention is illustrated in FIG. **3**. The principle variation is the provision of a piston **30'** with a larger area exposed to the fluid being pumped than to fluid in the drive chamber of the body **10**. In that manner, volume amplification is obtained to increase the average flow rate from the inlet port **22** to the outlet port **24**.

If force amplification were desired instead of volume amplification, the area of the piston **30'** in contact with the fluid in the chamber of the body **10** would have been greater than the area in contact with fluid being pumped. In either case, the piston cylinder **34** (i.e., the cylindrical passage through the body **10** to the pump valving means **20** containing the piston **30'**) would have a large diameter portion of sufficient length to allow maximum travel for the piston **30'**. A vent **33** is provided at the base of the enlarged portion of the piston cylinder to facilitate driving the piston **30'** down in response to an electrical signal and up again in response to force of the return spring **31**. Otherwise, a vacuum may be produced behind it as the piston **30'** is driven toward the pump chamber **25**.

Another variation illustrated in FIG. **3** is provision of the body **10** and the pump valving means **20** by integral metal castings of two longitudinal sections which are then welded, braised or otherwise fastened together in fluidtight manner after all of the internal elements have been properly placed. Electrical connections to the volumetric electroexpansive element are made in a manner similar to that described with reference to the embodiment of FIG. **1**.

Referring now to FIG. **4**, a second embodiment of the present invention is provided based on the dilation of volumetric electroexpansive material in the direction of applied field without significant, if any, contraction on the two complementary axes. Both inside and outside surfaces of electroexpansive material (in the form of a tube) will then act to displace fluid if the tube is placed within an annular chamber of a body having a passage through a wall thereof. Thus, in the embodiment of FIG. **4**, a body **40** is provided with an annular chamber **41** with a passage **42** from the chamber **41** to a piston cylinder **43** concentric with the chamber **41**. A signal source **45** is provided with one terminal connected directly to the body **40** and the other terminal passing into the chamber **41** where it is connected to the inner surface of a tube of electroexpansive material **44**. The inside and ouside surfaces of the tube **44** are coated with an electrically conductive coating, such as silver or nickel. The end surfaces of the tube **44** are coated with an electrically conductive coating, such as silver or nickel. The end surfaces of the tube are not coated. It should be understood that the tube **44** of electroexpansive material is electrically insulated from the body **40** as by rings **46** and **47** of dielectric material. Springs are then placed on the outside of the electroexpansive element **44**, such as spring **48** formed from a band of conductive spring material, in order to maintain electrical contact between the conductive coating on the outside surface of the electroexpansive element **44** and the body **40**. To assure that fluid pressure will always be equal on both sides of the electroexpansive element **44**, bypass slots are provided, such as a bypass slot **49**.

A piston **50** is provided with an arm or stem **51** extending from the body **40** in order to actuate a device as the piston **50** is moved up and down hydraulically in response to a signal from the source **45**. As shown, the device is a valve **55** having two ports **56** and **57** through which fluid may flow from one port to the other as the piston **50** is moved upwardly in response to a signal from the source **45**. A spring **58** and nut **59** are provided to adjust the position of the valve stem (arm or stem **51** of the piston **50**) to close the passage to the port **56** when no signal is applied.

The embodiment of FIG. **4** may be readily adapted for pumping a fluid by substituting for the valve device **55** a pump valving device **60** is substantially the same as the valve pumping means **20** illustrated in FIG. **1**, both in construction and in operation, and therefore will not be further described with reference to the second embodiment of the invention illustrated in FIG. **5**.

FIG. **6** illustrates a variant of the second embodiment described with reference to FIG. **4**. The principle variation is the provision of more than one tubular electroexpansive element. The first element **61** is substantially the same as the single element **44** shown in FIG. **4** with an electrical connection between the signal source **45** and the inside surface of the element **61** and between the outside surface of element **61** and the body **40'** by a spring **63**. Connections are provided for a second tubular electroexpansive element **64** in a corresponding but reverse manner with the inside surface thereof connected to the body **40'** by a spring **65**, and the outside surface directly connected to the signal source **45**. In that manner, multiple electroexpansive elements may be used to provide increased fluid displacement. Another variation is the provision of a piston **66** and pump valving means **67** in a manner similar to that described with reference to FIG. **3** for the first embodiment of the present invention such that volume amplification is achieved.

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IPR2023-00292

A third embodiment of the present invention is illustrated in FIG. 7. It consists of a body **70** having a cylindrical chamber in which segmental sections of electroexpansive elements are radially disposed, such as a section **71** shown in an isometric view in FIG. 8. As viewed in that FIG. **8**, the top surface is coated with a conductor **72**, such as silver, around to the far, narrow end. The bottom side is similarly coated with a conductor **73** around to the near, wide end. By applying a potential across the two ends, an electric field is established between the conductors **72** and **73**. Accordingly, when segmental sections have been so placed in the chamber of the body **70** that adjacent ones have their conductors **72** opposite each other and similarly have their conductors **73** opposite each other, a signal may be applied to all of the sections in parallel by a source **74**. The elements expand circumferentially with little or no radial contraction for a net volume increase. In that manner, fluid may be driven out of the chamber of the body **70**. A pump valving means **75** (the same as that described with reference to FIG. **1**) is provided in order that the electroexpansive driver may pump fluid from an inlet port **76** to an outlet port **77**.

A tube **78** is provided as a central column in the chamber of the body **70** to assure that the segmental sections remain in place substantially as shown in FIG. **7** with the wide end of each in contact with the cylindrical wall of the body **70**. A split ring **79** of conductive spring material is placed around the column **78**, as may be more clearly seen in FIG. **9**. As the split ring **79** seeks to expand in diameter, the segmental sections are maintained in electrical contact with the cylindrical wall of the body **70**. At the same time, the split ring **79** is in contact with the narrow end of each segment so that it may be employed as one electrode connected to the signal source **74** as shown in FIG. **7** while the cylindrical wall of the body **70** is employed as the other (ground) electrode. The tube **78** is provided with a plurality of holes, such as a hole **80**, in order that pressures quickly equalize throughout the chamber of the body **70**.

If the fluid being pumped is an electrical conductor, a nonconductive hydraulic fluid may be provided in the chamber of the body **70** and isolated from the fluid being pumped by a piston in the manner described hereinbefore with reference to FIG. **2** or, if volume amplification is desired, in a manner described hereinbefore with reference to FIG. **3**. Alternatively, the pump valving means **75** may be omitted and a valve or other device attached to the body **70** for actuation through a piston in a manner similar to that described hereinbefore with reference to FIG. **4**.

Although the pump valving means **75** is shown in FIG. **7** connected to a radial passage from the chamber of the body **70**, it should be appreciated that such a means or other device may be connected to an axial passage as shown in FIG. **10** by a pump valving means **81** connected to a body **82** which is otherwise the same as that illustrated in FIG. **7**. In that manner, the passage from chamber of the body **82** to the valving means **81** is through the center of an end wall to provide direct fluid transfer from a central tube of the form illustrated in FIG. **9**. Here again, the pump valving means **81** may be isolated from the hydraulic fluid in the chamber of the body **82** by a piston, and may also be substituted with a piston actuated device if desired.

Although the present invention has been shown and described with reference to particular embodiments, it should be apparent to one skilled in the art that many changes and modifications may be made without departing from the true spirit and scope of the invention.

What is claimed is:

1. An electroexpansively powered fluid driver comprising:
- a body having a chamber of a given volume and a passage in a wall thereof communicating with said chamber;
- volumetric electroexpansive material disposed in said chamber, said material being a solid and having a total volume less than said given volume of said chamber;
- nonconductive fluid filling said chamber and in direct contact with said electroexpansive material on all sides free to move in response to an electric field applied to said electroexpansive material such that all of said fluid will be at the same pressure at any given time; and
- means for applying an electric signal as a potential across said material to create said electric field to cause said material to undergo a total volume change to perform work by forcing fluid from said chamber through said passage.

2. Apparatus as defined in claim **1** including pump valving means comprising:
- a pump chamber having a port connected to said passage;
- fluid inlet means having a one-way valve communicating with said pump chamber; and
- fluid outlet means having a one-way valve communicating with said pump chamber.

3. Apparatus as defined in claim **1** wherein said chamber is a cylinder and said material is in the form of a plurality of segmental sections, said sections being disposed about a central spring tube through which electrical contact is made with each section while each section is being urged against the cylindrical wall of said chamber, said wall being made of electrical conductive material, and said means is connected between said spring tube and said cylindrical wall.

4. Apparatus as defined in claim **3** including pump valving means comprising:
- a pump chamber having a port connected to said passage;
- fluid inlet means having a one-way valve communicating with said pump chamber; and
- fluid outlet means having a one-way valve communicating with said pump chamber.

5. An electroexpansively powered driver comprising:
- a hydraulic cylinder;
- a body having an hydraulic fluid chamber of a given volume and a passage in a wall thereof communicating with said hydraulic cylinder;
- volumetric electroexpansive material so disposed in said chamber as to provide a hydraulic drive chamber between said material and walls of said chamber;
- a piston disposed in said cylinder;
- fluid filling said hydraulic drive chamber and passage to said piston in said cylinder, said fluid surrounding said electroexpansive material on all sides free to move in response to an electrical field applied to said electroexpansive material such that all of said fluid will be at the same pressure at any given time; and
- means for applying an electric field to said material to cause said material to undergo a total volume increase to hydraulically advance said piston in said cylinder.

6. Apparatus as defined in claim **5** including pump valving means comprising:
- a pump chamber having a port connected to said cylinder at the end thereof remote from said hydraulic drive chamber;
- fluid inlet means having a one-way valve , communicating with said pump chamber; and
- fluid outlet means having a one-way valve communicating with said pump chamber;

7. Apparatus as defined in claim **6** including a return spring in said cylinder between said piston and said pump valving means.

8. Apparatus as defined in claim **5** wherein said piston has a portion at one end thereof with an area that differs from the area at the other end thereof, and said cylinder is of a diameter substantially equal to that of said portion over a sufficient length thereof to receive said portion of said piston and allow maximum travel of said piston.

9. Apparatus as defined in claim **8** including means for venting said cylinder at the base of the enlarged portion thereof.

10. An electroexpansively powered fluid driver comprising:
- a hydraulic cylinder;

a body having an annular hydraulic fluid chamber of a given volume and a passage in a wall thereof communicating with said hydraulic cylinder;

at least one tube of volumetric electroexpansive material so disposed in said chamber as to provide a hydraulic drive chamber between said tube and walls of said body;

an actuating piston disposed in said cylinder;

fluid filling said hydraulic drive chamber and passage to said piston in said cylinder, said fluid surrounding said electroexpansive material on all sides free to move in response to an electrical field applied to said electroexpansive material such that all of said fluid will be at the same pressure at any given time; and

means for applying said electric field to said material to cause said material to undergo a total volume increase to hydraulically advance said piston in said cylinder.

11. Apparatus as defined in claim **10** including an arm extending from said cylinder for actuation of a device.

12. Apparatus as defined in claim **11** wherein said device is a valve and the end of said arm remote from said piston comprises a valving plunger.

13. Apparatus as defined in claim **11** wherein said device is a pump and the end of said arm remote from said piston comprises a pumping piston.

14. Apparatus as defined in claim **13** wherein said pumping piston has a diameter that differs from the diameter of said actuating piston.

15. Apparatus as defined in claim **10** wherein a second tube of volumetric electroexpansive material is disposed in said chamber and said means functions for said second tube in the same manner as for said one tube of volumetric electroexpansive material.

Exhibit C

UNITED STA[illegible] DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
09/522,130	03/09/00	WELCH	A 12541US02

EXAMINER

GIMIE,M

ART UNIT	PAPER NUMBER
3747	5

DATE MAILED: 03/21/01

QM02/0321
MCANDREWS HELD & MALLOY LTD
500 WEST MADISON STREET 34TH FLOOR
CHICAGO IL 60661

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev. 2/95)
*U.S. GPO: 2000-473-000/44602

1- File Copy

Office Action Summary	Application No.	Applicant(s)	
	09/522,130	WELCH ET AL.	
	Examiner	Art Unit	
	Mahmoud M Gimie	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136 (a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____ .

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-30* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☒ Claim(s) *21-30* is/are allowed.

6)☒ Claim(s) *1-20* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claims _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are objected to by the Examiner.

11)☐ The proposed drawing correction filed on _____ is: a)☐ approved b)☐ disapproved.

12)☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____ .

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14)☒ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

Attachment(s)

15)☒ Notice of References Cited (PTO-892)
16)☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
17)☒ Information Disclosure Statement(s) (PTO-1449) Paper No(s) *5* .
18)☐ Interview Summary (PTO-413) Paper No(s). _____
19)☐ Notice of Informal Patent Application (PTO-152)
20)☐ Other: .

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IPR2023-00292

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1-6,12,15,17 and 19 are rejected under 35 U.S.C. 102(b) as being anticipated by O'Neill (3,598,506).

O'Neill discloses an injection valve (55) for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising:

(a) a valve housing comprising: a fuel inlet port (57); an interior chamber fluidly connected to said fuel inlet port (not numbered); a nozzle comprising a nozzle orifice (56) providing a fluid passage from said interior chamber to said combustion chamber (not shown);

(b) a valve needle (51) 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 (56), 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 (51) lift equals the distance traveled by said sealing end away from said valve seat;

(c) a needle spring (58) associated with said valve needle, wherein said needle spring

applies a closing force to said valve needle (51) 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 needle stronger than said closing force, for moving said valve needle to said open position; and

(e) a hydraulic link assembly comprising a hydraulic link (42,43) having a fluid thickness through which said opening and closing forces are transmitted, wherein said thickness of said hydraulic link is adjustable in response to changes in the dimensional relationship between components of said injection valve to maintain a desired valve needle lift when said actuator assembly is activated, see figure 4.

Regarding claim 2, the thickness of said hydraulic link is auto-adjustable in response to changes in said dimensional relationship caused by differential thermal expansion.

Regarding claim 3, said thickness of said hydraulic link is auto- adjustable in response to changes in said dimensional relationship caused by wear to components of said injection valve.

Regarding claim 4, said hydraulic link assembly comprises a sealed hydraulic cylinder, with a piston and hydraulic fluid disposed within said hydraulic cylinder.

Regarding claim 5, said piston is an integral part of said valve needle.

Regarding claim 6, said actuator assembly comprises a magnetostrictive member or a piezoelectric stack.

Claim Rejections - 35 USC § 103

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. Claims 7-11,13,14,16,18 and 20 are rejected under 35 U.S.C. 103(a) as being unpatentable over O'Neill (3,598,506).

O'Neill discloses all the limitations as applied to claims 1-6,12,15,17 and 19 except for components of specific design of an electrostrictive actuator.

It would have been an obvious choice of design for one of ordinary skill in the art at the time of the invention was made to modify the invention of O'Neill by using an electrostrictive actuator comprised of magnetostrictive member, an electric coil disposed around said magnetostrictive member and a flux tube disposed around said electric coil.

The motivation to do so would have been to lower manufacturing cost.

Allowable Subject Matter

5. Claims 21-30 are allowed over prior art of record.

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. The cited references show fuel injection actuators.

7. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein

were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Mahmoud M Gimie whose telephone number is 703-305-1037. The examiner can normally be reached on 7:00-3:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Henry Yuen can be reached on 703-308-1946. The fax phone numbers for the organization where this application or proceeding is assigned are 703-308-7766 for regular communications and 703-308-7766 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0861.

Henry C. Yuen
Supervisory Patent Examiner
Group 3700

M Gimie, Examiner
March 20, 2001

Notice of References Cited

Application/Control No.	Applicant(s)/Patent Under Reexamination	
09/522,130	WELCH ET AL.	
Examiner	Art Unit	Page 1 of 1
Mahmoud M Gimie	3747	

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification	
	A	US-3598506-A	08-1971	O'Neill	417	383
	B	US-4803393-A	02-1989	Takahashi	310	328
	C	US-4022166-A	05-1977	Bart	123	32
	D	US-4101076-A	07-1978	Bart	239	584
	E	US-5821671-A	10-1998	Trzmiel	310	328
	F	US- -				
	G	US- -				
	H	US- -				
	I	US- -				
	J	US- -				
	K	US- -				
	L	US- -				
	M	US- -				

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification	
	N	- -					
	O	- -					
	P	- -					
	Q	- -					
	R	- -					
	S	- -					
	T	- -					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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Robert Bosch LLC et al. v. Westport Fuel Systems Canada Inc.
IPR2023-00292

Exhibit D

OIPE
JUN 22 2001
PATENT & TRADEMARK OFFICE

UTP-3747
#7

Attorney Docket No. 12541US02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION OF:

ALAN B. WELCH,
IRAWAN RAHARDJA and
MIKE HEBBES

SERIAL NO.: 09/522,130

FILED: March 9, 2000

FOR: DIRECTLY ACTUATED INJECTION VALVE

GROUP ART UNIT: 3747

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231 on June 20, 2001.

By _____
Kirk A. Vander Leest
Reg. No. 34,036

RECEIVED
JUN 27 2001
TECHNOLOGY CENTER R3700

TRANSMITTAL LETTER

Assistant Commissioner for Patents
Washington, D.C. 20231

We are transmitting herewith the following:

1. **AMENDMENT AND REQUEST FOR RECONSIDERATION; and**
2. **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT AND FORM PTO-1449**

Please charge any additional fees or credit overpayment to the deposit account of McAndrews, Held & Malloy, Ltd. Account No. 13-0017.

Respectfully submitted,

Date: June 20, 2001

Kirk A. Vander Leest
Reg. No. 34,036

McANDREWS, HELD & MALLOY, LTD.
500 West Madison Street
Suite 3400
Chicago, Illinois 60661
(312) 775-8000

A

OIPE
JUN 22 2001
PATENT & TRADEMARK OFFICE

#7/a
6/27/01
Reviewer

Attorney Docket No. 12541US02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION OF:

ALAN B. WELCH,
IRAWAN RAHARDJA and
MIKE HEBBES

SERIAL NO.: 09/522,130

FILED: March 9, 2000

FOR: DIRECTLY ACTUATED INJECTION VALVE

GROUP ART UNIT: 3747

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By _____
Kirk A. Vander Leest
Reg. No. 34,036

RECEIVED
JUN 27 2001
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AMENDMENT AND REQUEST FOR RECONSIDERATION

Assistant Commissioner for Patents
Washington, D.C. 20231

06/27/2001 DNGUYEN 00000001 09522130
01 FC:103 36.00 CH

Sir:

This responds to the Office Action mailed March 21, 2001. Please amend the application as follows:

IN THE CLAIMS:

Please replace claims 1-4 as follows:

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:

a fuel inlet port;

an interior chamber fluidly connected to said fuel inlet port;

54

A

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 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

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IPR2023-00292

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.

4. The injection valve of claim 1 wherein said hydraulic link assembly comprises a fluidly sealed hydraulic cylinder that is fluidly sealed from said interior chamber, said hydraulic link assembly comprising a piston and said hydraulic fluid is disposed within said hydraulic cylinder.

Please add new claims 31 and 32 as follows:

31. The injection valve of claim 17 wherein said hydraulic fluid is a liquid.

~~32~~ 22. The injection valve of claim 17 wherein said hydraulic fluid is a liquid selected from the group consisting of motor oil and grease.

REMARKS

Claims 1-32 remain in the application, claims 31 and 32 having been added by amendment. Claims 1-4 have been amended as set forth in the attached Appendix. Claims 1-20 stand rejected under 35 U.S.C. § 102 and 103, and claims 21-30 have been indicated as being allowable over the references of record. Reconsideration of the rejected claims is respectfully requested.

Claims 1-19 stand rejected as being unpatentable over O 'Neill under 35 U.S.C. §102(b) and 103. Claim 1 has been amended to specify that the hydraulic link is a "passive" hydraulic link. None of the cited references, including O 'Neill, disclose or suggest a "passive" hydraulic link, as defined in the present specification (see page 17, lines 22 through 32). Claim 1 has also been amended to clarify that the hydraulic fluid in the hydraulic link assembly "acts substantially as a solid . . . while said actuator assembly is activated," a feature which is neither disclosed nor suggested by the cited references, including O'Neill. Conversely, between injections, while the actuator assembly is not activated, the hydraulic fluid may flow within the sealed cylinder from one side of the piston to the other, to auto-adjust for changes, for example, caused by temperature, wear, etc. (See also claims 2 and 3).

The cited references, including O 'Neill, all disclose assemblies that rely on the dynamic flow of a hydraulic fluid to actuate/open the valve. That is, a change in the volume of the actuator causes a displacement of a fluid, which actuates the valve. A disadvantage of this

arrangement is that there are time delays associated with the dynamic flow of the fluid, compared to the present invention where the actuating force of the actuator is immediately transmitted through the thickness of the hydraulic fluid, which behaves as a solid during valve actuation. In this respect, O'Neill discloses an arrangement where an 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. (See Figures 4 and 6). Accordingly, to open the valve, the actuating fluid is displaced and flows dynamically (that is, behaves as a liquid and not a solid). By contrast, claim 1 specifies that the hydraulic fluid acts "substantially as solid while said actuator assembly is activated." In view of the above, claim 1 and its dependent claims, are believed to be allowable over the reference of record.

New claims 31 and 32 have been added to reflect another advantage the present invention has over the prior art. These claims ultimately depend from claim 1 and are believed allowable for the reasons given above.

Support for the claim amendments can be found in the specification as follows:

Claim 1:

- "passive" - support can be found in the specification, for example, on page 17, lines 22 through 32.
- "whereby said hydraulic fluid acts substantially as a solid with said thickness being substantially constant while said actuator assembly is activated" - support can be found in the specification, for example, on page 28, lines 9 through 15.

- "while said actuator is not activated" - support can be found in the specification, for example, on page 30, lines 28 through 32, and on page 34, lines 25 through 32.

Claims 2 and 3:

- "while said actuator assembly is not activated" - support can be found in the specification, for example, on page 30, lines 28 through 32, and on page 34, lines 25 through 32.

Claim 4

- Support can be found in the specification on page 27, lines 19 through 27.

New claims 31-32:

- Support can be found in the specification on page 28, lines 15 through 29.

In view of the foregoing, applicants submit that claims 1-32 are allowable. The examiner is invited to telephone the applicants' undersigned attorney at (312) 775-8000 if any unresolved matters remain. No fees are believed to be due in connection with this submission. The Commissioner is hereby authorized to charge any deficiency to Deposit Account No. 13-0017.

Respectfully submitted,

Date: June 20, 2001

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Reg. No. 34,036

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APPENDIX

AMENDMENTS TO THE CLAIMS

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:

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 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 [when] said actuator assembly-[is activated].

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.

4. The injection valve of claim 1 wherein said hydraulic link assembly comprises a fluidly sealed hydraulic cylinder that is fluidly sealed from said interior chamber, said hydraulic link assembly comprising [with] a piston and said hydraulic fluid is disposed within said hydraulic cylinder.

Exhibit E

US005630550A

United States Patent [19]

Kurishige et al.

[11] Patent Number: 5,630,550

[45] Date of Patent: May 20, 1997

[54] **FUEL INJECTION SYSTEM**

[75] Inventors: **Masahiko Kurishige; Koji Hasunaka; Masaaki Kawamoto; Michio Fujiwara; Shinji Nakadeguchi**, all of Amagasaki, Japan

[73] Assignee: **Mitsubishi Denki Kabushiki Kaisha**, Tokyo, Japan

[21] Appl. No.: **427,830**

[22] Filed: **Apr. 26, 1995**

[30] **Foreign Application Priority Data**

Aug. 25, 1994 [JP] Japan 6-201085

[51] **Int. Cl.**[6] **F02M 51/06**

[52] **U.S. Cl.** **239/533.8**; 239/584

[58] **Field of Search** 239/533.2, 533.4, 239/533.8, 533.9, 584

[56] **References Cited**

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Primary Examiner—Robert J. Oberleitner
Assistant Examiner—C. T. Bartz
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] **ABSTRACT**

A fuel injection system permits the use of hydraulic control oil as a pressure transmitting medium and enables reliable valve opening and closing performance regardless of operating environment. The housing of the fuel injection system is constituted by a valve main body and a cylinder main body, the flowing channel of fuel being airtightly separated from a pressure control chamber. The cylinder main body incorporates a piezoelectric element, which changes the fluid pressure of the pressure transmitting medium in the pressure control chamber, a piston, and a cylinder having an inflow/outflow hole. A needle valve is installed, penetrating the cylinder main body so that the distal end thereof is located in a needle guide cavity of the valve main body and the other end thereof is located in the cylinder.

7 Claims, 10 Drawing Sheets

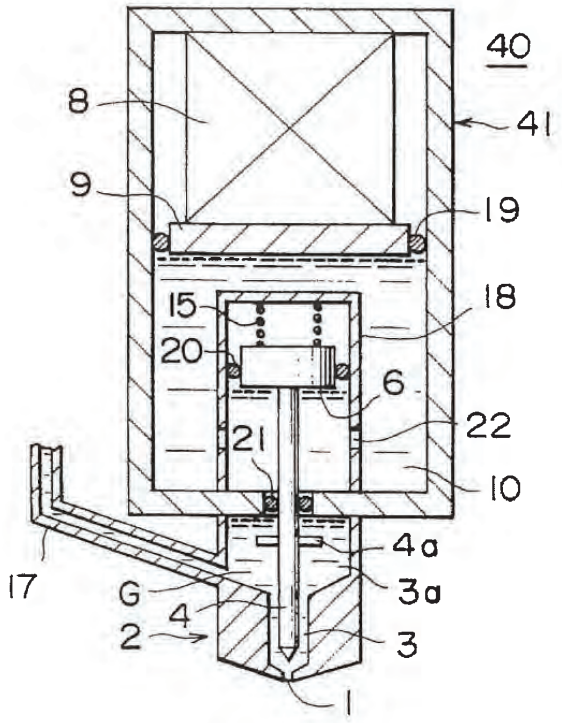


FIG. 1

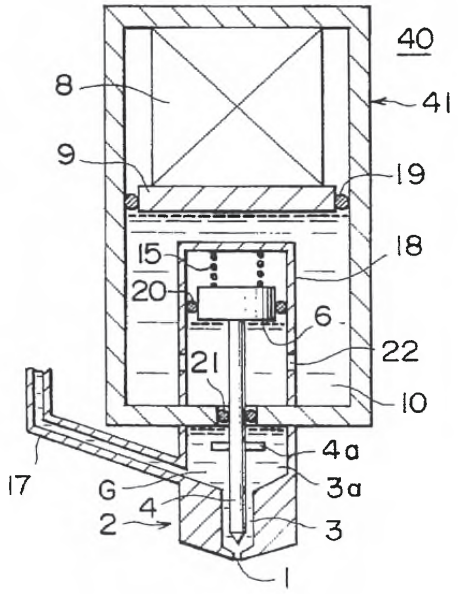


FIG. 2

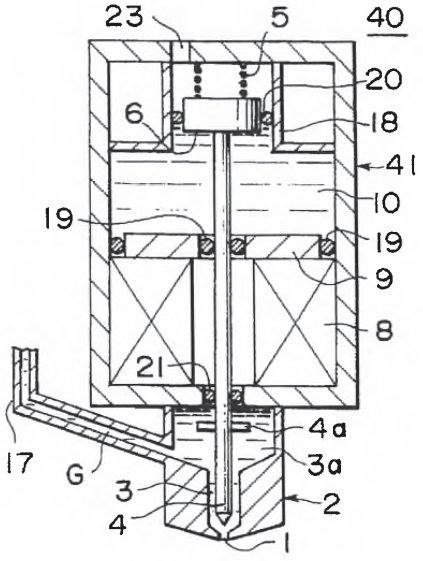


FIG. 3

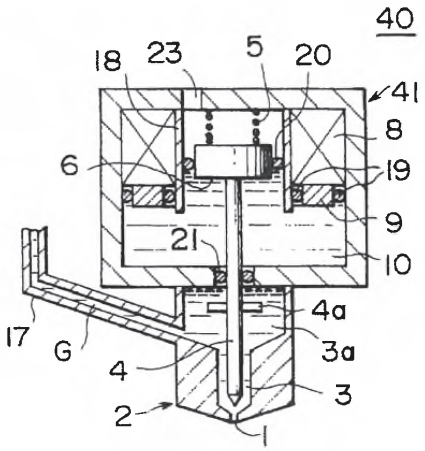


FIG. 4

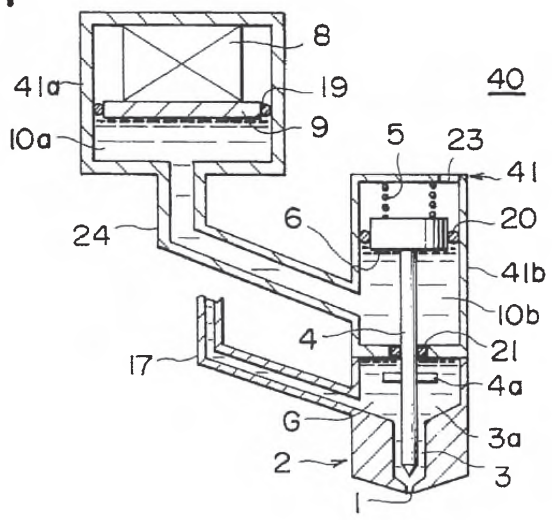

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10a
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41b
10b
4
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17
4a
G
3a
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FIG. 5

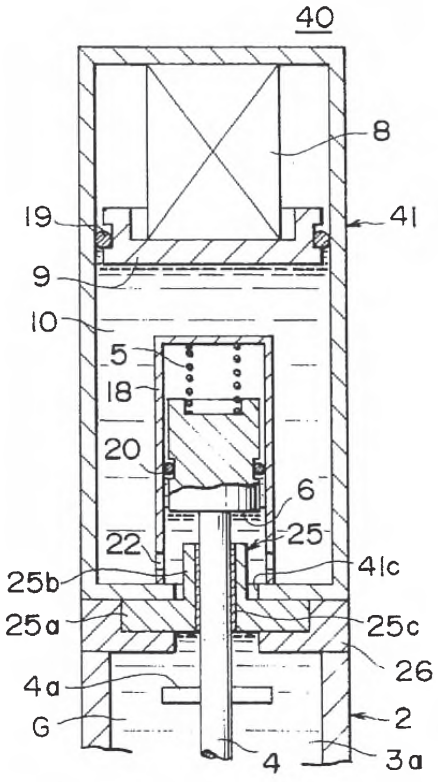

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FIG. 6

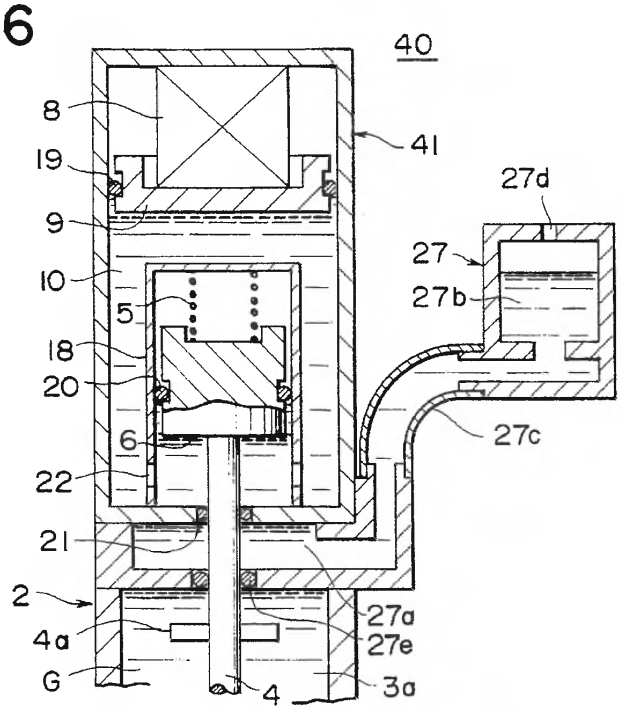

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FIG. 7

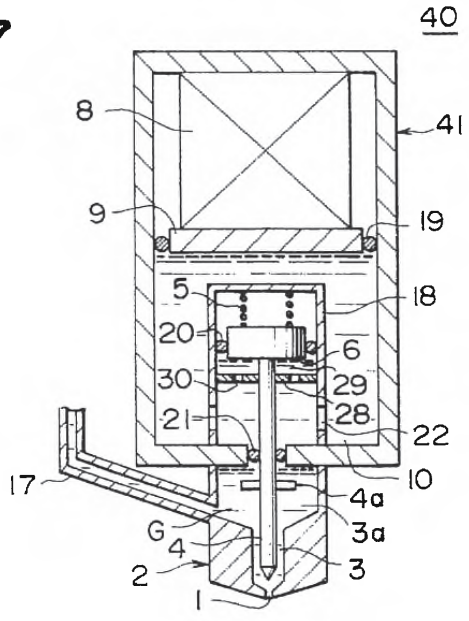

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FIG. 8A

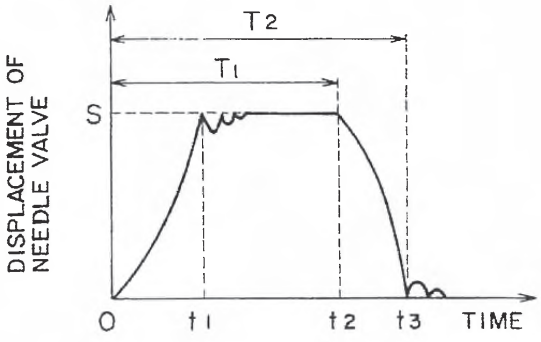


FIG. 8B

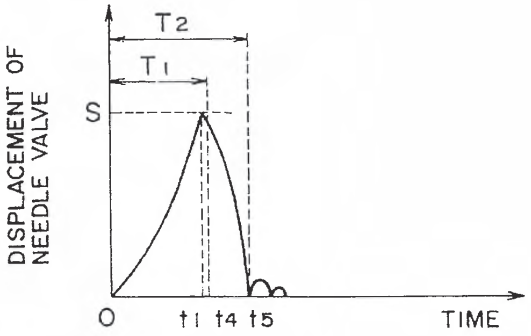


FIG. 8C

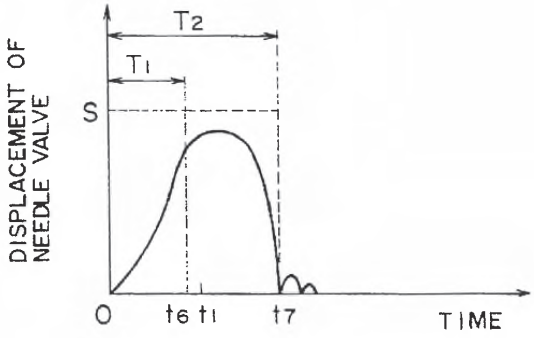


FIG. 9

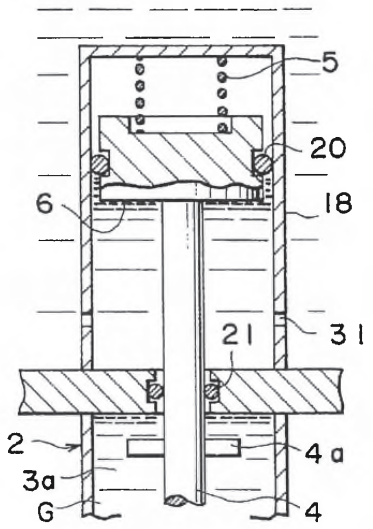


FIG. 10

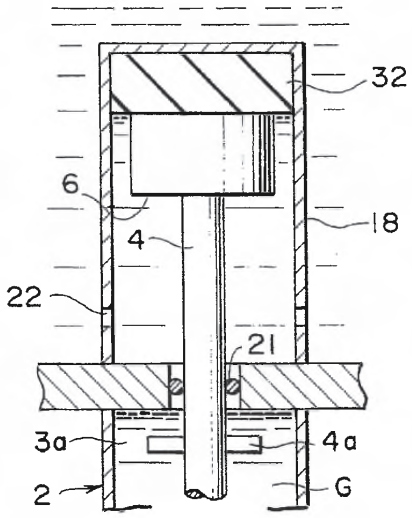


FIG. 11

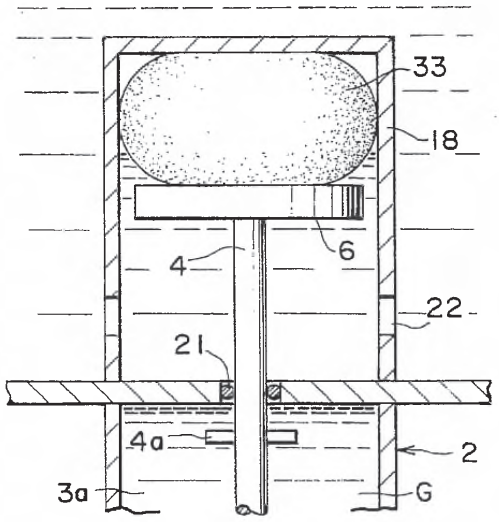


FIG. 12

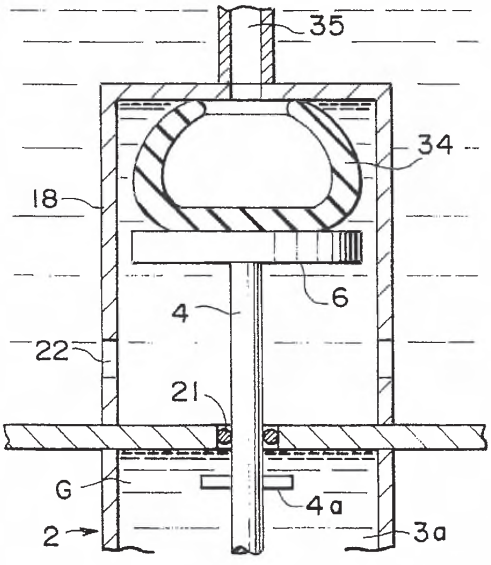


FIG. 13A

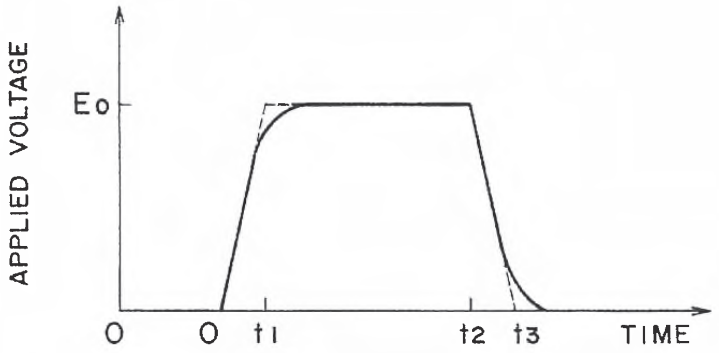


FIG. 13B

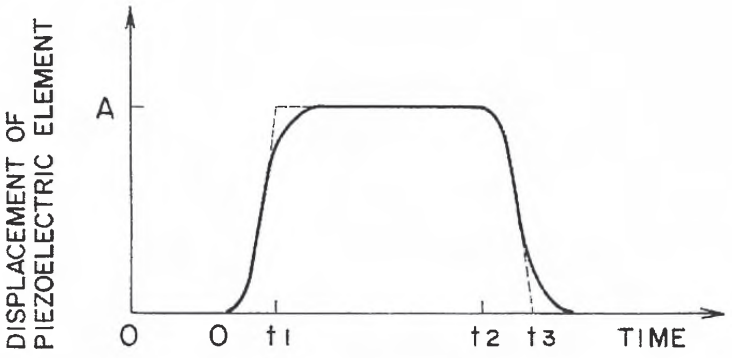


FIG. 14

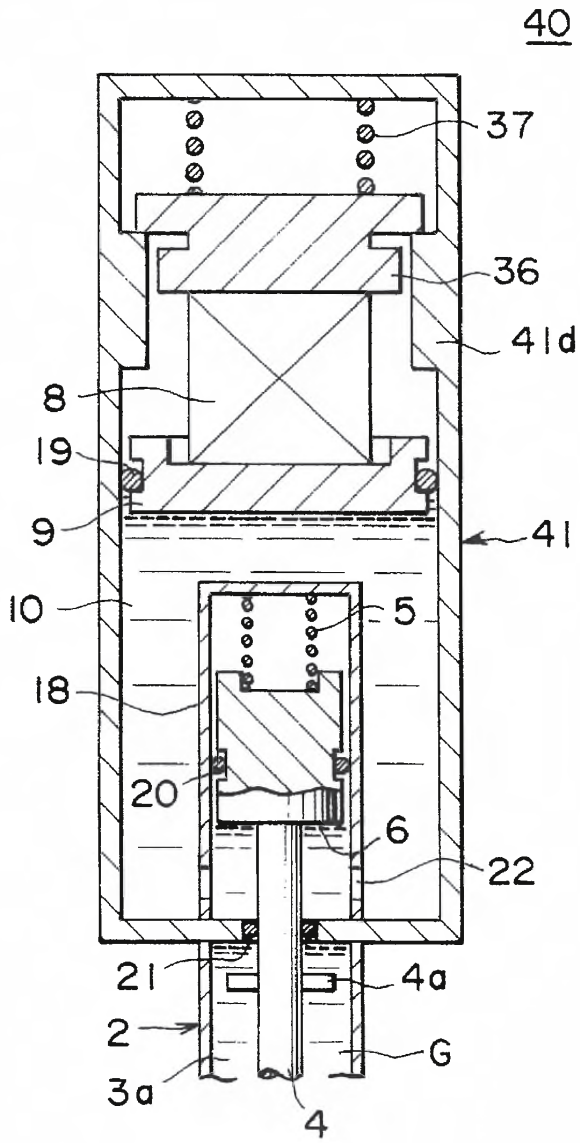


FIG. 15

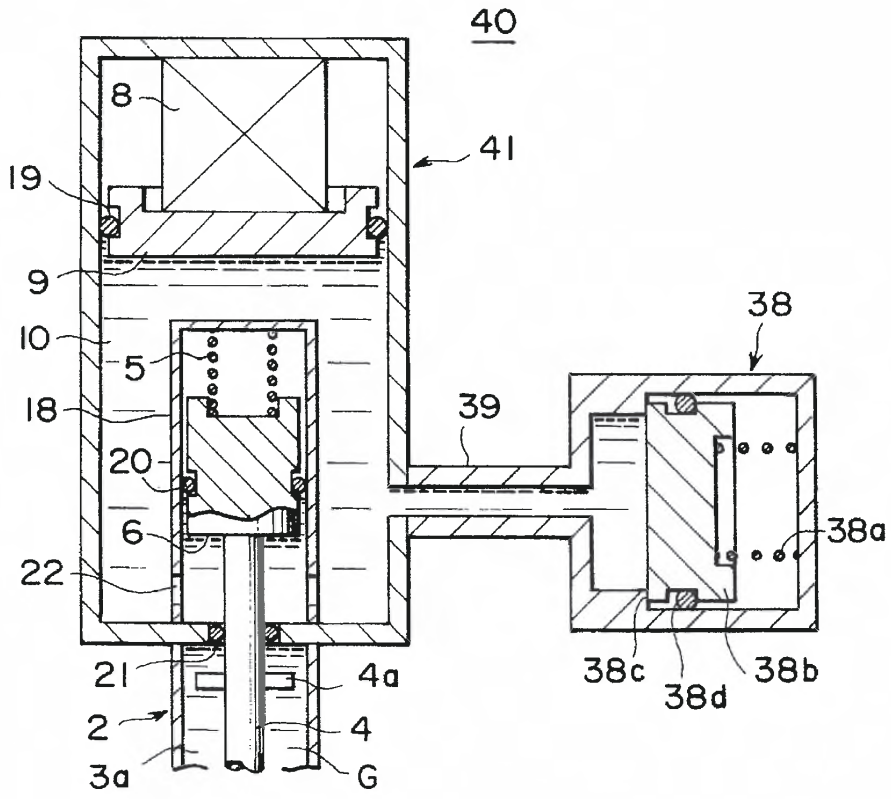
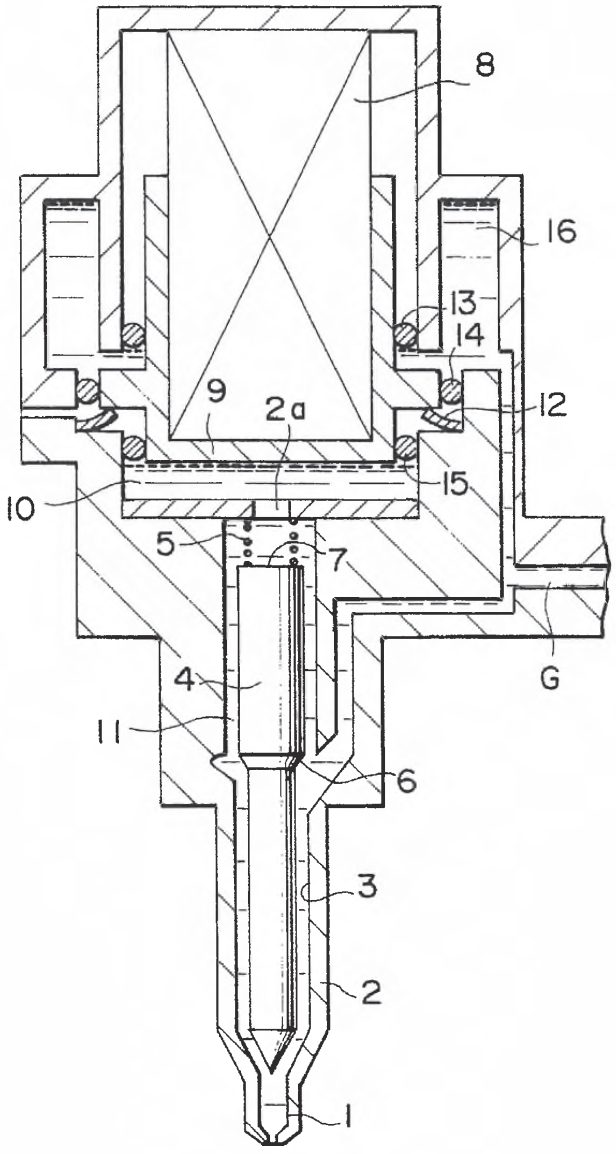


FIG. 16
PRIOR ART



FUEL INJECTION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel injection system of, for example, an internal-combustion engine.

2. Description of the Related Art

FIG. **16** is the longitudinal sectional view of a conventional fuel injection system disclosed in Japanese Patent Laid-Open No. 1-187363.

In the figure, a injection aperture **1** is provided at the distal end of a valve main body **2**, the injection aperture **1** being communicated with a needle guide cavity **3** formed at the axial center of the valve main body **2**. A needle valve is inserted in the needle guide cavity **3** in such a manner that it is allowed to move in the direction of the axis of the valve main body **2**. The needle valve **4** is pressed toward the injection aperture **1** by the urging force of a compression spring **5** when no fuel G is present in the needle guide cavity **3**, so that the distal end thereof engages with the injection aperture **1** to close the injection aperture **1**, Thus keeping the valve in a closed state. Further, an opening pressure receiving section **6** which receives valve opening pressure of fuel G in the needle guide cavity **3** is provided on the side of the injection aperture **1** of the needle valve **4**; a closing pressure receiving section **7** which receives valve closing pressure of fuel G is provided in a position opposite from the injection aperture **1** of the needle valve **4**. Thus, with fuel G present in the needle guide cavity **3**, a difference in pressure of fuel G applied to the opening pressure receiving section **6** and the closing pressure receiving section **7** causes the needle valve **4** to move in the needle guide cavity **3** toward the injection aperture **1** or away from the injection aperture **1**, so that the distal end of the needle valve **4** closes or opens the injection aperture **1**, thereby closing or opening the valve. A clearance **11** provided between the opening pressure receiving section **6** and the closing pressure receiving section **7** and between the needle guide cavity **3** and the needle valve **4** is formed to be narrow so as to allow only minimal fuel G to flow through.

A pressure control chamber **10** defined by seals **15**, the valve main body **2**, and a piston **9** is communicated with the needle guide cavity **3** through an aperture **2***a*. A piezoelectric element **8**, which is expanded and contracted by a charging/discharging drive circuit (not shown), is provided at the rear of the piston **9**. A disc spring **12** is provided so as to urge the piston **9** in a direction for contracting the piezoelectric element **8**. A high-pressure fuel chamber **16**, which is defined by seals **13** and **14**, is provided at the rear of the piston **9**. Fuel G supplied from a high-pressure fuel source (not shown) is led into the needle guide cavity **3** and the high-pressure fuel chamber **16**.

The operation of the conventional fuel injection system will now be described.

First, fuel G is led into the needle guide cavity **3** and the high-pressure fuel chamber **16**. When the charges accumulated in the piezoelectric element **8** are discharged by a driving circuit, the piezoelectric element **8** contracts. This causes the piston **9** to be pushed up by the urging force of the disc spring **12**, leading to an increase in the capacity of the pressure control chamber **10**. As a result, the pressure of fuel G in the pressure control chamber **10** decreases; the decreased pressure of fuel G is applied to the closing pressure receiving section **7** of the needle valve **4** through the aperture **2***a*. On the other hand, the opening pressure receiving section **6** of the needle valve **4** is subjected to the pressure of fuel G which is supplied from the high-pressure fuel source and which is maintained at a high level. Hence, the pressure applied to the opening pressure receiving section **6** grows higher than that applied to the closing pressure receiving section **7**, causing the needle valve **4** to overcome the urging force of the compression spring **5** and move up. The injection aperture **1** is then opened to communicate with the needle guide cavity **3**, thereby injecting fuel G through the injection aperture **1**.

While the valve is open, fuel G gradually flows from the opening pressure receiving section **6** side into the pressure control chamber **10** through the narrow clearance **11** between the needle valve **4** and the needle guide cavity **3**, causing the pressure in the pressure control chamber **10** and the pressure applied to the closing pressure receiving section **7** to approach the level of the pressure applied to the opening pressure receiving section **6**. At this time, the urging force of the disc spring **12** and the compression spring **5** and also the passage area of the clearance **11** between the needle valve **4** and the needle guide cavity **3** are controlled so that the valve stays open during the injection of fuel G.

Then, when the piezoelectric element **8** is charged by the driving circuit, the piezoelectric element **8** expands, causing the piston **9** to overcome the urging force of the disc spring **12** and accordingly move down, leading to a decreased capacity of the pressure control chamber **10**. As a result, the pressure of fuel G in the pressure control chamber **10** goes up; the increased pressure of fuel G and the urging force of the compression spring **5** are applied to the closing pressure receiving section **7** of the needle valve **4**. On the other hand, the opening pressure receiving section **6** of the needle valve **4** is subjected to the pressure of fuel G which is supplied from the high-pressure fuel source and which is maintained at a constant level. Hence, the pressure applied to the opening pressure receiving section **6** becomes lower than that applied to the closing pressure receiving section **7**, causing the needle valve **4** to come down. The injection aperture **1** is closed and the communication between the injection aperture **1** and the needle guide cavity **3** is cut off, thereby stopping the injection of fuel G through the injection aperture **1**.

During the operation described above, the pressure of fuel G, which is supplied from the high-pressure fuel source and which is applied to the piston **9** from the pressure control chamber **10**, is almost offset by the pressure of fuel G which is supplied from the high-pressure fuel source and which is applied to the piston **9** from the high-pressure fuel chamber **16**.

In most internal-combustion engines, the temperature changes during operation. For example, the ambient temperature of an automotive internal- combustion engine may be −30° C. or below at the time of starting in a cold district while on the other hand it may rise as high as 50° C. to 200° C. during continuous operation. Fuel G is not an oil produced for hydraulic control; the component proportion of fuel G may vary each time the fuel is supplied. Hence, no stable pressure transferring characteristic is ensured over a wide range of temperature. Taking, for example, gasoline which is extensively used as the fuel for an internal-combustion engine, there is a danger of partially evaporating at a section near the needle valve **4**, where the flow velocity increases, in a fuel injection system especially at high temperature because of the evaporation-prone characteristic thereof.

As stated above, since the conventional fuel injection system has the pressure control chamber **10** communicated

with the needle guide cavity **3** on the injection aperture **1** side, fuel G is employed as a pressure transmitting medium which is charged in the pressure control chamber **10** to transfer the driving force of the piezoelectric element **8** to the needle valve **4**. As a result, a problem was presented in that the pressure transmitting characteristic changes and the valve opening/closing duration heavily depends on temperature due to the temperature characteristic of fuel G stated above, preventing accurate fuel injection control.

There was another problem; bubbles generated in fuel G move close to the opening pressure receiving section **6** and temporarily decrease the pressure around the opening pressure receiving section **6**, preventing the opening of the valve. This results in poor fuel metering accuracy and in high toxic component content of the exhaust gas of an internal-combustion engine.

There was a conceivable method wherein the needle valve is directly driven without going through a liquid such as fuel G. This method, however, had a shortcoming in that the piezoelectric element is directly subjected to the force applied to the needle valve, leading to lower durability thereof.

SUMMARY OF THE INVENTION

This invention has been made with a view toward solving the above problems. It is an object of the present invention to provide a fuel injection system which permits the use of hydraulic control oil as a pressure transmitting medium for transmitting the driving force of a piezoelectric element to a needle valve, minimizes the influences exerted by temperature changes in the operating environment of an internal-combustion engine, and prevents bubbles generated in fuel from affecting fuel injection, thus enabling accurate fuel injection control.

To this end, according to one aspect of the present invention, there is provided a fuel injection system equipped with a valve main body, which has a needle guide cavity with the distal end thereof formed as a injection aperture, fuel passing through the needle guide cavity to be injected through the injection aperture; a pressure control chamber filled with a pressure transmitting medium; a piston for changing the fluid pressure of the pressure transmitting medium in the pressure control chamber; a needle valve having one end thereof located in the needle guide cavity and the other end thereof located in the pressure control chamber, the needle valve being installed in such a manner that it is allowed to move to open or close the injection aperture; a pressure receiving section which is provided on a portion of the needle valve located in the pressure control chamber and which is subjected to the fluid pressure; a pre-loading means for pre-loading the needle valve in a direction for closing the injection aperture; and a piezoelectric element which is changed the fluid pressure of the pressure transmitting medium by driving the piston, is applied the changed fluid pressure to the pressure receiving section, and is moved the needle valve in a direction for opening or closing the injection aperture so as to start or stop the injection of the fuel through the injection aperture; and wherein a flowing channel for the fuel is airtightly independent from the pressure control chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal sectional view illustrative of a fuel injection system according to a first embodiment of the present invention;

FIG. **2** is a longitudinal sectional view illustrative of a fuel injection system according to a second embodiment of the present invention;

FIG. **3** is a longitudinal sectional view illustrative of a fuel injection system according-to a third embodiment of the present invention;

FIG. **4** is a longitudinal sectional view illustrative of a fuel injection system according to a fourth embodiment of the present invention;

FIG. **5** is a longitudinal sectional view illustrative of a cylinder main body assembly of a fuel injection system according to a fifth embodiment of the present invention;

FIG. **6** is a longitudinal sectional view illustrative of a cylinder main body assembly of a fuel injection system according to a sixth embodiment of the present invention;

FIG. **7** is a longitudinal sectional view illustrative of a fuel injection system according to a seventh embodiment of the present invention;

FIGS. **8**A to **8**C are operation charts illustrative of the opening and closing operation of a needle valve in a fuel injection system;

FIG. **9** is a longitudinal sectional view illustrative of a cylinder assembly of a fuel injection system according to an eighth embodiment of the present invention;

FIG. **10** is a longitudinal sectional view illustrative of a cylinder assembly of a fuel injection system according to a ninth embodiment of the present invention;

FIG. **11** is a longitudinal sectional view illustrative of a cylinder assembly of a fuel injection system according to a tenth embodiment of the present invention;

FIG. **12** is a longitudinal sectional view illustrative of a cylinder assembly of a fuel injection system according to an eleventh embodiment of the present invention;

FIGS. **13**A and **13**B illustrate the operation of a piezoelectric element in a fuel injection system according to a twelfth embodiment of the present invention;

FIG. **14** is a longitudinal sectional view illustrative of a cylinder main body assembly of a fuel injection system according to a thirteenth embodiment of the present invention;

FIG. **15** is a longitudinal sectional view illustrative of a cylinder main body assembly of a fuel injection system according to a fourteenth embodiment of the present invention; and

FIG. **16** is a longitudinal sectional view illustrative of a conventional fuel injection system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention will now be described in conjunction with the accompanying drawings.

[First Embodiment]

FIG. **1** is the longitudinal sectional view illustrative of a fuel injection system according to the first embodiment of the present invention. In the figure, the identical or corresponding parts to those of the conventional fuel injection system shown in FIG. **16** are given the same reference numerals, and the explanation thereof will be omitted.

A housing **40** of the fuel injection system shown in the FIG. **1** is constituted by a valve main body **2** and a cylinder main body **41**, the valve main body **2** having a needle guide cavity **3** formed at the axial center thereof. The needle guide cavity **3** has an injection aperture **1** formed at the distal end thereof; the rear end is formed to have a large diameter to form a fuel chamber **3***a*. Fuel G is led from a high-pressure fuel source (not shown) into the fuel chamber **3***a* via a fuel passage **17**.

In the cylinder main body **41**, a piston **9** is disposed in such a manner that it is allowed to slide up and down in the drawing, a pressure control chamber **10** being defined by the piston **9**. The pressure control chamber **10** is filled with a pressure transmitting medium. A piezoelectric element **8** for driving the piston **9** is disposed in the cylinder main body **41**. A seal **19** on the piezoelectric side is provided between the outer periphery of the piston **9** and the inner wall surface of the cylinder main body **41** so as to prevent the pressure transmitting medium from flowing into the piezoelectric element **8** side from the pressure control chamber **10**.

Provided inside the pressure control chamber **10** is a cylinder **18** which serves as a housing chamber. A side wall of the cylinder **18** has an inflow/outflow hole **22**, the pressure transmitting medium moving into and out of the cylinder **18** through the inflow/outflow hole **22**.

The needle valve **4** extends beyond the bottom of the cylinder main body **41**; it is installed so that the distal end thereof is allowed to move in the direction for opening or closing the injection aperture **1**. At this time, one end of the needle valve **4** is located in the needle guide cavity **3** and the other end is located in the cylinder **18**. Provided on the other end of the needle valve **4** is an opening pressure receiving section **6** which serves as the pressure receiving section. A compression spring **5**, which functions as the pre-loading means, is provided between the cylinder **18** and the other end surface of the needle valve **4** in a compressed state, urging the needle valve **4** in the direction for closing the injection aperture **1**. Further, a stopper **4***a* is provided on the portion of the needle valve **4** located in a fuel chamber **3***a*, so that, when the needle valve **4** moves in the direction for opening the injection aperture **1**, the stopper **4***a* comes in contact with the cylinder main body **41** to regulate the stroke of the needle valve **4**.

A pressure receiving seal **20** is provided between the outer periphery of the opening pressure receiving section **6** of the needle valve **4** and the inner wall surface of the cylinder **18** so as to prevent the pressure transmitting medium from flowing into the compression spring **5** side, thereby maintaining the pressure difference between the areas above and below the opening pressure receiving section **6**. A fuel chamber seal **21** is provided at the portion where the needle valve **4** comes through the cylinder main body **41** in order to airtightly separate the pressure control chamber **10** from the flowing channel of fuel G.

The operation of the first embodiment will now be discussed.

When a driving circuit applies voltage to the piezoelectric element **8** until it is charged, the piezoelectric element **8** expands. The expansion of the piezoelectric element **8** causes the piston **9** to move down, decreasing the capacity in the pressure control chamber **10** with a resultant increase in the fluid pressure of the pressure transmitting medium. Then, the pressure transmitting medium in the pressure control chamber **10** flows into the cylinder **18** through the inflow/outflow hole **22**, thereby increasing the fluid pressure applied to the opening pressure receiving section **6**. The moment the fluid pressure applied to the opening pressure receiving section **6** surpasses the urging force of the compression spring **5**, the needle valve **4** moves in a direction for opening the injection aperture **1**, thus opening the injection aperture **1**. This allows fuel G, which is supplied from the high-pressure fuel source via a fuel passage **17**, to pass through the fuel chamber **3***a* and the needle guide cavity **3** to be injected through the injection aperture **1**. The needle valve **4** moves until the stopper **4***a* comes in contact with the cylinder main body **41** to restrict the stroke thereof.

Conversely, when the voltage applied to the piezoelectric element **8** is decreased until it is discharged, the piezoelectric element **8** contracts. The contraction of the piezoelectric element **8** causes the piston **9** to move up, increasing the capacity in the pressure control chamber **10** with a resultant decrease in the fluid pressure of the pressure transmitting medium. Then, the pressure transmitting medium in the cylinder **18** flows out into the pressure control chamber **10** through the inflow/outflow hole **22**, thereby decreasing the fluid pressure applied to the opening pressure receiving section **6**. The moment the fluid pressure applied to the opening pressure receiving section **6** is surpassed by the urging force of the compression spring **5**, the needle valve **4** moves in a direction for closing the injection aperture **1** and the distal end thereof comes in contact with the nozzle, thus closing the injection aperture **1** to stop the injection of fuel G.

According to the first embodiment, the fuel chamber seal **21** provides airtight separation of the pressure control chamber **10** from the flowing channel of fuel G. Hence, the pressure transmitting medium in the pressure control chamber **10** and fuel G are not mixed together, permitting unrestrained selection of pressure transmitting medium. Thus, the use of a liquid, which exhibits a better temperature characteristic than that of fuel G, as the pressure transmitting medium, makes it possible to obtain a pressure transmitting characteristic which is stable over a wide temperature range and also to protect the pressure transmitting characteristic from being affected by partially evaporated fuel G in the fuel injection system, thereby achieving stable valve opening and closing performance regardless of operating environment.

The pressure transmitting medium is required to have a low saturated vapor pressure even under high temperature to control the generation of bubbles. Further, the medium provides lubrication for the needle valve **4** to move as well as it transfers pressure; therefore, the medium is also required to exhibit stable lubricating property for the needle valve **4** to move smoothly, i.e., stable viscosity coefficient against temperature changes. For these reasons, the liquid used for the pressure transmitting medium should be a lubricant such as engine oil and gear oil or hydraulic oil for a hydraulic circuit which do not reach the saturated vapor pressure at 200° C. and atmospheric pressure to survive the operating temperature of the internal-combustion engine and which have good lubricating property.

By employing the engine oil, gear oil, or the hydraulic oil for a hydraulic circuit, the occurrence of bubbles in the pressure transmitting medium filled in the pressure control chamber **10** can be prevented and therefore the deterioration in the pressure transmitting characteristic can be prevented even when, for example, the ambient temperature reaches 150° C. to 200° C. from continuous operation in an automotive internal-combustion engine. Moreover, an increase in the viscosity coefficient of the pressure transmitting medium can be controlled and the lubricating property can be maintained to ensure smooth operation of the piston **9** and the needle valve **4** even if the ambient temperature goes down to −30° C. or less at the time of startup in a cold region.

[Second Embodiment]

FIG. **2** is the longitudinal sectional view illustrative of the fuel injection system according to the second embodiment of the present invention.

In the figure, the piezoelectric element **8** is configured to be a disc or a column with a throughhole provided at the center thereof. The piezoelectric element **8** is provided on the bottom side of the cylinder main body **41**, the needle

valve **4** coming through the through-hole of the piezoelectric element **8**. Provided on the piezoelectric element **8** in the cylinder main body **41** is the piston **9** which is disposed in such a manner that it is allowed to slide up and down. The piston **9** has a hole at the center thereof, the needle valve **4** coming through the hole. Seals **19** on the piezoelectric side are provided, one each on the outer periphery of the piston **9** and the inner circumference of the hole so as to prevent the pressure transmitting medium from flowing into the piezoelectric element **8** side.

Provided in the upper section inside the cylinder main body **41** is a cylinder **18**. The other end of the needle valve **4** is located in the cylinder **18**. Further, a compression spring **5** is provided between the cylinder **18** and the other end surface of the needle valve **4** in a compressed state, urging the needle valve **4** in the direction for closing the injection aperture **1**. A pressure receiving seal **20** is provided on the outer periphery of the opening pressure receiving section **6** of the needle valve **4** to prevent the pressure transmitting medium from flowing to the rear of the opening pressure receiving section **6** of the needle valve **4**. The rear of the opening pressure receiving section **6** where the compression spring **5** of the cylinder **18** is disposed is opened to the air through an opened-to-the-air aperture **23**. The pressure control chamber **10** is defined by the piston **9** and the opening pressure receiving section **6** of the needle valve **4**.

The rest of the construction of this embodiment is identical to the structure of the first embodiment described previously; the operation is also the same as that of the first embodiment.

According to the second embodiment thus constructed, the same advantages as those of the first embodiment stated above can be obtained. Furthermore, the length of the housing **40** can be reduced since the disc-shaped or column-shaped piezoelectric element **8** with the through-hole at the center thereof is located at the bottom in the cylinder main body **41** with the needle valve **4** coming through the through-hole of the piezoelectric element **8**; therefore, the completed fuel injection system can be made smaller. In addition, since the rear of the opening pressure receiving section **6**, where the compression spring **5** is disposed, is opened to the air via the opened-to-the-air aperture **23**, the pressure applied to the rear surface of the opening pressure receiving section **6** can be maintained at a constant level even if the pressure transmitting medium leaks through the pressure receiving seal **20**.

[Third Embodiment]

FIG. **3** is the longitudinal sectional view illustrative of the fuel injection system according to the third embodiment of the present invention.

In the figure, the cylinder **18** is configured by a cylindrical partition installed on the top inner surface of the cylinder main body **41**. The other end of the needle valve **4** is located in the cylinder **18**. Further, the disc-shaped or column-shaped piezoelectric element **8** with a through-hole in the center thereof is disposed aroung the cylinder **18** at the top inside the cylinder main body **41**. The piston **9** with a hole formed at the center thereof is disposed on the bottom of the piezoelectric element **8**. Seals **19** on the piezoelectric side are provided, one each on the outer periphery of the piston **9** and the inner circumference of the hole of the piston **9**. A pressure receiving seal **20** is provided on the outer periphery of the opening pressure receiving section **6** of the needle valve **4**. The rear of the opening pressure receiving section **6**, where the compression spring **5** of the cylinder **18** is disposed, is opened to the air through the opened-to-the-air aperture **23**. The pressure control chamber **10** is defined by the piston **9** and the opening pressure receiving section **6** of the needle valve **4**.

The rest of the construction of this embodiment is identical to the structure of the second embodiment described previously; the operation is also the same as that of the second embodiment.

According to the third embodiment thus constructed, the same advantages as those of the second embodiment stated above can be obtained. Furthermore, the disc-shaped or column-shaped piezoelectric element **8** with the through-hole at the center thereof is located at the top in the cylinder main body **41**, the cylinder **18** being housed in the through-hole of the piezoelectric element **8**; therefore, the length of the housing **40** can be further reduced, allowing the completed fuel injection system to be made even smaller.

[Fourth Embodiment]

FIG. **4** is the longitudinal sectional view of the fuel injection system according to the fourth embodiment of the present invention.

In the figure, the cylinder main body **41** is constituted by a first cylinder main body **41***a* and a second cylinder main body **41***b*. The first cylinder main body **41***a* incorporates the piezoelectric element **8** and the piston **9**; the second cylinder main body **41***b* contains the other end of the needle valve **4**. Further, a first pressure control chamber **10***a* defined by the piston **9** and a second pressure control chamber **10***b* defined by the opening pressure receiving section **6** of the needle valve **4** are communicated through a pressure transmitting pipe **24**. The rear of the opening pressure receiving section **6**, where the compression spring **5** of the second cylinder main body **41***b* is disposed, is opened to the air through the opened-to-the-air aperture **23**.

The rest of the construction of this embodiment is identical to the structure of the first embodiment described previously.

In the fourth embodiment, the piston **9** is driven by the piezoelectric element **8** to change the capacity inside the first pressure control chamber **10***a*. A change in the fluid pressure of the pressure transmitting medium in the first pressure control chamber **10***a* is transferred to the second pressure control chamber **10***b* via the pressure transmitting pipe **24** and it is applied to the opening pressure receiving section **6** of the needle valve **4**. The change in the fluid pressure applied to the opening pressure receiving section **6** causes the needle valve **4** to move in the direction for closing or opening the injection aperture **1**. The rest of the operation is the same as the operation in the first embodiment described previously.

According to the fourth embodiment thus constructed, the same advantages as those of the first embodiment previously stated are obtained. Furthermore, since the pressure control chamber **10** is divided into the first and second pressure control chambers **10***a* and **10***b*, respectively, the degree of freedom of the layout of the fuel injection system can be increased.

[Fifth Embodiment]

FIG. **5** is the longitudinal sectional view illustrative of the cylinder main body assembly of a fuel injection system according to the fifth embodiment of the present invention.

In the figure, a rubber body **25** made of, for example, silicone rubber, has a disc-shaped flange **25***a* and a cylindrical fitting section **25***b* which is provided at the center of the flange **25***a*. The rubber body **25** is fixed, with an adhesive agent **25***c*, to the shaft of the needle valve **4** which is fitted in the central hole of the fitting section **25***b*. The rubber body **25** is disposed so that the fitting section **25***b* is fitted in an opening **41***c* provided in the bottom of the cylinder main

body **41**, a holding frame **26** being applied to the rubber body **25** from the bottom being tightened and fixed to the bottom of the cylinder main body **41**. At this time, the flange **25***a* of the rubber body **25** is pressed and compressed by the cylinder main body **41** and the holding frame **26** so as to provide airtight isolation of the pressure control chamber **10** from the flowing channel of fuel G.

The rest of the construction-is the same as the construction of the first embodiment stated above.

In the fifth embodiment, when the piston **9** is driven by the piezoelectric element **8**, the fluid pressure of the pressure transmitting medium applied to the opening pressure receiving section **6** of the needle valve **4** changes and the needle valve **4** moves in the direction for closing or opening the injection aperture **1** as in the case of the first embodiment discussed above. In the fifth embodiment, the rubber body **25** is elastically deformed in the direction of the movement of the needle valve **4** by the driving force which moves the needle valve **4** up or down, thereby permitting the opening and closing operation of the needle valve **4**. The adhesive agent **25***c* fixes the fitting section **25***b* of the rubber body **25** to the needle valve **4** and the flange **25***a* of the rubber body **25** is pressurized and compressed by the cylinder main body **41** and the holding frame **26**; therefore, the pressure transmitting medium does not leak into the fuel chamber **3***a*.

The rest of the operation is the same as the operation of the first embodiment.

According to the fifth embodiment thus constructed, the same advantages as those of the first embodiment discussed above can be obtained. In addition, the pressure transmitting medium does not leak into the fuel chamber **3***a* since the pressure control chamber **10** is securely separated from the fuel chamber **3***a* in an airtight manner. Hence, a constant amount of the pressure transmitting medium in the pressure control chamber **10** is maintained and the pre-loading can be maintained, enabling reliable valving operation.

In the fifth embodiment described above, the flange **25***a* of the rubber body **25** is pressurized and compressed by the cylinder main body **41** and the holding frame **26**; alternatively, an adhesive agent may be used to glue the flange **25***a*, the cylinder main body **41**, and the holding frame **26** together to fix them. This will provide even more secure airtight isolation of the pressure control chamber **10** from the fuel chamber **3***a*.

[Sixth Embodiment]

FIG. **6** is the longitudinal sectional view illustrative of the cylinder main body assembly of a fuel injection system according to the sixth embodiment of the present invention.

In the figure, a liquid amount regulator **27**, which controls the amount of the pressure transmitting medium in the pressure control chamber **10**, is provided at the bottom of the cylinder main body **41**. The liquid amount regulator **27** is constituted by a liquid chamber **27***a* provided at the bottom of the cylinder main body **41**, a liquid reservoir **27***b* having an air hole **27***d* for releasing to the air, and a liquid channel **27***c* which communicates the liquid chamber **27***a* and the liquid reservoir **27***b*. The liquid amount regulator **27** is filled with the pressure transmitting medium. Further, a liquid seal **27***e* is provided at a portion of the liquid chamber **27***a* where the needle valve **4** comes through.

The rest of the construction is the same as the construction of the first embodiment described above.

In the sixth embodiment, when the needle valve **4** moves to open the injection aperture **1**, the piezoelectric element **8** drives the piston **9** and the capacity of the pressure control chamber **10** decreases, causing the pressure of the pressure transmitting medium to increase. At this time, if the fuel chamber seal **21** is defective, the pressure transmitting medium leaks out through the fuel chamber seal **21**. This gives rise to a problem in that the volume of the pressure transmitting medium decreases, causing a change in the pressure transmitting characteristic of the pressure control chamber **10**

A fuel injection system is not in operation at all times; the engine is stopped for a considerable period of time in the case of a car, for example. If the amount of the pressure transmitting medium in the pressure control chamber **10** has been decreased, then the fluid pressure in the pressure control chamber **10** goes down and becomes lower than the fluid pressure in the liquid chamber **27***a*. Hence, while the engine is in a stopped state, according to the difference in fluid pressure between the pressure control chamber **10** and the liquid chamber **27***a*, the pressure transmitting medium flows into the pressure control chamber **10** from the liquid chamber **27***a* through the fuel chamber seal **21**, thus controlling the pressure transmitting medium in the pressure control chamber **10** to a predetermined amount.

According to the sixth embodiment thus constructed, the same advantages as those of the first embodiment described previously will be obtained. In addition, since the pressure transmitting medium in the pressure control chamber **10** is controlled to a predetermined amount, time-dependent changes of the pressure transmitting characteristic of the pressure control chamber **10** can be prevented, enabling stable valve opening and closing operation.

[Seventh Embodiment]

FIG. **7** is the longitudinal sectional view illustrative of a fuel injection system according to the seventh embodiment of the present invention.

In the figure, provided in the cylinder **18** is a partitioning plate **28** which provides a partition between the area on the opening pressure receiving section **6** side and the area on the inflow/outflow hole **22** side with respect to the needle valve **4**. A cylinder sub-chamber **29** defined by the opening pressure receiving section **6** and the partitioning plate **28** is provided. A small orifice **30** is formed in the partitioning plate **28**, the cross-sectional area of the small orifice **30** being set so that the cross-sectional area of the small orifice **30**<< the cross-sectional area of the inflow/outflow hole **22**. As the pressure transmitting medium, engine oil or other liquid which has higher viscosity than fuel G and which exhibits a minimum of temperature-dependent change in the characteristic.

The rest of the construction of this embodiment is the same as the construction of the first embodiment described above.

In the seventh embodiment, when the piston **9** is driven by the piezoelectric element **8**, the capacity of the pressure control chamber **10** changes and the fluid pressure of the pressure transmitting medium changes accordingly as in the case of the first embodiment discussed above. Further, the fluid pressure of the pressure transmitting medium applied to the opening pressure receiving section **6** of the needle valve **4** changes to open or close the needle valve **4**.

In the operation stated above, the pressure transmitting medium passes through the small orifice **30** and flows into the cylinder sub-chamber **29** or flows out of the cylinder sub-chamber **29**. At this time, since the viscosity of the pressure transmitting medium is high, resistance, which is proportional to the moving velocity of the needle valve **4**, is produced when the pressure transmitting medium passes through the small orifice **30**. This results in a reduced colliding force of the stopper **4***a* of the needle valve **4** against the cylinder main body **41** at the time of opening and a

reduced colliding force of the distal end of the needle valve **4** against the nozzle at the time of closing. The reduced colliding forces lead to a reduction in the repelling forces of the cylinder main body **41** and the nozzle applied to the needle valve **4**.

According to the seventh embodiment thus construction, resistance, which is proportional to the moving velocity of the needle valve **4**, is produced when the pressure transmitting medium passes through the small orifice **30**. This reduces the colliding force of the stopper **4***a* of the needle valve **4** against the cylinder main body **41** at the time of opening and also the colliding force of the distal end of the needle valve **4** against the nozzle at the time of closing. The reduced colliding forces prevent parts from being damaged, resulting in a prolonged service life of the fuel injection system.

Furthermore, the reduced colliding force also leads to reduced repelling force. This solves the problem of the undesirable nonlinear relationship between a set valve opening period of time and an actual valve opening time of period. To be more precisely about the problem of the undesirable nonlinear relationship, when the valve opening period of time is set so that the closing operation is initiated immediately after the collision, the actual valve opening period of time is shorter than when the valve opening period of time is set so that the closing operation is initiated immediately before the collision because of the repulsion to the collision.

Moreover, the leakage of fuel G after the valve is closed, which is caused by the repulsion to the collision at the time of closing, is controlled, permitting highly accurate control of the injecting amount of fuel G.

In addition, since the temperature-dependent changes in the characteristics of the pressure transmitting medium, i.e., the changes in viscosity, is minimized, the colliding force can be reduced regardless of temperature changes. Thus, the advantages described above can be obtained over a wide range of temperature.

With reference to FIGS. **8**A to **8**C, detailed description will now be given to the undesirable nonlinear relationship between a set valve opening period of time and an actual valve opening period of time and the leakage of fuel G after closing the valve caused by the repulsion provoked by the collision taken place at the time of valve closing. FIGS. **8**A to **8**C show the displacement of the needle valve observed when the valve is opened and closed, the axis of ordinate representing the displacement of the needle valve **4** and the axis of abscissa representing time. Set valve opening period of time T_1 denotes the duration in which electric current is allowed to flow through the piezoelectric element **8** to open the injection aperture **1**; actual valve opening period of time T_2 denotes the duration in which the injection aperture **1** actually stays open. Further, S denotes the position of the stopper **4***a*.

Referring to FIG. **8**A, the case, wherein set valve opening period of time T_1 is sufficiently long, will be described.

Electric current is supplied to the piezoelectric element **8** until time t_2 to open the injection aperture **1**. This causes the needle valve **4** to be displaced in the opening direction and the stopper **4***a* collides with the cylinder main body **41** in time t_1. At this time, the cylinder main body **41** applies a repelling force to the stopper **4***a* and the needle valve **4** is displaced in the closing direction. The needle valve **4** is, however, under the driving force for opening it; therefore, the needle valve **4** is displaced in the opening direction again. Then, the colliding force exerted by the stopper **4***a* on the cylinder main body **41** gradually weakens and the bounce of the needle valve **4** is attenuated until the stopper **4***a* comes in contact with the cylinder main body

In time t_2, the supply of electric current to the piezoelectric element **8** is stopped. This causes the needle valve **4** to be displaced in the closing direction; in time t_3, the distal end of the needle valve **4** collides with the nozzle. At the time of this collision, the nozzle exerts a repelling force on the needle valve **4** to displace the needle valve **4** in the opening direction. The needle valve **4** is, however, under the driving force for opening it; therefore, the needle valve **4** is displaced in the closing direction again. Then, the colliding force exerted by the stopper **4***a* on the nozzle gradually weakens and the bounce of the needle valve **4** is attenuated until the distal end of the needle valve **4** closes the injection aperture **1**.

Thus, fuel G is injected through the injection aperture **1** for actual valve opening period of time T_2 ($=t_4$).

Referring to FIG. **8**B, the case, wherein set valve opening period of time T_1 is set so that closing is started immediately following the collision between the stopper **4***a* and the cylinder main body **41**, will now be described.

Electric current is supplied to the piezoelectric element **8** until time t_4 to open the injection aperture **1**. This causes the needle valve **4** to be displaced in the opening direction and the stopper **4***a* collides with the cylinder main body **41** in time t_1. At this time, the cylinder main body **41** applies a repelling force to the stopper **4***a* and the needle valve **4** is displaced in the closing direction. In time t_4, the supply of electric current to the piezoelectric element **8** is stopped. This causes the needle valve **4** to be displaced in the closing direction; in time t_5, the distal end of the needle valve **4** collides with the nozzle. At this time, the needle valve **4** has initial velocity in the closing direction due to the repelling force; therefore, the time required for closing is shorter than that shown in FIG. **8**A. Hence, $t_3-t_2>t_5-t_4$.

Thus, fuel G is injected through the injection aperture **1** for actual valve opening period of time T_2 ($=t_5$).

It should be noted that, when the injection aperture **1** is closed, the needle valve **4** bounds as in the case shown in FIG. **8**A.

Referring to FIG. **8**C, the case, wherein set valve opening period of time T_1 is set so that closing is started immediately preceding the collision between the stopper **4***a* and the cylinder main body **41**, will now be described.

Electric current is supplied to the piezoelectric element **8** until time t_6 to open the injection aperture **1**. This causes the needle valve **4** to be displaced in the opening direction. In time t_6, the supply of electric current to the piezoelectric element **8** is stopped. This causes the needle valve **4** to be displaced in the closing direction; in time t_7, the distal end of the needle valve **4** collides with the nozzle. At this time, the needle valve **4** has initial velocity in the-opening direction due to inertia; therefore, the time required for closing is longer than that shown in FIG. **8**A. Hence, $t_3-t_2>t_7-t_6$.

Thus, fuel G is injected through the injection aperture **1** for actual valve opening period of time T_2 ($=t_7$).

It should be noted that, when the injection aperture **1** is closed, the needle valve **4** bounds as in the case shown in FIG. **8**A.

A fuel injection system controls the injecting amount of fuel G by controlling actual valve opening period of time T_2 by using set valve opening period of time T_1. Specifically, to increase the injecting amount of fuel G, set valve opening period of time T_1 is increased. As described above, however, actual valve opening period of time T_2, which is obtained when valve opening period of time T_1 is set so that the closing operation is begun immediately after the collision

between the stopper **4***a* and the cylinder main body **41**, undesirably becomes shorter than actual valve opening period of time T_2 which is obtained when set valve opening period of time T_1 is set so that the closing operation is begun immediately before the collision between the stopper **4***a* and the cylinder main body **41**. In other words, set valve opening period of time T_1 and the actual valve opening period of time T_2 are inverted, presenting nonlinear relationship between the two.

Further, the repelling force generated by the collision of the distal end of the needle valve **4** against the nozzle causes the needle valve **4** to bound. Therefore, after the closing operation, the injection aperture **1** is opened due to the bounce of the needle valve **4**, resulting in the leakage of fuel G.

According to the seventh embodiment, the colliding force of the stopper **4***a* of the needle valve **4** applied to the cylinder main body **41** at the time of opening decreases; therefore, the repelling force of the cylinder main body **41** applied to the stopper **4***a* at the time of the collision accordingly reduces. Thus, if valve opening period of time T_1 is set so that the closing operation is begun immediately after the collision between the stopper **4***a* and the cylinder main body **41**, when the supply of electric current to the piezoelectric element **8** is cut off in t_4, a smaller repelling force in the closing direction is applied to the needle valve **4**. As a result, the time required for completing the valve closing operation approaches that shown in FIG. **8**A ($t_3-t_2 \approx t_5-t_4$). Thus, it is possible to avoid the inversion of set valve opening period of time T_1 and actual valve opening period of time T_2.

Further, the colliding force of the distal end of the needle valve **4** applied to the injection aperture **1** at the time of valve closing operation decreases, resulting in a reduced repelling force exerted by the injection aperture **1** on the needle valve **4**. The reduced repelling force leads to less bounce of the needle valve **4** which takes place when the injection aperture **1** is closed, thus making it possible to control the occurrence of the leakage of fuel G after the valve closing operation is completed.

[Eighth Embodiment]

FIG. **9** is the longitudinal sectional view illustrative of the cylinder assembly of a fuel injection system according to the eighth embodiment of the present invention.

In the eighth embodiment, an opening **31** is provided in the side wall of the cylinder **18**. The cross-sectional area of the opening **31** is smaller than that of the inflow/outflow hole **22**, therefore, the opening **31** serves as an orifice. The rest of the construction is the same as the construction of the first embodiment described above.

In the eighth embodiment, when the piston **9** is driven by the piezoelectric element **8**, the pressure transmitting medium flows into the cylinder **18** from the pressure control chamber **10** through the opening **31**, or it flows into the pressure control chamber **10** from the cylinder **18** through the opening **31**. At this time, since the opening **31** has a small cross-sectional area, the opening **31** functions as an orifice, restricting the flow rate of the pressure transmitting medium going through the opening **31**. This causes a delay in the rise or fall of the fluid pressure in the cylinder **18** in relation to the rise or fall of the fluid pressure in the pressure control chamber **10**, thus restraining the moving velocity of the needle valve **4**.

Therefore, the eighth embodiment provides the same advantages as those of the seventh embodiment described above.

[Ninth Embodiment]

FIG. **10** is the longitudinal sectional view illustrative of the cylinder assembly of a fuel injection system according to the ninth embodiment of the present invention.

In the ninth embodiment, in place of the compression spring **5**, a low-resilience rubber **32** is disposed between the cylinder **18** and the other end surface of the needle valve **4**. The low-resilience rubber **32** is preferably made of silicone rubber or other material which exhibits good attenuation characteristic, that is, high resistance to deforming velocity, and which has an impact resilience of **50** or less. The rest of the construction is the same as the construction of the first embodiment discussed above.

According to the ninth embodiment, the low-resilience rubber **32** applies pre-load to the needle valve **4**. When the fluid pressure applied to the opening pressure receiving section **6** of the needle valve **4** goes up, the needle valve **4** moves in the direction for opening the injection aperture **1** and the low-resilience rubber **32** contracts. At this time, the low-resilience rubber **32** develops high resistance, restraining the moving velocity of the needle valve **4**. Thus, the ninth embodiment also provides the same advantages as those of the seventh embodiment described above.

In the ninth embodiment, if the low-resilience rubber **32** is disposed in contact with the other end surface of the needle valve **4**, then there is no need to provide the pressure receiving seal **20**.

[Tenth Embodiment]

In the ninth embodiment above, the low-resilience rubber **32** is employed as the pre-loading means. In the tenth embodiment, as shown in FIG. **11**, a balloon-like rubber **33**, which has air or oil sealed in to allow high deformation, is employed for the pre-loading means to provide the same advantages. While in the ninth embodiment, the spring constant is determined by the disposing space and the material of the low-resilience rubber **32**, in the tenth embodiment, the spring constant can be adjusted by adjusting the pressure of the air or oil to be sealed in. Hence, the tenth embodiment adds another advantage in that a higher degree of freedom of the spring constant with respect to the shape is obtained.

[Eleventh Embodiment]

Instead of the low-resilience rubber **32** used as the pre-loading means in the ninth embodiment, a buffer **34** is employed as the pre-loading means for the eleventh embodiment as illustrated in FIG. **12**. The buffer **34** is made of silicone rubber, for example, and it has a predetermined spring constant. Further, the buffer **34** is designed so that it develops a predetermined attenuation characteristic by the resistance produced when air passes through an opened-to-the-air aperture **35** which is formed in the cylinder **18**. Accordingly, the buffer **34** restrains the moving velocity of the needle valve **4**, enabling the eleventh embodiment to provide the same advantages as those of the seventh embodiment discussed above. The attenuation characteristic is controlled by the cross-sectional area of the opened-to-the-air aperture **35**.

[Twelfth Embodiment]

In the twelfth embodiment, a voltage controlling means is used to reduce a time-dependent change in the driving voltage applied to the piezoelectric element **8** immediately before the completion of the lift of the needle valve **4**.

Conventionally, the waveform of the driving voltage applied to the piezoelectric element **8** at the time of valve opening indicates that the driving voltage is increased from 0 volt to E_0 volts (until time t_1) at a constant step-up rate then the voltage of E_0 volts is maintained as shown by the dashed line of FIG. **13**A. The waveform of the driving voltage at the time of valve closing indicates that the voltage is decreased from the voltage of E_0 volts (from time t_2) to 0 volt at a constant step-down rate. When the driving voltage applied to

the piezoelectric element **8** is controlled in this manner, the piezoelectric element **8** expands in proportion to the driving voltage as indicated by the dashed line of FIG. **13B**; it expands by displacement A, which corresponds to the driving voltage of E_0 volts, in time t_1; it contracts in proportion to the driving voltage from time t_2, then it restores the original dimensions thereof in time t_3.

In the twelfth embodiment, the voltage controlling means is provided with, e.g. a time function so that the gradient of the driving voltage is dulled immediately before the completion of the valve opening and closing operation, thereby the step-up rate of the driving voltage applied to the piezoelectric element **8** is decreased immediately before the completion of the valve opening operation and the step-down rate is also decreased immediately before the completion of the valve closing operation as shown by the waveform indicated by the solid line of FIG. **13A**. This means that the time-dependent change, i.e. the gradient, of the driving voltage is dulled immediately before the completion of the lift of the needle valve **4** as it is shown by the waveform of the driving voltage. Thus, the displacement ratio of the piezoelectric element **8** decreases immediately before the completion of the lift of the needle valve **4** as indicated by the solid line in FIG. **13B**. Accordingly, the change in the fluid pressure of the pressure transmitting medium decreases immediately before the completion of the lift of the needle valve **4** and the moving velocity of the needle valve **4** decreases immediately before the completion of the lift. This results in a reduced colliding force exerted by the stopper **4***a* of the needle valve **4** on the cylinder main body **41** at the time of valve opening and also a reduced colliding force exerted by the distal end of the needle valve **4** on the nozzle at the time of valve closing.

According to the twelfth embodiment, the colliding force exerted by the stopper **4***a* of the needle valve **4** on the cylinder main body **41** at the time of valve opening and the colliding force exerted by the distal end of the needle valve **4** on the nozzle at the time of valve closing can be reduced by dulling the driving voltage applied to the piezoelectric element **8** immediately before the completion of the lift of the needle valve **4** through the controlling means. This makes it possible to obtain the same advantages as those of the seventh embodiment discussed above without adopting any special structure.

[Thirteenth Embodiment]

FIG. **14** is the longitudinal sectional view illustrative of the cylinder main body assembly of a fuel injection system according to the thirteenth embodiment of the present invention.

In the figure, a holding plate **36** is provided on the top of the piezoelectric element **8**. A spring **37** is provided in a compressed state between the holding plate **36** and the top inner surface of the cylinder main body **41**. Provided on the inner surface of the side wall of the cylinder main body **41** is the stopper **41***d* which engages with the outer periphery of the holding plate **36** to prevent the holding plate **36** from moving downward. The holding plate **36**, the spring **37**, and the stopper **41***d* constitute a pressure relaxing means. The rest of the construction is the same as the construction of the first embodiment already described.

The operation of the thirteenth embodiment will now be described.

The holding plate **36** is pushed downward by the urging force of the spring **37**; the outer periphery of the holding plate **36** engages with the stopper **41***d* to prevent the holding plate **36** from moving downward. Downward load Fk is applied to the holding plate **36** by the spring **37**, load Fk being received by the stopper **41***d* via the holding plate **36**.

When the piezoelectric element **8** is expanded to open the injection aperture **1**, upward driving force is applied to the holding plate **36**. Downward load Fk applied to the holding plate **36** is, however, set to be larger than the driving force generated by the piezoelectric element **8**; therefore, the upward movement of the holding plate **36** is prevented. As a result, the driving force generated by the piezoelectric element **8** is applied to the piston **9** and the valve opening operation by the needle valve **4** is implemented.

In this case, if, for some reason, an excess rise takes place in the fluid pressure of the pressure transmitting medium in the pressure control chamber **10**, then the increased fluid pressure pushes up the piston **9**. This force applied to the piston **9** is transmitted to the holding plate **36** via the piezoelectric element **8**. When the force applied to the piston **9** overcomes load Fk, the spring **37** contracts, moving the holding plate **36** upward. This in turn causes the capacity of the pressure control chamber **10** to increase, easing the rise in the fluid pressure of the pressure transmitting medium.

According to the thirteenth embodiment thus constructed, an excessive rise in the fluid pressure of the pressure transmitting medium in the pressure control chamber **10** can be prevented. The piezoelectric element **8** is not subjected to load which exceeds Fk. Therefore, it is possible to protect the piezoelectric element **8** from damage by setting proper load Fk applied by the spring **37** according to the pressure resistance of the piezoelectric element **8**.

[Fourteenth Embodiment]

FIG. **15** is the longitudinal sectional view illustrative of the cylinder main body assembly of a fuel injection system according to the fourteenth embodiment of the present invention.

In the figure, a cylinder chamber **38**, which functions as the pressure relaxing means, is provided so that it is communicated with the pressure control chamber **10** of the cylinder main body **41** via a liquid channel **39**. Provided in the cylinder chamber **38** are a spring **38***a*, which has been set to load Fk, and a piston **38***b*. A stopper **38***c* provided on the inner wall surface of the cylinder chamber **38** prevents the piston **38***b* from moving in one direction. Further, a piston seal **38***d* is provided around the outer periphery of the piston **38***b* to prevent the pressure transmitting medium from flowing to the spring **38***a* side. The rest of the construction is the same as the construction of the first embodiment described above.

In the fourteenth embodiment, the urging force of the spring **38***a* pushes the piston **38***b* toward the stopper **38***c*. Further, the outer periphery of the piston **38***b* engages with the stopper **38***c*, so that the piston **38***b* is not allowed to move toward the stopper **38***c*. The piston **38***b* is subjected to load Fk in the direction of the stopper **38***c* by the spring **38***a*, load Fk being received by the stopper **38***c* via the piston **38***b*.

If, for some reason, an excessive rise takes place in the fluid pressure of the pressure transmitting medium in the pressure control chamber **10**, then the increased fluid pressure is applied to the piston **38***b* through the liquid channel **39**. When the force applied to the piston **38***b* surpasses load Fk, the spring **38***a* contracts, causing the piston **38***b* to move toward the spring **38***a*. This increases the capacity of the pressure control chamber **10**, easing the rise in the fluid pressure of the pressure transmitting medium.

Thus, according to the fourteenth embodiment, the same advantages as those of the thirteenth embodiment described above are obtained.

What is claimed is:

1. A fuel injection system comprising:

a valve main body having a needle guide cavity with the distal end thereof formed as an injection aperture, fuel

passing through said needle guide cavity to be injected through said injection aperture;

a pressure control chamber filled with a pressure transmitting medium;

a piston for changing the fluid pressure of said pressure transmitting medium in said pressure control chamber;

a needle valve having one end thereof located in said needle guide cavity and the other end thereof located in said pressure control chamber, said needle valve being installed in such a manner that it is allowed to move to open or close said injection aperture;

a pressure receiving section which is provided on a portion of said needle valve located in said pressure control chamber and which is subjected to said fluid pressure;

a pre-loading means for pre-loading said needle valve in a direction for closing said injection aperture; and

a piezoelectric element which changes said fluid pressure of said pressure transmitting medium by driving said piston, applies said changed fluid pressure to said pressure receiving section, and moves said needle valve in a direction for opening or closing said injection aperture so as to start or stop the flow of an injection fuel through said injection aperture,

wherein a flow channel for said injection fuel is airtightly independent from said pressure control chamber, and

wherein said pressure transmitting medium is completely sealed off from said injection fuel by a sealing member.

2. A fuel injection system according to claim **1**, wherein a housing chamber for containing the other end of said needle valve is disposed inside said pressure control chamber, a small hole is provided on said housing chamber for communicating between said pressure receiving section side of said needle valve and said pressure control chamber, and said pressure transmitting medium filled in said pressure control chamber and said housing chamber is a liquid which has a higher viscosity coefficient than that of the fuel and which exhibits a small temperature-dependent change in the characteristic thereof.

3. A fuel injection system according to claim **1**, wherein an orifice is provided in a pressure transmitting passage between said piston and said pressure receiving section in said pressure control chamber.

4. A fuel injection system according to claim **1**, wherein said pre-loading means is made of a material which has an excellent attenuation characteristic.

5. A fuel injection system according to claim **1**, further comprising a voltage controlling means which controls a driving voltage applied to said piezoelectric element so that a time-dependent change in said driving voltage is reduced immediately before the lift of the needle valve is completed.

6. A fuel injection system according to claim **1**, further comprising a control relaxing means for relaxing said fluid pressure of said pressure transmitting medium in said pressure control chamber, whereby an excessive increase in said fluid pressure of said pressure transmitting medium is prevented.

7. A fuel injection system according to claim **1**, wherein said pre-loading means is disposed in a gaseous chamber.

* * * * *

Exhibit F

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/863,187	05/23/2001	Alan B. Welch	12541US03	2084

7590 11/14/2002

Robert W. Fieseler
McAndrews, Held & Malloy, Ltd.
34th Floor
500 West Madison Street
Chicago, IL 60661

EXAMINER
GIMIE, MAHMOUD

ART UNIT	PAPER NUMBER
3747	5

DATE MAILED: 11/14/2002

Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 07-01)

Office Action Summary	Application No.	Applicant(s)	
	09/863,187	WELCH ET AL	
	Examiner	Art Unit	
	Mahmoud M Gimie	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *27 August 2002* .

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-41* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-41* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *23 May 2001* is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

11)☐ The proposed drawing correction filed on _____ is: a)☐ approved b)☐ disapproved by the Examiner.

If approved, corrected drawings are required in reply to this Office action.

12)☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____ .

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).

a)☐ The translation of the foreign language provisional application has been received.

15)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449) Paper No(s) *4* .
4) ☐ Interview Summary (PTO-413) Paper No(s). _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other:

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DETAILED ACTION

Drawings

1. This application has been filed with informal drawings, which are acceptable for examination purposes only. Formal drawings will be required when the application is allowed.

2. The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they do not include the following reference sign(s) mentioned in the description: (a) 100 mentioned on various parts of the specification including page 25, line 19 and page 28, line 8. (b) 202 mentioned on page 27, line 8. A proposed drawing correction or corrected drawings are required in reply to the Office action to avoid abandonment of the application. The objection to the drawings will not be held in abeyance.

Specification

3. The abstract of the disclosure is objected to because it exceeds 150 words in length.

Correction is required. See MPEP § 608.01(b).

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the

invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

5. Claims 1-41 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kurishige et al (5,630,550).

Kurishige, et al, discloses an injection valve for injecting fuel into a combustion chamber of an internal combustion engine, said injection valve comprising: (a) a valve housing comprising: a fuel inlet port (17); an interior chamber fluidly connected to said fuel inlet port (3a); and a valve seat for cooperating with a valve member (4) 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 (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 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.

Kurishige, et al, does not teach the pressure transmitting fluid acts substantially as a solid. However, teaches that an increase/decrease of the viscosity coefficient can be of the pressure transmitting medium can be controlled between -30° C and 200°C which suggests that the fluid acts substantially as a solid.

Therefore, It would have been obvious to one of ordinary skill in the art at the time of the invention was made to modify the invention of Kurishige et al by realizing that the pressure transmitting fluid acts as a solid. The motivation to do so would have been to show that the pressure transmitting fluid characteristics does not heavily depend on ambient temperature.

With regard to claim 4, the hydraulic link assembly comprises a fluidly sealed hydraulic cylinder (18) that is fluidly sealed from said interior chamber, said hydraulic link assembly comprising a piston (6) and said hydraulic fluid is disposed within said hydraulic cylinder.

With regard to claim 5, said piston (6) is an integral part of said valve member (4).

With regard to method claims see above and figures 8A-8C and 13A-B.

All other claims see above and figures 1-15.

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. The cited references show directly actuated fuel injectors.

7. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Mahmoud M Gimie whose telephone number is 703-305-1037. The examiner can normally be reached on 7 a.m. -3:30 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Henry Yuen can be reached on 703-308-1946. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9302 for regular communications and 703-872-9302 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0861.



Mahmoud M Gimie
Examiner
Art Unit 3747

M Gimie, Examiner
November 12, 2002

Notice of References Cited	Application/Control No. 09/863,187	Applicant(s)/Patent Under Reexamination WELCH ET AL.	
	Examiner Mahmoud M Gimie	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-5,630,550	05-1997	Kurishige et al.	239/533.8
	B	US-2,721,100	10-1955	Bodine, Jr.	239/99
	C	US-4,750,706	06-1988	Schlagmuller, Walter	251/129.06
	D	US-6,311,950	11-2001	Kappel et al.	251/129.06
	E	US-6,313,568	11-2001	Sullivan et al.	310/346
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable; Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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Exhibit G

O.I.P.E. JC176 FEB 21 2003 PATENT & TRADEMARK OFFICE

3747

Attorney Docket No. 12541US03

#6/a Drwp 2/27/03 DBrewer

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION OF:	
ALAN B. WELCH IRAWAN RAHARDJA and MICHAEL HEBBES	Group Art Unit 3747 Examiner M. Gimie
SERIAL NO. 09/863,187	
FILED: May 23, 2001	
FOR: DIRECTLY ACTUATED INJECTION VALVE	

RECEIVED
FEB 26 2003
TECHNOLOGY CENTER R3700

AMENDMENT AND REQUEST FOR RECONSIDERATION

Commissioner of Patents
Washington, D.C. 20231

Sir:

This Amendment and Request for Reconsideration is submitted in response to the Office Action dated November 14, 2002. A marked-up version of the abstract and specification (insertions underlined; deletions bracketed) is attached as Appendix A. Appendix B hereto contains the substitute formal drawings. Appendix C hereto contains a version of the substitute formal drawings with the added reference numerals shown in red.

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IN THE DRAWINGS:

Please substitute the five (5) sheet(s) of formal drawings containing FIG. 1, FIG. 2, FIGs. 2a and 2b, FIG. 3, and FIG. 4, respectively, for the five (5) sheets of informal drawings presently of record in the present application.

IN THE ABSTRACT:

Please substitute the following abstract for that presently of record in the present application, as follows:

A directly actuated injection valve comprises a hollow valve housing, a valve member disposed within the hollow interior, a biasing mechanism, an actuator assembly and a passive hydraulic link assembly. The valve member is movable between a closed position and an open position for governing the flow of fuel into the combustion chamber of an internal combustion engine. The biasing mechanism, preferably a spring, biases the valve member in the closed position. The actuator assembly generates an opening force that acts against the valve spring to open the valve. The hydraulic link assembly is interposed between the valve member and the valve spring and the actuator assembly. The hydraulic link assembly transmits respective closing and opening forces to the valve member. The hydraulic link preferably comprises a piston disposed within a cylinder that is filled with a hydraulic fluid.

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IN THE SPECIFICATION:

Please amend the paragraph in the "Cross-Reference to Related Application(s)" section of the specification at page 1, lines 2-13, to read as follows:

Cross-Reference to Related Application(s)

This application is a continuation-in-part of U.S. Patent Application Serial No. 09/522,130 filed March 9, 2000, entitled "Directly Actuated Injection Valve", now U.S. Patent No. 6,298,829 issued October 9, 2001. The '130 application relates to and claims priority benefits from U.S. Provisional Patent Application Serial No. 60/159,791 filed October 15, 1999, entitled "Directly Actuated Injector". The '130 application and the '791 application are each incorporated herein by reference in their entirety.

REMARKS

Claims 1-41 remain pending in the present application.

Amendments to the Drawings

As to the drawing objection set forth in the November 14, 2002 Office Action, five (5) sheets of formal drawings containing FIG. 1, FIG. 2, FIGs. 2a and 2b, FIG. 3, and FIG. 4, respectively, have been substituted for the five (5) sheets of informal drawings presently of record in the present

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application. In the substitute drawings, reference numeral 100 has been added to designate the corresponding element in FIGs. 1 and 2, and reference numeral 202 has been added to designate the corresponding element in FIG. 2a, all as shown in Appendices B and C. Applicants submit that the written description in the specification, taken in combination with the drawings as originally filed, fully supports the substitute drawings, and that the substitute drawings submitted herewith overcome the drawing objection(s) set forth in the Office Action.

Amendments to the Abstract

The Abstract of the disclosure has been amended so as not to exceed 150 words in length, as set forth in Appendix A hereto, and as required in the Office Action.

Amendments to the Specification

The specification has been amended to insert the number and issue date of the patent that was granted from the application, Serial No. 09/522,130 filed March 9, 2000, of which the present application is a continuation-in-part.

Claim Rejections

In the Office Action dated November 14, 2002, claims 1-41 were rejected for obviousness under 35 U.S.C. §103(a) in view of

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Kurishige U.S. Patent No. 5,630,550 (the '550 patent). The '550 patent discloses a fuel injection system that permits the use of a hydraulic control oil as a pressure transmitting medium in a hydraulically actuated injector. At column 3 of the '550 patent, beginning at line 25, Kurishige states,

> It is an object of the present invention to provide a fuel injection system which permits the use of hydraulic control oil as a pressure transmitting medium for transmitting the driving force of a piezoelectric element to a needle valve.

The '550 patent thus distinguishes its fuel injection system from prior hydraulically actuated injection valve arrangements, such as the one illustrated in Figure 16 of the '550 patent. Like conventional fuel injectors, however, the fuel injector disclosed and claimed in the '550 patent relies upon the displacement and dynamic flow of hydraulic fluid to cause movement of the needle valve. For example, as shown in Figure 1 of the '550 patent, when a voltage is applied to piezoelectric element 8, it expands and displaces hydraulic oil from pressure control chamber 10. The hydraulic oil flows into cylinder 19 through inflow/outflow hole 22, thereby increasing the fluid pressure applied the opening pressure receiving section 6. The '550 patent describes the operation of this first embodiment at column 5, beginning at line 48.

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The "dynamic" hydraulic system of the '550 patent is the same type of conventional hydraulically actuated injection valve discussed in the background portion of the present application at, for example, page 4, beginning at line 18:

> Nearly all known direct fuel injection systems in internal combustion engines have been hydraulically actuated. These systems rely on a hydraulic fluid to provide the force that is needed to open an injection valve (or valves, when the engine comprises a plurality of combustion chambers). Accordingly, at typical engine operating speeds, hydraulically actuated injectors rely on rapid changes in the hydraulic fluid pressure to open and close the injection valve(s). An injection valve is typically opened by increasing the hydraulic fluid pressure and closed by reducing the hydraulic fluid pressure, such that the opening force applied to the injection valve is reduced, causing the valve to close. However, in the context of a conventional gaseous injection valve, hydraulic operation presents several drawbacks, including:
>
> ...
>
> - delayed response of the system caused by time delays associated with the dynamic flow of the hydraulic fluid, the actuation of the electronic hydraulic valve

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> hardware and the movement of the needle that controls gas flow from the injection valve.
>
> Moreover, the degree of controllability of the movement of the injection valve is low when the motive force is provided by a pressurized fluid rather than by a directly controllable source. In this respect, it is difficult to control lift, resulting in limited lift control capabilities when using hydraulically actuated injection valve with a double-spring configuration. Therefore, it is desirable to avoid the use of hydraulics to operate gaseous fuel injectors, particularly for high-speed engines.

A conventional "dynamic" hydraulic system, which relies upon the flow of hydraulic fluid to actuate a needle valve, 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 (subparagraph (e)), because the hydraulic fluid must flow from one chamber to another to cause needle movement. This is even acknowledged in the Office Action itself: "Kushige, et al, does not teach [that] the pressure transmitting fluid acts substantially as a solid."

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The Office Action cited the description of preferred viscosity in the '550 patent as suggesting "that the fluid acts substantially as a solid". To the contrary, the '550 patent discloses an apparatus that relies upon the flow of hydraulic oil as a **liquid** from one chamber to another chamber in order move the valve needle between closed and open positions. The '550 patent describes the preferred viscosity of the hydraulic oil at, for example, column 6, beginning at line 32 (emphasis added):

> The pressure transmitting medium is required to have a low saturated vapor pressure even under high temperature to control the generation of bubbles. Further, the medium provides lubrication for the needle valve 4 to move as well as it transfers pressure; therefore, the medium is also required to exhibit stable lubricating property for the needle valve 4 to move smoothly, i.e., stable viscosity coefficient against temperature changes. For these reasons, **the liquid used for the pressure transmitting medium should be a lubricant such as engine oil and gear oil or hydraulic oil** for a hydraulic circuit which do not reach the saturated vapor pressure at 200.degree. C. and atmospheric pressure to survive the operating temperature of the internal-combustion engine and which have good lubricating property.
>
> **By employing the engine oil, gear oil, or the hydraulic oil for a hydraulic circuit**, the occurrence of bubbles in the pressure transmitting medium filled in the pressure control chamber 10 can be prevented and therefore the deterioration in the

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> pressure transmitting characteristic can be prevented even when, for example, the ambient temperature reaches 150.degree. C. to 200.degree. C. from continuous operation in an automotive internal-combustion engine. Moreover, an increase in the viscosity coefficient of the pressure transmitting medium can be controlled and the lubricating property can be maintained to ensure smooth operation of the piston 9 and the needle valve 4 even if the ambient temperature goes down to -30.degree. C. or less at the time of startup in a cold region.

Applicants therefore submit that the '550 patent cannot be interpreted as disclosing or suggesting that the hydraulic oil acts as a solid when the valve needle is actuated. Rather, the description of preferred viscosity in the '550 patent simply states that the hydraulic oil must be suitable to avoid the formation of bubbles and to provide favorable lubricating properties over a broad range of temperatures.

A major difference between a "dynamic" hydraulic system and a "passive" hydraulic system is the presence in dynamic hydraulic systems of fluid passages that allow the hydraulic fluid to flow during an actuation event (that is, inflow/outflow hole 22 in Figure 1 of the '550 patent). In passive hydraulic systems like the applicants', the hydraulic oil is substantially contained, thereby avoiding the flow of hydraulic fluid during an actuation event when the valve member is moving from a closed

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position to an open position. As set forth in the present application at page 41, beginning at line 21, for example:

> As previously discussed, because valve actuation occurs suddenly (on the order of 200 μs), hydraulic fluid 164b does not have time to flow through the narrow clearance gap between piston 114b and hydraulic cylinder 160. Instead, hydraulic fluid 164b acts as a solid and transfers the movement of magnetostrictive member 130 to valve member 114 via piston 114b, causing valve member 114 to lift away from valve seat 112. Because injection valve 100 stays open for such a brief period (typically less than 3 milliseconds), as long as the viscosity of hydraulic fluid 164 is properly selected and the clearance gap is suitably sized, the flow of hydraulic fluid 164 through the clearance gap while injection valve 100 is open is insignificant so that any displacement caused by such flow is much less than the total displacement of valve member 114.

As to the method claims pending in the present application, the Office Action cited Figures 8A-8C and 13A-13B of the '550 patent as the basis for rejecting those claims. The '550 patent's method for controlling an injection valve employs a piezoelectric actuator and a needle element that moves inward

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from the nozzle tip to open. The '550 patent describes and illustrates an "undesirable nonlinear relationship between a set valve opening period of time and an actual valve opening period of time". Figure 8A shows a difference between the desired "set valve opening period of time T1" and the "actual valve opening period of time T2", thus supporting the applicants' submission that a characteristic of conventional hydraulically actuated injection valves is a delay associated with the dynamic flow of hydraulic fluid. Figure 8A also shows a "bounce" effect when the stopper 4a collides with the cylinder main body (immediately after time T1) and when the needle valve 4 collides with the nozzle (immediately after time T3). Figures 8B and 8C of the '550 patent illustrate alternative strategies for controlling displacement of the needle valve with the objective of avoiding needle bounce by closing the valve immediately following the collision between stopper 4a and cylinder main body 41 (Figure 8B), or by starting to close the needle valve immediately preceding collision between stopper 4a and cylinder main body 41 (Figure 8C). Figures 13A and 13B of the '550 patent show Kurishige's preferred strategies for controlling applied voltage and displacement of a piezoelectric element.

The problem addressed and illustrated by Figures 8A-8C of the '550 patent is needle bounce and controlling the duration of

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the injection event. Such problems are typically associated with hydraulically actuated injection valves, and the method of the '550 patent overcomes those problems as follows:

> [The] step-up rate of the driving voltage applied to the piezoelectric element 8 is decreased immediately before the completion of the valve opening operation and the step-down rate is also decreased immediately before completion of the valve closing operation.

(Column 15, lines 8-43.) The objective of the '550 patent is thus to slow down the needle to avoid needle bounce when the inward moving needle strikes the needle stopper.

The applicants' claimed technique differs markedly from that disclosed in the '550 patent because of their important structural differences. Unlike the '550 patent's injection valve, the applicants' claimed injection valve employs a valve member that moves outwardly from the nozzle tip to the open position. The applicants' claimed directly actuated injection valve therefore contains no feature that corresponds to stopper 4a in the '550 patent. The valve element of the '550 patent moves between a closed position and an open position defined by the needle stopper. In the applicants' claimed technique, the movement of the valve member is defined by the controllable length of the actuator, and not by a stopper. For example, in

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FIG. 4 of the present application, waveform A depicts an injection event with a larger valve member displacement than the injection event represented by waveform C. In the outward opening arrangement disclosed and claimed in the embodiments described in the present application, a mechanical stopper is not necessary to limit the travel of the valve member, so there is no problem with "bounce" due to collision of the actuated part with the stop upon opening the injection valve. In closing the applicants' injection valve, a negative current can be applied to rapidly contract the dimensionally-responsive actuator, followed by the application of a positive current immediately before the valve member is seated in the closed position.

Because the applicants' claimed actuator is used to control the "lift" of the valve member, claim 36, for example, in subparagraph (a), defines the claimed method as comprising:

> initiating an injection event by rapidly increasing current **to a magnitude that is known to correspond to a desired lift**.

In the '550 patent, current is not controlled in this way because the needle stopper controls the degree of lift at a fixed constant.

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As to the concerns regarding common ownership set forth in paragraph 4 of the October 24, 2002 Office Action, applicants confirm that the subject matter of the various claims pending in the present application was commonly owned at the time they inventions covered therein were made.

* * * * *

In view of the foregoing amendments and remarks, applicants submit that claims 1-41 are allowable. The Examiner is invited to telephone the applicant's undersigned attorney at (312) 775-8123 if any unresolved matters remain.

Please charge any fees incurred in connection with this submission to Deposit Account No. 13-0017.

Respectfully submitted,

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APPENDIX A

MARKED-UP VERSION SHOWING AMENDMENTS MADE

The Abstract has been amended as follows:

A directly actuated injection valve comprises a hollow valve housing, a valve member disposed within the hollow interior, a biasing mechanism, an actuator assembly and a **passive** hydraulic link assembly. The valve member is movable between a closed position and an open position for governing the flow of fuel into the combustion chamber of an internal combustion engine. The biasing mechanism, preferably a spring, biases the valve member in the closed position. The actuator assembly generates an opening force that acts against the valve spring to open the valve. The hydraulic link assembly is interposed between the valve member and the valve spring and the actuator assembly. The hydraulic link assembly transmits respective closing and opening forces to the valve member. The hydraulic link preferably comprises a piston disposed within a cylinder that is filled with a hydraulic fluid. **[The opening and closing forces are transmitted through a thickness of the hydraulic fluid that is trapped between the**

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planar surfaces of the piston and the head and base of the hydraulic cylinder.]

The paragraph in the "Cross-Reference to Related Application(s)" section of the specification at page 1, lines 5-16 has been amended as follows:

Cross-Reference to Related Application(s)

This application is a continuation-in-part of U.S. Patent Application Serial No. 09/522,130 filed March 9, 2000, entitled "Directly Actuated Injection Valve", now U.S. Patent No. **6,298,829** issued **October 9, 2001**. The '130 application relates to and claims priority benefits from U.S. Provisional Patent Application Serial No. 60/159,791 filed October 15, 1999, entitled "Directly Actuated Injector". The '130 application and the '791 application are each incorporated herein by reference in their entirety.

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Exhibit H



Merriam-Webster's Collegiate® Dictionary

TENTH EDITION

Merriam-Webster, Incorporated
Springfield, Massachusetts, U.S.A.

BOSCH_WP_0072358



A GENUINE MERRIAM-WEBSTER

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²neat *adv* (1649) : without admixture or dilution : STRAIGHT
neat·en \'nē-tᵊn\ *vt* **neat·ened; neat·en·ing** \'nēt-niŋ, 'nē-tᵊn-iŋ\ (1898) 1 : to set in order : make neat 2 : to finish (as a piece of sewing) carefully
neath \'nēth\ *prep* (1787) *dial* : BENEATH
neat-herd \'nēt-ˌhərd\ *n* (14c) : HERDSMAN
neat's-foot oil \'nēts-ˌfůt-\ *n* (1787) : a pale yellow fatty oil made esp. from the bones of cattle and used chiefly as a leather dressing
neb \'neb\ *n* [ME, fr. OE; akin to ON *nef* beak] (bef. 12c) 1 a : the beak of a bird or tortoise : BILL b *chiefly dial* : a person's mouth c : NOSE 1, SNOUT 2 : NIB, TIP
neb·bish \'ne-bish\ *n* [Yiddish *nebekh* poor, unfortunate, fr. Czech *nebohý*] (1951) : a timid, meek, or ineffectual person — **neb·bishy** \-bi-shē\ *adj*
ne·ben·kern \'nā-bən-ˌkərn, -ˌkern\ *n* [G, lit., subsidiary nucleus] (1898) : a 2-stranded helical structure of the proximal tail region of a spermatozoon that is derived from mitochondria
neb·u·la \'ne-byə-lə\ *n, pl* **-lae** \-ˌlē, -ˌlī\ *also* **-las** [NL, fr. L, mist, cloud; akin to OHG *nebul* fog, Gk *nephelē, nephos* cloud] (ca. 1738) 1 : any of numerous clouds of gas or dust in interstellar space 2 : GALAXY; *esp* : a galaxy other than the Milky Way galaxy — not used technically — **neb·u·lar** \-lər\ *adj*
nebular hypothesis *n* (1837) : a hypothesis in astronomy: the solar system has evolved from a hot gaseous nebula
neb·u·lize \'ne-byə-ˌlīz\ *vt* **-lized; -liz·ing** [*L nebula*] (1872) : to reduce to a fine spray — **neb·u·li·za·tion** \ˌne-byə-lə-'zā-shən\ *n* — **neb·u·liz·er** \'ne-byə-ˌlī-zər\ *n*
neb·u·los·i·ty \ˌne-byə-'lä-sə-tē\ *n, pl* **-ties** (1761) 1 : the quality or state of being nebulous 2 : nebulous matter; *also* : NEBULA 1
neb·u·lous \'ne-byə-ləs\ *adj* [L *nebulosus* misty, fr. *nebula*] (1784) 1 : of, relating to, or resembling a nebula : NEBULAR 2 : INDISTINCT, VAGUE — **neb·u·lous·ly** *adv* — **neb·u·lous·ness** *n*
nec·es·sar·i·ly \ˌne-sə-'ser-ə-lē\ *adv* (15c) 1 : of necessity : UNAVOIDABLY 2 : as a logical result or consequence
¹nec·es·sary \'ne-sə-ˌser-ē\ *adj* [ME *necessarie*, fr. L *necessarius*, fr. *necesse* necessary, prob. fr. *ne-* not + *cedere* to withdraw — more at NO] (14c) 1 a : of an inevitable nature : INESCAPABLE b (1) : logically unavoidable (2) : that cannot be denied without contradiction c : determined or produced by the previous condition of things d : COMPULSORY 2 : absolutely needed : REQUIRED
²necessary *n, pl* **-sar·ies** (14c) : an indispensable item : ESSENTIAL
necessary condition *n* (1817) 1 : a proposition whose falsity assures the falsity of another 2 : a state of affairs that must prevail if another is to occur : PREREQUISITE
ne·ces·si·tar·i·an·ism \ni-ˌse-sə-'ter-ē-ə-ˌni-zəm\ *n* (1854) : the theory that results follow by invariable sequence from causes — **ne·ces·si·tar·i·an** \-'ter-ē-ən\ *adj or n*
ne·ces·si·tate \ni-'se-sə-ˌtāt\ *vt* **-tat·ed; -tat·ing** (1628) 1 : to make necessary : REQUIRE 2 : FORCE, COMPEL — **ne·ces·si·ta·tion** \-ˌse-sə-tā-shən\ *n*
ne·ces·si·tous \ni-'se-sə-təs\ *adj* (1611) 1 : NEEDY, IMPOVERISHED 2 : URGENT, PRESSING 3 : NECESSARY — **ne·ces·si·tous·ly** *adv* — **ne·ces·si·tous·ness** *n*
ne·ces·si·ty \ni-'se-sə-tē, -'ses-tē\ *n, pl* **-ties** [ME *necessite*, fr. MF *necessité*, fr. L *necessitat-, necessitas*, fr. *necesse*] (14c) 1 : the quality or state of being necessary 2 a : pressure of circumstance b : physical or moral compulsion c : impossibility of a contrary order or condition d : the fatality or state of being in need; *esp* : POVERTY 4 a : something that is necessary : REQUIREMENT b : an urgent need or desire — **of necessity** : in such a way that it cannot be otherwise; *also* : as a necessary consequence
¹neck \'nek\ *n* [ME *nekke*, fr. OE *hnecca;* akin to OHG *hnac* nape] (bef. 12c) 1 a (1) : the part of an animal that connects the head with the body (2) : the siphon of a bivalve mollusk (as a clam) b : the part of a garment that covers or is next to the neck 2 : a relatively narrow part suggestive of a neck: as a (1) : the constricted end of a bottle (2) : the slender proximal end of a fruit b : CERVIX 2 c : the part of a stringed musical instrument extending from the body and supporting the fingerboard and strings d : a narrow stretch of land e : STRAIT 1b f : the part of a tooth between the crown and the root — see TOOTH illustration g : a column of solidified magma of a volcanic pipe or laccolith 3 : a narrow margin (won by a ~) 4 : REGION, PART (my ~ of the woods)
²neck *vt* (1842) 1 : to kiss and caress amorously 2 : to reduce in diameter ~ *vi* 1 : to engage in amorous kissing and caressing 2 : to become constricted : NARROW
neck and neck *adv or adj* (1799) : very close (as in a race)
necked \'nekt\ *adj* (14c) : having a neck esp. of a specified kind — often used in combination ⟨long-*necked*⟩
neck·er·chief \'ne-kər-chəf, -(ˌ)chif, -ˌchēf\ *n, pl* **-chiefs** *also* **-chieves** *see* HANDKERCHIEF *pl*\ [ME *nekkerchef*, fr. *nekke* + *kerchef* kerchief] (14c) : a kerchief for the neck
neck·ing \'ne-kiŋ\ *n* (1804) 1 : a narrow molding near the top of a column or pilaster 2 : the act or practice of kissing and caressing amorously
neck-lace \'ne-kləs\ *n* (ca. 1590) : an ornament worn around the neck
neck-line \'nek-ˌlīn\ *n* (1904) : the line of the neck opening of a garment
neck–rein \-ˌrān\ *vi* (1940) *of a saddle horse* : to respond to the pressure of a rein on one side of the neck by turning in the opposite direction ~ *vt* : to direct (a horse) by pressures of the rein on the neck
neck-tie \-ˌtī\ *n* (1838) : a narrow length of material worn about the neck and tied in front; *esp* : FOUR-IN-HAND
neck-wear \-ˌwar, -ˌwer\ *n* (ca. 1879) : articles of clothing (as ties and scarves) worn about the neck
necr- *or* **necro-** *comb form* [LL, fr. Gk *nekr-, nekrō-*, fr. *nekros* dead body — more at NOXIOUS] 1 : those that are dead ⟨*necr*ophilia⟩ 2 : one that is dead ⟨*necro*psy⟩
ne·crol·o·gy \nə-'krä-lə-jē, ne-\ *n, pl* **-gies** [NL *necrologium*, fr. *necr-* + *-logium* (as in ML *eulogium* eulogy)] (1799) 1 : OBITUARY 2 : a list of the recently dead — **nec·ro·log·i·cal** \ˌne-krə-'lä-ji-kəl\ *adj* — **ne·crol·o·gist** \nə-'krä-lə-jist, ne-\ *n*
nec·ro·man·cy \'ne-krə-ˌman(t)-sē\ *n* [alter. of ME *nigromancle*, fr. MF, fr. ML *nigromantia*, by folk etymology fr. LL *necromantia*, fr. LGk *nekromanteia*, fr. Gk *nekr-* + *-manteia* -mancy] (1522) 1 : conjuration of the spirits of the dead for purposes of magically revealing the future or influencing the course of events 2 : MAGIC, SORCERY — **nec·ro·man·cer** \-sər\ *n* — **nec·ro·man·tic** \ˌne-krə-'man-tik\ *adj* — **nec·ro·man·ti·cal·ly** \-ti-k(ə-)lē\ *adv*
ne·croph·a·gous \nə-'krä-fə-gəs, ne-\ *adj* (1835) : feeding on corpses or carrion ⟨~ insects⟩
nec·ro·phil·ia \ˌne-krə-'fi-lē-ə\ *n* [NL] (1892) : obsession with and sexual erotic interest in or stimulation by corpses — **nec·ro·phil·i·ac** \-'fi-lē-ˌak\ *adj or n* — **nec·ro·phil·ic** \-'fi-lik\ *adj*
ne·croph·i·lism \nə-'krä-fə-ˌli-zəm, ne-\ *n* (1864) : NECROPHILIA
ne·crop·o·lis \nə-'krä-pə-ləs, ne-\ *n, pl* **-lis·es** *or* **-les** \-ˌlēz\ *or* -leis \-ˌlās\ *or* **-il** \-ˌlī, -ˌlē\ [LL, city of the dead, fr. Gk *nekropolis*, fr. *nekr-* + *-polis* -polis] (1819) : CEMETERY; *esp* : a large elaborate cemetery of an ancient city
¹nec·rop·sy \'ne-ˌkräp-sē\ *n, pl* **-sies** (1856) : AUTOPSY 1
²necropsy *vt* **-sied; -sy·ing** (1927) : to perform an autopsy on
ne·cro·sis \nə-'krō-səs, ne-\ *n, pl* **ne·cro·ses** \-ˌsēz\ [LL, fr. Gk *nekrōsis*, fr. *nekroun* to make dead, fr. *nekros* dead body] (1665) : usu. localized death of living tissue — **ne·crot·ic** \-'krä-tik\ *adj*
nec·ro·tiz·ing \'ne-krə-ˌtī-ziŋ\ *adj* [Gk *nekrōtikos* necrotic, fr. *nekrōsis*] (1899) : causing, associated with, or undergoing necrosis ⟨~ infections⟩ ⟨~ tissue⟩
nec·tar \'nek-tər\ *n* [L, fr. Gk *nektar*] 1 a : the drink of the Greek and Roman gods b : something delicious to drink c : a beverage of fruit juice and pulp ⟨apricot ~⟩ 2 : a sweet liquid that is secreted by the nectaries of a plant and is the chief raw material of honey — **nec·tar·ous** \-t(ə-)rəs\ *adj*
nec·tar·ine \ˌnek-tə-'rēn\ *n* [obs. *nectarine*, adj., like nectar] (1611) : a peach with a smooth-skinned fruit that is a frequent somatic mutation of the normal peach; *also* : its fruit
nec·tary \'nek-t(ə-)rē\ *n, pl* **-tar·ies** [NL *nectarium*, irreg. fr. L *nectar* + *-arium* -ary] (1759) : a plant gland that secretes nectar
née *or* **nee** \nā\ *adj* [F *née*, fem. of *né*, lit., born, pp. of *naître* to be born, fr. L *nasci* — more at NATION] (1758) 1 — used to identify a woman by her maiden family name 2 : originally or formerly called ⟨the Brewers ~ Pilots who also are in their third year —Fred Clamps⟩
¹need \'nēd\ *n* [ME *ned*, fr. OE *nīed, nēd;* akin to OHG *nōt* distress, need, OPruss *nautin* need] (bef. 12c) 1 : necessary duty : OBLIGATION 2 a : a lack of something requisite, desirable, or useful b : a physiological or psychological requirement for the well-being of an organism 3 : a condition requiring supply or relief 4 : lack of the means of subsistence : POVERTY
²need *vb* **need·ed; need·ing; needs** *or (auxiliary)* **need** *vt* (bef. 12c) 1 : to be necessary or essential 2 : to be in want ~ *vi* : to be in need of : REQUIRE ~ *verbal auxiliary* : be under necessity or obligation to ⟨you ~ not answer⟩
¹need·ful \'nēd-fəl\ *adj* (12c) 1 : being in need 2 : NECESSARY, REQUISITE — **need·ful·ly** \-fə-lē\ *adv* — **need·ful·ness** *n*
²needful *n* (1709) 1 : something needed or requisite 2 : MONEY
¹nee·dle \'nēd-ᵊl\ *n* [ME *nedle*, fr. OE *nǣdl;* akin to OHG *nādala* needle, *nâjan* to sew, L *nēre* to spin, Gk *nēn*] (bef. 12c) 1 a : a small slender usu. steel instrument that has an eye for thread or surgical sutures at one end and that is used for sewing b : any of various devices for carrying thread and making stitches (as in crocheting or knitting) c (1) : a slender hollow instrument for introducing material into or removing material from the body parenterally (2) : any of various slender devices used to introduce matter (as air) into or remove it from an object (as a ball) 2 a : a slender bar of magnetized steel that when allowed to turn freely (as in a compass) indicates the direction of a magnetic field (as of the earth) b : a slender usu. sharp-pointed indicator on a dial 3 a : a slender pointed object resembling a needle: as (1) : a pointed crystal (2) : a sharp rock (3) : OBELISK b : a needle-shaped leaf (as of a conifer) c : a slender rod (as of jewel or steel) with a rounded tip used in a phonograph to transmit vibrations from a record : STYLUS d : a slender pointed rod controlling a fine inlet or outlet (as in a valve) 4 : a teasing or gibing remark — **nee·dle·like** \'nē-dᵊl-ˌlīk\ *adj*
²needle *vb* **nee·dled; nee·dling** \'nēd-liŋ, 'nē-dᵊl-iŋ\ *vt* (ca. 1715) 1 : to sew or pierce with or as if with a needle 2 a : TEASE, TORMENT b : to incite to action by repeated gibes ⟨*needled* the boy into a fight⟩ ~ *vi* : SEW, EMBROIDER — **nee·dler** \'nēd-lər, 'nē-dᵊl-ər\ *n*
nee·dle·fish \'nē-dᵊl-ˌfish\ *n* (1601)
1 : any of a family (Belonidae) of elongate green and silvery chiefly marine bony fishes with long slender jaws 2 : PIPEFISH


needlefish 1

nee·dle·point \-ˌpȯint\ *n* (1865) 1 : lace worked with a needle over a paper pattern 2 : embroidery done on canvas usu. in simple even stitches across counted threads — **needlepoint** *adj*
need·less \'nēd-ləs\ *adj* (14c) : not needed : UNNECESSARY ⟨~ waste⟩ ⟨~ to say⟩ — **need·less·ly** *adv* — **need·less·ness** *n*
nee·dle·wom·an \'nē-dᵊl-ˌwů-mən\ *n* (1535) : a woman who does needlework; *esp* : SEAMSTRESS
nee·dle·work \-ˌwərk\ *n* (14c) 1 : work done with a needle; *esp* : work (as embroidery) other than plain sewing 2 : the occupation of one who does needlework — **nee·dle·work·er** \-ˌwər-kər\ *n*
needn't \'nēd-ᵊnt\ (1865) : need not
needs \'nēdz\, *adv* [ME *nedes*, fr. OE *nēdes*, fr. gen. of *nēd* need] (bef. 12c) : of necessity : NECESSARILY ⟨must ~ be recognized⟩
needy \'nē-dē\ *adj* **need·i·er; -est** (12c) : being in want : POVERTY-STRICKEN ⟨~ families⟩ — **need·i·ness** *n*
neem \'nēm\ *n* [Hindi *nīm*, fr. Skt *nimbaḥ*] (1813) : a large East Indian tree (*Azadirachta indica* of the family Meliaceae) whose trunk exudes a tenacious gum and has a bitter bark used as a tonic and whose fruit and seeds yield a medicinal aromatic oil
neep \'nēp\ *n* [ME *nepe*, fr. OE *nēp*, fr. L *napus* — more at NAPIFORM] (bef. 12c) *chiefly Scot* : TURNIP
ne'er \'nar, 'ner\ *adv* (13c) : NEVER
ne'er–do–well \'ner-dü-ˌwel\ *n* (1736) : an idle worthless person — **ne'er–do–well** *adj*

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Exhibit I

needle

NOUN

ETYMOLOGY

Summary

A word inherited from Germanic.

Cognate with **Old Frisian** *nedle*, **Old Saxon** *nāðla* (**Middle Low German** *nātel*, *nattel*, (rare) *nādel*), **Old High German** *nādala*, *nādel*, *nādila* (**Middle High German** *nādele*, *nādel*, **German** *Nadel*), **Old Icelandic** *nál* (with loss of medial *þ*), **Swedish** *nål*, **Danish** *nål*, **Gothic** *nēþla* < a suffixed (instrumental: see below) form of the same **Germanic** base as **Middle Dutch** *naeyen* (**Dutch** *naaien*), **Middle Low German** *neien*, *neyen*, *neigen*, etc., **Old High German** *nāen*, *nājan*, *nāwan*, etc. (**Middle High German** *næjen*, *næn*, *nægen*, etc., **German** *nähen*), all in sense 'to sew', probably ultimately < the same **Indo-European** base as **classical Latin** *nēre*, **ancient Greek** *νεῖν*, *νήθειν* to spin, **Middle Welsh**, **Welsh** *nyddu* to spin, twist, and with initial *s-*, **Early Irish** *sníid* spins, twists (also *snímaid*, **Irish** *sníomh*).

Notes

The same suffix (forming names of tools and instruments) is shown by e.g. **bottle** *n.*[1], **spattle** *n.*[1], **staddle** *n.*

With the β forms compare **Old Frisian** *nēlde*, **Middle Dutch** *naelde*, *nalde* (**Dutch** *naald*), **Middle Low German** *nālde*, **Old High German** *nālda* (**Middle High German** *nālde*, *nōlde*, *nulde*), and see further discussion s.v. **bold** *n.*

The modern spelling reflects pronunciations in early modern **English** with the reflex of **Middle English** close *ē*; however, spellings with *-ea-*, *-ai-* suggest the persistence until the early 18th cent. (and later in regional **English**) of pronunciations with the reflex of **Middle English** open *ē*: see quot. 1559 at sense I.2a, and (with explicit comment on the pronunciation) quot. 1701 at sense I.1aβ; compare also:

1610 *Vsh.* One of you answer the names of your playes. *Post.* Mother Gurtons neadle.
Histrio-mastix ii. sig. C3

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MEANING & USE

I. Senses relating to tools or implements.

I.1.a. A slender pointed instrument (now usually of polished steel) for piercing and drawing thread through cloth, etc., having a hole or eye at one end for thread to pass through. Also: any of various pointed pins or implements resembling a needle. Also *figurative*. **Old English–**

darning-, *knitting-*, *larding-needle*, etc.: see the first element.

α forms

eOE *Pictus acu*, mið naeðlae asiuuid.
Épinal Glossary (1974) 42
...

2003 Who can forget that first, massive, awful hangover..? Piercing needles of light herald the dreadful dawning of the morning after, clashing sounds jar the discordant day.
Times (Nexis) 1 July 17

β forms

?c1225 (?a1200) Sopere þet ne bereð naut bute sope & nelden.
Ancrene Riwle (Cleopatra MS. C.vi) (1972) 120
...

1902 [North-east Worcestershire] Nild and thread.
in *English Dialect Dictionary* (1903) vol. IV. 244/2

needlework

I.1.b. † As the type of something of trifling importance or value; a very small or negligible amount. Chiefly in negative contexts. Cf. **pin bush** *n*. *Obsolete*. **?c1225–1777**

?c1225 (?a1200) Sahsunes strengðe..Alisandres hereword..alle somed aȝein mibodi nebeoð naut wurð anelde.
Ancrene Riwle (Cleopatra MS. C.vi) (1972) 293
...

1777 They warna a needle o' differ between their dadies.
Whole Proceedings of Jockey & Maggy (revised edition) iv. 26

I.1.c. *Surgery*. Any of numerous thin, usually sharply pointed instruments, originally resembling sewing needles, used esp. to suture or puncture tissue. **a1400–**

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a1400 Haue a nedle þre cornerid, whos iȝe schal be holid on boþe sidis, so þat þe þred þat is in þe nedle may lie in þe holowȝ place.
translation of Lanfranc, *Science of Cirurgie* (Ashmole MS.) (1894) 36 (Middle English Dictionary)
...

2000 Punctures were made with hollow-bore and solid surgical needles of various configurations.
American Surgeon vol. 66 302

needlework surgery

I.1.d. **a needle in a haystack** and variants: something that would be immensely difficult to find. Usually taken as an example of something it is foolish to attempt to find. Chiefly in proverbial phrases, as **to look for a needle in a haystack**. **c1530–**

With *a needle in a bottle of hay* cf. **bottle** *n.*[4]

***c*1530** To seke out one lyne in all hys bookes wer to go looke a nedle in a medow.
T. More, *Let. Impugnynge J. Fryth* in *Workes* (1557) 837/2
...

2000 Today's biologists need computing power to find even the most obvious needles in molecular haystacks of information.
Science News 29 April 284/1

I.1.e. † (By metonymy) **the needle**: needlework; (also) a needlewoman. *Obsolete. rare.* **1617–1857**

1617 The Florentines..good at the needle.
F. Moryson, *Itinerary* iii.i. i. 51
...

1857 There was no favor in half-a-crown a-day to such a needle as herself.
C. Dickens, *Little Dorrit* ii. xvii. 468

needlework

I.2.a. A piece of magnetized steel (originally a sewing needle) used as an indicator of direction, *spec.* as a part of a compass, or in connection with magnetic or electric apparatus in telegraphy, etc. Also **magnetic needle**. Formerly also short for 'needle telegraph'. Also *figurative*. **a1393–**

***a*1393** He hath his rihte cours forth holde Be Ston and nedle til he cam To Tharse.
J. Gower, *Confessio Amantis* (Fairfax MS.) viii. 541 (Middle English Dictionary)
...

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1988 Dr Gowin Knight..had invented a machine for magnetizing needles more strongly.
Journal Navigation vol. 41 320

needlework | electrical | nautical

I.2.b. † = **touch needle** *n.* Cf. **proof needle** *n.* *Obsolete.* **1469–1825**

1469 That ii gode stones and good nedeles for to touche be alwey ther, redie..to make assaie of gold.
in *Archaeologia* (1806) vol. 15 173
...
1825 Assayers make a comparison upon a touch~stone, between it and certain needles composed of gold and silver,..which are called Proof Needles.
J. Nicholson, *Operative Mechanic* 766

metal industry

I.2.c. † A tongue or index of a scale or balance. *Obsolete.* **1589–1856**

1589 A needle , or tongue of a ballance or beame, *examen*.
J. Rider, *Bibliotheca Scholastica* 989
...
1856 A needle is usually fixed to the beam.., which points vertically upwards or downwards when the beam is in a horizontal position.
Orr's Circle Sci.: Mech. Philosophy 107

measurement

I.2.d. A pointer on the dial of a measuring instrument, esp. on a speedometer. **1869–**

1869 It is simply a retort containing white marble, the neck of which, by means of a tube, is connected with a needle that moves upon a dial-plate.
Appleton's Journal September 187
...
1987 Departure time came, and Joe had timed it very well, with the needle just below the blowing-off point.
Railway World November 675/3

measurement | motoring

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I.3.a. A knitting needle or netting pin. **1598–**

1598 *Fare a gucchia*, to knit as silke hosen be with needles.
J. Florio, *Worlde of Wordes*
...
1992 A very brief discussion of yarns and needles is followed by step by step instructions in casting on and off, plain and purl stitches.
Popular Crafts March 15/2

knitting

I.3.b. Any of a set of metal pins, rods, or wires for manipulating the threads in a knitting, weaving, or lacemaking machine. **1829–**

1829 Machinery for embroidering fabrics by the use of a large number of needles formed with an eye in the centre and a point at each end; which needles are passed through the fabric from opposite sides alternately by means of pincers.
H. Bock in P. Earnshaw, *Lace Machines & Machine Laces* (1986) viii. 226/2
...
1986 The needles [in a Raschel machine], like the guides, are rigidly attached to a bar, in this case a single needle bar.
P. Earnshaw, *Lace Machines & Machine Laces* ii. 43

knitting lace weaving

I.4.a. A pointed instrument used in engraving or etching. **1662–**

1662 The use both of the Point, Needle, and Etching in A. Fortis.
J. Evelyn, *Sculptura* i. 9
...
1988 Parts of the plate can be etched normally with needles and acid to form the coloured aspects.
Artist's & Illustrator's Magazine February 47/3

engraving and etching

I.4.b. In a breech-loading firearm: a slender steel pin by the impact of which a cartridge is exploded. **1818–**

1818 A communication must then be secured through the matter which is immediately to be rammed over it, and this is effected by..'*driving the neele*', (a corruption, I presume, of the

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word needle), which is an iron skewer about two feet long, having a large eye resembling that of a needle.

Transactions Royal Geol. Society Cornwall vol. 1 83

...

1979 Soldiers were issued with spare needles.

J. Walter, *German Rifle* 23

gunnery and firearms

I.4.c. *Surgery* and *Physiology*. More fully **needle electrode**. A very fine pointed electrode, used in electrophysiological studies and for electrolysis and electrocautery. **1878–**

1878 A pair of needle electrodes, covered with a thin layer of sealing-wax..were [*sic*] inserted.

Journal of Physiology vol. 1 371

...

2001 The test—needle electromyography or EMG—involves inserting a needle into the muscle in the area of a purported injury and moving the needle to measure muscle activity.

Hartford Courant 21 November (New Haven County/Shoreline edition) b2/3

physiology surgery

I.4.d. A thin pointed or tapering rod used to provide fine adjustment in closing an aperture, as in a valve. **a1884–**

***a*1884** In order to regulate the supply of oil [from a needle lubricator], a metallic feed-rod (needle) passes through the tube, and rests upon the shaft to be lubricated.

E. H. Knight, *Practical Dictionary of Mechanics* Suppl. 632/2

...

1989 Modifications are essentially restricted to the exhaust system, carb jets and needles, rear shocks and fork springs.

Cycle October 28/3

mechanics

I.4.e. A small hard point (originally of steel; later also of compressed fibre, diamond, sapphire, or other material) which rests in the groove of a gramophone record when it is being played and transmits the vibrations set up to the pick-up or diaphragm; a similar device used to cut the grooves in records; = **stylus** *n.* 2b. **1902–**

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1902 The marker..instead of being a stiff needle coming from the centre of the membrane or glass plate, is now a lever.
Encyclopædia Britannica vol. XXXI. 679/2
...
1994 The cuckoo piped again in the silence, like a needle stuck on a gramophone record.
S. Dawson, *Forsytes* (1996) ii. iii. 280

sound recording

I.5.a. *Medicine* and *Surgery*. A thin, sharply pointed, hollow tube used to aspirate fluid or air from the body, inject drugs and other solutions, etc., usually as an attachment to, or part of, a syringe; (also) a hollow tubular instrument used to obtain small samples of tissue for biopsy. **1744–**

1744 A very small hollow Needle with Perforations, as in that used by some instead of the Trocar.
Philosophical Transactions 1740–41 (Royal Society) vol. 41 644
...
2000 Identifying the type—by bronchoscopy or a biopsy with a fine needle guided by a CT scan—is crucial in determining best treatment.
Guardian 18 July ii. 10/1

surgery

I.5.b. *colloquial* (originally U.S.). A hypodermic injection, esp. of an illegal drug; a measure of a drug for injecting. Also (*rare*): a drug addict who injects drugs. **on the needle**: addicted to injecting drugs. **1903–**

1903 The doctor came and gave him the 'needle'—a hypodermic injection.
'J. Flynt', *Rise of Ruderick Cloud*
...
1973 Middle Britain thinks..one puff on the joint leads to the needle.
Listener 6 September 306/1

drug use | U.S. English | colloquial and slang

I.6.a. † A metal pin or rod used as a fixing. *Obsolete*. **1811–37**

1811 To making ridg batton and putting in niddl hols.
Foord Manuscript 108

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1837 Long iron needles pass through holes in the strips of saw-plate, and pin them to the ground.
Civil Engineer & Architect's Journal vol. 1 6/1

building

I.6.b. *Mining.* A pointed metal rod used to make a hole in the tamping of a blast-hole. Now *historical.* **1838–**

1838 Drawings of the jumpers, the tamping bar, the needle, and the discharging reed.
Civil Engineer & Architect's Journal vol. 1 292/1
...
1909 *Stemmer*, in mining, a copper or bronze rod inserted into a powder charge, so as to leave a passage through the tamping for the fuse; a blasting needle.
Hawkins' Mech. Dictionary

mining historical

II. Other man-made objects.

II.7. [After post-classical Latin *acus* obelisk, spec. of St Peter's needle in Rome (from late 12th cent. in British sources), extended application of classical Latin *acus* a needle or pin.] A pillar; an obelisk. **a1387–**

Chiefly in the names of such monuments, usually with attribution (often fanciful) to some historical personage.

***a*1387** Iulius his piler..now pylgryms clepeþ Seynt Petres nedle [*variant reading* neld; Latin *acus Petri*].
J. Trevisa, translation of R. Higden, *Polychronicon* (St. John's Cambridge MS.) (1872) vol. IV. 211 (Middle English Dictionary)
...
1991 The false idea that lichen planus is rare goes back to 1869, when Erasmus Wilson presented the condition to the medical world—just a few years before he presented Cleopatra's needle to London.
British Medical Journal 9 March 544/1

II.8. A beam or post of wood; (now) *spec.* a short horizontal beam at the top of a strut or shore, which is inserted into a wall to provide support, esp. during underpinning. Also more fully **needle-beam.** **1428–**

1428 [Oak for repair of mill] nedelys.
Acct. Rolls Newlond in *Middle English Dict.* at *Nedle*

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...

1988 With one man at each side of the wall, start to tighten up the adjustable metal props under both ends of the needles.
D.I.Y. Success vol. 4 20/1

woodworking

II.9. A narrow passage at Ripon Abbey with a small hole at the end, by squeezing through which one could enter the crypt. **1472–**

1472 Lez Cruddes voc. Seint Wilfride nedyll.
in J. T. Fowler, *Memorials of Church Saints Peter & Wilfrid, Ripon* (1888) vol. III. 225
...
1997 Beneath..is the 7th-cent. crypt featuring the small aperture connecting the crypt with an adjacent passage, known as 'St Wilfrid's Needle'.
E. A. Livingstone, *Oxford Dictionary Christian Church* (ed. 3) 1399/2

III. A natural object resembling a needle.

III.10. A sharply pointed rock. Chiefly in *plural* in the names of particular formations, such as that to the west of the Isle of Wight or (now *rare*) those forming groups of summits in the Swiss Alps. **c1400–**

c1400 La terre deuaunt les nedeles del Isle de Wight.
Petition (Public Records Office) 9425 (Middle English Dictionary)
...
1998 Beating avoids bunching 15 miles down the track, at the Needles.
Yachts & Yachting 12 June 39/1

III.11. †

III.11.a. A garfish. Cf. **sea-needle** *n.*, **needlefish** *n.* *Obsolete. rare.* **1589–1603**

1589 Nedelis, a kind of fish, *belone*.
J. Rider, *Bibliotheca Scholastica* 1722
1603 The Erle or needle whose fynes growe forward contrarie to the nature of all fishe.
G. Owen, *Description Penbrokshire* (1892) vol. I. 123

fish

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III.11.b. A gastropod mollusc with a long, pointed shell (not identified). Cf. **needle-shell** *n.* **1713–78**
Obsolete. rare.

1713 *Strombus*..Curl girdled Needle.
J. Petiver, *Aquatilium Animalium Amboinæ* 3/2

1778 Snails of a very long slender and taper shape, like the strombi, or needles.
E. M. da Costa, *Historia Naturalis Testaceorum Britain* 107

shells and shellfish

III.12.a. *Chemistry* and *Mineralogy*. A long, narrow, pointed crystal or piece of crystalline material. **1676–**

1676 These *Stiriæ*, or Needles, I observed in the water of all the Baths, yet in a different shape and consistence.
T. Guidott, *Discourse of Bathe* iv. 24
...
1991 The inorganic crystals [of tooth enamel] are long thin needles.
Nature 24 January 285/1

crystals minerals

III.12.b. A spicule of a sponge, esp. when unbranched and pointed. **1870–**

1870 The sponge mass is described as composed of loosely interwoven cords of fine silicious needles.
American Naturalist vol. 4 19
...
1998 The mesohyl..contains ameboid cells (amebocytes) and support spicules (skeletal needles) or spongin fibers.
L. Margulis & K. V. Schwartz, *Five Kingdoms* (ed. 3) iii. 214/1

invertebrates

III.13. In *singular* and *plural*. The arable weed shepherd's needle, *Scandix pecten-veneris*. Also: the long, needle-shaped seed-pod of this plant. Now *rare*. **1793–**

1793 Unaccountably foul with catlock, needles, &c.
Transactions of Society Arts vol. 11 52
...

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1996 The plant has proved impervious to herbicides, and the needles impossible to separate from the grain.
R. Mabey, *Flora Britannica* 285/2

agriculture plants

III.14. A linear, usually pointed, leaf, esp. of a coniferous tree. **1798–**

1798 Its needles are longer and darker than those of the famous Weymouth Pine.
Transactions of Society Arts vol. 16 357
...
1998 Important drugs in cancer therapy have been derived from botanical sources: Taxol, for breast and ovarian tumors, from the needles of the Pacific yew tree.
New Yorker 26 October 100/1

plants

III.15. A sharp, slender spine or quill projecting from the body or shell of an animal. **1874–**

1874 The spines radiate symmetrically from the direction of the centre of each chamber of the shell, and the sheaves of long transparent needles ..have a very beautiful effect.
Proceedings of Royal Society vol. 23 35
...
2000 I have a chart showing the porcupine as being black but (this one) was a light tan with darker tan needles.
Morning Call (Allentown, Pennsylvania) (Nexis) 2 April c11

animals

IV. Senses relating to people.

IV.16. *slang*. The penis. *rare* in later use. Now *historical*. **1592–**

1592 *Cupid.* I say I will pricke as well with my needle, as euer I did with mine arrowes.
J. Lyly, *Gallathea* iv. ii. sig. F2
...
1980 'Won't ye have a Nestlecock?' cries the second Tart, '..a Needlewoman fer yer e'er-loving Needle?'
E. Jong, *Fanny* ii. i. 165

colloquial and slang historical

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IV.17. † A cheat, thief, or sharper. Cf. earlier **needlepoint** *n.* 2. *Obsolete.* **1790–1821**

1790 *Needle*, a sharp fellow, a sharper, a cheat.
H. T. Potter, *Dictionary Cant & Flash Language*

1821 Among the needles at the West end of the town.
P. Egan, *Life in London* 138 (Farmer)

IV.18.a. With *the*. Anger, bad temper, pique, irritation; (also occasionally as a count noun) a fit or display of irritation, temper, etc. Chiefly in **to get the needle**: to become angry or upset, to lose one's temper.**to give (put in,** etc.**) the needle**: to provoke or annoy, esp. by criticism, teasing, or sarcasm. **1874–**

1874 To 'cop the needle' is to become vexed or annoyed.
Hotten's Slang Dictionary (revised edition) 235
...

1992 Lady likes him for believing that, but she gives him the needle because she knows it isn't true.
Harper's Magazine December 76/2

IV.18.b. Originally and chiefly *Sport*. Competitiveness, competitive rivalry; antagonism provoked by this. Also: a stimulus or spur to improve one's performance. Cf. **needle match** *n.* **1923–**

1923 It may be, of course, that there was too much 'needle' (to employ a boxing term which means bad spirit) about this contest.
Daily Mail 1 August 8/2
...

1996 Hill and Villeneuve had already shown an edginess that suggested there was an increased level of needle in their rivalry.
Sunday Telegraph 13 October (Sport section) 6/2

sport

PRONUNCIATION

BRITISH ENGLISH	U.S. ENGLISH
/ˈniːdl/	/ˈnid(ə)l/
NEE-duhl	NEE-duhl

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FORMS

Variant forms

α.

Old English	**naeðl** (*rare*), **nedl** (*non-West Saxon*), **nethl** (*rare*), **netl** (*rare*)
Old English–early Middle English	**nædl**
Middle English	**medyl** (transmission error), **nedelde** (transmission error), **nedele**, **nedil**, **nedile**, **nedille**, **nedull**, **nedyl**, **nedylle**, **nydle**
Middle English–1500s	**nedel**, **nedell**, **nedill**, **nedle**, **nedyll**, **needell**, **nydel**
Middle English–	**needle**
1500s	**neadle**, **nidel**, **niedle**
1500s–1600s	**nedel**, **needel**

English regional

1800s–	**neeadle** (*northern*), **niddil** (chiefly *western*), **niddle** (chiefly *western*)

Scottish

pre-1700	**nedel**, **nedil**, **nedill**, **nedle**, **nedyll**, **needel**, **neiddel**, **neiddell**, **neiddill**, **neidel**, **neidil**, **neidile**, **neidill**, **neidle**, **neydyll**, **niddill**, **nidel**, **nidle**, **nyddill**, **nydill**
pre-1700; 1700s–	**needle**
1800s	**niddl**

β.

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Middle English	**neelde**, **uelde** (transmission error)
Middle English–1500s	**nylde**
Middle English–1600s	**neeld**, **neld**, **nelde**
1500s	**neilde**, **nild**, **nyeld**, **nyld**
1500s–1600s; 1800s	**neele**

English regional

1700s	**neald** (*Devon*), **neeald** (*Devon*), **neld** (*Derbyshire*)
1700s–	**neeld**
1800s	**neal** (*northern*), **nield** (*northern*)
1800s–	**nail** (chiefly *western*), **neel** (chiefly *western*), **neele** (chiefly *western*), **nild** (chiefly *western*), **nill** (chiefly *western*)

Irish English

1800s	**neal**

FREQUENCY

needle is one of the 5,000 most common words in modern written English. It is similar in frequency to words like *accelerate*, *bitter*, *headquarters*, *railway*, and *shoe*.

It typically occurs about 20 times per million words in modern written English.

needle is in frequency band 6, which contains words occurring between 10 and 100 times per million words in modern written English. More about OED's frequency bands

Frequency of *needle, n.*, 1750–2010

BOSCH_WP_0072384

* Occurrences per million words in written English

Historical frequency series are derived from Google Books Ngrams (version 2), a data set based on a corpus of several million books printed in English between 1500 and 2010. The Ngrams data has been cross-checked against frequency measures from other corpora, and re-analysed in order to handle homographs and other ambiguities.

The overall frequency for a given word is calculated by summing frequencies for the main form of the word, any plural or inflected forms, and any major spelling variations.

Frequency of *needle, n.*, 2017–2023

* Occurrences per million words in written English

Modern frequency series are derived from a corpus of 20 billion words, covering the period from 2017 to the present. The corpus is mainly compiled from online news sources, and covers all major varieties of World English.

Smoothing has been applied to series for lower-frequency words, using a moving-average algorithm. This reduces short-term fluctuations, which may be produced by variability in the content of the corpus.

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COMPOUNDS & DERIVED WORDS

Sort by Date (oldest first)

needle eye, n. a1225–
The eye of a needle; frequently in allusions to the biblical use.

needler, n. 1275–
A person who goads, irritates, or torments others, esp. with the intention of provoking a reaction.

pack-needle, n. 1327–
A large strong needle of a type originally used to sew up packs made of tough material.

needling, n.² 1347–
The action or process of using a needle of any kind; work done with a needle.

needlecraft, n. a1382–
(A craft involving) skill in needlework; embroidery or embroidered work.

needlefodder, n. a1382
A case for needles.

needlework, n. a1382–
Work done with a needle; spec. the art or practice of sewing or embroidery. Also: sewn or embroidered items collectively.

eld, n.³ a1400–50
Middle English ane eld = a neld, a needle, n.

ground-needle, n. a1400–
Erodium moschatum.

puckle's needle, n. a1400
= pookneedle, n.

needle-house, n. c1400–1547
A needle-case.

pookneedle, n. a1425–
Any of several plants having needle-like or long-beaked fruits, esp. either of the storksbills, Erodium cicutarium and E. moschatum, and the...

needle case, n. 1440–
A case for keeping sewing needles in.

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Milan needle, n. 1495
A sail-needle.

sail-needle, n. 1497–
A large needle used in sewing canvas.

devil's needle, n. a1500–
A flying insect with a long thin body; spec. a dragonfly or damselfly. Cf. devil's darning-needle, n. 1.

needle, v. 1502–
intransitive. To move or pass (through or in and out) like a needle.

needlewoman, n. 1536–
A woman who works with a needle; a seamstress.

pink needle, n. 1548–
Either of two European storksbills, common storksbill, Erodium cicutarium, and musk storksbill, E. moschatum, both of which are naturalized in North...

needle-wrought, adj. 1562–
Worked with a needle; embroidered. Also figurative.

shepherd's needle, n. 1562–
†(a) Geranium, (b) Scandix pecten-veneris (family Apiaceae, formerly Umbelliferae).

needle-pointed, adj. 1565–
Having a point like that of a needle; sharply pointed. In early use frequently figurative.

needle-maker, n. 1571–

needle chervil, n. 1578
Shepherd's needle, Scandix pecten-veneris (cf. needle, n. III.13).

Spanish needle, n. 1584–

needlepoint, n. 1590–
Originally U.S. Embroidery worked over canvas.

needle furze, n. 1597–
Petty whin, Genista anglica.

packing needle, n. 1597–
= pack-needle, n.

Venus needle, n. 1597
Venus's comb.

needleful, n. 1598–

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An amount of thread which can be conveniently used at one time with a needle; a length of thread enough for the purpose at hand. Also figurative.

mariner's needle, n. **1600–62**

(The needle of) a sailor's compass.

needlefish, n. **1601–**

Any of various fishes with elongated bodies; spec. any fish of the family Belonidae, which comprises the garfishes and long-toms, characterized by...

sea-needle, n. **1603–**

The gar-fish, Belone vulgaris (cf. needlefish, n.).

needle-painted, adj. **?1609–**

needleworker, n. **1611–**

A person who works with the needle; spec. an embroiderer.

sewing needle, n. **1613–**

needleman, n. **1621–**

U.S. slang. A drug-addict who takes drugs by injection.

larding needle, n. **1622–**

A pointed instrument used to place pieces of bacon or other foods into lean meat, poultry, or fish in the process of larding; = larding pin, n.

touch needle, n. **a1632–**

†(a) The magnetic needle of a compass (cf. touch, n. II.11) (obsolete rare); (b) any of a set of needles or small bars of gold or silver of varying...

netting-needle, n. **1632–**

needle-alphabet, n. **1663**

A sampler consisting of embroidered letters of the alphabet.

needle screw, n. **1663–**

(Perhaps) a very fine screw.

needle-like, adj. **1672–**

Resembling a needle in shape; long, slender, and pointed.

magnetic needle, n. **1674–**

A piece of magnetized steel used as an indicator of direction, esp. as part of a compass; cf. needle, n. I.2a.

probe needle, n. **1676–**

A needle used as a probe.

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proof needle, n. **1683–1849**

A needle used for testing something; spec. = touch needle, n.

stroking needle, n. **1683**

= touch needle, n.

cataract-needle, n. **1688–**

A knife and needle used in the extraction of cataract, or in couching.

matting needle, n. **1688–**

crake-needle, n. **1691–**

The Shepherd's Needle or Venus's Comb (Scandix Pecten).

needle-book, n. **1693–**

A needle-case resembling a small book.

needly, adj.² **1694–**

Resembling a needle or needles; forming sharp points; covered with or full of needles.

needle-shuttle, n. **1699–1855**

A shuttle resembling a large needle.

pins and needles, n. **1710–**

A prickling or tingling sensation, paraesthesia; on pins and needles: in a state of agitated suspense or extreme uneasiness.

needle-urchin, n. **1713**

A sea urchin.

hair-needle, n. **1725**

= hairpin, n.

Adam's Needle, n. **1730–**

Any of several yucca plants with narrow sharp-pointed leaves, esp. (in early use) Yucca gloriosa, and (now more usually) Y. filamentosa, both native...

crow-needle, n. **1733–**

The Umbelliferous plant Scandix Pecten.

needle-housewifery, n. **1747**

Darning.

needle-worm, n. **a1750–1831**

A small parasitic worm of horses (perhaps a pinworm or small strongyle).

thread-needle, n. **1751–**

A children's game, in which, all joining hands, the player at one end of the string passes between the last two at the other end, the rest following.

BOSCH_WP_0072389

needle-shell, n. 1752–
Any of various marine gastropod molluscs with tall, pointed shells; (now esp.) = needle whelk, n.

needle whelk, n. 1758–
A horn shell of the genus Bittium (family Cerithiidae); esp. B. reticulatum of the north-east Atlantic and Mediterranean.

needleworked, adj. 1763–
Ornamented with needlework.

needle-formed, adj. 1784–

needle rock, n. 1784–
A sharply pointed rock (cf. needle, n. III.10); also figurative.

needle-shaped, adj. 1786–

needle-weed, n. 1787
Shepherd's needle, Scandix pecten-veneris.

needlewood, n. 1789–
†(a) Coniferous timber (cf. needle-timber, n.) (obsolete rare); (b) Australian a needlebush (Hakea species) (also needle-wood tree).

dry-needle, n. ?1790–
= dry-point, n.

needle greenweed, n. 1796–
= needle furze, n.

compass-needle, n. 1797–

tambour-needle, n. 1798–
The needle used in tambour-work, a small steel hook set in a handle.

needle-jerker, n. 1801
A tailor.

needle-tailed, adj. 1801–

needle-timber, n. 1802
Coniferous timber.

needle ore, n. 1805–
= aikinite, n.

needle-spitter, n. 1805
A person who snaps or is sharp in speech.

needlestone, n. 1805–

BOSCH_WP_0072390

A form of zeolite with needle-like crystals; mesotype.

needle zeolite, n. 1805–
A variety of zeolite (now regarded as identical to mesotype).

needle-form, adj. 1807–

rib needle, n. ?1812–

needle-monger, n. 1814–37

theodolite-needle, n. 1820–
The needle of the compass of a theodolite.

etching-needle, n. 1821–

needle pointer, n.[1] 1821–
A person who sharpens the points of needles. Now historical.

needle-toil, n. 1822

needle-grinder, n. 1823–

needle-hand, n. 1827–

ice needle, n. 1831–
(a) An elongated, needle-like ice crystal; (b) a strong needle used to break up (a piece of) ice.

needle-bar, n. 1831–
A bar to which the needles are attached on a sewing or knitting machine.

feeding-needle, n. 1832–

needle-puncturing, n. 1834–

needle-trade, n. 1834–

needle job, n. 1836–

needle-sharp, adj. 1836–
As sharp as a needle; figurative acute, quick-witted.

needle-spar, n. 1836–
= aragonite, n.

needle factory, n. 1839–

exploring needle, n. 1840–
A needle used in an exploratory surgical procedure, esp. to obtain a sample of tissue or fluid; cf. explorator, n. 2b.

pine needle, n. 1844–

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The needle-shaped leaf of a pine tree.

needle-grinding, n. 1845–

needle-making, n. 1845–

needle puncture, n. 1845–

Spanish needles, n. 1846–
The American plant Bidens bipinnata or its prickly fruit.

trussing-needle, n. 1846–

needle-hole, n. 1847–

needle telegraph, n. 1847–
A telegraph in which the signals are given by deflection of a magnetic needle.

needle whin, n. 1847–
= needle furze, n.

darning-needle, n. 1848–
(a) A long and stout needle used in darning; (b) (see devil's darning-needle, n., compounds C.3c).

needledom, n. 1848–
The world of needlework.

needle grass, n. 1848–
Any of various grasses, chiefly of the genera Stipa, Aristida, and Triodia, having long stiff awns or spiny leaves.

needle-leaf, n. a1849–

crochet-needle, n. 1849–

needle-tree, n. 1849–
A coniferous tree.

needle-gun, n. 1850–
A rifle in which the cartridge is exploded by the impact of a long pointed firing pin.

roping needle, n. 1850–

slop needle, n. 1851–

needle paper, n. 1852–
Strong black paper of a type originally used for packaging needles.

tape-needle, n. 1852–
An eyed bodkin for inserting tape.

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needle-seller, n. 1853–

needle-leaved, adj. 1854–

needle-scarred, adj. 1854–

needle mark, n. 1855–
A mark made by a needle, esp. one made on the skin by injection of illegal drugs.

needle rifle, n. 1856–
= needle-gun, n.

mattress-needle, n. 1858–
A long needle of a type used in making mattresses.

needle wire, n. 1858–
High grade steel wire; the steel wire from which needles are made.

needle and thread, n. 1859–
Any of various long-awned grasses of the genus Stipa, esp. S. comata.

ribbing needle, n. 1860–

single-needle, adj. 1860–

nerve needle, n. 1861–
An instrument for cleaning out the pulp cavity of a tooth.

lappet-needle, n. 1863–

needle threader, n. 1863–
A device for threading needles.

needle-spire, n. 1864–

needle lace, n. 1865–
Lace made with a needle and single thread, the design being formed of various arrangements of surface buttonhole stitches connecting an outline which...

needle-made, adj. 1865–

declination-needle, n. 1866–

needle iron-ore, n. 1867–85
= needle-ironstone, n.

needleloom, n. & adj. 1867–
A machine which produces non-woven fabrics and carpets by driving closely spaced barbed needles through a layer or web of loose fibres, usually on a...

needle-bolt, n. 1868–

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The bolt which carries the needle in a needle-gun.

needle-dial, n. 1868–
A dial bearing a needle in an electrical apparatus.

needle-ironstone, n. 1868–
A variety of goethite (hydrated iron oxide) occurring as needle-shaped crystals.

quilting needle, n. 1869–

needle bearing, n. 1870–
(a) A compass bearing read from a needle; (b) a bearing using needle rollers.

needleless, adj. 1872–
Lacking a needle or needles (in various senses); functioning or effected without a needle or needles, esp. in the administration of drugs.

needle-leafed, adj. 1873–

needle lubricator, n. 1873–
A form of lubricator in which the supply of lubricant is controlled by a wire fitted in the supply tube and resting on the shaft to be lubricated.

fissure-needle, n. 1874–
(See quot.).

latch-needle, n. 1875–
A kind of knitting-machine needle, the hook of which is closed by a latch (see latch, n.[1] 3a(e)).

needle file, n. 1875–
A small file with a knurled cylindrical shaft, used by jewellers, watchmakers, etc.

needle manganese, n. 1876
A form of manganese dioxide.

needle-board, n. 1879–
Originally: a board in a Jacquard loom, having perforations through which the ends of the needles pass (see needle, n. I.3b). Now chiefly: a piece of...

seine-needle, n. 1879–
A needle with which the meshes of a seine are netted.

dip-needle, n. 1881–
= dipping-needle, n.

milium needle, n. 1881–
A fine curved needle with a hastate point (perhaps originally used to remove milia).

needle foliage, n. 1882–

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needle-tin, n. 1882–
A variety of cassiterite occurring as long prismatic crystals.

wool-needle, n. 1882–
A blunt needle used for wool-work.

fir-needle, n. 1883–
(See quot.).

naevus needle, n. a1884–95
A surgical needle used to remove naevi.

hook needle, n. 1884–
(See quot. 1884).

needlebush, n. 1884–
(a) Any of several shrubs or small trees of the genus Hakea (family Proteaceae) having stiff needle-like leaves, esp. H. leucoptera and H...

gusset needle, n. 1885–
One of the two side needles used in knitting the foot of a stocking.

needle valve, n. 1886–
A valve worked by a narrow pointed rod fitting into a conical seating.

stocking needle, n. 1886–
A darning-needle.

needle-bath, n. 1887–
= needle-shower, n.

needle track, n. 1888–
(a) A track made by a needle inserted into a solid culture medium, tissue, etc.; (b) a pigmented linear mark on the skin, esp. of the forearm or back...

tapestry needle, n. 1888–
A blunt needle with a large eye used in tapestry-making and canvas embroidery.

straw-needle, n. 1889–
A long thin needle used for sewing together straw braids (Cent. Dict.); cf. straw, n.[1] II.10c.

two-needle, adj. 1890–

needle ice, n. 1892–
Ice forming needle-like crystals, esp. when occurring just beneath the soil surface and often pushing up through it.

needle gorse, n. 1893–
= needle furze, n.

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needle-run, adj. 1894–

needle-syringe, n. 1894
A hypodermic syringe.

needle-cast, n. 1895–
Any of various fungal diseases of conifers characterized by discoloration and premature shedding of foliage.

needle-bug, n. 1896
The water measurer Hydrometra stagnorum.

needle girder, n. 1898
A girder acting as a needle (needle, n. II.8).

needle-musket, n. 1898
= needle-gun, n.

needle-polisher, n. 1898–

float needle, n. 1901–
A thin rod attached to a float (float, n. III.9a) which by passing into or out of the inlet to the float-chamber allows less or more petrol to enter...

needlecord, n. & adj. 1901–
A finely ribbed corduroy fabric (in earliest use needlecord corduroy); (in plural) trousers made of this.

record needle, n. 1901–

stop-needle, n. 1901–
(See quot. 1901).

syringe-needle, n. 1903–

needle-shower, n. 1906–
A shower bath of strong fine jets of water; an act of bathing in such a shower.

gramophone needle, n. 1907–

needle gate, n. 1909–
A dam or weir consisting of narrow spars placed vertically side by side in a movable frame.

needlenose, adj. & n. 1911–
Of a tool, piece of machinery, etc.: tapering to a needle-like point; spec. designating a pair of pliers having long, pointed jaws, used esp. for...

fibre needle, n. 1913–
A gramophone needle made of fibre.

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raffia needle, n. 1914–
A blunt, large-eyed needle used in raffia work.

radium needle, n. 1915–
A hollow needle filled with radium, inserted into tissue to provide localized radiotherapy.

needle gap, n. 1916–
A pair of needle-shaped electrodes placed in line, separated by a gap across which an electric discharge can take place when the potential difference...

microneedle, n. 1921–
A very fine needle used in micromanipulation.

needle contest, n. 1922–

needle beer, n. 1923–
Near-beer mixed with ethyl alcohol or an alcoholic drink; cf. needle, v. 6.

needle match, n. 1923–
A sporting contest attracting much interest and excitement, or arousing exceptional personal antagonism between the contestants; a closely or keenly...

needle artist, n. 1925–
A person adept at embroidery.

needle fight, n. 1927–

needle-nosed, adj. 1931–

needle-weaving, n. 1932–
A kind of drawn-thread-work in which the drawn threads are largely replaced by coloured threads woven or darned into a pattern by hand.

needle roller, n. 1935–
A roller in the form of a long, thin, sometimes tapered cylinder, used in roller bearings.

needle and pin, n. 1937–
Gin.

sapphire needle, n. 1940–

idle needle, n. 1943–

needle biopsy, n. 1947–
Biopsy performed, often percutaneously, using a hollow needle; an instance of this.

swing needle, n. 1954–
A sewing machine needle which can move sideways to the direction of work to accommodate another needle or to form zigzag or patterned stitches...

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needle-felt, n. 1957–

Felt or other non-woven fabric made by a needleloom.

space needle, n. 1961–

(a) Each of a large number of short copper fibres placed experimentally in earth orbit to reflect communication signals (now rare); (b) a very tall...

needle oiler, n. 1962–

= needle lubricator, n.

needle scar, n. 1962–

A scar made by a hypodermic injection.

needle time, n. 1962–

An agreed limited amount of time during which recorded music may be broadcast.

needle spray, n. 1963–

A fine but powerful jet of water from a shower head.

needle coke, n. 1964–

A high-grade petroleum coke, used in making graphite for the electrodes of electric-arc furnaces, in which the carbon has a highly anisotropic...

needle park, n. 1965–

A public area in a city, usually with trees, bushes, benches, etc., where drug addicts gather.

needle freak, n. 1968–

A habitual drug user who administers drugs hypodermically; (also) a person who is addicted to hypodermic injections.

needledick, n. 1969–

coarse slang. A man with a small penis; as a term of abuse.

needle-free, adj. 1969–

Lacking needles, needleless, not involving needles; esp. (in relation to the administration of drugs) functioning or effected without a needle or...

match-needle, adj. 1970–

Designating or relating to a technique for obtaining correct exposure, which involves varying the shutter-speed setting of a camera until two...

needle game, n. 1970–

needle-sharing, n. 1970–

The sharing of a hypodermic needle by intravenous drug users, esp. as a risk factor for the spread of hepatitis B and HIV infection.

needle-stick, n. 1975–

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An accidental stab wound produced by a hypodermic or surgical needle, esp. as a risk factor for the transmission of blood-borne diseases to...

needle exchange, n. 1987–

A service making sterile hypdodermic needles available to intravenous drug users, in order to reduce transmission of blood-borne infections; a place...

hanging-needle, n.

A seine-needle, used in attaching a fishing-net to the cork-line and foot-line.

tag-needle, n.

A needle for attaching labels to bags, bales, etc.

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needle, *n.*

(ˈniːd(ə)l) Forms: α. 1–2 **nædl**, **nédl**, (1 **naeðl**, **nethl**, **netl**), 3–6 **nedle**, 4–5 **nedel**, (5 **-ele**), 4–6 **nedill**, (5 **-il**, **-ille**, **-yl**, **-ylle**, 6 **-yll**), 5–6 **nedell**, **nydel**, (5 **nydle**), 6 **neidil**, **neadle**; 5–6 **needell**, 6–7 **needel**, (6 **-il**), 6– **needle**. β. 3–7 **neld(e**, 4 **neelde**, 6–9 **neeld**, 6 **neilde**, 8 **ne(e)ald**, 9 **nield**, **nild**; 6, 9 **neele**, 9 **neel**, **neal**, **nill**, **nail**. [OE. *nǽdl* fem. = OFris. *nedle*, *nidle*, OS. *nâdla*, *nâthla*, MLG. *nâtel*, OHG. *nâdela*, *nâdla*, *nâdal* (MHG. *nâdele*, *nâdel*, G. *nadel*), ON. *nál* (for **náþl*; Sw. *nål*, Da. *naal*), Goth. *nêþla*:—pre-Teut. **nētlā*, f. the root **nē-* to sew, which appears in OHG. *nâian* (G. *nähen*), MDu. *nayen* (Du. *naaien*), and prob. in L. *nēre* to spin, Gr. νῆσις spinning, νῆμα thread. The ME. metathetic form *neld(e* has parallels in OFris. *nelde*, MDu. *naelde* (Du. *naala*), OHG. *nalda* (MHG. *nalde*): forms representing it are still common in northern and western dialects.]

I. 1. **a.** An instrument used in sewing, usually a small and slender piece of polished steel having a fine point at one end and at the other a hole or eye (see EYE *n.* 20a) through which the thread is passed.

naked, or *sharp, as a needle*: see the adjs. *pins and needles*: see PIN *n.* 3d.

α **c725** *Corpus Gloss.* (Hessels) A 160 *Acus*, netl. *Ibid.* P 421 *Pictus acu*, mið nethle [*Ep.* naeðlæ, *Erf.* nedlæ] asiowid. ***a*1000** *Soul & Body* 120 gifer hatte se wyrm, þam þe geaflas beoð nædle scearpran. ***a*1000** *Colloq. Abp. Ælfric* in Wr.-Wülcker 99/17 Hwanon fiscere ancgel oþþe sceowyrhton æl oþþe seamere nædl? ***c*1200** ORMIN 6341 Wiþþutenn cnif & shæþe & camb & nedle. **?*a*1366** CHAUCER *Rom. Rose* 97 A sylvre nedle forth I drogh Out of an aguiler queynt. ***c*1400** *Lanfranc's Cirurg.* 36 Haue a nedle þre cornerid..& þe lippis of þe wounde schal be sowid togideris. **1484** CAXTON *Æsop* iii. i, [The shepherd] with a nydle subtylly drewe oute of his foote the thorne. **1523** FITZHERB. *Husb.* §142 [Have] thimble, nedle, threde,..leste that thy gurthe breake. **1584** R. SCOT *Discov. Witchcr.* xii. vii. (1886) 182 She sticketh also needels fine In livers, whereby men doo pine. **1653** WALTON *Angler* v. 111 With a needle or pin divide the wing into two. **1712** STEELE *Spect.* No. 430 ¶1 With a Needle and Thread thriftily mending his Stockings. **1751** JOHNSON *Rambler* No. 85 ¶12 A knot of misses busy at their needles. **1835** SIR J. ROSS *Narr. 2nd Voy.* xxxvii. 515 Presenting the women with a needle each. **1865** LUBBOCK *Preh. Times* xii. 407 For needles they use bones either of birds or fishes.

fig. **1678** *Yng. Man's Call.* 156 This [sin] is..that needle, that too surely draws a thread of divine vengeance after it. **1860** READE *Cloister & H.* lxxv, Catherine ran infinite pins and needles of speech into them. **1872** BLACK *Adv. Phaeton* xx. 279 Sticking another needle in her mental image of that poor monarch.

β ***a*1225** *Ancr. R.* 152 A sopare, þet ne bereð buten sope & nelden. ***a*1300** *Estorie del Euangelie* 358 (Vernon MS.) in *Engl. Stud.* VIII. 258 Þat mayde won hire bred Wiþ hire nelde and hire þred. **1387** TREVISA *Higden* (Rolls) VIII. 249 That childe was..prikkede thro alle the body with nalles, neldes, and pynnes. **1432–50** tr. *Higden* (Rolls) I. 225 They made a subtile hoole vnder hit with a nelde. ***a*1557** M. BASSET tr. *More's Treat. Passion* M.'s Wks. 1365 Yf a man do but with a neldes point pricke them in ye eye. **1575** *Gamm. Gurton* i. iv. 5 My fayre, longe, strayght neele, that was myne onely treasure! **1600** FAIRFAX *Tasso* xx. xcv, For thee fit weapons weare Thy neeld and spindle. **1701** J. WHITE *Cy. Man's Conductor* 127/2 *Neald*, Needle. The *ea* sounded as in yea. **1775** WATSON *Hist. Halifax* Vocab. 543 *Neeld*, a Needle. **1814** *Monthly Mag.* XXXVIII. 127 Needle, *neel*. **1825** JENNINGS *Obs. Dial. W. Eng.* 166 Whitechapel nills all sizes. **1848–** in many dial. glossaries (usually in form *neeld*).

†**b.** As an object of trifling importance or value; hence, a particle. *Obs.*

***a*1225** *Ancr. R.* 400 Alle þeos þingis somed, aȝean mine bode, ne beoð nout wurð a nelde. ***c*1330** *Arth. & Merl.* 4012 (Kölbing), Þo he þe stede was opon, He ȝaue a nedel of his fon. ***c*1400** *Plowman's Tale* in *Pol.*

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Poems (Rolls) I. 327 Soche willers witte is not worth a nelde. ***c*1460** *Towneley Myst.* ii. 123 When all mens corn was fayre in feld Then was myne not worth a neld. *Ibid.* xiii. 233, I ete not an nedyll Thys moneth and more.

c. Phr. *to look for,* or *seek, a needle in a meadow*, *haystack*, *bottle (truss* or *bundle) of hay*, to attempt an extremely difficult, impossible, or foolish task.

***c*1530** More *Answ. Frith* Wks. 837/2 To seke out one lyne in all hys bookes wer to go looke a nedle in a medow. **1592** [see bottle *n.*[3] 1]. **1690** W. Walker *Idiomat. Anglo-Lat.* (1695) Pref., A labour much like that of seeking a needle in a Bottle of Hay. **1711** E. Ward *Vulgus Brit.* viii. 95 Seeking we may say, A Needle in a Truss of Hay. **1742** Gray *Lett.* (1900) I. 105 A coach that seem'd to have lost its way, by looking for a needle in a bottle of hay. **1855** Kingsley *Westw. Ho!* xxx, But it's ill looking for a needle in a haystack. [**1875** Lowell *Spenser* Prose Wks. 1890 IV. 268 These thin needles of wit buried in unwieldy haystacks of verse.]

d. *needle's eye*, denoting a minute opening or space, chiefly in echoes of Matt. xix. 24, etc.
Direct citations of the N.T. passages are frequent. The rendering *the eye of a needle* goes back to Tindale (1526).

***a*1530** T. Lupset *Compendious Treat. Dyenge Well* (1534) 35 For as harde a thynge it is to plucke through the smale nedels eie a greatte caboull rope, as to brynge a ryche man in at heuens wycket. **1579** Gosson *Sch. Abuse* (Arb.) 27 Euerie one of them may..daunce the wilde Morice in a Needles eye. **1593** Shakes. *Rich. II*, v. v. 17 It is as hard to come, as for a Camell To thred the posterne of a Needles eye. **1622** C. Fitzgeffrey *Elisha* 46 He had learned also how to make the Camell passe through the needles eye, namely by casting off the bunch on the back. **1668** Davenant *Man's the Master* i. i, The invisible rogue threaded a lane as narrow as a needle's eye. **1872** Besant & Rice *Ready-Money Mortiboy* III. xiii. 234 A single-hearted..rich man, for whom the needle's eye is as easy to pass, as for the poorest pauper. **1925** A. Huxley *Those Barren Leaves* i. i. 11 Those roaring lions at Lady Trunion's..had no hope of passing through the needle's eye. **1929** H. W. Nevinson *The English* vi. 43 They are well fitted to carry on the traditions of Victorian vulgarity, and to prove yet again that no camel will ever get through the needle's eye. **1940** V. W. Brooks *New England* xx. 414 People solemnly chewed their food very fine and slowly to be slender enough to pass through the eye of the needle. **1957** F. R. Scott (*title*) Eye of the needle.

e. *transf.* A needlewoman. *rare*.

1834 Beckford *Italy* II. 83 Sister Francisca Salesia..is acknowledged to be one of the first needles in Christendom. **1855** Dickens *Dorrit* ii. xvii, There was no favour in half-a-crown a day to such a needle as herself.

2. a. A piece of magnetized steel (orig. a needle in sense 1) used as an indicator of direction (in later use as a part of the compass), or in connexion with magnetic or electric apparatus such as the telegraph. Also *ellipt.* = needle telegraph.

1375 Barbour *Bruce* v. 23 Thai wist nocht quhar thai wer, For thai na nedill had na stane. **1436** *Libel Eng. Policy* in *Pol. Poems* (Rolls) II. 191 Men have practised by nedle and by stone Thider-wardes wythine a lytel whylle. **1475** *Bk. Noblesse* (Roxb.) 58 Yet the eldist man..seethe to the nedille for to gide the ship to alle costis. **1555** Eden *Decades* Contents (Arb.) 45 Who fyrst founde the nedle of the compass and the vse thereof. **1625** N. Carpenter *Geog. Del.* i. iii. (1635) 66 At Guinea the magneticall needle inclines to the East. **1665** Glanvill *Scepsis Sci.* xiv. 78 As is the trembling Needle, till it find its beloved North. **1774** M. Mackenzie

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Maritime Surv. 16 They will be less affected by any Inaccuracy in the Bearing by the Needle. **1837** WHEATSTONE & COOKE in *Repert. Pat. Invent.* (1839) XI. 9 Whenever the needle does so point upwards and downwards, it denotes that it is quiescent. **1867** SMYTH *Sailor's Word-bk.* 462 After an action at sea, the needles are often found to be useless, until re-magnetized. **1876** PREECE & SIVEWRIGHT *Telegraphy* 96 The Needle is specially adapted for railway purposes and for linking together several towns on one wire.

fig. **1679** *Establ. Test* 2, I do not pretend..to meddle with the Needle and Compass of the Publique Bottom. ***a*1700** KEN *Hymnotheo* Poet. Wks. 1721 III. 335 The Needle turn'd from God, to point at ill.

b. A small strip of gold or silver of known or standard fineness used with a touchstone in testing the purity of other pieces of those metals.

1469 in *Archaeol.* (1806) XV. 173 That ii gode stones and good nedeles for to touche be alwey ther redie..to make assaie of gold. **1753** CHAMBERS *Cycl. Supp.* s.v. *Touch-Needles*, You will be able to determine..what allay it is of, by the mark of the Needle. **1763** W. LEWIS *Phil. Comm. Arts* 119 Oblong pieces, called needles,.. kept in readiness..as standards of comparison. **1825** J. NICHOLSON *Operat. Mechanic* 766 Assayers make a comparison upon a touch~stone, between it and certain needles composed of gold and silver,..which are called Proof Needles.

c. (See quots.)

1589 RIDER *Bibl. Schol.* 989 A needle, or tongue of a ballance or beame, *examen*. **1616–61** B. HOLYDAY *Persius* (1673) 301 The parts of the balance... The Needle (or Tongue) that arises from the middle of the beam [etc.]. **1789** M. MADAN tr. *Persius* (1795) 8 *note*, The tongue, needle, or beam of a balance. **1856** *Orr's Circle Sci., Mech. Phil.* 107 A needle is usually fixed to the beam.., which points vertically upwards or downwards when the beam is in a horizontal position.

d. A slender, usu. pointed, indicator on a dial or other measuring instrument, *spec.* on a speedometer.

1928 KIPLING *Limits & Renewals* (1932) 60 She preferred cars to her own feet... Her place was at his left elbow, nose touching his sleeve, until the needle reached fifty. **1937** D. L. SAYERS *Busman's Honeymoon* xiv. 244 He let the needle drop back to twenty-five and they dawdled on through the lanes. **1958** 'CASTLE' & 'HAILEY' *Flight into Danger* ii. 31 The altimeter needle on the winking instrument panel steadily registered a climb of five hundred feet a minute. **1962** J. GLENN in *Into Orbit* 42 The periscope..gives you an horizon-to-horizon view of the earth below so you can check your actual attitude against the needles. **1973** 'S. HARVESTER' *Corner of Playground* ii. v. 118 He drove faster, watching the needle flick up to a hundred.

3. a. A pointed instrument used in engraving or etching.

1662 EVELYN *Chalcogr.* (1769) 22 The use both of the point, needle, and etching in aquafortis. **1727–38** CHAMBERS *Cycl.* s.v. *Engraving*, The design..is traced through on the copper, with a point or needle. ***c*1790** J. IMISON *Sch. Arts* II. 32 The principal instruments for etching are needles, oil~stone [etc.]. **1837** *Penny Cycl.* IX. 441/2 Etching-points or needles are nearly similar in appearance to sewing-needles, but fixed into handles four or five inches long.

b. *Surg.* A long slender pointed instrument used in operations; the sharply pointed end of a hypodermic or other syringe; a pointed electrode used in surgical electrolysis.

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1727–38 CHAMBERS *Cycl.* s.v. *Cataract*, Turning the needle round, they twist the cataract about its point. **1803** *Med. Jrnl.* X. 566 If the anterior part of the capsula remain,..the needle is retracted from the lens. **1846** F. BRITTAN tr. *Malgaigne's Man. Oper. Surg.* 309 A silver or golden needle about three inches long... The oculist holds this needle as a pen. **1895** *Arnold & Sons' Catal. Surg. Instr.* 267 Syringe, Laryngeal,..with needles for injecting the Larynx hypodermically. **1899** *Allbutt's Syst. Med.* VIII. 828 The positive needle should be held in position and the negative needle passed in various directions through the nævoid tissue.

(*b*) *spec.* A hypodermic needle used to inject drugs; the use of, or addiction to, injected drugs, esp. in phr. *on the needle*, engaged in, or addicted to, injecting drugs; also *rarely*, a morphine-addict; a dose of a drug for injection. *slang* (orig. *U.S.*).

1929 M. A. GILL *Underworld Slang* (s.v. *don't*), *Don't break the needle*, don't use all the dope. **1936** L. DUNCAN *Over Wall* i. 21, I saw and became familiar with the hopheads or cokes—the cocaine addicts on the snow; the needles or hypes—morphine users. **1943** *N.Y. Times* 9 May ii. 5/6 He's got a band that don't need a five o'clock needle like some other bands. **1953** W. BURROUGHS *Junkie* (1972) x. 94 'You've been hooking that spot so much it's about to get infected,' he said, pointing to a needle welt. **1955** W. GADDIS *Recognitions* i. v. 196 I've heard about her... On the needle. A schiz. **1957** C. MACINNES *City of Spades* ii. iv. 102 He's using all his dope allowance now... You know who put him on the needle and supplied him? **1968** R. JEFFRIES *Traitor's Crime* i. 8 'When d'you get your fixes?' asked Elwick. 'In—in the evenings.' 'How much?' 'Fifteen bob a needle.' **1973** *Listener* 6 Sept. 306/1 Middle Britain thinks..one puff on the joint leads to the needle.

c. In breech-loading fire-arms, a slender steel pin by the impact of which the cartridge is ignited.

1853 URE *Dict. Arts* (ed. 4) I. 727 On pulling the trigger, the interior needle, from which the musquet takes its name, is darted forward..and thus effects the ignition. **1876** VOYLE & STEVENSON *Milit. Dict.* 270/1 The spiral spring..forces the needle into the cartridge and fires the piece.

d. A thin pointed or tapering rod used to secure fine adjustment in closing apertures, as in valves.

1884 KNIGHT *Dict. Mech.* Suppl. 632/2 In order to regulate the supply of oil [from a needle lubricator], a metallic feed-rod (needle) passes through the tube, and rests upon the shaft to be lubricated. **1909** *Chambers's Jrnl.* Nov. 698/1 The gas-regulator can be adjusted to the fiftieth part of an inch, with dead centralisation of the needle. **1927** G. W. C. KAYE *High Vacua* iv. 52 The needle readily beds itself into its seating, and very little pressure is needed to close the valve completely. **1965** C. M. VAN ATTA *Vacuum Sci. & Engin.* viii. 328 The principal feature of the design [of the needle valve] is the slowly tapering needle fitting snugly into a carefully reamed conical seat.

e. The small pointed jewel or piece of metal, wood, etc., which rests in the groove of a gramophone record when it is being played and communicates the undulations to the pick-up or diaphragm; also, a similar device used to cut the groove; = STYLUS 2.

1902 *Encycl. Brit.* XXXI. 679/2 The marker..instead of being a stiff needle coming from the centre of the membrane or glass plate, is now a lever. **1930** A. B. WOOD *Textbk. Sound* 438 The vibrations of the diaphragm cause a needle to cut grooves on the surface of a prepared cylinder or disc. **1949** FRAYNE & WOLFE *Elem. Sound Recording* xiii. 240 Motion of the needle can be utilized to apply a force to a piezoelectric crystal and thus generate a voltage. **1957** *Records & Recording* Nov. 20/1 These grooves..must be tracked with absolute accuracy by the pickup needle—nowadays it is more usually called a stylus. **1973** D. RAMSAY

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Deadly Discretion 190 The concerto came to an end. The needle began to click against the ungrooved portion of the record.

4. a. A knitting or netting pin.

1719 D'URFEY *Pills* (1872) V. 282 She let her Iv'ry Needle fall. **1753** CHAMBERS *Cycl. Suppl.* s.v. *Net*, All the tools necessary to it are wooden needles, of which there should be several of different sizes. **1797** *Encycl. Brit.* (ed. 3) XVII. 805/1 The method of knitting stockings by wires or needles. **1843** *Penny Cycl.* XXVII. 180/1 In the process of knitting..polished steel needles or wires are used to link threads together into a series of loops.

b. One of a set of parallel pieces of wire forming part of the mechanism of a stocking-frame or of the Jacquard loom.

1839 URE *Dict. Arts* 660 There must be as many endless cords in this frame as needles in the weaving-loom. **1843** *Penny Cycl.* XXVII. 178/2 Each bar or needle is a lever by which certain warp-threads are governed.

5. a. A metal pin or rod used as a fixing.

1837 *Civil Eng. & Arch. Jrnl.* I. 6/1 Long iron needles pass through holes in the strips of saw-plate, and pin them to the ground.

b. *Mining.* (See quot. 1883.)

1839 *Penny Cycl.* XV. 241/2 The charge having been firmly rammed down with clay..the wire or 'needle' is withdrawn. **1883** GRESLEY *Gloss. Coal-mining* 173 *Needle*, a sharp-pointed copper or brass rod with which a small hole is made through the stemming to the cartridge in blasting operations.

II. 6. **a.** A pillar or obelisk, usually with fanciful attribution to some historical person.

1387 TREVISA *Higden* (Rolls) IV. 211 Iulius his piler þat now pylgryms clepeþ Seynt Petres nedle. **1615** G. SANDYS *Trav.* 114 An Hieroglyphicall Obelisk of Theban marble..called Pharos Needle. **1660** F. BROOKE tr. *Le Blanc's Trav.* 278 There is yet left a kind of Obeliske or Needle. ***a*1693** HUNTINGDON in Ray *Travels* (1693) II. 153 The Franks call them Aguglia's, the English particularly Cleopatra's Needles. **1842** GWILT *Archit.* 1009 s.v. *Obelisk*, Two obelisks, one at Alexandria, vulgarly called Cleopatra's Needle.

†**b.** (See quot. 1617.) *Obs. rare.*

1617 MORYSON *Itin.* iii. 143 Rippen had a most flourishing Monastery, where was the most famous needle of the Archbishop Wilfred. It was a narrow hole, by which the chastity of women was tried. **1650** T. FULLER *Pisgah* iii. iii. §17. 323 We.. account the threading of Saint Wilffride's needle as a conceit..to have as much gravity and truth therein.

7. A sharp-pointed mass of rock; *esp.* in *pl.* as the name of those to the west of the Isle of Wight, or those which form the summits of many Swiss mountains.

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***c*1400** *Anc. Pet.* 9425 (Public Rec. Office), La terre deuaunt les nedeles del Isle de Wight. **1594** NASHE *Terrors of Night* Wks. (Grosart) III. 263 A fortunate blessed Iland, nere those pinacle rocks called the Needles. **1706** PHILLIPS (ed. Kersey), The *Needles*, certain Shelves in the Sea, about the Isle of Wight. **1721** *New Gen. Atlas* 146 On the Platform of the Mountain there is a natural Pyramid, whence it was called a needle. **1775** C. & F. DAVY tr. *Bourrit's Journ. Glaciers* (1776) 67 The chain..is composed of masses of rocks, which terminate in pikes, or spires called the Needles. **1820** M. STARKE *Trav. Cont.* ii. 66 The *Mer de Glace* ..on its margin rise pyramidical rocks, called Needles. **1852** MITCHELL *Rev. Bachelor* 279 Far behind them..Mont Blanc and the Needles of Chamouni.

8. A beam or post of wood, *esp.* one used as a temporary support for a wall during underpinning.

1471 *Acc. Bodmin Ch.* (Camden) 25 Cariage of neldis for scafelys. **1512–13** *Rec. Nottingham* (1889) IV. 452 Item for a tree, the hewyng and sawyng in neldes v.*s.* **1587** FLEMING *Contn. Holinshed* III. 1541/1 What prouision of stuffe should be made..of timber,..needels, keies, beetels. **1684** I. MATHER *Remark. Provid.* (1856) 5b, A violent flash, or rather flame of lightning, which brake and shivered one of the needles of the katted or wooden chimney. **1842** GWILT *Archit.* 1008 *Needle*, an horizontal piece of timber serving as a temporary support to some superincumbent weight. **1867** *Guardian* 24 Dec. 1383/1 One of the 'needles'—upright pieces of timber supporting the keystone of the arch—slipped from under. **1889** *Whitby Gaz.* 5 Apr. 3/7 If a plank had been placed between the needles, the stone could not have fallen upon plaintiff.

9. a. A common wild plant (*Scandix pecten*), also called *Adam's*, *beggar's*, *shepherd's needle*, etc.

1793 *Trans. Soc. Arts* XI. 52 Unaccountably foul with catlock, needles, &c. **1851** *Jrnl. R. Agric. Soc.* XII. ii. 348 Weeds are very troublesome, especially the wild oat, buttercup, and 'needle'. **1877** *N.W. Linc. Gloss.*, *Needles*, a weed, with sharp needle-like seed-pods, which grows among corn.

b. The name of a fish. (Cf. NEEDLE-FISH.) *rare*.

1589 RIDER *Bibl. Schol.* 1722 Nedelis, a kind of fish, *belone*. **1603** OWEN *Pembrokeshire* (1892) I. 123 The Erle or needle whose fynes growe forward contrarie to the nature of all fishe.

c. Some kind of shell. *rare*$^{-1}$.

1713 PETIVER *Aquat. Anim. Amboinæ* 3/2 *Strombus*..Curl girdled Needle.

10. *Chem.* and *Min.* A crystal or spicule resembling a needle in shape.

1712 tr. *Pomet's Hist. Drugs* I. 184 Benjamin being very full of volatile Particles.., the Flowers ascend in little Needles very white. **1758** REID tr. *Macquer's Chym.* I. 215 Pyrites..being broken present a number of shining needles, all radiating, as it were, from a center. **1800** tr. *Lagrange's Chem.* II. 128 You will obtain a salt under the form of small needles. **1855** KINGSLEY *Glaucus* (1878) 87 A twisted wisp of strong flexible flint needles. **1880** COLLINS in *Mineral. Mag.* IV. 104 Some of these 'needles' [of needle-tin] are extremely fine.

11. One of the sharp slender leaves of the fir and pine trees.

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1798 *Trans. Soc. Arts* XVI. 357 Its needles are longer and darker than those of the famous Weymouth Pine. **1845** *Zoologist* III. 901 A pine tree..stripped of its leaves, or needles, as the Germans more aptly term them. **1883** JEFFERIES *Nat. near Lond.* 159 His golden crest distinctly seen among the dark green needles of the fir.

12. *slang.* †**a.** A sharper. *Obs.*

***a*1790** POTTER *New Dict. Cant*, *Needle*, a sharp fellow, a sharper, a cheat. **1821** EGAN *Life in London* 138 (Farmer), Among the needles at the West end of the town.

b. *the needle*, a fit of irritation or nervousness. Also (sometimes without *the*), anger, bad temper, enmity; esp. *to get the needle*, to become angry or upset, to lose one's temper.

1874 HOTTEN *Slang Dict.* 235 To 'cop the needle' is to become vexed or annoyed. **1884** [see BIRD *n.* 5b]. **1887** *Punch* 30 July 45 It give 'im the needle.. being left in the lurch this way. **1890** BARRÈRE & LELAND *Dict. Slang* II. 84/2 It gives a man the needle when he hasn't got a bob, To see his pals come round and wish him joy. *Ibid.*, To get the needle is to feel very nervous and funky. **1900** G. SWIFT *Somerley* 83 But when the final gun has gone and you are 'off', nervousness, 'needle', everything goes. **1923** *Daily Mail* 1 Aug. 8/2 It may be, of course, that there was too much 'needle' (to employ a boxing term which means bad spirit) about this contest. **1929** H. A. VACHELL *Virgin* viii. 141 The silly ass got the needle, 'cos she asked for the ring. **1959** *Times* 8 June 3/1 Perhaps it was this very lack of needle, this air of unreality in the late evening of Saturday.. that failed to see Davies home to a victory. **1967** *Time* 22 Dec. 48 A needle from [Bob] Hope becomes an emblem instead of a scar. **1970** G. F. NEWMAN *Sir, You Bastard* v. 130 He's got the needle with you. You've got to go very careful.

III. 13. *attrib.* and *Comb.* **a.** Objective, and obj. genitive, as *needle-grinder*, *needle-grinding*, *needle-maker*, *needle-making*, *needle-monger*, *needle-pointer*, *needle-polisher*, *needle-seller*.

***c*1836** *Encycl. Metrop.* (1845) VIII. 672/2 A back elevation of a *needle-grinder's wheel. *Ibid.*, The injurious effect of needle grinding upon the health of the individuals.**1611** COTGR., *Esguillier*, a *needle-maker. **1723** *Lond. Gaz.* No. 6134/4 John Lowe,..Needle-maker. ***c*1836** *Encycl. Metrop.* (1845) VIII. 673/1 Measures to be taken by the larger needle-makers themselves.*Ibid.* 671/1 *Needle-making, old process. **1872** YEATS *Techn. Hist. Comm.* 343 In England needle-making has become a staple trade.**1837** WHEELWRIGHT tr. *Aristophanes* I. 13 The *needlemonger too with Pamphilus.**1835** URE *Philos. Manuf.* 402 The Sheffield dry-grinders and *needle-pointers.**1898** *Allbutt's Syst. Med.* V. 159 Flint-workers, *needle-polishers,..supply the largest contingent of pulmonary diseases.**1848** HICKIE tr. *Aristophanes* (Bohn) II. 692 And will not the *Needle~seller [suffer] along with Pamphilus?

b. Instrumental, as *needle-made*, *needle-painted*, *needle-run*, *needle-scarred*, *needle-worked* adjs.; also *needle-hole*, *needle-puncture*, *needle-puncturing*.

1847 *Nat. Encycl.* I. 851 A very minute *needle-hole made in the centre of it.**1883** *Cassell's Fam. Mag.* July 500/2 The lacet point is a *needle-made lace.**1598** CHAPMAN *Iliad* iii. 386 The *needle-painted lace, with which his helm was tied Beneath his chin. **1910** *Westm. Gaz.* 2 Feb. 5/4 An exhibition of needle-painted wild flowers of South Africa was opened yesterday.**1899** *Allbutt's Syst. Med.* VIII. 847 Cancerous deposits may form at the sites of the *needle punctures.**1822–34** *Good's Study Med.* (ed. 4) III. 268 Advantage has sometimes been derived from *needle-puncturing.**1894** *Westm. Gaz.* 31 May 3/3 The mingling of *needle-run..lace and broad white satin ribbon.**1854** G. J. WHYTE-MELVILLE *Gen. Bounce* ix, Holding up her *needle-scarred hands to the

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bystanders.**1856** DICKENS in *Househ. Words* XXXIV. 130/2 Of rich oak carvings and quaint *needleworked tapestry there was none.

c. Similative, as *needle-form*, *needle-formed*, *needle-like*, *needle-nosed*, *needle-shaped*, *needle-sharp*, *needle-tailed* adjs.; also *needle-foliage*, *needle-leaf*, *needle-rock*, *needle-spire*.

1898 CATH. PHILLIMORE *Dante at Ravenna* 152 Through their *needle foliage passes a sweet murmur.**1807** T. THOMSON *Chem.* (ed. 3) II. 623 It may, however, be obtained in small *needleform crystals.*Ibid.* 289 Some of them lance-shaped, others *needle-formed.**1856** C. M. YONGE *Daisy Chain* ii. xxii. (1879) 600 The dark path, bestrewn with brown slippery *needle-leaves.**1672** J. JOSSELYN *New Eng. Rarities* 7 They feed upon Honey, which they suck out of Blossoms..with their *Needle-like Bills. **1797** *Encycl. Brit.* (ed. 3) XI. 440/2 The smoothness and needle-like figure of the particles. **1847–9** *Todd's Cycl. Anat.* IV. 66/2 In the shape of simple needle-like crystals.**1955** *Sci. News Let.* 26 Mar. 196/2 An eight-foot-tall, *needle-nosed rocket. **1973** *Times* 4 June 1/3 The crash came at the end of the last of three passes the needle-nosed plane made to show off its qualities.**1867** SMYTH *Sailor's Word-bk.* 495 In California many of the *needle rocks are of volcanic origin.**1786** AIKEN tr. *Beaumé's Man. Chem.* 94 The liquor..furnishes *needle-shaped crystals. **1863** A. C. RAMSAY *Phys. Geog.* 22 Needle-shaped masses of rocks.**1923** J. GALSWORTHY *Captures* 161 That fellow was *needle-sharp, though not always correct in his conclusions. **1973** *Times* 5 Oct. (Safety Suppl.) p. i/3 Everything depends on needle-sharp reflexes.**1864** *Daily Tel.* 23 Sept., Its tall brick cathedral, with the two *needle-spires.**1801** LATHAM *Syn. Birds* Suppl. II. 259 *Needle-tailed Sw[allow].

d. Attributive, as *needle-factory*, *needle-hand*, *needle-housewifery*, *needle-job*, *needle-toil*, *needle-trade*, *needle-wire*.

1747 in *Chester Misc.* (1750) 247 Jacintha employ'd in Needle-housewifry. **1822** LAMB *Elia* Ser. ii. *Thoughts on Bks.*, The milliner..after her long day's needle-toil. **1836** *Going to Service* xi. 122 Several little needle jobs. **1839** URE *Dict. Arts* 879 The first operation..of the needle factory. **1862** *Catal. Internat. Exhib., Brit.* II. No. 6449 The early history of the needle-trade. *Ibid.*, The distance between the two eyes in each needle-wire. **1899** *Allbutt's Syst. Med.* VIII. 14 Cases of break-down in the needle-hand of tailors and seamstresses.

14. Special combs., as **needle-alphabet** (*nonce-wd.*), one in which stitches are substituted for letters according to a pre-arranged code; **needle-and-pin**, rhyming slang for GIN *n.*[2]; **needle-and-thread**, rhyming slang for 'bread'; **needle-bath**, a form of shower-bath with a very fine and strong spray; **needle-beam**, a transverse beam in the flooring of a bridge (Knight, 1875); **needle bearing**, a bearing using needle rollers; **needle beer** *U.S. slang* (see quot. 1928); **needle board** (see quots.); **needle-bolt**, the bolt which carries the needle in a needle-gun; **needle-book**, a needle-case resembling a small book; **needle-bug** (see quot.); **needle-bush** *Austral.*, (*a*) either of two shrubs or small trees of the genus *Hakea*, *H. leucoptera* or *H. vittata*, of the family Proteaceæ; (*b*) the nealie or nelia, *Acacia rigens*, of the family Leguminosæ; **needle-cast**, a fungus disease of conifers, causing the leaves to go brown and drop off; **needle-chervil** = NEEDLE 9a; **needle contest** = *needle match*; **needlecord**, a finely ribbed cut-pile fabric; **needle-craft**, the art of using the needle for sewing or embroidering; **needle-dial**, a dial bearing a needle in an electrical apparatus; **needle-felt**, **needlefelt** = *needle-loom* (b); **needle fight** = *needle match*; **needle-file** [cf. G. *nadelfeil*], a fine round file used by jewellers (Knight, 1875); **†needle-fodder**, a needle-case; **needle-furze** or **-gorse**, *Genista anglica*; **needle game** = *needle match*; **needle gap** *Electr.*, a pair of needle-shaped electrodes placed in line, between which an electric discharge can take place when the potential difference between them exceeds a value dependent on the size of the gap; **needle gate**, a dam or sluice consisting of several thin spars which are placed vertically one after the other into a frame; **needle-girder** (cf. *needle-beam* above); **needle-grass**, a species of grass (*Aristida oligantha*), common in the south-western U.S.; **needle greenweed** = *needle-furze*; **†needle-house** [cf. Da. *naalehus*, Sw. *nålhus*], a needle-case; **needle ice**, ice formed into thin needle-like crystals just beneath the soil surface and often pushing up through it; **needle iron-ore** or **iron-stone**, a variety of hydrate of iron; **needle-jerker**, (*slang*) a tailor; **needle-lace**, lace made with the needle, as opposed to bobbin-lace; **needle-**

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loom, **needleloom**, (*a*) (see quot. *a*1877); also *attrib.*; (*b*) carpeting made of felt attached to a base of rubber, hessian, or other material; **needle lubricator**, **oiler**, a form of lubricator in which the supply of lubricant is controlled by a needle fitted in the supply tube and resting on the shaft to be lubricated; **needle manganese** (see quot.); **needle mark**, a mark made by a hypodermic injection; **needle match**, a match or contest that arouses much interest and excitement; a crucial or keenly fought match; a contest in which the contestants have a grudge against each other; a dispute; **needle-musket**, one fired by means of a needle; **needle-ore** (see quots.); **needle paper**, a stout black paper orig. used for wrapping up needles; **needle-rifle** (cf. *needle-musket*); **needle roller**, a roller in the form of a long, thin, sometimes tapered cylinder, used in roller bearings; freq. *attrib.*; **needle scar**, a scar made by a hypodermic injection; **†needle-screw**, ? a very fine screw; **needle-shell** (see quots.); **needle shower**, **spray**, a shower-bath of strong fine jets of water; also *fig.*; **†needle-shuttle**, a shuttle resembling a large needle; **†needle-spar**, aragonite; **needle-spitter** (*nonce-wd.*), one who uses sharp language; **needle-syringe**, a sharp-pointed hypodermic syringe; **needle-telegraph**, a telegraph in which the needle is employed as an indicator; **needle-threader**, a device for threading needles; **needle-timber**, **-tin** (see quots.); **needle time**, an agreed time during which gramophone records are allowed to be broadcast; **needle track** = *needle mark*; **needle-tree**, a tree bearing needles, as the pine or fir; **needle-urchin** (see quot.); **needle valve**, a valve which works by means of a narrow pointed rod fitting into a conical seating and is operated either automatically or by a screw; **needle-weaving** (see quots.); **needle-weed** = NEEDLE 9a; **needle-whin**, = *needle-furze*; **needle-wood** = *needle-bush* (*a*) ; also *attrib.*; **needle-worm** [G. *nadelwurm*, Du. *naaldworm*], a small worm parasitic in horses; **needle zeolite**, natrolite.

Also in a number of other technical combs., as *needle-bar*, *needle-forceps*, *needle-loom*, *needle-valve*; *needle-bearer*, *needle-holder*, etc. (see Knight *Dict. Mech.*).

1655 MARQUIS OF WORCESTER *Cent. Invent.* Index, *A Needle~alphabet.**1937** PARTRIDGE *Dict. Slang* 555/2 **Needle and pin*, gin. **1973** J. LEASOR *Host of Extras* vi. 118 You owe him some needle and pin—gin.**1859** HOTTEN *Dict. Slang* 144 **Needle and thread*, bread. **1935** A. J. POLLOCK *Underworld Speaks* 80/1 *Needle and thread*, bread.**1887** *Brit. Med. Jrnl.* 11 June 1291/2 There are reclining baths;..*needle-baths; local baths; and special baths.**1930** *Automotive Industries* LXIII. 869/1 The *needle bearing offers particular advantages for certain applications in high speed engines, as on crankpins. **1946** L. E. O. CHARLTON *R. Air Force July 1943 to Sept. 1944* 154 (*caption*) Bomber Command launched an attack on a needle-bearing factory..in France. **1972** R. C. GUNTHER *Lubrication* xiii. 408 Needle bearings are suited for slow speeds, or for oscillating and intermittent motion which permits the rollers to return to their required position upon load relief.**1928** *Flynn's* 14 Apr. 29/2 On the same spot you can get your *needle beer—near beer shot with alki or ether. **1936** J. DOS PASSOS *Big Money* 81 He..had a session with the helpwanted columns over some glasses of needle beer.**1879** T. R. ASHENHURST *Pract. Treat. Weaving & Designing Textile Fabrics* 63 The pressure thus bestowed upon the crosswires keeps them in position through the *needle-board. **1889** *Cent. Dict.*, *Needle-board*, in the Jacquard loom, a perforated board or plate through which the points of the needles presented to the cards pass, and the perforations of which act as guides for the needles when the latter are actuated by the cards. The needle-board holds all the needles in proper relation with the prism or cylinder to which the cards are attached, and with the perforations in the cards. **1961** WEBSTER, *Needle board*, a board covered with very short fine wires that is used for pressing pile fabrics.**1868** *Rep. Govt. U.S. Munitions War* 24 The catch *h* is drawn down sufficiently to allow the *needle-bolt shoulder *a* to pass over it.**1693** *Lond. Gaz.* No. 2905/4 A little Silk Bag, with a *Needle-Book and a little Key in it. **1858** MRS. GATTY *Aunt Judy's Tales* (1859) 75 The needle-book that he'd bought for me in his hand.**1896** LYDEKKER *Royal Nat. Hist.* VI. 191 *Limnobates stagnorum*..is remarkable for its elongated slender body, whence its name of *needle bug or water gnat.**1889** J. H. MAIDEN *Usef. Native Pl.* 34 *Hakea leucoptera*,..'*Needle-bush', 'Pin-bush'. *Ibid.* 314 *Acacia rigens*,..'Nealie', or 'Needle Bush'. **1909** A. E. MACK *Bush Calendar* 4 All through the bush the needlebush showed white blossoms amongst its spiky leaves. **1944** *Living off Land* iii. 47 One of the main water supplies of the aborigines came from tree roots, principally those of the mallee, the needle-bush. *Ibid.* 48 The needlebush, a dark green shrub with sharp-pointed needles in place of leaves. **1965** *Austral. Encycl.* VI. 266/2 Needlewood or Needlebush, popular names for *Hakea leucoptera* and *H. vittata*, dry-country shrubs or small trees possessing rigid acicular leaves. *Ibid.*, The so-called 'nealie', *Acacia rigens*, is sometimes referred to as

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needle-bush, because of its long terete phyllodes.**1895** W. R. FISHER *Schlich's Man. Forestry* IV. 408 This sudden shedding of pine needles is the characteristic of the disease so widely spread in Germany, and termed *Schütte*, or *needle-cast. **1964** W. E. HILEY *Forestry Venture* iv. 81 We are inclined to associate the trouble with a needle-cast fungus (*Phaeocryptopus gaumannii*).**1578** LYTE *Dodoens* 615 This herbe is called..in Englishe, Shepheardes Needel, wilde Cheruel, and *Needel Cheruill.**1922** *Daily Mail* 22 Nov. 11 There is also a '*needle' contest, recently arranged, between two stable-lads. **1963** *Times* 15 Jan. 9/4 And then what about that 'needle' contest, the University match?**1959** *Manch. Guardian* 26 June 5/3 A *needlecord in a dove-like grey was excellent for slacks or jackets. **1973** 'D. HALLIDAY' *Dolly & Starry Bird* xvi. 236 Charles had on a needlecord shirt with a flower pattern.**1382** WYCLIF *Ex.* xxxix. 28 The girdil forsothe of bijs foldun aȝen, iacynct, purpur and reed clooth, twynned with *nedle craft. **1846** B. BARTON *Select.* (1849) 41 A piece of sempstress~ship or needle-craft, forming the forepart of a waistcoat.**1868** *Rep. Govt. U.S. Munitions War* 241 A short circuit is thus made with a *needle-dial.**1957** *Textile Terms & Definitions* (Textile Inst.) (ed. 3) 67 **Needle felt*, felt produced by the needleloom process.**1927** *Daily News* 25 May 8/1 England's native champion..went down in a *needle fight with Samuel Robinson, an experienced golfer. **1970** *Globe & Mail* (Toronto) 28 Sept. 21/2 In soccer there is a word for a tense match, it is called a needle game and this one fitted into that category.**1382** WYCLIF *Isa.* iii. 20 Combys, and ribanes,..and oynement boxes [*altered from* *nedle foddris]. **1650–1738** *Needle Furze [see FURZE 2]. **1785** MARTYN *Rousseau's Bot.* xxv. (1794) 352 Needle Furze or Petty-Whin, which you will find wild on heaths.**1916** C. C. GARRARD *Electr. Switch & Controlling Gear* viii. 563 One source of uncertainty can be removed if needles are used for the measuring gap, in which case the result obtained is termed the 'equivalent *needle gap'. **1927** *Ibid.* (ed. 3) viii. 641 Let us assume that this [line] is protected by a needle gap with a breakdown voltage..of 66,000 volts. **1962** *Newnes Conc. Encycl. Electr. Engin.* 701/2 Needle gaps have been used for measuring voltages of a few kilovolts as they have larger, and therefore more convenient, spacings than sphere gaps at these low voltages.**1909** H. M. WILSON *Irrigation Engin.* (ed. 6) 230 Simple flash-board or *needle gates should be used only where the pressure upon them is low.**1898** *Daily News* 18 Nov. 2/1 '*Needle' girders were then 'threaded' crosswise over the main girders.**1893** TURNER in *Annals Andersonian Nat. Soc.* 2 On the drier banks..the *needlegorse (*Genista anglica*) is not quite unknown.**1885** H. C. MCCOOK *Tenants Old Farm* 341 A sort of grass known as ant-rice, or *needle-grass.**1796** WITHERING *Brit. Plants* (ed. 3) III. 625 *Genista anglica*, *Needle Greenweed.***c1425** *Voc.* in Wr.-Wülcker 659 *Hec acuaria*, *nedylhows. **1483** *Cath. Angl.* 250/2 A Nedylle howse, *acuarium*. **1547** SALESBURY *Welsh Dict.*, *Nildws*, a nedle ouse.**1918** *Engineering-News Record* 7 Feb. 262/2 The ice columns, or '*needle ice', formed on bare clayey soils are familiar to most people living in regions where the nights are cold enough for heavy frosts. **1939** H. H. BENNETT *Soil Conservation* xii. 284 Where there is sufficient soil moisture, a freeze will produce layers of needle ice, or spew frost, which will lift the overlying soil and vegetation as much as several inches. **1968** R. W. FAIRBRIDGE *Encycl. Geomorphol.* 381 Such 'needle ice' is sometimes called pipkrake.**1885** A. RAMSAY *Min.* (ed. 3) 178 *Needle-iron Ore; Onegite; Ferric Monohydrate.**1807** *Sporting Mag.* XVII. 19 His galligaskins have been made by the same *needle-jerker.**1891** *Daily News* 13 Nov. 5/5 There is Irish lace of all kinds, and some of the *needle lace is really exquisite.***a1877** KNIGHT *Dict. Mech.* II. 1519/1 **Needle-loom*, one in which the weft is carried by a needle instead of a shuttle. The usual form of loom for narrow wares, such as ribbons, tapes, bindings, etc. **1956** *Good Housek. Home Encycl.* (ed. 4) 92/2 Needleloom carpetings have a rubber or plastic back. **1957** *Textile Terms & Definitions* (Textile Inst.) (ed. 3) 68 The needleloom process is essentially a method of attaching a lap or batt..of loose fibrous material to a base, e.g. fabric, paper, rubber and/or plastic materials. **1957** *Observer* 20 Oct. 10/2 Almost all the new *tufted* carpets (which have, to a large extent, superseded the rubber-backed felt called *needleloom*) are made almost entirely of rayon. **1969** A. J. HALL *Stand. Handbk. Textiles* (ed. 7) iii. 161 For the manufacture of needle~loom carpets a machine is used which comprises rows of vertical

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needles.**1884** KNIGHT *Dict. Mech.* Suppl. 632/2 *Needle lubricator. **1887** D. A. LOW *Introd. Machine Drawing & Design* vii. 32 In the block illustrated the journal is lubricated by a needle lubricator.**1876** PREECE & SIVEWRIGHT *Telegraphy* 26 The binoxide of manganese which is used is of the form known as *needle manganese.**1949** N. MARSH *Swing, Brother, Swing* ix. 206 He hasn't been long on the injection method… Curtis had a look for needle~marks and didn't find many. **1971** 'D. SHANNON' *Murder with Love* (1972) iv. 69, I doubt very much whether he's really hooked… No needle marks on him.**1923** *Daily Mail* 16 Jan. 9 There will be a '*needle' match in Sheffield if Barnsley beat Swindon and visit the Wednesday. **1952** L. A. G. STRONG *Darling Tom* xvii. 136 (*headline*) Needle match. Family quarrel will be fought out at Olympia. **1962** *Listener* 1 Nov. 732/3 More enjoyable was an off-beat needle match between Hans Keller, who held that Gershwin was a neglected genius, and Deryck Cooke, who didn't. **1965** D. FRANCIS *For Kicks* iii. 41, I..watched Paddy and one of Granger's lads engage in a needle match of dominoes.**1898** *Edin. Rev.* Apr. 350 The so-called *needle~musket of the Prussians.**1810** *Nicholson's Jrnl.* XXVII. 236 The *Needle-ore has been considered..an auriferous ore of Nickel. **1836** T. THOMSON *Min., Geol.*, etc. I. 596 Needle ore of Bismuth..was first described and analyzed by Karsten and John. **1875** *Ure's Dict. Arts* (ed. 7) III. 412 *Needle-ore* or Aciculite. A native sulphide of bismuth, copper, and lead, in acicular crystals, found in Siberia.**1909** *Westm. Gaz.* 3 Apr. 14/2 If *needle-paper of the required kind is not available a very excellent substitute can be prepared by placing good stout paper in a solution of gelatine and glycerine to which has been added some good strong black colouring. **1973** *Sci. Amer.* May 118/1 Black needle paper and white typewriter bond differ by about a factor of 15 in reflectance all across the spectrum.**1866** *Chambers's Encycl.* VIII. 259/2 The Prussians, meanwhile, had armed their troops with the *needle-rifle.**1935** *Jrnl. R. Aeronaut. Soc.* XXXIX. 470 The crankshaft was mounted on roller bearings, and the connecting rod big ends were mounted on *needle rollers in split housings. **1951** *Engineering* 26 Oct. 533/1 An open propeller shaft provided with Hardy Spicer needle-roller joints transmits the drive to the rear axle. **1959** R. R. SLAYMAKER *Mech. Design & Analysis* ii. xv. 299 Loose needle rollers are now universally used throughout the automotive industry to serve as bearings in planetary gear systems. **1974** 'A. HAIG' *Peruvian Printout* 37 A rubber-wheeled trolley which glided on needle roller bearings.**1962** K. ORVIS *Damned & Destroyed* vii. 52, I made a mental note of the *needle~scar item.**1655** MARQUIS OF WORCESTER *Cent. Inv.* (1663) §81 The head being opened with a *Needle-scrue drawing a Spring towards them.**1752** HILL *Hist. Anim.* 134 The slender Turbo, with ventricose spires, and a small rounded mouth. The *Needle-shell. **1863** J. G. WOOD *Nat. Hist.* III. 380 The Spotted Needle~shell, or Spotted Auger, derives its name from the long and sharply pointed form of the shell.**1935** A. J. CRONIN *Stars look Down* i. xix. 183 After that a *needle shower and a hard rub down. **1973** 'H. HOWARD' *Highway to Murder* iii. 34 Ten minutes under a needle-shower washed the clammy heat out of me. **1974** E. MCGIRR *Murderous Journey* 6, I..shivered under a cold needle shower.**1699** L. WAFER *Voy.* 86 The Men make Arrow-Heads of this Wood; the Women *Needle-Shuttles to weave their Cotton.**1967** *Freedomways* VII. 153 A scattered *needle-spray of unrelated, often ephemeral, facts and events which confuse the readers more than they inform them. **1970** H. MCLEAVE *Question of Negligence* (1973) vii. 54 In the shower room he..focussed the needle spray on his head and body.**1836** T. THOMSON *Min., Geol.*, etc. I. 117 Arragonite, igloite, flos ferri, *needle spar.**1805** *Sporting Mag.* XXV. 315 My landlady—a perfect *needle-spitter.**1894** *Daily News* 15 Jan. 3/2 This is inserted beneath the skin of the stomach by means of a small *needle-syringe.**1849** NOAD *Electricity* (ed. 3) 375 The telegraph here patented they call their *needle telegraph. **1860** G. B. PRESCOTT *Electr. Telegr.* 100 The essential part of the needle telegraph is the multiplier.**1889** *Cent. Dict.*, **Needle~threader*, a device for passing a thread through the eye of a needle. **1964** *McCall's Sewing* v. 66/1 If you have an eyesight problem, or just find threading needles a chore, use a needle threader.**1802–3** tr. *Pallas's Trav.* (1812) I. 36 *Needle-timber, that is, resinous-trees, or such as have acuminated leaves.**1962** *Sunday Express* 30 Dec. 1/6 '*Needle time'—the number of hours given to records. **1970** *B.B.C. Handbk.* 223 An agreement with *Phonographic*

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Performance Ltd. provides for the right to broadcast commercial gramophone records 'live', the B.B.C.'s various radio and television services being allocated fixed periods of 'needle time' in return for an annual lump sum payment.**1880** J. H. COLLINS in *Mineral. Mag.* (1882) IV. 7 F. Becke regards Wood Tin as an extreme form of the well known acicular crystals sometimes spoken of as '*Needle Tin'.**1959** A. K. LANG in H. Q. Masur *Murder Most Foul* (1973) 69 The kid had been a user; they'd know that from the gear in her purse and the *needle-tracks in her arm. **1973** J. MARTIN *95 File* 80 He checked her arms but found no needle tracks.**1849** OTTÉ tr. *Humboldt's Cosmos* II. 455 In the *needle-tree we have the greatest contraction of the leaf vessels. **1868** G. STEPHENS *Runic Mon.* I. 209 The stuff could scarcely be of birch, or of any other leaf-tree, but rather of a needle-tree.**1713** PETIVER *Aq. Anim. Amb.* 1/2 *Echinus setosus*..*Needle-Urchin.**1903** *Sci. Amer. Suppl.* 24 Jan. 59/2 The inventor's idea, in designing the vaporizer, was to do away with the *needle-valve usually employed for controlling the flow of gasoline. **1925** N. E. ODELL in E. F. Norton *Fight for Everest 1924* 362 The pressure gauge was connected close to the mouths of the cylinders on the back [of the breathing apparatus], and the rate of flow regulated by a needle~valve close beside it. **1971** *Sci. Amer.* Sept. 222/3 All gases are admitted through needle valves to a manifold that connects to the laser.**1932** D. C. MINTER *Mod. Needlecraft* 16/1 *Needleweaving is a form of embroidery worked on the threads of the material when the threads in the opposite direction (i.e. either the warp or the weft) have been withdrawn. **1967** E. SHORT *Embroidery & Fabric Collage* ii. 48 *Needleweaving.* This is a variation of drawn thread work which could be used effectively on accessories such as handbags and belts.**1787** W. MARSHALL *Norf.* (1795) Gloss., *Needleweed, *Scandix pecten Veneris*, shepherd's needle.**1890** *Daily News* 8 Sept. 3/1 Though there is plenty of *needle-whin in places, its green spines are too tender to goad the hides of horses much.**1911** C. E. W. BEAN *'Dreadnought' of Darling* xv. 141 The pretty grey *needle-wood. **1936** F. CLUNE *Roaming round Darling* xxv. 286 Plenty of mulga, needlewood, belah, budda, and broad leaf-box. **1941** I. L. IDRIESS *Great Boomerang* i. 1 Upon a needlewood-tree a crow waited. *Ibid.* iii. 22 It [*sc.* the gold] lay by a needlewood bush. **1959** A. UPFIELD *Bony & Black Virgin* xiii. 111 He sat in the shade of the needlewood tree, or rather its trunk, for the narrow leaves give but scant shelter.**1766** *Compl. Farmer*, *Ascarides*, small worms common in horses, resembling needles… They are often called *needle~worms by the farriers. **1831** YOUATT *Horse* 210 A smaller, darker coloured worm, called the needle worm or *ascaris*, inhabits the large intestines.**1805** S. WESTON *Werneria* 95 Scapolite is not solvable in nitric acid,..in..which it differs from the *needle-zeolite. **1836** T. THOMSON *Min., Geol.*, etc. I. 314 Thomsonite.., needle zeolite of Werner in part.

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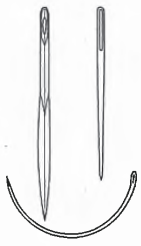
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needle
Sailmaking needle (*top left*), tapestry needle (*top right*), and curved embroidery needle (*bottom*)

necro– or **necr–** *pref.* **1.** Dead body; corpse: *necrophilia.* **2.** Death: *necrobiosis.* [Greek *nekro-*, from *nekros.* See **nek-**[1] in Appendix.]

nec·ro·bi·o·sis (nĕk′rō-bī-ō′sĭs) *n.* The natural death of cells or tissues through aging, as distinguished from necrosis or pathological death. —**nec′ro·bi·ot′ic** (-ŏt′ĭk) *adj.*

ne·crol·o·gy (nə-krŏl′ə-jē, nĕ-) *n., pl.* **-gies. 1.** A list of people who have died, especially in the recent past or during a specific period. **2.** An obituary. —**nec′ro·log′ic** (nĕk′rə-lŏj′ĭk), **nec′ro·log′i·cal** *adj.* —**ne·crol′o·gist** *n.*

nec·ro·man·cy (nĕk′rə-măn′sē) *n.* **1.** The practice of supposedly communicating with the spirits of the dead in order to predict the future. **2.** Black magic; sorcery. **3.** Magic qualities. [Alteration of Middle English *nigromancie*, from Old French *nigremancie*, from Medieval Latin *nigromantia*, alteration (influenced by Latin *niger*, black) of Late Latin *necromantia*, from Greek *nekromanteia* : *nekros*, corpse; see **nek-**[1] in Appendix + *manteia*, divination; see –MANCY.] —**nec′ro·man′cer** *n.* —**nec′ro·man′tic** (-măn′tĭk) *adj.*

ne·cro·pha·gia (nĕk′rə-fā′jə) *n.* The act or practice of feeding on dead bodies or carrion.

ne·croph·a·gous (nə-krŏf′ə-gəs, nĕ-) *adj.* Feeding on carrion or corpses: *necrophagous organisms.*

nec·ro·phil·i·a (nĕk′rə-fĭl′ē-ə) also **nec·roph′i·lism** (nĭ-krŏf′ə-lĭz′əm, nĕ-) *n.* **1.** Obsessive fascination with death and corpses. **2.** Erotic attraction to or sexual contact with corpses. —**nec′ro·phil′i·ac′** (-ē-ăk′) *adj.* & *n.* —**nec′ro·phile′** (-fīl′) *n.* —**nec′ro·phil′ic** (-fĭl′ĭk) *adj.*

nec·ro·pho·bi·a (nĕk′rə-fō′bē-ə) *n.* An abnormal fear of death or corpses. —**nec′ro·pho′bic** *adj.*

ne·crop·o·lis (nə-krŏp′ə-lĭs, nĕ-) *n., pl.* **-lis·es** or **-leis** (-lās′). A cemetery, especially a large and elaborate one belonging to an ancient city. [Greek *nekropolis* : *nekro-*, necro- + *polis*, city; see **pele-**[3] in Appendix.]

nec·rop·sy (nĕk′rŏp′sē) *n., pl.* **-sies.** See **autopsy** (sense 1). —**nec′rop′sy** *v.*

ne·crose (nĕ-krōs′, -krōz′, nĕk′rōs′, -rōz′) *intr. & tr.v.* **-crosed, -cros·ing, -cros·es.** To undergo or cause to undergo necrosis. [Back-formation from NECROSIS.]

ne·cro·sis (nə-krō′sĭs, nĕ-) *n., pl.* **-ses** (-sēz′). Death of cells or tissues through injury or disease, especially in a localized area of the body. [Late Latin *necrōsis*, a causing to die, killing, from Greek *nekrōsis*, death, from *nekroun*, to make dead, from *nekros*, corpse. See **nek-**[1] in Appendix.] —**ne·crot′ic** (-krŏt′ĭk) *adj.*

nec·ro·tize (nĕk′rə-tīz′) *intr. & tr.v.* **-tized, -tiz·ing, -tiz·es.** To undergo necrosis or cause to necrose.

ne·crot·o·my (nĭ-krŏt′ə-mē, nĕ-) *n., pl.* **-mies. 1.** Surgical excision of dead tissue. **2.** Dissection of a dead body.

nec·tar (nĕk′tər) *n.* **1.** A sweet liquid secreted by flowers of various plants, consumed by pollinators, such as hummingbirds and insects, and gathered by bees for making honey. **2.** *Greek & Roman Mythology.* The drink of the gods. **3.** A delicious or invigorating drink. [Latin, from Greek *nektar*. See **nek-**[1] in Appendix.] —**nec′tar·ous** *adj.*

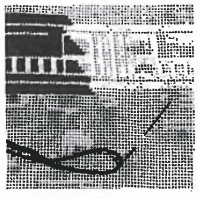
nec·tar·ine (nĕk′tə-rēn′) *n.* A variety of aromatic peach of ancient origin, having a smooth, waxy skin. [From obsolete *nectarine*, sweet as nectar, from NECTAR.]

nec·ta·ry (nĕk′tə-rē) *n., pl.* **-ries.** A glandlike organ, located outside or within a flower, that secretes nectar. [New Latin *nectārium*, from NECTAR.] —**nec·tar′i·al** (-târ′ē-əl) *adj.*

Ne·der·land (nē′dər-lănd′). A city of southeast Texas between Beaumont and Port Arthur. Population, 16,855.

née also **nee** (nā) *adj.* **1.** Born. Used to indicate the maiden name of a married woman. **2.** *Usage Problem.* Formerly known as. [French, feminine past participle of *naître*, to be born, from Old French *naistre*, from Latin *nāscī*. See **gen-** in Appendix.]

USAGE NOTE: The traditional conventions of address dictate that *née* or *nee* be followed only by a family name (which is, to be sure, the only name one has at birth): *Mrs. Mary Parks, née Case,* not *née Mary Case.* • *Née* is a feminine form in French, and both its spelling and its pronunciation indicate that it has not been fully nativized. Its use to describe men who have changed their names is likely to raise eyebrows among people who recognize the etymology of the word, unless the intention is clearly jocular. A phrase like *John Smith, née Schmidt,* would be more accurately—and less affectedly—paraphrased with an unexceptionally English word such as *born* or *formerly known as.*



needlepoint

need (nēd) *n.* **1.** A lack of something required or desirable: *crops in need of water; a need for affection.* **2.** Something required or wanted; a requisite: *Our needs are modest.* **3.** Necessity; obligation: *There is no need for you to go.* **4.** A condition of poverty or misfortune: *The family is in dire need.* —**need** *v.* **need·ed, need·ing, needs.** —**need** *aux.* To be under the necessity of or the obligation to: *They need not come.* —*tr.* To have need of; require: *The family needs money.* —*intr.* **1.** To be in need or want. **2.** To be necessary. [Middle English *nede*, from Old English *nēod, nēd*, distress, necessity.]

SYNONYMS: *need, necessity, exigency, requisite.* These nouns denote a condition in which something essential is required or wanted; they also refer to that which is required or wanted. *Need* is the most general: *There's no need to be concerned. She is serene and contented; her emotional and spiritual needs are being met. Necessity* more strongly than *need* suggests urgency, inevitability, or unavoidable obligation: *"I think the necessity of being ready increases.—Look to it"* (Abraham Lincoln). *"The rehabilitation of the cabin became a necessity"* (Bret Harte). *Exigency* implies acute urgency, especially that arising from conditions or circumstances such as those of an emergency: *"No . . . more pernicious* [doctrine] *was ever invented . . . than that any of* [the Constitution's] *provisions can be suspended during any of the great exigencies of government"* (David Davis) *Requisite* applies to something indispensable: *"a place where the three grand requisites of water, fuel and fodder were to be obtained"* (James Fenimore Cooper). See also Synonyms at **lack.**

USAGE NOTE: Depending on the sense, the verb *need* behaves sometimes like an auxiliary verb (such as *can* or *may*) and sometimes like a main verb (such as *want* or *try*). When used as a main verb, *need* agrees with its subject, takes *to* before the verb following it, and combines with *do* in questions, negations, and certain other constructions: *He needs to go. Does he need to go so soon? He doesn't need to go.* When used as an auxiliary verb, *need* does not agree with its subject, does not take *to* before the verb following it, and does not combine with *do*: *He needn't go. Need he go so soon?* The auxiliary forms of *need* are used primarily in present-tense questions, negations, and conditional clauses. They differ subtly in meaning from the main verb forms in that they always refer to an externally imposed obligation. Hence one might say *You needn't* (or less formally, *don't need to*) *fill out both forms,* but where the sense of necessity is internal to the subject, only the main verb can be used: *I don't need to* (not *needn't*) *be told how to manage my own affairs.* Note also that the use of *need* as an auxiliary is often accompanied by a presupposition that the activity in question has in fact been performed. *The boys needn't have spoken frankly* implies that they did in fact speak frankly, whereas the sentence *The boys did not need to speak frankly* does not; only the latter could be followed by a clause like *they conveyed their meanings by indirection.*

need·ful (nēd′fəl) *adj.* Necessary; required. See Synonyms at **indispensable.** —**need′ful·ly** *adv.* —**need′ful·ness** *n.*

Need·ham (nē′dəm). A town of eastern Massachusetts, a mainly residential suburb of Boston. Population, 27,901.

nee·dle (nēd′l) *n.* **1.a.** A small, slender implement used for sewing or surgical suturing, made usually of polished steel and having an eye at one end through which a length of thread is passed and held. **b.** Any one of various other implements, such as one used in knitting or crocheting. **2.** A small, pointed stylus used to transmit vibrations from the grooves of a phonograph record. **3.a.** A slender pointer or indicator on a dial, scale, or similar part of a mechanical device. **b.** A magnetic needle. **4.a.** A hypodermic needle. **b.** *Informal.* A hypodermic injection; a shot. **5.** A narrow stiff leaf, as those of conifers. **6.** A fine, sharp projection, as a spine of a sea urchin or a crystal. **7.** A sharp-pointed instrument used in engraving. **8.** *Informal.* A goading, provoking, or teasing remark or act. —**needle** *v.* **-dled, -dling, -dles.** —*tr.* **1.** To prick, pierce, or stitch with a small, slender, sharp-pointed implement. **2.** *Informal.* To goad, provoke, or tease. **3.** *Slang.* To increase the alcoholic content of (a beverage). —*intr.* To sew or do similar work with a small, slender, sharp-pointed implement. [Middle English *nedle*, from Old English *nēdl.* See **(s)nē-** in Appendix.] —**nee′dler** *n.*

nee·dle·craft (nēd′l-krăft′) *n.* The art or process of needlework.

nee·dle·fish (nēd′l-fĭsh′) *n., pl.* **needlefish** or **-fish·es.** 1. Any of several marine fishes of the family Belonidae, having slender bodies, needlelike teeth, and narrow jaws. **2.** Any of various other fishes, such as the pipefish, having projecting jaws.

needle grass *n.* See **feather grass.**

nee·dle·point (nēd′l-point′) *n.* **1.** Decorative needlework on canvas, usually in a diagonal stitch covering the entire surface of the material. **2.** A type of lace worked on paper patterns with a needle. In this sense, also called *point lace.* —**nee′dle·point′** *v.*

need·less (nēd′lĭs) *adj.* Not needed or wished for; unnecessary. —**need′less·ly** *adv.* —**need′less·ness** *n.*

needle valve *n.* A valve having a slender point fitting into a conical seat, used to regulate accurately the flow of a liquid or gas.

nee·dle·work (nēd′l-wûrk′) *n.* Work, such as sewing or embroidery, that is done with a needle.

need·n't (nēd′nt). Need not.

needs (nēdz) *adv.* Of necessity; necessarily: *We must needs go.* [Middle English *nedes*, from *nede*, from Old English *nēde*, genitive of *nēd*, necessity. See NEED.]

need·y (nē′dē) *adj.* **-i·er, -i·est.** Being in need; impoverished. See Synonyms at **poor.** —**need′i·ness** *n.*

Né·el (nā-ĕl′), **Louis Eugène Félix.** Born 1904. French physicist. He shared a 1970 Nobel Prize for his research on magnetism.

neem (nēm) *n.* A tall, usually evergreen East Indian tree (*Azadirachta indica*) widely cultivated in tropical Asia for its timber, resin, bitter bark, and aromatic seed oil. [Hindi *nīm*, from Sanskrit *nimbah.*]

Nee·nah (nē′nə). A city of eastern Wisconsin on Lake Winnebago north-northeast of Oshkosh. Population, 23,272.

ne'er (nâr) *adv.* Never.

ne'er-do-well (nâr′dōō-wĕl′) *n.* An idle, irresponsible person. —**ne'er′-do-well′** *adj.*

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Exhibit L

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Mechanical Engineering

SECOND EDITION

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AND
MARCEL ESCUDIER

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needle-roller bearing *See* BEARING.

needle valve A regulating valve with a relatively small outlet, a long tapered seat, and a needle-shaped plunger moved axially by a fine-threaded screw.

negative feedback Where the feedback in a closed-loop system is subtracted from the set point to give the error.

negative rake (Unit °) The inclination of the cutting tool in machining in the direction of cutting, so that rake angle, measured perpendicular to the cut surface, is negative. Often used with tools made of brittle materials since loading on the tool is mainly compressive.

neper (Np) The Naperian logarithm (i.e. logarithm to base *e*) of a ratio of two amplitudes. The conversion to SI is 1 Np = 8.685 890 dB.

Nernst heat theorem The entropy change for a chemical reaction between pure substances approaches zero as the absolute temperature approaches zero.

Nernst theorem *See* THIRD LAW OF THERMODYNAMICS.

net calorific value *See* CALORIFIC VALUE OF A FUEL.

net positive suction head (Unit m) The absolute pressure, in terms of head, of a liquid at the inlet to a suction pump less the vapour pressure of the liquid. It is a measure of the likelihood of cavitation.

netting analysis The materials-mechanics analysis of fibre-reinforced materials, assuming that loads are borne entirely by the filaments in tension, neglecting bending and shear, and ignoring any contribution from matrix material.

net weight (Unit N) The difference between the gross weight of any container including its contents and the tare weight of the empty container.

Neumann–Kopp rule (Kopp–Neumann law) An approximate empirical formula stating that the molar heat capacity *C* of a solid substance is equal to a weighted sum of the heat capacities of its constituents according to the equation

$$C = \sum_{i=1}^{N} x_i C_i$$

where x_i is the mass fraction of constituent i and C_i is its heat capacity.

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Exhibit M

THE AMERICAN HERITAGE® DICTIONARY OF THE ENGLISH LANGUAGE

THIRD EDITION



HOUGHTON MIFFLIN COMPANY
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gent is both sound and compelling: *cogent testimony; a cogent explanation. Convincing* implies the power to dispel doubt or overcome resistance or opposition: *convincing proof. Telling* means strikingly effective: *The attorney's summation was telling.*



Valkyrie

val·i·date (văl′ĭ-dāt′) *tr.v.* **-dat·ed, -dat·ing, -dates.** **1.** To declare or make legally valid. **2.** To mark with an indication of official sanction. **3.** To establish the soundness of; corroborate. See Synonyms at **confirm.** —**val′i·da′tion** *n.*

val·ine (văl′ēn′, vā′lēn′) *n.* An essential amino acid, $C_5H_{11}NO_2$. [VAL(ERIC ACID) + -INE².]

val·in·o·my·cin (văl′ə-nō-mī′sĭn) *n.* An antibiotic, $C_{54}H_{90}N_6O_{18}$, produced by the actinomycete B *Streptomyces fulvissimus,* that increases the transport of potassium across cell membranes. [VALIN(E) + -MYCIN.]

va·lise (və-lēs′) *n.* A small piece of hand luggage. [French, from Italian *valigia.*]

Val·i·um (văl′ē-əm). A trademark used for diazepam.

Val·kyr·ie (văl-kĭr′ē, -kĭr′rē, văl′kə-rē, văl′-) also **Wal·kyr·ie** (wăl-kĭr′ē, -kĭr′rē, wăl′-, wăl′kə-rē, văl′-) *n. Mythology.* Any of Odin's handmaidens who conducted the souls of the slain to Valhalla. [Old Norse *Valkyrja.* See **wele-** in Appendix.]

Val·la·do·lid (văl′ə-də-lĭd′, bä′lyä-*th*ō-lēth′). A city of northwest-central Spain north-northwest of Madrid. It became the chief residence of the Castilian court in the mid-15th century and was the site of the marriage of Ferdinand and Isabella in 1469. Population, 331,404.

val·la·tion (vă-lā′shən) *n.* **1.** An earthwork wall used for military defense; a rampart. **2.** The process of planning or erecting earth fortifications. [Late Latin *vallātiō, vallātiōn-,* from Latin *vallātus,* past participle of *vallāre,* to surround with a rampart, from *vallum,* rampart, from *vallus,* stake.] —**val′la·to′ry** (văl′ə-tôr′ē, -tōr′ē) *adj.*

val·lec·u·la (vă-lĕk′yə-lə, və-) *n., pl.* **-lae** (-lē′). A shallow groove, depression, or furrow, as between the hemispheres of the brain. [Late Latin, diminutive of Latin *vallēs,* valley.] —**val·lec′u·lar, val·lec′u·late** (-lĭt, -lāt′) *adj.*

Val·le d'A·os·ta (văl′lā dä-ō′stə, -ô′stä). A region of northwest Italy bordering on France and Switzerland. Separated from Piedmont in the 1940's, it has a predominantly French linguistic and cultural heritage.

Val·le·jo (və-lā′ō, -hō). A city of western California on San Pablo Bay north of Oakland. It is a trade and processing center and has a large naval shipyard, founded by Adm. David Farragut in 1854. Population, 80,188.

Val·let·ta (və-lĕt′ə). The capital of Malta, on the northeast coast of the main island. Dating to the 16th century, it contains many relics of the Knights of Malta. Population, 14,013.

val·ley (văl′ē) *n., pl.* **-leys.** *Abbr.* **val.** **1.** An elongated lowland between ranges of mountains, hills, or other uplands, often having a river or stream running along the bottom. **2.** An extensive area of land drained or irrigated by a river system. **3.** A depression or hollow resembling or suggesting a valley, as the point at which the two slopes of a roof meet. [Middle English *valey,* from Old French *valee,* from Vulgar Latin **vallāta,* from Latin *vallēs.* See **wel-²** in Appendix.] —**val′leyed** *adj.*



vambrace
c. 1550 Spanish

Val·ley East (văl′ē). A town of central Ontario, Canada, a suburb of Sudbury. Population, 20,433.

valley fever *n.* See **coccidioidomycosis.**

Val·ley·field (văl′ē-fēld′). A city of southern Quebec, Canada, on the St. Lawrence River southwest of Montreal. It is a port of entry and an industrial center. Population, 29,574.

Valley Forge. A village of southeast Pennsylvania on the Schuylkill River northwest of Philadelphia. It was the site of the Continental Army headquarters from December 1777 to June 1778. The encampment was subjected to severe winter weather that caused extensive illness and suffering.

Valley of Ten Thou·sand Smokes (tĕn′ thou′zənd smōks′). A volcanic region of southwest Alaska at the upper end of the Alaska Peninsula. It was formed by the eruption of Mount Katmai in 1912 and continues to emit hot gases through countless cracks in the surface.

Valley of the Kings (kĭngz). A narrow valley of east-central Egypt surrounding the site of ancient Thebes between Karnak and Luxor. The valley contains the tombs of numerous pharaohs of the XVIII, XIX, and XX Dynasties, including that of Tutankhamen.

Valley Stream. A village of southeast New York on southwest Long Island. It is mainly residential. Population, 35,769.

Va·lois¹ (văl′wä, văl-wä′). A French ruling dynasty (1328–1589) that succeeded the Capetian line when Philip VI ascended to the throne.

Va·lois² (văl′wä′, văl-wä′). A historical region and former duchy of northern France. A county from the 10th to the 12th century, it was an appanage of the royal house of Valois after 1285.

va·lo·ni·a (və-lō′nē-ə, -lōn′yə) *n.* The dried acorn cups of an oak tree *(Quercus aegilops)* of the eastern Mediterranean, used chiefly in tanning and dyeing. [Italian *vallonia,* from Modern Greek *balania,* pl. of *balani,* acorn, from Greek *balanos.*]

val·or (văl′ər) *n.* Courage and boldness, as in battle; bravery. [Middle English *valour,* from Old French, from Late Latin *valor,* from Latin *valēre,* to be strong. See **wal-** in Appendix.]

val·or·ize (văl′ə-rīz′) *tr.v.* **-ized, -iz·ing, -iz·es.** **1.** To establish and maintain the price of (a commodity) by governmental action. **2.** To give or assign a value to: *"The prophets valorized history"* (Mircea Eliade). [Portuguese *valorizar,* from *valor,* value, from Late Latin. See VALOR.] —**val′or·i·za′tion** (-ər-ĭ-zā′shən) *n.*

val·or·ous (văl′ər-əs) *adj.* Marked by or possessing great personal bravery; valiant. See Synonyms at **brave.** —**val′or·ous·ly** *adv.* —**val′or·ous·ness** *n.*

val·our (văl′ər) *n. Chiefly British.* Variant of **valor.**

Val·pa·rai·so (văl′pə-rī′zō). **1.** Also **Val·pa·ra·i·so** (băl′pä-rä-ē′sō). A city of central Chile on the Pacific Ocean west-northwest of Santiago. Founded in 1536, it has frequently been subject to severe earthquakes. The modern city developed as an industrial center and the chief port of Chile in the early 20th century. Population, 265,355. **2.** A city of northwest Indiana southeast of Gary. It is a manufacturing and educational center. Population, 22,247.

val·pro·ate (văl-prō′āt) *n.* An anticonvulsive drug, $C_8H_{15}NaO_2$, given orally in the treatment of epilepsy. [*valproic acid*] (VAL(ERIC ACID) + PRO(PYL) + -IC) + -ATE².]

Val·sal·va maneuver (văl-săl′və) *n.* **1.** Expiratory effort when the mouth is closed and the nostrils are pinched shut, which forces air into the eustachian tubes and increases pressure on the inside of the eardrum. **2.** Expiratory effort against a closed glottis, which increases pressure within the thoracic cavity and thereby impedes venous return of blood to the heart. [After Antonio Maria *Valsalva* (1666–1723), Italian anatomist.]

val·u·a·ble (văl′yōō-ə-bəl, văl′yə-) *adj.* **1.** Having considerable monetary or material value for use or exchange: *a valuable diamond.* **2.** Of great importance, use, or service: *valuable information; valuable advice.* **3.** Having admirable or esteemed qualities or characteristics: *a valuable friend.* —**valuable** *n.* A personal possession, such as a piece of jewelry, having a relatively high monetary value. Often used in the plural. —**val′u·a·ble·ness** *n.* —**val′u·a·bly** *adv.*

val·u·ate (văl′yōō-āt′) *tr.v.* **-at·ed, -at·ing, -ates.** To set a value for; appraise. [Back-formation from VALUATION.]

val·u·a·tion (văl′yōō-ā′shən) *n. Abbr.* **val.** **1.** The act or process of assessing value or price; an appraisal. **2.** Assessed value or price. **3.** An estimation of worth, merit, or character: *set a high valuation on friendship.* —**val′u·a′tion·al** *adj.*

val·u·a·tor (văl′yōō-ā′tər) *n.* One that estimates values; an appraiser.

val·ue (văl′yōō) *n. Abbr.* **val.** **1.** An amount, as of goods, services, or money, considered to be a fair and suitable equivalent for something else; a fair price or return. **2.** Monetary or material worth: *the fluctuating value of gold and silver.* **3.** Worth in usefulness or importance to the possessor; utility or merit: *the value of an education.* **4.** A principle, standard, or quality considered worthwhile or desirable: *"The speech was a summons back to the patrician values of restraint and responsibility"* (Jonathan Alter). **5.** Precise meaning or import, as of a word. **6.** *Mathematics.* An assigned or calculated numerical quantity. **7.** *Music.* The relative duration of a tone or rest. **8.** *Color.* The relative darkness or lightness of a color: *"I establish the colors and principal values by organizing the painting into three values—dark, medium . . . and light"* (Joe Hing Lowe). **9.** *Linguistics.* The sound quality of a letter or diphthong. **10.** One of a series of specified values: *issued a stamp of new value.* —**value** *tr.v.* **-ued, -u·ing, -ues.** **1.** To determine or estimate the worth or value of; appraise. **2.** To regard highly; esteem. See Synonyms at **appreciate.** **3.** To rate according to relative estimate of worth or desirability; evaluate: *valued health above money.* **4.** To assign a value to (a unit of currency, for example). [Middle English, from Old French, from feminine past participle of *valoir,* to be strong, be worth, from Latin *valēre.* See **wal-** in Appendix.] —**val′u·er** *n.*

val·ue-add·ed (văl′yōō-ăd′ĭd) *adj.* Of or relating to the estimated value that is added to a product or material at each stage of its manufacture or distribution: *"Unlike the steel or aluminum industries, where heavier profits come from value-added fabrication, mining is the most lucrative stage of copper production"* (Forbes).

value-added tax *n. Abbr.* **VAT, V.A.T.** A tax on the estimated market value added to a product or material at each stage of its manufacture or distribution, ultimately passed on to the consumer.

val·ued policy (văl′yōōd) *n.* An insurance policy requiring the insurer to pay the insured the full face value of the policy in the event of total loss, regardless of the actual value of the lost property.

value judgment *n.* A judgment that assigns a value, as to an object or action; a subjective evaluation.

val·ue·less (văl′yōō-lĭs) *adj.* Having no value; worthless. —**val′ue·less·ness** *n.*

val·var (văl′vər) *adj.* Valvular.

val·vate (văl′vāt′) *adj.* **1.** Having valvelike parts. **2.** *Botany.* **a.** Meeting at the edges without overlapping, as some petals do. **b.** Opening by valves, as the capsule of a lily or iris.

valve (vălv) *n.* **1.** *Anatomy.* A membranous structure in a hollow organ or passage, as in an artery or a vein, that folds or closes to prevent the return flow of the body fluid passing through it. **2.a.** Any of various devices that regulate the flow of gases, liquids, or loose materials through piping or through apertures by opening, closing, or obstructing ports or passageways. **b.** The

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movable control element of such a device. **c.** *Music.* A device in a brass wind instrument that permits change in pitch by a rapid varying of the air column in a tube. **3.** *Biology.* **a.** One of the paired, hinged shells of certain mollusks and of brachiopods. **b.** One of the two silicified halves of the cell wall of a diatom. **c.** The entire, one-piece shell of a snail and certain other mollusks. **4.** *Botany.* **a.** One of the sections into which the wall of a seedpod or other dehiscent fruit splits. **b.** A lidlike covering of an anther. **5.** *Chiefly British.* An electron tube or a vacuum tube. **6.** *Archaic.* Either half of a double or folding door. —**valve** *tr.v.* **valved, valv·ing, valves.** **1.** To provide with a valve. **2.** To control by means of a valve. [Middle English, leaf of a door, from Latin *valva*. See **wel-**[2] in Appendix.] —**valve′less** *adj.*

valve-in-head engine (välv′ĭn-hĕd′) *n.* An internal-combustion engine, as in some automobiles, that has the inlet and exhaust valves in the cylinder head instead of in the engine block.

val·vu·la (väl′vyə-lə) *n.* Variant of **valvule.**

val·vu·lar (väl′vyə-lər) *adj.* Relating to, having, or operating by means of valves or valvelike parts.

val·vule (väl′vyōol′) also **val·vu·la** (-vyə-lə) *n., pl.* **-vules** also **-vu·lae** (-vyə-lē′). A small valve or valvelike structure.

val·vu·li·tis (väl′vyə-lī′tĭs) *n.* Inflammation of a valve, especially a cardiac valve.

val·vu·lo·plas·ty (väl′vyə-lə-plăs′tē) *n., pl.* **-ties.** Plastic surgery to repair a valve, especially a heart valve.

vam·brace (văm′brās′) *n.* Armor used to protect the forearm. (Middle English *vambras*, from Anglo-Norman *vauntbras* : *vaunt* (variant of Old French *avaunt*, before; see VANGUARD) + *bras*, arm; see BRACER[2].]

va·moose (vă-mōōs′, və-) *intr.v.* **-moosed, -moos·ing, -moos·es.** *Slang.* To leave hurriedly. [From Spanish *vamos*, let's go, from Latin *vādāmus*, first person pl. subjunctive of *vādere*, to go.]

vamp[1] (vămp) *n.* **1.** The upper part of a boot or shoe covering the instep and sometimes extending over the toe. **2.a.** Something patched up or refurbished. **b.** Something rehashed, as a book based on old material. **3.** *Music.* An improvised accompaniment. —**vamp** *v.* **vamped, vamp·ing, vamps.** —*tr.* **1.** To provide (a shoe) with a new vamp. **2.** To patch up (something old); refurbish. **3.** To put together; fabricate or improvise: *With no hard news available about the summit meeting, the reporters vamped up questions based only on rumor.* **4.** *Music.* To improvise (an accompaniment, for example) for a solo. —*intr. Music.* To improvise simple accompaniment or variation of a tune. [Middle English *vampe*, sock, from Old French *avanpie* : *avaunt*, before; see VANGUARD + *pie*, foot (from Latin *pēs*; see **ped-** in Appendix).] —**vamp′er** *n.*

vamp[2] (vămp) *Informal. n.* An unscrupulous, seductive woman who uses her sex appeal to entrap and exploit men. —**vamp** *v.* **vamped, vamp·ing, vamps.** —*tr.* To seduce or exploit (someone) in the manner of a vamp. —*intr.* To play the part of a vamp. [Short for VAMPIRE.] —**vamp′ish** *adj.* —**vamp′ish·ly** *adv.* —**vamp′y** *adj.*

vam·pire (văm′pīr′) *n.* **1.** A reanimated corpse that is believed to rise from the grave at night to suck the blood of sleeping people. **2.** A person, such as an extortionist, who preys upon others. **3.** A vampire bat. [French, from German *Vampir*, of Slavic origin.] —**vam·pir′ic** (văm-pĭr′ĭk), **vam·pir′i·cal** (-ĭ-kəl), **vam′pir·ish** (-ĭsh) *adj.*

WORD HISTORY: Dracula might terrify some younger members in the audience of a horror film, but we know he is an imaginary creature. The word *vampire*, however, comes to us from other words and other times, when these bloodsucking reanimated corpses were considered real. The word entered English by way of French (*vampire*) and German (*Vampir*), but it came into German from an Old West Slavic source of the form **vŭmpir*. The word *vampire* is first recorded in English in a work written before 1734.

vampire bat *n.* **1.** Any of various tropical American bats of the family Desmodontidae that bite mammals and birds to feed on their blood and that often carry diseases such as rabies. **2.** Any of various other bats, as those of the family Megadermatidae, erroneously believed to feed on blood.

vam·pir·ism (văm′pĭr-ĭz′əm) *n.* **1.** Belief in vampires. **2.** The behavior of a vampire.

van[1] (văn) *n.* **1.a.** An enclosed boxlike motor vehicle having rear or side doors and side panels especially for transporting people. **b.** A covered or enclosed truck or wagon often used for transporting goods or livestock. **2.** *Chiefly British.* A closed railroad car used for carrying baggage or freight. —**van** *v.* **vanned, van·ning, vans.** —*tr.* To transport by van: *vanned the horses to the racetrack.* —*intr.* To drive or travel in a van: *vanned around the country.* [Short for CARAVAN.]

van[2] (văn) *n.* The vanguard; the forefront. [Short for VANGUARD.]

van[3] (văn) *n.* **1.** A wing. **2.** *Archaic.* A winnowing device, such as a fan. [Middle English, from Old English *fann* and Old French *van*, both from Latin *vannus*. See **wet-**[1] in Appendix.]

Van (văn, vän), **Lake.** A salt lake of eastern Turkey. The largest lake in the country, it has no known outlet.

van·a·date (vān′ə-dāt′) *n.* Any of three anions, VO_3, VO_4, or V_2O_7, containing pentavalent vanadium. [VANAD(IUM) + -ATE[2].]

va·na·dic acid (və-nā′dĭk, -năd′ĭk) *n.* **1.** An acid containing a vanadate group, especially HVO_3, H_3VO_4, or $H_4V_2O_7$, not existing in a pure state. **2.** See **vanadium pentoxide.**

va·na·di·nite (və-năd′n-īt′, -năd′-, vān′ə-dē′nīt′) *n.* A red, yellow, or brown mineral, essentially an ore of vanadium and lead. [VANAD(IUM) + -IN + -ITE[1].]

va·na·di·um (və-nā′dē-əm) *n. Symbol* **V** A bright white, soft, ductile metallic element found in several minerals, notably vanadinite and carnotite, having good structural strength and used in rust-resistant high-speed tools, as a carbon stabilizer in some steels, as a titanium-steel bonding agent, and as a catalyst. Atomic number 23; atomic weight 50.942; melting point 1,890°C; boiling point 3,000°C; specific gravity 6.11; valence 2, 3, 4, 5. See table at **element.** [From Old Norse *Vanadīs*, the goddess Freya. See **wen-**[1] in Appendix.]

vanadium pentoxide *n.* A yellow to red crystalline powder, V_2O_5, used as a catalyst in various organic reactions and as a starting material for other vanadium salts. Also called *vanadic acid.*

vanadium steel *n.* Steel alloyed with vanadium for added strength, hardness, and high-temperature stability.

Van Al·len belt (văn ăl′ən) *n.* Either of two zones of high-intensity particulate radiation trapped in Earth's magnetic field and surrounding the planet, beginning at an altitude of about 800 kilometers (500 miles) and extending tens of thousands of kilometers into space. [After James Alfred *Van Allen* (born 1914), American physicist.]

Van·brugh (văn′brə, văn-brōō′), Sir **John.** 1664–1726. English playwright and architect who wrote *The Provok'd Wife* (produced 1697) and designed Blenheim Palace.

Van Bu·ren (văn byōōr′ən), **Martin.** 1782–1862. The eighth President of the United States (1837–1841). A powerful Democrat from New York, he served in the U.S. Senate (1821–1828), as secretary of state (1829–1831), and as Vice President (1833–1837) under Andrew Jackson before being elected President in 1836. He unsuccessfully sought reelection in 1840 and 1848.

van·co·my·cin (văng′kə-mī′sĭn, văn′kə-) *n.* An antibiotic, $C_{66}H_{75}Cl_2N_9O_{24}$, produced by the actinomycete *Streptomyces orientalis*, found in Indonesian and Indian soil, and effective against staphylococci and spirochetes. [*vanco-* (of unknown origin) + -MYCIN.]

Van·cou·ver (văn-kōō′vər). **1.** A city of southwest British Columbia, Canada, on the Strait of Georgia opposite Vancouver Island. The largest city in the province, it is a major port, commercial and industrial center, and railroad hub. Population, 414,281. **2.** A city of southwest Washington on the Columbia River opposite Portland, Oregon. Founded as Fort Vancouver by the Hudson's Bay Company in the 1820's, it is a deep-water port with shipyards, lumber mills, and other processing facilities. Population, 42,834.

Vancouver, George. 1757–1798. British navigator who led an expedition to the coasts of Australia, New Zealand, and the Hawaiian Islands (1791–1792) and to the Pacific coast of North America (1792–1794).

Vancouver, Mount. A peak, 4,873.6 m (15,979 ft) high, in the St. Elias Mountains of southwest Yukon Territory, Canada, near the border of Alaska.

Vancouver Island. An island of southwest British Columbia, Canada, in the Pacific Ocean separated from the mainland by the Strait of Georgia and Queen Charlotte Strait. The Strait of Juan de Fuca flows between the southern end of the island and the coastline of northwest Washington. First sighted by Spanish explorers in 1774 and visited by Capt. James Cook in 1778, it was named in honor of Capt. George Vancouver, who circumnavigated the island in 1792.

Van·dal (văn′dl) *n.* **1. vandal.** One who willfully or maliciously defaces or destroys public or private property. **2.** A member of a Germanic people that overran Gaul, Spain, and northern Africa in the fourth and fifth centuries A.D. and sacked Rome in 455. [Latin *Vandalus*, probably of Germanic origin.] —**Van·dal′ic** (văn-dăl′ĭk) *adj.*

van·dal·ism (văn′dl-ĭz′əm) *n.* Willful or malicious destruction of public or private property. —**van′dal·is′tic** *adj.*

van·dal·ize (văn′dl-īz′) *tr.v.* **-ized, -iz·ing, -iz·es.** To destroy or deface (public or private property) willfully or maliciously. —**van′dal·i·za′tion** (-ĭ-zā′shən) *n.*

Van de Graaff generator (văn′ də grăf′) *n.* An electrostatic generator in which an electric charge is either removed from or transferred to a large hollow spherical electrode by a rapidly moving belt, accelerating particles to energies of about ten million electron volts. [After Robert Jemison *Van de Graaff* (1901–1967), American physicist.]

Van·der·bilt (văn′dər-bĭlt′), **Cornelius.** Known as "Commodore Vanderbilt." 1794–1877. American transportation promoter and financier who amassed a great fortune through railroad and shipping interests. His heirs included his son **William Henry** (1821–1885), a financier and philanthropist, and William Henry's sons **Cornelius** (1843–1899), a railroad director; **William Kissam** (1849–1920), a railroad executive and philanthropist; **Frederick William** (1856–1938), a railroad manager; and **George Washington** (1862–1914), who commissioned Biltmore, located in Asheville, North Carolina, the largest private home in America.

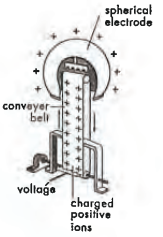
Van Der Ro·he (văn dər rō′ə, fän). See Ludwig **Mies Van Der Rohe.**



vampire bat



Martin Van Buren



Van de Graaff generator

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Stress marks: ′ (primary); ˌ (secondary), as in **dictionary** (dĭk′shə-nĕr′ē)

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Exhibit N

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valve Any of various manual or automatic devices that are able to initiate, regulate, or stop the flow of a fluid through a conduit or from a closed container.

valve bounce The tendency of a valve in a piston engine to be open when it should be closed, usually due to overspeeding or spring resonance. Particularly at high engine speed, a valve may no longer follow the cam profile but assumes a partially open state (**valve float**).

valve disc That part of a valve, such as a gate valve, in which there is an orifice to permit flow when the valve is actuated to the open position. Wedge shapes and parallel discs are the most common.

valved pulse jet *See* PULSE-JET ENGINE.

valve face The bevelled surface of a valve that seals against the valve seat.

valve gear Any of various mechanisms by which valves in a piston engine are opened and closed at the correct time in a cycle.

valve guide The cylindrical hole, usually containing a bushing, in the cylinder head or block of a piston engine, which aligns the stem of a poppet valve.

valve head The mushroom-shaped disc of a poppet valve containing the sealing face.

valve insert A hard-wearing alloy-steel valve seat pressed into the head of a high-performance piston engine.

valveless engine *See* PULSE-JET ENGINE.

valve lifter **1.** A device for compressing the valve springs of piston engines in order to permit valve removal. **2.** A similar device employed on motor-cycle engines when stopped on top-dead centre to enable the crankshaft to be rotated, and hence the engine started. **3.** *See* TAPPET.

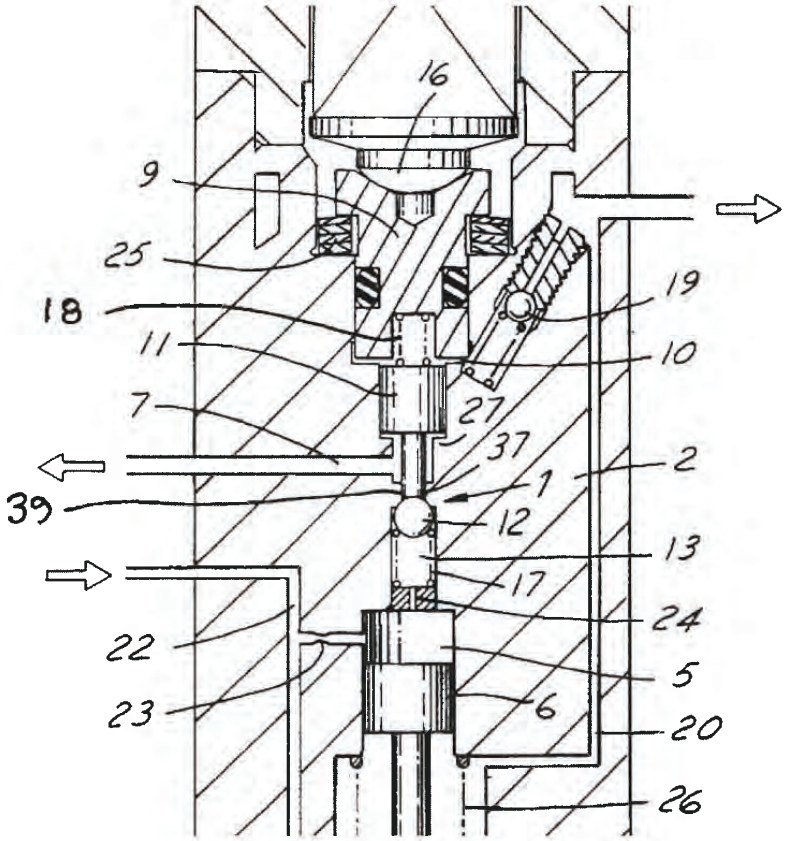
valve overlap (Unit °) In a reciprocating engine, the crankshaft rotation between the opening of the inlet valve and the closing of the exhaust valve.

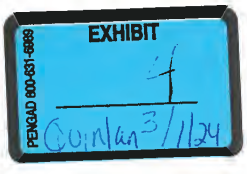
valve plug A conical or cylindrical plug, in which there are transverse holes, in a valve, such as a plug valve. Flow through the holes occurs when the plug is rotated.

valve port Any opening in a valve through which fluid can flow.

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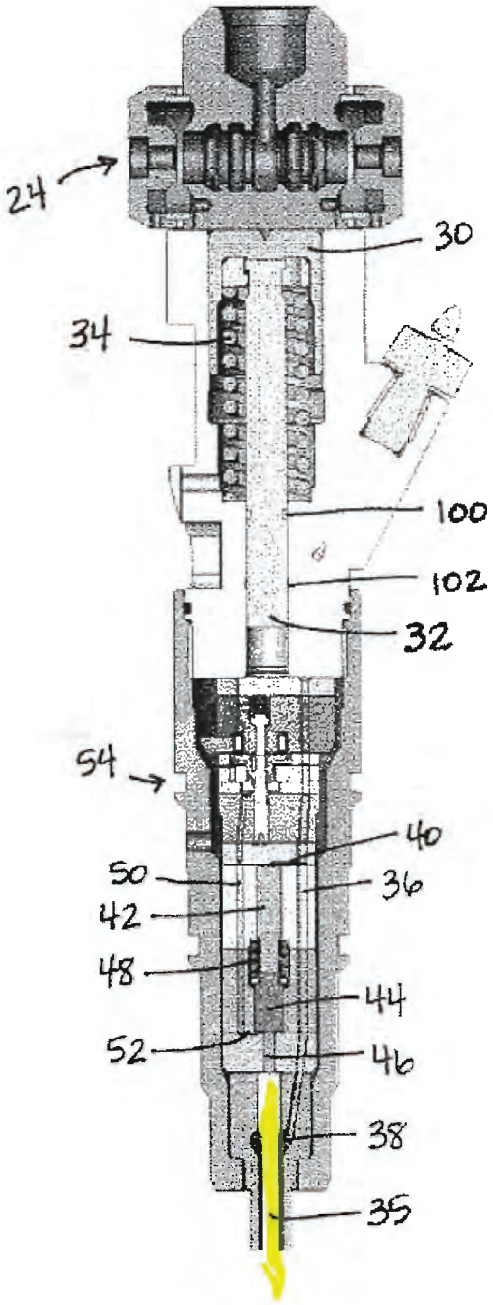

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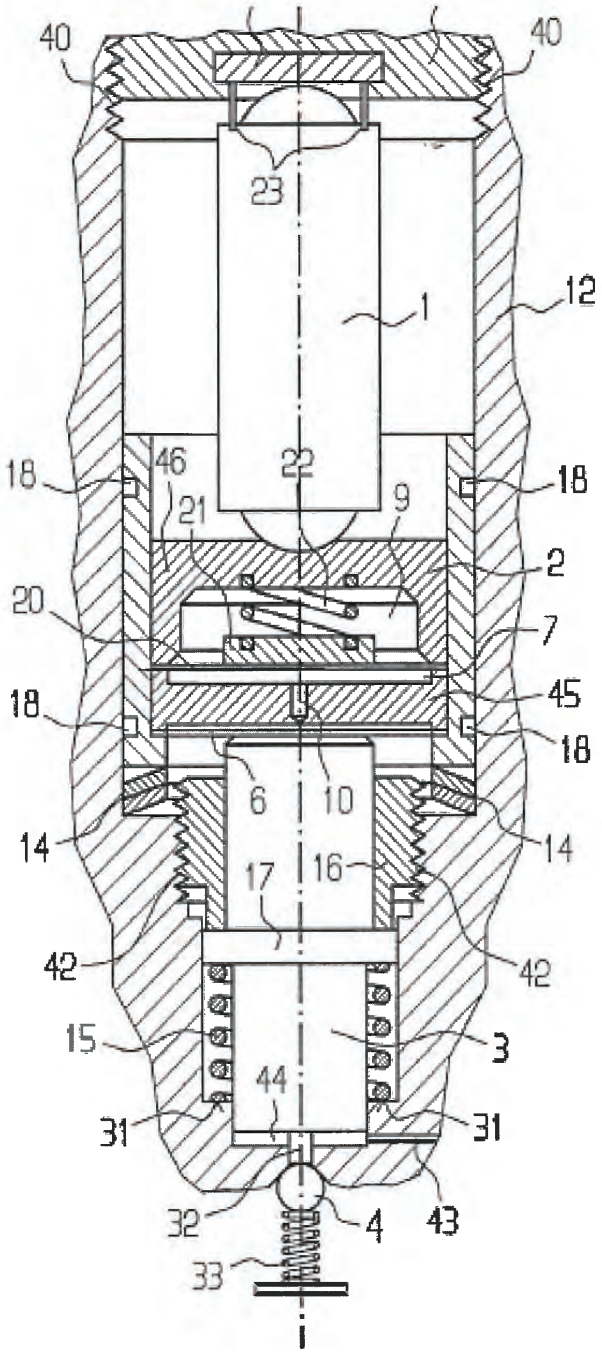

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