

THE SULLIVAN GROUP OF COURT REPORTERS

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UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN TUOZHU TECHNOLOGY CO., LTD,

Petitioner,

v.

STRATASYS, INC.,

Patent Owner.

Case IPR2025-00531 (US Patent No 9,168,698)
Ref. 56224-0008IP1

Case IPR2025-00532 (US Patent No 10,556,381)
Ref. 56224-0009IP1

VIDEOCONFERENCE DEPOSITION OF

DR. TIM A. OSSWALD

MAY 6, 2026

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6:59 a.m. - 10:20 a.m.

REPORTED BY:

Tamara L. Houston

CA CSR No. 7244, RPR, CCRR No. 140

Job Number J14709605

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REMOTE VIDEOCONFERENCE DEPOSITION OF Dr. Tim A. Osswald, taken on behalf of the Petitioner, commencing from 6:59 a.m. to 10:20 a.m., Wednesday, May 6, 2026, before Tamara L. Houston, CSR No. 7244, CCRR, RPR.

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1 APPEARANCE OF COUNSEL:

2

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WEDNESDAY, MAY 6, 2026, 6:59 a.m.

--o0o--

All counsel present stipulate
that the witness shall be sworn remotely
by the court reporter

* * *

COURT REPORTER: My name is Tamara Houston,
California Certified Shorthand Reporter, License Number
7244.

Whereupon, DR. TIM A. OSSWALD, having been
called as a witness was duly sworn
to tell the truth, the whole truth,
and nothing but the truth testified
as follows:

EXAMINATION BY MR. BROWN:

Q. Good morning, Dr. Osswald.

Can you please state your name for the record?

A. Tim Andreas Osswald.

Q. And please state your city of residence.

A. Madison, Wisconsin.

Q. And where are you located today? Are you in
Madison?

A. Yes.

Q. And you understand that we are here today
regarding two IPR proceedings; IPR Number 2025-00531,

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1 and 2025-00532 regarding U.S. Patent Numbers 9,168,698,
2 and 10,556,381; is that right?

3 A. Yes.

4 Q. Okay. And you understand you're taking this
5 deposition under oath, right?

6 A. Yes.

7 Q. And this is the same oath as if you were in a
8 court.

9 Do you understand that?

10 A. Correct.

11 Q. And you understand you have to tell the truth
12 and nothing but the truth, and you'll do that today; is
13 that right?

14 A. Yes.

15 Q. Okay. If you ever don't understand a
16 question, will you let me know? Okay?

17 A. Yes.

18 Q. And so if you answer a question, I will assume
19 that you understood the question; is that fair?

20 A. Correct.

21 Q. We'll try to take breaks about every hour, but
22 if you need a break at any point, please just let me
23 know, and we can do our best and wrap up and get you to
24 a break.

25 Is that okay?

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1 A. Okay.

2 Q. And the court reporter is typing everything
3 today for a transcript.

4 Do you understand that?

5 A. Yes.

6 Q. So we can make her job easier if we don't
7 speak over each other and if you stick with verbal
8 answers like "yes" or "no" instead of nodding your head.

9 Is that okay?

10 A. Yes.

11 Q. You're doing a great job already, so thank
12 you.

13 Is there any reason that you cannot give
14 truthful, complete, and accurate testimony today?

15 A. No.

16 Q. And if that changes at any point, it's
17 important that you inform me immediately. Okay?

18 A. Okay.

19 Q. Is there anyone else in the room with you
20 today?

21 A. No.

22 Q. Do you have any documents with you?

23 A. No.

24 Q. Do you have any notes?

25 A. No.

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1 Q. And do you have anything on your computer open
2 other than this Zoom window?

3 A. Yes. Here, let me close them. There, quit,
4 and I'll quit my e-mail. I think that's it.

5 Q. Okay. So you don't have any messaging
6 services or systems open on your computer anymore?

7 A. No.

8 Q. Okay. Please let me know if that changes.
9 Okay?

10 A. Okay.

11 Q. Do you have copies of your report on your
12 computer or printed with you?

13 A. I would have them on my computer but not
14 printed here with me.

15 Q. Okay. And I think you just said that you
16 don't have them open right now; is that correct?

17 A. No.

18 Q. Okay. So there are several terms I'll be
19 using today, and I want to make sure we're on the same
20 page for; is that okay?

21 A. Yes.

22 Q. When I use the terms "patent owner" or
23 "Stratasys," I'm referring to Stratasys, Incorporated,
24 the patent owner in this proceeding.

25 Do you understand that?

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1 A. Yes.

2 Q. And when I use the term '698 patent, I'm
3 referring to U.S. Patent Number 9,168,698.

4 Do you understand that?

5 A. Yes.

6 Q. And similarly, when I use the term '381
7 patent, I'm referring to U.S. Patent Number 10,556,381.

8 Do you understand that?

9 A. Yes.

10 Q. And if I use the term "these IPRs" or "these
11 proceedings," something like that, I'm referring to the
12 proceeding numbers IPR 2025-00531 and 532 filed against
13 the '698 and '381 patents.

14 Do you understand that?

15 A. Yes.

16 Q. Okay. And do you understand that the patents,
17 the '698 patent, '381 patent are Exhibits 1001 in their
18 respective proceedings?

19 A. Yes.

20 Q. Okay. And you've reviewed those patents
21 before; is that right?

22 A. Yes.

23 Q. Great. And when I use the acronym POSITA or
24 POSITA, I'm referring to a person of ordinary skill in
25 the art at the time of the alleged invention.

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1 Do you understand that?

2 A. Yes.

3 Q. Okay. Great. So in these proceedings you've
4 submitted two declarations.

5 Is that right?

6 A. Correct.

7 Q. One declaration was for -- or addressed to the
8 '381 patent, right?

9 A. Yes.

10 Q. And I believe that declaration is Exhibit 2027
11 in the respective proceeding.

12 Does that sound right?

13 A. That sounds right.

14 Q. Okay. And it was dated January 30th, 2026.

15 Is that right?

16 A. Yeah, I believe you. I mean, I don't have it
17 in front of me. That sounds about right.

18 Q. Okay. And that you also submitted a
19 declaration for the '698 patent.

20 Is that right?

21 A. Yes.

22 Q. And that was also Exhibit 2027 in that
23 proceeding, correct?

24 A. That sounds about right. Yes.

25 Q. And it was also dated the same date,

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1 January 30th, 2026.

2 Does that sound right?

3 A. It sounds right, yes.

4 Q. Okay. Let's go ahead and -- I'm going to put
5 these two declarations into the Zoom chat. They are
6 both labeled Exhibit 2027. The patent number has
7 been -- the last two digits of the patent number have
8 been appended to the end.

9 Can you go ahead and download those and open
10 them when you get a chance. Let me know when you have
11 them open.

12 A. They're open.

13 Q. Okay. Let's take a look at the '381 patent
14 first.

15 Can you go ahead and open that document and
16 pull it up?

17 A. Yes.

18 Q. Okay. And this looks like the declaration
19 that you submitted with respect to the '381 patent.

20 Is that right?

21 A. Correct.

22 Q. Okay. And if you scroll to page 126 of the
23 PDF. Let me know when you're there.

24 A. Yes.

25 Q. This is your signature on that declaration,

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1 correct?

2 A. Yes.

3 Q. And it was dated on January 30th, 2026, right?

4 A. Yeah.

5 Q. Okay. Great. Let's put the other one, the
6 '698 --

7 Does this look like the declaration that you
8 submitted with respect to the '698 patent?

9 A. Yes.

10 Q. And, again, if you scroll to the signature
11 page, it should be again 126 on the PDF.

12 Let me know when you're there.

13 A. Yes.

14 Q. And this is your signature on page 122 of the
15 declaration, correct?

16 A. Yes.

17 Q. And it's dated January 30th, 2026?

18 A. Yes.

19 Q. So you understand that these two patents, the
20 '698 and '381 patents, are related patents, right?

21 A. Correct.

22 Q. And both these patents claim priority to the
23 same original disclosure.

24 Is that right?

25 A. Yes.

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1 Q. And so that means that both these have the
2 same priority date, right?

3 A. Yes.

4 Q. And that priority date that you used for this
5 declaration is October 29, 2012, correct?

6 A. Yes, as I recall.

7 Q. Okay. And the two patents share substantially
8 the same specification.

9 Is that right?

10 A. Correct.

11 Q. And this is why your declarations have a large
12 amount of overlapping opinions.

13 Is that fair?

14 A. Yes.

15 Q. What are the primary differences between the
16 inventions in the '381 and '698 patents?

17 A. One of them is a method patent, the '698. And
18 the '381 is a product. I don't remember the term. It's
19 a piece of equipment method. And the '381 requires
20 computation, calculating a force.

21 Q. Okay. And so I think you were saying --
22 looking for maybe the word "system patent"; is that
23 right?

24 A. Yes.

25 Q. Can you think of any other primary

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1 differences, or is that -- does that cover it?

2 A. No, there are other differences, but, I mean,
3 I think that's a bird's eye view of them. I'd have to
4 go back and look at the detail.

5 Q. That's the main difference that you remember.
6 Is that fair?

7 A. That I remember right now, yes.

8 Q. Did you review any materials to prepare for
9 this deposition today?

10 A. Yes.

11 Q. What did you review?

12 A. These two documents, the references.

13 Q. The two patents; is that what you mean?

14 A. Yeah, and the references used in the IPR, in
15 each one of them and the different grounds. And I
16 reviewed the validity report. And I reviewed some other
17 documents to refresh my memory with all of that.

18 Q. When you say "validity report," are you
19 referring to the declarations that we looked at just a
20 second ago?

21 A. No.

22 Q. Okay. What do you mean by "validity report"?

23 A. The rebuttal to the invalidity report from the
24 experts.

25 Q. Are you referring to opinions that you offered

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1 in the district court --

2 A. Yes.

3 Q. -- case?

4 Okay. Did you review your declarations that
5 you submitted in these IPRs that we just looked at a
6 minute ago?

7 A. Yes.

8 Q. And you said you reviewed, I believe, the
9 invalidity grounds.

10 Did that include looking at each of the prior
11 art references that were cited in the grounds in these
12 IPR petitions?

13 A. Yes.

14 Q. Okay. Besides what you've already listed, can
15 you think of anything else that you reviewed?

16 A. I can't think of anything right now.

17 Q. Other than reviewing these documents, what
18 else did you do to prepare for this deposition?

19 A. I met with the attorneys.

20 Q. Who did you meet with?

21 A. With Mr. Oaks and Mr. Kapadia online.

22 Q. And when did you meet with those -- with your
23 attorneys?

24 A. Yesterday.

25 Q. Did you meet with them any other time other

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1 than yesterday?

2 A. I've met them on different occasions, but I
3 don't think regarding this preparation.

4 Q. Okay. So for preparing for today's
5 deposition, you just met with them yesterday.

6 Is that right?

7 A. Correct.

8 Q. And approximately how much time yesterday did
9 you meet with the Stratasys attorneys?

10 A. About six hours.

11 Q. Did you meet with anyone else to discuss this
12 deposition?

13 A. No.

14 Q. Did you talk to anyone else about this
15 deposition other than Stratasys counsel?

16 A. My wife.

17 Q. Did you talk about any of the details with
18 your wife?

19 A. No.

20 Q. I'm sure she was very jealous of you getting
21 to have a deposition today.

22 A. Yeah, she was actually. No, she wasn't.

23 Q. Have you ever spoken with any of the named
24 inventors of the '698 or '381 patents?

25 A. Oh, gosh, it has been a while. No, I don't

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1 think so. I don't think I've spoken to any of the
2 inventors.

3 Q. And so you haven't -- you didn't speak with
4 any of the inventors in preparation for your deposition,
5 I assume?

6 A. No.

7 Q. Dr. Osswald, did you conduct any independent
8 searches or searches on the Internet related to your
9 opinions in this case?

10 A. I mean, in the past, sure. I mean, I've done
11 literature searches and things like that in the past.
12 I've searched through my own writings, and that's all in
13 my -- in my report -- reports.

14 Q. When would you have conducted those searches,
15 approximately?

16 A. I don't remember. Obviously before
17 January 30th.

18 Q. Have you done any searches related to this
19 case after January 30th?

20 A. Relating to the IPR?

21 Q. Correct.

22 A. No.

23 Q. How about relating to these patents more
24 generally?

25 A. Well, I have. I mean, I was deposed sometime

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1 after my report, so I probably looked at -- searched for
2 the information, some of the papers that I had
3 references to patents, that I referenced. I downloaded
4 them again from Google Patents and things like that. I
5 mean, just typical things, but not related to the IPR.

6 The IPR obviously was turned in on the 30th
7 of -- of January. And I had all of the references for
8 that.

9 Q. Okay. Approximately how many times have you
10 been deposed before?

11 A. I should know that, but I would say anywhere
12 between 50 and 100 times.

13 Q. Were all of those depositions -- were you
14 acting as an expert?

15 A. Yes.

16 Q. And about how many of those depositions
17 occurred in IPR proceedings?

18 A. I don't remember. I don't remember.

19 Q. Do you think it would be around half?

20 A. I don't know. I don't know. Maybe 20 times.
21 I don't know. I'm not sure.

22 Q. Okay. Somewhere -- but it sounds like, you
23 know, more than -- more than ten; is that fair?

24 A. Yes, that's fair.

25 Q. And how many of those depositions were about

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1 patents?

2 A. I would say 80 percent of them.

3 Q. And so 20 of those depositions would have been
4 for cases that did not involve patents; is that right?

5 A. Yeah. Product liability cases and trade
6 secrets. Maybe more than 20 percent. I don't know.
7 I'm not sure. I just sort of grabbed that number.

8 Q. And in your -- in the cases where you were
9 being deposed for an IPR, approximately how many of
10 those cases were you working for the patent owner?

11 A. I think most of them.

12 Q. Have you -- have you ever served as an expert
13 for the Petitioner in an IPR?

14 A. I may have. I'd have to go back and look.

15 Q. And for --

16 A. Yeah, I have. I have. I'm sorry.

17 Q. Do you remember how many times? It sounds
18 like you just maybe remembered one?

19 A. Yeah, I don't remember how many times.

20 Q. For each of the times when you were deposed,
21 were you offering an accompanying expert report or
22 declaration in those cases?

23 A. I think most of them, yes.

24 Q. Do you know if your opinions have ever been
25 excluded by a tribunal?

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1 A. No. I mean, there was one time when I opined
2 what potable water was, and the judge said I'm not a
3 water expert, but that's about it. It was a case
4 related to plastic containers for sippy cups.

5 Q. And you were opining on the status of potable
6 water; is that right?

7 A. Well, it was one of the terms in one of the
8 elements in the claim. So potable water or potable
9 liquid or something like that.

10 Q. And was -- were your opinions just as to that
11 term struck or excluded, or was it all of your opinions?

12 A. No, just that term. I think the other side
13 raised the -- they always do try to sort of discredit
14 you, and they said, "Well, he's opining on potable
15 water, and that's not his area."

16 And so the judge said, "Okay, I give you
17 that."

18 But it didn't -- it was not so substantial in
19 the whole claim.

20 Q. And you were, generally speaking in that case,
21 opining on the plastics and plastic water bottles; is
22 that right?

23 A. It was a case of sippy cups, so the plastic
24 and the design of the product.

25 Q. Okay. Was that a patent case?

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1 A. Yes.

2 Q. And was it in a district court or in front of
3 the patent office?

4 A. No, it was in the district court. Although at
5 one point I did go to the patent office with the
6 attorneys.

7 Q. And so other than that case with the sippy
8 cups, have any of your other opinions been excluded by
9 either a district court or the patent office?

10 A. No.

11 Q. When did you first start working on the
12 declarations for these two IPR proceedings?

13 A. I don't remember. Something last year.
14 Summer of 2025.

15 Q. And you submitted those, at least
16 declarations, in January, so is it fair to assume that
17 you worked on these for somewhere between three and six
18 months?

19 A. Something like that. Yeah. I don't remember
20 exactly. Yeah.

21 Q. Do you know -- did you start on one of the
22 declarations first?

23 A. Yeah, I think I was first working on the '698.

24 Q. How long would you say you spent drafting the
25 declaration for the '698 patent?

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1 A. Oh, gosh. I don't remember. I have -- yeah,
2 I don't remember. Maybe 50 to a hundred hours. I don't
3 know. I'd have to look and -- because I was working on
4 different patents and all of that, and this one is
5 probably what it was.

6 Q. So your -- your best guess is somewhere
7 between 50 hours and a hundred hours over those span of
8 a couple months; is that right?

9 A. Something like that, yes. Maybe more. I
10 don't know. I don't remember.

11 Q. And what about for the '381 patent; do you
12 remember approximately how much time you spent drafting
13 that declaration?

14 A. I mean, I re -- I recycled a lot of what I
15 wrote for the '698 declaration, and so it was obviously
16 less, but I don't remember.

17 Q. Did you spend -- did you draft the entirety of
18 the declaration for the '698 patent before you kind of
19 switched over to work on the '381 declaration?

20 A. I don't remember how I was -- I think that
21 happened parallel.

22 Q. And did you draft both of these declarations
23 yourself?

24 A. Well, they both contain -- I got a structure
25 of it, general structure from the attorneys. I filled

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1 in the blanks. I had discussions with them. I sent
2 drafts and they inserted them. I corrected them. So it
3 was -- I mean, like it always goes with attorneys and
4 experts. But, yes, I -- it fully contains my opinion.

5 Q. I believe you said that you filled in some
6 drafts. Does that mean -- or some gaps, I apologize.

7 Does that mean that Stratasys's attorneys sent
8 you sort of a first draft with things to fill in?

9 A. No, I mean, I think -- I think I sent them my
10 background and things like that, and they inserted it
11 into a skeleton. I mean -- and then I started filling
12 in, and we had discussions with them. I sent them more
13 writings, and they would add things and subtract. I
14 mean, I physically didn't type the whole thing, but it
15 certainly contains all my opinions.

16 Q. Would you say that you've drafted or prepared
17 the first draft of this declaration?

18 A. Well, the substantial opinions, yeah. If it
19 wasn't typed in by me, it was a discussion between me
20 and the attorneys.

21 Q. Approximately how many discussions about these
22 declarations would you estimate that you had over the
23 course of drafting?

24 A. Oh, gosh, I don't remember. I don't remember.
25 A lot of them.

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1 Q. If you had to put an estimate on it, do you
2 think it was more than ten?

3 A. I don't remember.

4 Q. So it could be more than ten?

5 A. Possibly.

6 Q. Could be less than ten; you just don't
7 remember?

8 A. I don't remember. Sufficient to get my points
9 across and discuss things with the attorneys. And there
10 were other patents, so I'm having a hard time separating
11 them in my brain right now when we drafted things.

12 Q. Did you -- well, strike that.

13 Did you read every word of your declaration
14 before you submitted it in this case?

15 A. Yes. Several times probably.

16 Q. And I'll say -- I guess I should clarify, and
17 that's for both declarations; is that right?

18 A. Yes.

19 Q. And you said you didn't type every word.

20 Do you have any estimate on the percentage of
21 words that you, yourself, wrote or typed?

22 A. No.

23 Q. Are there any specific sections in your
24 declaration that you drafted without the assistance of
25 Stratasys counsel?

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1 A. Yes, many of them.

2 Q. Which sections would those be?

3 A. Things under technical issues of the patents
4 or on the references that were given, but I don't
5 remember which ones exactly. I'd have to go back and
6 look at the report.

7 Q. Would the summaries of the prior art
8 references have been something that you typed without
9 assistance?

10 A. Yes. I think it was edited back and forth
11 between the attorneys and me.

12 Q. So you might have had some assistance with
13 those sections?

14 A. Yes.

15 Q. What about your responses to the substantive
16 grounds presented in the petition? Would those have
17 been something that you prepared without assistance?

18 A. Can you ask again that question?

19 Q. Yeah. The responses to the specific grounds,
20 prior art grounds in the petitions, would that have been
21 something that you drafted without assistance?

22 A. Yeah, I mean, we certainly had discussions,
23 but I don't remember who exactly typed things in, but
24 they certainly contain a hundred percent my opinions on
25 those grounds.

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1 Q. Were there any sections in your report that
2 you did not personally draft?

3 A. I mean, there were some things. I think -- I
4 don't remember in this report if there's any legal --
5 legalese in there, so I'd have to go back and look. And
6 whenever there is some legal -- I'm told by attorneys
7 that -- infringement as well, whatever -- those are
8 typically drafted by the attorneys.

9 Q. Okay. Let's -- and I guess it may be easier
10 here. We can pull up your declaration for maybe the
11 '381 patent.

12 Is the legal standard section, that is
13 Section 4 of your report, is that what you're referring
14 to as the legalese?

15 A. Yes.

16 Q. Okay. And so that would have been something
17 that Stratasys counsel helped prepare for you; is that
18 right?

19 A. Yes.

20 Q. Okay. And though you -- I'm sorry, strike
21 that.

22 That legal standard section is still something
23 that you would have reviewed and agree with; is that
24 right?

25 A. Oh, yes. Everything that is in those -- that

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1 is in those reports I agree with in stance. But
2 obviously I'm not an attorney, so I -- I like having my
3 brain refreshed on those legal issues.

4 Q. And those legal standards are the standards
5 that you applied throughout your report; is that right?

6 A. Yes.

7 Q. Did Stratasys's lawyers provide any facts or
8 assumptions that you relied on in reaching your opinions
9 in this case?

10 A. I don't understand your question.

11 Q. Were there any underlying facts or assumptions
12 that you relied on for your declaration that were
13 provided by Stratasys counsel?

14 A. I think all of the facts and assumptions and
15 opinions are mine. I don't think they told me what I
16 should assume. I mean, I think -- other than what
17 obviousness means and anticipation, et cetera, grounds
18 of validity or invalidity; but, no, I don't think any
19 substantial things that have to do with the technical
20 background of the patents was given to me by the
21 attorneys.

22 Q. Okay. So other than the legal standards we've
23 already talked about, they did not provide anything that
24 you relied on?

25 A. No. I mean, look, there were other reports

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1 that I read and that I had an opinion on. And so --
2 so -- of the experts on the other side, et cetera, or
3 the petitions, I read those too, and so I had an opinion
4 of those.

5 So this was all sort of a fluid discussion
6 between the attorneys and me. But the technical aspects
7 of my opinions and the technical aspects of both patents
8 are certainly of my opinions. The legal standards, I
9 mean, I'm not an attorney, and so there was a
10 back-and-forth between the attorneys and me, so...

11 Q. When were you first contacted to work on this
12 matter?

13 A. I don't remember. Something at the beginning
14 of 2025, end of 2024.

15 Q. Was that when Stratasys first contacted you
16 about working on -- on any matters for these two
17 patents?

18 A. Yeah. I don't remember how -- how exactly it
19 evolved with these two patents, but obviously I was
20 already deposed on the other patents that I offered an
21 opinion in the IPR proceedings. And so I don't remember
22 exactly the timeline. I mean, and I don't care about
23 the timeline. I simply am shown the IPRs, and I give my
24 opinion on them. I don't remember the timing on those.

25 Q. When you were first approached by Stratasys,

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1 were you asked if you would give opinions in this
2 specific IPR? Or these two IPRs.

3 A. I don't remember. I mean, I do remember
4 seeing the patents from the beginning. And I do
5 remember seeing the Warren reference and going through
6 that long patent trying to figure out what it meant.
7 But I don't remember the timing, when that happened and
8 all of that. So --

9 Q. Do you remember if that was before you were
10 retained by Stratasys or while you were discussing
11 engagement?

12 A. No, no. That all happened afterwards. I
13 wouldn't spend hours on some patent if I'm not going to
14 be engaged.

15 Q. When you -- when Stratasys first contacted
16 you, did they send you either the '698 or '381 patents
17 to consider?

18 A. I don't remember. I remember I got a bunch of
19 patents.

20 Q. When you say you got a bunch of patents, was
21 that sort of in the initial contact with Stratasys
22 counsel?

23 A. Yes.

24 Q. And had you seen -- do you recall if you've
25 seen the '698 or '381 patents prior to that initial

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1 reach-out from Stratasys?

2 A. Yeah, I believe I have. I mean, I look at a
3 lot of manufacturing patents, particularly for the
4 course that I teach on additive manufacturing, and those
5 I have. Those I had. At least the '698 patent, I had
6 seen that.

7 Q. When do you think you first saw the '698
8 patent?

9 A. I don't remember. A few years back when I was
10 working on -- on melting and FFF printer.

11 Q. How often do you teach the course that you
12 just mentioned in additive manufacturing?

13 A. I teach at UW Madison and University of
14 Wisconsin here. I taught it at least once a year to
15 seniors and graduate students. I retired two years ago,
16 the summer of 2024. So I became professor emeritus, but
17 I'm still teaching the class at the University of
18 Erlangen in Germany. In fact, I will be teaching it the
19 second week of June.

20 And I've taught it at the university in
21 Columbia, additive manufacturing course, and in the
22 additive manufacturing course, I have a whole unit on
23 intellectual property.

24 Q. Did you ever specifically -- or did the '698
25 patent ever come up in your -- in your lectures?

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1 A. No. That's not one of the patents that I show
2 in my lectures.

3 Q. How did you find the '698 patent originally?

4 A. I don't remember. A search.

5 Q. And that's something that you said -- it
6 sounds like you typically do is search for patents in
7 the space?

8 A. Yes.

9 Q. Do you remember what you were searching for
10 specifically when you found it?

11 A. I was searching for --

12 (Reporter requested clarification.)

13 THE WITNESS: Force transducers.

14 BY MR. BROWN:

15 Q. And why were you searching for force
16 transducers at that time?

17 A. We were -- we developed a model that -- to
18 predict melting in an FFF printer, and the harder you
19 push on the filament into the nozzle, the higher the
20 force generated by -- to measure the -- to melt the
21 material. And so it was -- we -- our model related the
22 force to the speed of printing, to the speed of the
23 filament, or visa versa, the speed of the filament to
24 predict the force.

25 And so the model worked really well. I had

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1 somebody install force transducers in the -- in the
2 nozzle region to be able to determine the force that is
3 used to push down into -- in an encoder to measure the
4 speed to test the model. And that's published material.
5 We published that in additive manufacturing.

6 Q. Would that have been part of research that you
7 were conducting at the time?

8 A. Correct.

9 Q. And were you searching -- what was the purpose
10 of your -- your search for patents on force transducers?
11 What were you looking for?

12 A. To see how someone would measure force with a
13 nozzle. I mean, except the '698 and the '381 patents
14 were not exactly what we were looking for. But I did
15 see them. I thought it was interesting.

16 Q. Did you find something that was closer to what
17 you were looking for?

18 A. No.

19 Q. And you said you published on this research;
20 is that right?

21 A. Yes.

22 Q. Do you remember approximately when that would
23 have been?

24 A. I think one of the papers was -- I don't
25 know -- early 2020, 2021. Something like that. I don't

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1 remember exactly when it was, and then I published a
2 couple of papers afterwards -- afterwards.

3 Q. Do you remember the title of any of those
4 papers?

5 A. Pardon?

6 Q. Do you remember the title of any of those
7 papers?

8 A. Yeah, I think the melting one is called the
9 "Melting Model in the FFF Printer," in the fused
10 filament fabrication printer.

11 Q. And all of those publications would have used
12 or involved a system with a force transducer? Is that
13 right?

14 A. I think the first one wasn't, but then the
15 ones afterwards were to test the model with the real
16 printer.

17 Q. Okay. And before you were contacted by
18 Stratasys in this case, had you ever heard of or read
19 any of the prior art that were cited in the petition?

20 A. No.

21 Q. So was it -- so it was the first time that you
22 had you seen these prior references when you started
23 your work on your declarations; is that right?

24 A. Yeah. I don't -- I mean, the thing is I don't
25 remember. I think I -- if I recall, I think I had seen

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1 the Ashton patent before. I mean, I see a lot of
2 reference. I think the Ashton patent looked familiar.
3 I don't remember exactly.

4 Q. And you said you do regularly or at least you
5 did when you were teaching class do searches for kind of
6 patents in the additive manufacturing space; is that
7 right?

8 A. Yeah, I still do. I mean, I look at patents
9 that are -- that come up. I read articles that come out
10 on additive manufacturing. I'm a reviewer of the
11 journal so I've edited a whole set of papers in my own
12 journal and polymer composites that deal with additive
13 manufacturing. So, I mean, I keep up in the field quite
14 a bit, so I still look at patents. I mean, I'm still
15 interested in it.

16 Q. Do you find it helpful to review patents to
17 help you keep up with the field; is that fair?

18 A. Yes.

19 Q. And you mentioned a journal that you're an
20 editor on.

21 What journal is that?

22 A. Polymer Composites.

23 Q. Did you review the petition for these two IPR
24 proceedings or -- let me rephrase that question.

25 Have you reviewed the -- both of the petitions

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1 for these two IPR proceedings?

2 A. Yes.

3 Q. And approximately how many times would you say
4 you looked at the petition for, let's say, the '381
5 patent?

6 A. I don't know how many times; but, I mean, I
7 always go back and review to refresh my memory. So I
8 don't know exactly how many times. But I certainly read
9 through the petitions.

10 Q. Do you think it's more than five times?

11 A. I don't know.

12 Q. Could be less than five times?

13 A. No. I think looking into them, probably more
14 than five times, but I don't know how many times.

15 Q. But you definitely read through the entirety
16 of the petition at least one time; is that fair?

17 A. Yes.

18 Q. And same for the '698 patent; is that right?

19 A. Correct.

20 Q. You don't remember how many times you've
21 looked at or reviewed the petition for the '698 patent,
22 do you?

23 A. I don't remember exactly how many times.

24 Q. Likely more than five times, you think?

25 A. I don't know.

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1 Q. Is it fair to say that you disagree with the
2 conclusions in the petition?

3 A. Yes.

4 Q. Are there any portions of the petition that
5 you agree with?

6 A. I don't remember. I mean, I'd have to look at
7 my -- my own report. But I disagree with the grounds.
8 And it's all in my -- both of my reports.

9 Q. What about the -- the overall summary of the
10 patents? Do you generally agree with that?

11 A. I think the description of the patents is
12 probably -- I would agree with it. I mean, I don't
13 know. I would have to go back and look and see how they
14 describe them again.

15 Q. What about the general overview or summary of
16 the prior art, was there anything that you agreed with
17 there?

18 A. I don't remember exactly what Dr. Wolfe wrote
19 in those, but I certainly disagree on his interpretation
20 of the -- of the references. I don't remember exactly
21 what he wrote, so I'd have to go back and look at that.

22 Q. And you mentioned Dr. Wolfe. Did you review
23 Dr. Wolfe's declarations along with each of the
24 petitions?

25 A. Yes.

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1 Q. And just to clarify, did you -- you separately
2 reviewed kind of the substance of the petitions in
3 addition to Dr. Wolfe's declarations; is that right?

4 A. Yes. I remember reading Dr. Wolfe's
5 declarations as well.

6 Q. Okay. Are you aware the patent owner --
7 (Reporter requested clarification.)

8 BY MR. BROWN:

9 Q. Are you aware that patent owner filed a
10 preliminary response to the petition in July 2025?

11 A. I can't remember what the terms are, so I'm --
12 yeah. I mean, I remember reading the -- the petition.
13 I remember reading reports from Dr. Wolfe. I don't
14 remember the names, what -- whatever that means. So I'm
15 not an attorney.

16 Q. Fair enough. We like to add convoluted names
17 where probably unnecessary.

18 Let me rephrase it this way: Did you review
19 any filings in these IPRs that were prior to your
20 declaration that maybe helped informing your opinions in
21 the declaration?

22 A. I mean, I remember -- I think I remember
23 reading a patent owner responses. Again, there are five
24 patents I'm working with, and so I remember that there
25 was a petition where there was an expert reported

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1 petition. I don't remember which order they were or
2 are, and then I -- I remember also reading patent owner
3 responses.

4 But I don't remember timings and all of that.
5 Yeah, I think that was not really relevant to my own
6 opinion. I mean, it was relevant to my own opinion, but
7 the timing I don't -- I don't -- I'm not sure.

8 Q. Were you working on drafting your declarations
9 in this case in July of 2025?

10 A. I mean, working on drafting -- I mean, I was
11 forming opinions in my head. That's -- I would say that
12 would be working on drafting an opinion in the report.

13 Q. Well, let's break that down then.

14 Were you actually drafting the reports in
15 July 2025?

16 A. I don't remember if I wrote -- I don't think I
17 wrote anything at that point. Maybe I had. Maybe I
18 was. Yes, maybe.

19 Q. When you were working on -- I'll say more
20 generally working on these -- these proceedings and
21 forming your opinions; is that fair?

22 A. Yeah. I was forming my opinions the moment I
23 read -- I started reading the reports that were at hand.

24 Q. Okay. And so you don't recall for sure if you
25 read a patent owner's preliminary response to the

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1 petition prior to drafting your declarations, do you?

2 A. Patent owner's preliminary response? I think
3 I did read that, yes.

4 Q. Okay. And would you have read that --
5 actually, strike that.

6 Are you aware that patent owner then filed a
7 response to the petition; is that right?

8 A. I don't remember. I mean, there's a lot of
9 documents. I'm sure they are listed -- there must be a
10 list of documents that I reviewed in my reports.

11 Q. So this is the -- the patent owner response
12 would have been submitted along with your declaration.

13 Does that sound familiar?

14 A. I don't remember.

15 Q. Okay. Do you remember reviewing the patent
16 owner --

17 (Reporter requested clarification.)

18 MR. BROWN: You know, we've been going --
19 maybe -- we've been going about 50 minutes. Let's maybe
20 go off the record and take a quick break, and I'll try
21 and fix my mic.

22 (Recess.)

23 BY MR. BROWN:

24 Q. Okay. Dr. Osswald, did you speak to anyone
25 during the break?

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1 A. No.

2 Q. All right. So before we were -- before we
3 took that break, we were talking about the patent owner
4 response.

5 Have you reviewed the patent owner response in
6 this case or in these two petitions?

7 A. I don't remember. I've looked at so many
8 documents. Whatever I reviewed is probably on the list
9 of documents that is in my report or that are in my
10 reports.

11 Q. You mentioned that you are involved with
12 several IPRs for StratasyS.

13 Is it -- do you typically review the patent
14 owner response that's being sort of accompanying your
15 declaration?

16 A. Yeah. I mean, I think I do. I mean, whatever
17 I review in those responses should be in the documents.
18 If it's not in my documents, then I haven't reviewed it.

19 Q. Are you involved in -- in drafting the patent
20 owner response at all?

21 A. Well, I mean, the attorneys do ask me for my
22 opinion on different grounds and things, and so I would
23 imagine, yes, my opinion is there somehow, but I don't
24 type anything in the patent owner response. I mean, I
25 have discussions with attorneys. I'm sure they take my

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1 opinion and -- and weave that into their legal response.

2 Q. Do you know if you reviewed a draft of the
3 patent owner response while you were preparing your
4 declarations in this case -- in these proceedings?

5 A. No. No.

6 Q. Sorry. Is that a "no," you don't recall; or
7 "no," you did not review?

8 A. I don't think I review drafts of their work
9 like that, no.

10 Q. So is it fair to say that all of the arguments
11 in the patent owner response were drafted by someone
12 other than yourself?

13 A. Yes.

14 Q. Okay. And we looked at your two declarations
15 that are both titled Exhibit 2027 earlier. Right?

16 A. Yes.

17 Q. Those two declarations set forth your opinions
18 concerning both the '381 patents and -- '381 and '698
19 patents and the prior art; is that right?

20 A. Yes.

21 Q. Were there any opinions that you have with
22 either of those patents or the prior art that was
23 omitted from your declaration?

24 A. No.

25 Q. Have you -- well, strike that.

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1 In forming your opinions did you rely on any
2 assumptions that are not identified in your declaration?

3 A. I mean, in an expert report there's always
4 sort of a general knowledge of the expert, and so I
5 don't know if that -- if I have a specific reference for
6 every single technical statement. So I don't know. I
7 mean, the references are there; my opinions are there in
8 both of those reports.

9 Q. So you can't think of any explicit assumptions
10 that you would have made and omitted from your report
11 though, right?

12 A. That's correct.

13 Q. And I think you mentioned earlier that part of
14 your preparation for today's deposition was reviewing
15 both of your declarations, right?

16 A. Yes.

17 Q. Did you find any errors or anything that you
18 think should be corrected in your declarations?

19 A. No.

20 Q. Okay. So you stand by the declarations that
21 you submitted; is that right?

22 A. Yes.

23 Q. And there's nothing that you would change in
24 those declarations?

25 A. No, not right now.

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1 Q. Are there any opinions in those two
2 declarations that you are maybe less certain about than
3 other opinions?

4 MR. OAKS: Object to the form of the question.

5 BY MR. BROWN:

6 Q. And just to repeat. Did you say no to that?

7 A. Yeah, correct.

8 Q. You have -- so that means you're a hundred
9 percent confident in the opinions that you offer in your
10 declaration; is that right?

11 A. As of right now, yes.

12 Q. I think we mentioned this earlier, but are you
13 aware there's a district court case that involves these
14 patents and Stratasyms right now as well?

15 A. Yes.

16 Q. Are you involved in that district court case?

17 A. Yes.

18 Q. What's your role?

19 A. I'm an expert in some of the patents. I think
20 in infringement and validity. I wrote two more reports
21 in which I was deposed. Not this spring.

22 Q. And so you've offered expert opinions through
23 those reports that you'd submitted in the district court
24 case; is that right?

25 A. Yes.

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1 Q. And did you offer opinions on the '381 or '698
2 patents?

3 A. Yes.

4 Q. Is the "yes" to both of those two patents?

5 A. Yes.

6 Q. Did you offer your opinions on those two
7 patents before or after your declarations in these IPR
8 proceedings?

9 A. I think that -- some of those ran parallel to
10 each other. I don't remember when the due date was. I
11 think there were a lot of reports due in those days. So
12 I was working on them parallel.

13 Q. So approximately similar timing for the
14 reports in the district court and your declarations in
15 these IPRs; is that right?

16 A. Yes, around -- give or take a couple months.

17 Q. Did any of your opinions change based on the
18 analysis or testimony that you provided in the district
19 court?

20 A. No.

21 Q. So nothing that you learned in the district
22 court case changes your opinions that you presented in
23 your declarations; is that right?

24 A. Correct.

25 Q. And are your opinions consistent between the

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1 IPR declarations and the reports and opinions you've
2 offered in the district court?

3 A. Yes.

4 Q. Are there any inconsistencies that you're
5 aware of?

6 A. No.

7 Q. Have you ever heard of Dr. Wolfe before this
8 IPR?

9 A. No.

10 Q. So you've never worked with him or read
11 anything by Dr. Wolfe; is that fair?

12 A. That's fair.

13 Q. What degrees have you earned over the course
14 of your career, Dr. Osswald?

15 A. They're all in my CV, but I received a
16 Bachelor's of Science in mechanical engineering in 1981.
17 I received a Master's of Science in 1982 and also
18 mechanical engineering. I received a Ph.D. in the field
19 of polymer processing and manufacturing, things with
20 polymers and plastics in 19 -- early 1987.

21 And I did a postdoctoral research internship
22 postdoc at the Institute for Polymer Processing in
23 Aachen, Germany. And I worked on -- in the field of
24 polymer processing, polymer engineering for the past
25 40 years.

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1 Q. And your Ph.D. you mentioned was in polymer
2 manufacturing and processing, I believe; is that right?

3 A. Yes.

4 Q. Is that -- did that Ph.D. fall under kind of
5 the umbrella of mechanical engineering or was it under a
6 different department?

7 A. No, it was in mechanical engineering, but
8 obviously there were courses there in mechanics and
9 mechanical engineering, et cetera. I mean, polymers is
10 kind of like a field. Some universities have polymer
11 processing. Chemical engineering in Wisconsin happens
12 -- Illinois happens to be out of mechanical engineering,
13 but it's a field that falls within the material science,
14 mechanical engineering, chemical engineering.

15 Q. Was your training kind of spread out across
16 all of those fields as well, or did it focus more on the
17 mechanical engineering side of polymers?

18 A. I think from a Ph.D. it was spread over the
19 different fields in the work that I did in subsequent
20 years. It was interdisciplinary between all those
21 fields.

22 Q. What is it about the polymer manufacturing and
23 processing that specifically ties it to the field of
24 mechanical engineering versus some of those other
25 options that you said?

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1 A. Well, I mean, polymer processing involves
2 mixing and flows, flow -- fluid flow, solidification,
3 melting, which is heat transfer. And, I mean, there's
4 an overlap between different departments. Transfer
5 phenomena, which is more material science and chemical
6 engineering.

7 Q. How would you, at a high level, describe kind
8 of the field of polymer processing and manufacturing?

9 A. Well, I mean, in general, I would say my field
10 is polymer engineering, which is in the material science
11 of polymers as used in engineering, which involves the
12 material itself, the polymer. It involves the process
13 that is used to make something. It involves the product
14 that you make. It involves the performance, and it
15 involves the recycling, the sustainable aspects of
16 polymers, which is a topic that is of importance today.

17 So it's -- one of those fields in polymer
18 engineering is polymer processing. My Ph.D. was in
19 polymer processing. My general field is engineering,
20 polymer engineering.

21 Q. After your Ph.D., did you focus on any
22 specific facets that you just mentioned?

23 A. Yes, on all of those. When I did a
24 two-and-a-half-year postdoc in Germany, I worked with
25 all of those in sort of preparing for courses that I was

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1 going to teach, and I started teaching, relatively soon
2 in Wisconsin when I arrived, a course in polymer
3 processing which I was most familiar with at the time.

4 But I also started teaching a course,
5 Engineering Design With Polymers, where I wrote the
6 textbook, Materials Science of Polymers For Engineers,
7 which is used as a textbook for that course, but it's
8 used in other universities and other places. So it's
9 part of it -- that's a bigger umbrella of polymer
10 engineering.

11 Q. And do you hold yourself out to be a
12 specialist at all in any of these particular facets
13 within polymer engineering?

14 A. I think I'm an expert in all of those. I've
15 written textbooks in all of those fields. I am the
16 editor of the Plastics Handbook, which also literally
17 covers the -- the field of polymer engineering.

18 So I'm -- I'm involved now, and I just
19 finished publishing the fifth edition of the Plastics
20 Handbook. I'm working now on the 33rd edition or 34th
21 edition of the German version of that book. I wasn't
22 involved in all 30 some, but in the last, I think, ten
23 editions, I was involved in.

24 Q. Was the Plastics Handbook -- what is the
25 general purpose of that book?

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1 A. It's a resource for plastics engineers.

2 Q. So those are, you know, engineers working in
3 the field of plastics, not necessarily students; is that
4 right?

5 A. Students. Also students actually get a free
6 copy of it. At least in Germany they do. All of the
7 students in polymer engineering, they get a free copy of
8 it, and I used to hand out free copies that were
9 actually funded by BASF, so they printed extra versions
10 for students.

11 Q. And how do practitioners generally use this
12 book?

13 A. As a resource -- like the title says, the
14 resource for plastics engineers. It talks about the
15 different processes. It has a whole chapter on
16 different polymer materials and the processes. There's
17 a whole section on additive manufacturing which
18 obviously is evolving, is changing.

19 Q. Is it it designed more as a teaching tool or
20 something like a quick reference guide, would you say?

21 A. Both.

22 Q. So it has kind of the information that the
23 engineer may go look up as part of their -- their
24 day-to-day practice of polymer engineering?

25 A. Yes. If they want to find out about some test

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1 method to measure something, the standards are listed in
2 there. If they want to learn a little bit about a
3 material, that material likely has a whole section in
4 one of the chapters. The handbook is about a thousand
5 pages long, so there's a lot of information in there.

6 Q. And what led you to pursue this particular
7 field when you were getting your Ph.D.?

8 A. I -- with my master's work, I worked on
9 simulation on finite element simulation of hip bone
10 prostheses, and so I took a lot of courses in modeling
11 and program writing. So I wrote a whole software to do
12 the finite element analysis.

13 And so my Ph.D. advisor, when I applied, he
14 liked the background, and he hired me to develop a
15 software to predict mold filling in compression molding
16 processes, and that's how I got into it.

17 Q. Were those -- was your work in -- I think you
18 said it was hip prostheses in your master's; is that
19 what you said?

20 A. Yes.

21 Q. Were those made out of polymers or plastics?

22 A. Some of them are. So there's the bone, there
23 is the adhesive, and then there is the titanium implant.

24 Q. Okay. Have -- you've taught -- I think we've
25 already mentioned this, but you've taught numerous

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1 classes on -- on the study of polymers over the course
2 of your career; is that right?

3 A. Yes.

4 Q. And that -- that was primarily when you were a
5 professor at the University of Wisconsin, Madison?

6 A. Also -- so I also taught the courses -- I've
7 been teaching a course in modeling and simulation in
8 polymer processing at the University of
9 Erlangen-Nuremberg. The first time I taught it there
10 was in 1993. I've taught it every year, so it's been
11 33 years that I've taught there.

12 I eventually became an honorary professor
13 there in 2006. I taught that course -- many years I
14 taught it twice a year. And I also became an honorary
15 professor at the National University in Colombia where I
16 teach courses in Material Science of Polymers For
17 Engineers but also teach courses in additive
18 manufacturing.

19 So I've -- so I've taught different places,
20 different universities, so not just University of
21 Wisconsin.

22 Q. Is it fair to say that most of your time spent
23 teaching was at University of Wisconsin?

24 A. Yes.

25 Q. And so you said earlier that the University of

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1 Wisconsin kind of puts the polymer field under the
2 umbrella of mechanical engineering department.

3 Have you taught any classes that were focused
4 on mechanical engineering but not polymers?

5 A. Yes. So the University of Wisconsin doesn't
6 put all polymers in mechanical engineering but polymer
7 processing.

8 Q. Okay.

9 A. There's a distinction there.

10 And I've taught courses to chemical
11 engineering students. So my engineering design with
12 polymers, it was taught to chemical engineering
13 students, material science students, civil engineering
14 students. Sometimes there were electrical engineering
15 students.

16 But, yes, I have taught courses that relate to
17 fields like, for example, kinematic and dynamics of
18 machinery, and I taught those at the University of
19 Illinois when I was a graduate student and then when I
20 was an instructor at the South Dakota School of Mines
21 and Technology. So I have taught courses that are
22 really regular mechanical engineering sources.

23 I taught thermodynamics as well.

24 Q. Okay. And you mentioned that the Plastics
25 Handbook is not only -- was not only written as a

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1 textbook for students.

2 Are there any textbooks that you've written?

3 A. Yes.

4 Q. And how many textbooks have you written?

5 A. Well, I wrote a textbook called Polymer
6 Processing Fundamentals. That eventually became
7 Understanding Polymer Processing, and that one had just
8 came out last year and it's third edition, and so that
9 one has been translated into Spanish, Farsi, and I
10 think -- well, no, the Material Science of Polymer
11 Science for Engineers, that's been translated into
12 Korean and to Japanese and Chinese.

13 So I've written several textbooks. Also
14 Modeling and Simulation in Polymer Processing, that was
15 also a textbook that I wrote. So I would say maybe, in
16 general, four textbooks.

17 Q. What -- what level courses are these textbooks
18 usually used in?

19 A. Understanding Polymer Processing is a textbook
20 for junior, senior students. And Polymer
21 Introduction -- sorry, Materials Science of Polymers for
22 Engineers that's for maybe seniors, graduate students.
23 Most students that took that class are seniors.

24 And so -- so it varies. It goes all the way
25 from -- and then of course, Modeling and Simulation of

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1 Polymer Processing, that's just for graduate students.

2 Q. And so throughout the course of your -- your
3 teaching career, you've taught both undergraduate and
4 graduate students; is that right?

5 A. Yes.

6 Q. Let's -- let's talk about the polymer
7 processing fundamental textbook.

8 When did you first get involved with writing
9 that? I know you said there's been multiple editions,
10 but when did you first start with that?

11 A. So the first edition could be -- the first
12 version of that book was Polymer Processing
13 Fundamentals, which came out in 1998.

14 Q. And you were involved with that first edition?

15 A. Yeah, I was the only author.

16 Q. Okay. And what about the Materials Science
17 For Engineers, when did you first start working on that?

18 A. I started working on that in 1994, and it was
19 published in 1996, the first edition.

20 Q. And what about the Modeling and Simulation
21 textbook?

22 A. That one I -- I was involved writing it --
23 well, basically for many, many years, and eventually it
24 evolved in a book that was published in the early 2000s.

25 Q. And did you use these textbooks when you were

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1 teaching?

2 A. Yes.

3 Q. And I think we already touched on this
4 briefly, but you mentioned a few classes that you taught
5 that were not polymer or were not specifically --
6 polymer is kind of more broadly under the umbrella of
7 mechanical engineering.

8 Did any of those courses come after you earned
9 your Ph.D., or was that all while you were working
10 towards your master's and Ph.D.?

11 A. That was after my master's and during my Ph.D.

12 Q. We've -- we've already talked about quite a
13 few projects that you've had kind of in this field.

14 What -- what would you consider to be the most
15 relevant or closest to the technology of the '381 and
16 '698 patents?

17 A. My work that I did, research projects that I
18 worked in additive manufacturing.

19 Q. And when did you start doing those research
20 projects in additive manufacturing?

21 A. I mean, I've been working on and off in
22 additive manufacturing, at least reading the literature
23 and talking to graduate students at the University of
24 Erlangen-Nuremberg since probably the early 2000s. And
25 the first course that I taught was many, many years

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1 later, but I worked on -- on a research project to make
2 powders for selective laser centering, which is an
3 additive manufacturing technique.

4 And I worked on a research project with some
5 students, undergraduate students, developing a color 3D
6 printer which -- where the students got a prize from
7 the -- first prize from the patent office for student
8 projects. That resulted in a patent dealing with FFF
9 printing.

10 And then I started researching and trying to
11 understand exactly how the melting occurs inside of an
12 FFF printer.

13 And that came out with the publication of
14 Melting Model for Fuse Filament Fabrication Processes.
15 So I mean it's been on and off. So I've worked on
16 different area -- also on fiber filled -- FFF systems.
17 I mean, so I have worked on -- also on fiber filled
18 systems, not just FFF, but also injection molding and
19 compression molding.

20 So my research areas have gone across -- over
21 different areas of processing -- polymer processing,
22 which includes additive manufacturing.

23 Q. Are there any specific research projects or --
24 that you were involved with or oversaw in the additive
25 manufacturing space that were particularly close to the

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1 technology at issue in these two patents?

2 A. Somewhat. I think the -- what I've mentioned
3 earlier, the -- the measuring of the force that the
4 filament exerts on the -- on the nozzle of the printer.

5 Q. You mentioned that some of your students
6 received a prize from the patent office in relation to
7 FFF printing.

8 What does FFF stand for?

9 A. Fuse filament fabrication. The tradename -- a
10 lot of people know it by FDM, which is Fused Deposition
11 Modeling, which is the tradename of Stratasys.

12 Q. So FDM and FFF are kind of equivalent terms --

13 A. Yes.

14 Q. -- from a technical standpoint?

15 A. Yes, they are extrusion additive manufacturing
16 techniques. They are the same, FDM and FFF.

17 Q. And so what was the project focusing on that
18 received the prize?

19 A. It was trying to use the FFF process to print
20 in color.

21 Q. Is that something that at the time was not
22 being done, or was there some specific improvement to
23 printing in color?

24 A. It was a way to print in color and also to add
25 additives, different additives in the FFF process. And

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1 the patent was -- there was a patent that was granted
2 for that.

3 Q. The additives, were they designed to primarily
4 change the color of the filament, or what was the
5 purpose?

6 A. Well, basically what it was, it was depositing
7 additive to the center of the filament, so the filament
8 was no longer circular, but were two half circles or
9 other geometries where you could introduce the additive
10 in the center of the filament.

11 And so additives could have been different
12 colors to print in different colors, but it could have
13 also been like a medical -- a medicine or a chemical or
14 a plasticizer to make it softer. And so -- so that's --
15 that's in general what the patent is.

16 Q. Do you know if this patent was ever
17 commercialized?

18 A. I don't know. It was sold to MakerBot.

19 Q. Okay. So we talked a little bit earlier, and
20 you just mentioned again the research you did on -- with
21 a force transducer, and I believe you were saying that
22 was directed at monitoring the force from extrusion; is
23 that right?

24 A. Yes, the force that the filament exerts on the
25 nozzle.

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1 Q. So could you explain what you mean by the
2 force that the filament exerts on the nozzle?

3 A. Sure. When the filament is pushed into the
4 nozzle, depending what speeds you use, if you use
5 relatively normal speeds, then the material melts inside
6 of the nozzle and literally to predict what force is
7 required is determined by the speed of the filament.

8 So it's just squishing the polymer melt
9 through the capillary at the end. Most of the force is
10 generated that way.

11 But as you increase the speed, eventually the
12 transition between solid and melt reaches the bottom of
13 the -- of the -- of the nozzle, and then the force --
14 the whole melting mechanics or kinematics changes, and
15 your force are increasing to the power of four with --
16 through the model. And so -- and so the model was
17 developed to determine a limiting speed and how that --
18 how we can predict that.

19 And so that was the first paper that we --
20 that we submitted. So in order -- in order to see if it
21 works for an FFF printer, so we -- then what we did is
22 we built a little nozzle and we did a very simple
23 experiment to prove the model without printing, and now
24 we wanted to do it with a printer, with an FFF printer.

25 And so we wanted to measure that force in the

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1 FFF printer, and we wanted to measure the speed, and
2 that was the general view of that -- of that research
3 project.

4 Q. Why was the force important?

5 A. Well, our model used force to predict speed or
6 used speed to predict force, and we wanted to see if our
7 model worked.

8 Q. And what was the kind of primary purpose of
9 the model?

10 A. To find a limit of the FFF printing process.
11 What's the fastest we can print.

12 Q. And that's kind of to optimize the process, I
13 guess?

14 A. Yeah, to know what the limiting factors are.
15 And that -- based on that then, we did another research
16 project which -- how can we speed up the melting. And
17 so then we developed the spinning nozzle so we developed
18 an FFF printer where the nozzle spins at really high
19 speeds, and where the friction ends between the filament
20 and the nozzle enhanced the mixing and speed up the
21 printing process.

22 So I mean, it was -- there are several
23 papers -- there's a patent that came out on that as
24 well. I think it's come out already on the spinning
25 nozzle.

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1 Q. And when you were measuring force, what kind
2 of sensor did you use?

3 A. We used a donut, a kind of sensor that held --
4 that held the nozzle. We wanted -- we knew we couldn't
5 have strain gauges close to the nozzle because of the
6 heat, the problem of heat and strain measurement.

7 And so the donut held the nozzle and so the
8 strain gauges or the sensors were inside of that donut
9 far away from the nozzle to be allow the measurement of
10 force of the filament exerting onto the -- onto the
11 nozzle.

12 Q. When you say donut, is that referring to a
13 specific type of sensor, or is that the -- maybe the --
14 some sort of piece of protection? I wasn't entirely
15 sure I followed that.

16 A. It's a transducer that measures axial force.
17 So it's donut shaped. It's held on the outside, and the
18 nozzle is held on the inside part. And so it's to
19 measure the force that you push the center portion. It
20 wasn't developed for FFF printing, but it was something
21 that was out there that you could -- one could use for
22 something like that.

23 Q. Is that a common type of sensor?

24 A. Not really. I mean it took us some searching
25 with a company that manufactured -- that manufactured

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1 the printer for us.

2 Q. But it's a commercial -- it was a commercially
3 available sensor?

4 A. It was a commercially available sensor, yes.

5 Q. And how does it -- how does that donut sensor,
6 I guess, measure the force?

7 A. It's like a -- like a cantilever beam except
8 it's not a cantilever beam. It's a cantilever disc held
9 on the outside and then -- and then it bends down or it
10 moves down as you apply the force to the center hole.

11 Q. And does it measure displacement like that
12 downward movement?

13 A. It measures the strain. I mean, the
14 displacement is varied, but it measures the strain, and
15 that strain on the donut surface is translated into
16 force. There is a calibration that is used for that.

17 Q. What do you mean by a collaboration [sic]?

18 A. No, calibration.

19 Q. Calibration, okay. So the calibration is a
20 way to -- to -- to determine what specific force it's
21 using based on the output from the sensor; is that
22 right?

23 A. Yes.

24 Q. And is that calibration something that is
25 material specific?

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1 A. No. No, it's just to measure the force.

2 Q. So it's just a general calibration that you do
3 for the sensor?

4 A. Yes, just to measure the force, correct.

5 Q. And does -- I think you differentiated or
6 mentioned that the donut sensor is different than a
7 strain gauge. Is that what you said earlier?

8 A. No. There's strain gauges inside, but those
9 strain gauges are removed from the area where they could
10 be -- where the measurement can be affected by the heat
11 of the nozzle.

12 Q. Okay. So the donut sensor is maybe a more
13 specialized type of strange gauge -- strain gauge; is
14 that fair?

15 A. No. I mean, it's just the -- it's just the
16 geometry. It's just the -- a way to -- that we saw that
17 would be beneficial without having the effect of heat.

18 Q. Okay. So the -- the donut really is -- the
19 purpose of the donut sensor is to kind of isolate the
20 heat in some sense or at least protect it from the heat?

21 A. Yeah, and it was a practical way of holding
22 the nozzle, so there are two things there.

23 Q. And so the -- the strain gauges within the
24 donut sensor essentially monitor strain as -- as part of
25 this monitoring or detection of force; is that right?

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1 A. Yeah. The signal that comes out has been
2 calibrated to the force -- force and voltage that comes
3 out is related to the force that you apply on the center
4 of the donut.

5 Q. And sorry, just to clarify. Did you say force
6 and voltage or force in voltage?

7 A. No. The voltage is transformed to force.

8 Q. Okay. Would you consider this donut sensor a
9 type of force sensor?

10 A. Yes. I mean, it is -- it is a force. It's a
11 load cell. I mean, sometimes they are called -- I mean,
12 you measure stress strain of materials. There are load
13 cells. So a load cell is always a force sensor. You
14 apply a force. That force causes some deformation in
15 some metal part, which is a strain, and that is
16 translated to a force you calibrated.

17 Some of them are very sensitive, like when you
18 do testing of polymers when you stretch a polymer
19 specimen, you have very, very sensitive load cells that
20 can detect very small loads. Even -- and then --
21 then -- and measure and translate that into a force.
22 So -- so it's a load cell, literally, yeah, which have
23 existed. They exist.

24 Q. And are there a variety of different types of
25 load cells?

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1 A. I'm sure there are, yeah.

2 Q. Okay. Do you -- have you taught any classes
3 that kind of cover force sensors when you're teaching
4 the course?

5 A. Well, I mean, I taught a course on rheology.
6 That's another textbook that I wrote, which is called
7 Polymer Rheology. And I taught a course in polymer
8 rheology. That would be R-H-E-O-L -- rheology. And --
9 and in that course we cover sort of the viscoelastic
10 properties of complex fluids like polymers, but there is
11 also a whole area in that course that teaches rheometry,
12 rheometry, which is measuring them.

13 And a rheometer has load cells and
14 deformation. You need to measure the stress and you
15 need to measure the strain and all of that. And so --
16 and so, yeah, in that I've taught how one uses those
17 sensors to characterize polymer melts.

18 Q. What is -- what is the field of -- or maybe
19 subfield or what is polymer rheology?

20 A. Rheology is the study of flows, the study of
21 the deformation of fluids, how fluids deform and
22 polymers. And the same with physiological fluids. For
23 example, blood, physiological flows. They all have a
24 very complex behavior, which is viscoelastic. And so
25 the field of rheology studies that.

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1 So there's even a Society of Rheology in the
2 United States with maybe, I don't know, 700 members.
3 There's a German Society of Rheology. There's a Journal
4 of Rheology. There is -- thermologically -- where we've
5 published papers in that.

6 So it's a field that this part -- it's kind of
7 in the crossroads between material science, mechanical
8 engineering, and chemistry and chemical engineering.

9 Q. What -- what was the class that you were
10 teaching the polymer rheology in using rheometers?

11 A. Yeah, so it was a course called Introduction
12 to Polymer Rheology.

13 Q. And did you teach that at Wisconsin or
14 somewhere else?

15 A. Yes, I've taught that at Wisconsin, but I've
16 also taught a course in rheology in Colombia a couple of
17 times.

18 Q. What level class is that typically?

19 A. Well, the Introduction to Polymer Rheology was
20 a course for seniors and also grad students. I did once
21 teach -- so the numbering of that course, I believe, was
22 in the 400 level or 500 level, the one that I taught,
23 which is seniors. Then I also taught one in the 700
24 level, which is for graduate students.

25 Q. And how do force sensors generally -- or

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1 rheometers come up in that class?

2 A. I mean for -- you need to measure a stress and
3 you need to relate that stress to the rate of
4 deformation to the speed. So you measure with solids.
5 You relate the stress to the strain to find out a
6 modulus.

7 In rheology, you measure the stress and relate
8 it to the rate of the deformation to find the viscosity.

9 And with complex fluids, you find a viscosity
10 and -- or a loss modulus and a storage modulus, which
11 actually I talk about in my report, in both of my
12 reports, and that's the field of rheology. And to --

13 Q. And --

14 A. -- measure the stress -- sorry, to measure the
15 stress you need sensors to do that.

16 Q. And so, in the class, it was teaching how to
17 use these sensors to do this or something else?

18 A. It was how to -- how to -- how the sensors or
19 how the stress is measured with what type of sensors and
20 how the strain or the strain rate is measured also using
21 some form of encoders or strain input programs.

22 Q. Was it generally focused more on -- I would
23 say the material characteristics as in, you know,
24 determining these characteristics of different materials
25 or -- or something else?

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1 A. Yeah. That rheology is related as material
2 characterization.

3 Q. Okay.

4 A. How the fluids behave under deformation.

5 Q. Okay. And so did the sensors come up in the
6 class to kind of understand how some of these material
7 characteristics were determined?

8 A. Yes. How -- what kind of sensors are used.

9 Q. Okay. Okay. Did it also focus on, you know,
10 what -- how these sensors are used kind of in the field
11 from a practitioner's standpoint?

12 A. Yeah. I mean, it literally is -- I mean, in
13 the senior design -- or the senior course, it was how
14 they are used in industry, how the practitioners -- so
15 literally a person that takes the course either could go
16 work for Dow and now know what rheometer to buy or how
17 to modify a rheometer to measure properties of whatever
18 new polymer they are going to develop.

19 Q. Did the students in these classes actually use
20 force sensors in a lab or anything or was it just more
21 theoretical learning?

22 A. No. That one was more theoretical and showing
23 them the -- giving presentations on that.

24 But mechanical engineering students do take a
25 measurements course where they do learn about strain

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1 gauges and learn about that, so that's a classic
2 mechanical engineering measurements course where they
3 know about those things. So I don't have to teach them.
4 They already have hands-on experience with that.

5 Q. When do mechanical engineering students
6 usually learn or take that class?

7 A. Yeah. Probably end of the sophomore year,
8 beginning of the junior year. That's -- even when I
9 took mechanical engineering classes in undergraduate,
10 that's -- the measurements class was done then.

11 Q. Okay. And that, you said, covers things like
12 learning stress and strain and strain gauges; is that
13 right?

14 A. Yeah, it's -- and there is a lab that goes
15 along with the engineering mechanics course as an
16 undergraduate where people do -- do measurements of
17 stress and strain.

18 Q. And so by the time they get to your class,
19 they kind of have that basic understanding already?

20 A. Correct.

21 Q. And I think you mentioned -- there's another
22 term, modulus for -- I think that was for solids; is
23 that right?

24 A. Yes.

25 Q. And then what was the equivalent for liquids?

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1 A. Well, for regular liquids it was -- it's
2 viscosity, but for viscoelastic materials like polymers,
3 you have -- when you stretch the material or you shear
4 it, you have two responses. One response is an elastic
5 response. And so with that one you measure what is
6 called the storage modulus or the elastic portion of it.

7 And then the inner friction, which is the more
8 viscous portion of the viscoelastic material, that's
9 what we call a loss modulus, which is friction which is
10 lost energy.

11 So the elastic energy is recovered because
12 it's elastic. It's a spring. And the viscous portion,
13 the loss modulus, it's lost because it's a flow, and the
14 flow is not -- the flow can't be recovered. So the
15 combination of the two. So that's what is called a
16 complex modulus.

17 Q. Okay. Is the viscosity for regular liquids,
18 or modulus for solids, is that also kind of taught in
19 that more basic engineering class? The mechanical
20 engineering measurements, I think you called it?

21 A. Yes. Yes. The modulus -- people do
22 stress/strain experiments in mechanical engineering, and
23 they also have a fluids lab which -- where they talk
24 about the viscous portions.

25 Q. Okay. So, again, you're -- they already have

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1 the basic understanding when they come to you, and you
2 kind of further develop that for polymers and rheology?

3 A. Rheology.

4 Q. Rheology. Thank you.

5 Is that right?

6 A. Yes.

7 Q. So we talked about the modulus for solids.

8 Is that referred to as Young's modulus?

9 A. For some of them, yes. So Young's modulus or
10 elastic modulus is for elastic materials; and, yeah, you
11 can -- there is a modulus or an elastic modulus.
12 Young's modulus is equivalent to that, yes.

13 Q. Okay. And, again, that's something that would
14 have been taught in that kind of more junior level
15 mechanical engineering class?

16 A. Probably sophomore.

17 Q. Okay. Sorry. I used "junior" more loosely as
18 not senior but junior; but, yes, thank you for that.

19 And did you use the Young's modulus -- is that
20 something that you would use in your rheology class?

21 A. I use that more in engineering design with
22 polymers when I define the mechanical behavior of
23 polymer.

24 So if you make a polymer structure, you try to
25 find the modulus. With polymers it's complicated

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1 because it's time dependent. With metals it's a
2 constant material. So with metals you have an elastic
3 material where you have one modulus.

4 With polymers the materials are deforming and
5 flowing when you apply a stress, so the modulus is
6 time-dependent. And that's what is more -- that is
7 different with polymers than it is with metal materials.

8 Q. And that's true of polymers more generally or
9 specifically for polymers used in 3D printing?

10 A. No. Polymers in general.

11 Q. And so it sounds like you've taught maybe
12 several classes that kind of cover these modulus
13 concepts for -- for maybe different materials, even more
14 specifically for polymers?

15 A. Yes.

16 Q. And I guess, if you could explain maybe more
17 generally, why is -- what is -- let's start with Young's
18 modulus.

19 What is that a character -- or what does that
20 describe?

21 A. Well, a modulus is a ratio between stress and
22 strain. So if you have a metal, like steel -- if you
23 take the stress, divide it by the strain, it stays
24 constant because it's a straight line. So steel has a
25 modulus of about 207 gigapascals and that you would take

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1 and design.

2 The polymer is a little bit different because
3 when you stretch it, if you stretch it slowly, it's more
4 compliant. You measure at a lower modulus because it's
5 time-dependent.

6 If you stretch it fast, it behaves as a
7 stiffer material. So the frequency matters. Frequency
8 is time. So one hertz is equivalent to one second. If
9 you stretch it in one second, it is -- is -- has one
10 property; but if you stretch it in a tenth of a second,
11 it's gonna appear stiffer because you don't allow
12 relaxation.

13 So with polymers, that plays a role. So
14 polymers, you don't really have one modulus. You have a
15 modulus as a function of time.

16 Q. And so one thing that you use to define it was
17 stress.

18 What is -- how would you define stress?

19 A. Stress is the load divided by the area that it
20 acts on. So if you stretch something, if you stretch a
21 specimen that has a rectangular cross-section, you have
22 the force, which when you stretch it, divided by the
23 area of that rectangle, is the stress in that area.

24 Or if you shear something, the shear force
25 divided by the area that you're shearing, that's also

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1 stress. That's a shear stress. So you have
2 elongational stresses, and you have shear stresses.

3 Q. And how would you define strain then?

4 A. Strain, if you have -- if you have a
5 specimen -- that rectangular specimen has a certain
6 length. If that length grows a certain distance, the
7 growth of that distance that it changed in length,
8 either decreased or increased, divided by the original
9 length, that's a strain. Could be compressive or could
10 be a tensile strain. Same with stress, could be tensile
11 or compressive.

12 And shear is a little bit different. You take
13 the amount -- the distance of the two plates and travel
14 in shear divided by the thickness of that shear
15 specimen, and that's the shear strain.

16 Q. Okay. And so when I asked about Young's
17 modulus, you clarified that for polymers the modulus
18 changes as a function of time.

19 Is that -- just to make sure I'm using the
20 right terminology, does that mean a polymer wouldn't
21 have a Young's modulus, or it's just a more complicated
22 Young's modulus?

23 A. It's a complex modulus.

24 Q. Complex modulus.

25 A. That has both an elastic component and a

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1 viscous component and a time dependence.

2 Q. So that's sort of the same idea as a Young's
3 modulus, but it's something different because it has
4 more -- more being taken into consideration; is that
5 right?

6 A. Can you repeat that again? Sorry.

7 Q. So the complex modulus is kind of the same
8 idea as the Young's modulus; it's just -- you know, has
9 more factors being considered or -- I just want to make
10 sure I'm using that term right.

11 A. Yes. Literally both of them are stress
12 divided by strain. And if it's a metal, if it's a
13 regular material, the stress and the strain are in sync
14 with each other.

15 If you have a complex fluid and you apply a
16 strain input, then the stress will be shifted. It will
17 be -- there was a shift between, so you can literally
18 take the stress divided by the strain because the -- the
19 time is shifted, and that's why it's called complex, but
20 they're similar.

21 Q. So the -- I'm sorry.

22 Go ahead. Continue.

23 A. The concept is the same; but, yeah, it's more
24 complicated to analyze it.

25 Q. So these modulus -- different modulus are

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1 always kind of a ratio of stress to strain?

2 A. Yes.

3 Q. And these modulus are specific to a material;
4 is that right?

5 A. The modulus or moduli are specific to
6 materials, but they are also specific to the frequency
7 of that at which -- or the time scale at which that
8 material is being -- the loads are being applied to that
9 material.

10 Whereas in elastic material, you can deform
11 something fast or slow, and you're still gonna get the
12 same modulus. But in a viscoelastic material, you're
13 going to get different values.

14 Q. Okay. So the modulus for some materials are
15 maybe static, but they would vary from material to
16 material; is that right?

17 A. Yes. For elastic materials, correct.

18 Q. And that's something that a practitioner could
19 look up and find what that modulus is for the specific
20 material?

21 A. Yeah, if you have steel or if you have
22 aluminum or those known materials, yeah, they could read
23 it off a handbook or some other system. If you have a
24 new alloy or something you develop, then you need to
25 measure the standard form of measurement.

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1 Q. Okay. And then for more complex materials,
2 you now have this element of time, but it's the same
3 kind of basic idea, it just becomes a more complex
4 modulus?

5 A. Yeah, it becomes -- and it depends what time
6 scales you're looking at.

7 Q. Is that also -- I'm sorry. Continue.

8 A. Yeah. Some polymers, for example, if you load
9 a polymer, you want to know what it's gonna be doing in
10 five years. You're going to have to do some creep
11 experiment, which is putting a weight on it. It's a
12 constant stress, and the strain varies over time. So it
13 always -- there's a time aspect to it.

14 But if you want to know impact, how does a
15 bumper behave in a crash, there you need to do either a
16 very high frequency, in order of a millisecond maybe
17 type of test, impact test. So you do impact testing to
18 determine the properties. So it's more complicated with
19 polymers.

20 Q. Can you look up the complex moduli or modulus
21 for a specific polymer?

22 A. Well, they are -- there is data -- creep data,
23 there is time-dependent data for design, but not all of
24 that is in there. So that's -- I mean, so in our
25 handbook or even in the Material Science of Polymers For

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1 Engineers I have, for general polymers, general
2 properties.

3 But there are data banks, so -- at Dow and
4 SABIC and BASF and all of those, they are -- they
5 measure -- they have to measure the properties, the
6 creep properties or the dynamic properties which is the
7 complex modulus and have those in data sheets, and they
8 are all in data banks. So people could look up some
9 polymers in the databank. Not all of them are there.
10 New materials are -- are obviously not there. That
11 needs to be measured by a rheologist. That's why I
12 teach the rheology course.

13 Q. So the standard -- maybe more standard
14 polymers kind of have that information more readily
15 accessible; is that right?

16 A. More standard polymers have it more
17 accessible. Yeah. Exactly.

18 Q. And how did -- how do these kind of tables get
19 created? I think you mentioned a company like Dow might
20 put one together for new material. How is that
21 generally created?

22 A. They usually -- if they want time-dependent
23 modulus, then they do creep tests or they take a
24 specimen. They hang a weight from it. But you need to
25 have several stresses. So they -- they have maybe five

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1 or six different weights hanging from the specimen, and
2 they measure the strain over time, and that strain over
3 time is recorded as a function of also the different
4 stresses. And you can generate stress anchors where you
5 can extract a modulus that is time-dependent.

6 Q. Okay. So the modulus is calculated from
7 empirical tests; is that right?

8 A. Not from tests. From stress/strain tests. I
9 mean, they are all -- they are not really empirical.
10 There is science behind it, so it's not really
11 empirical, so...

12 Q. Okay. But it's from, I guess, physical
13 testing, right?

14 A. Yes.

15 Q. Okay. As opposed to, you know, theoretically
16 using the -- I guess the theoretical properties of the
17 material? So that's not generally how it's done?

18 A. Yeah. You need to measure the properties.
19 You need to measure the time-dependent properties or you
20 need to do a dynamic testing to get the complex modulus,
21 which is also useful.

22 Q. What is dynamic testing?

23 A. It's when you apply a sinusoidal deformation
24 on your specimen either by shear or by compression, and
25 then you input a strain input, and you measure the

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1 stress. And taking that stress divided by strain gives
2 you a complex modulus.

3 Q. Okay. So if you're not doing dynamic testing,
4 it's kind of the same idea where you apply a specific
5 stress, and then you can divide by a strain; is that
6 right?

7 A. Yes, in all of those. I mean, there are
8 different test methods. In my book, Materials Science
9 of Polymers For Engineers, I show what measurement
10 techniques are used for different time scales.

11 So are you measuring properties that you're
12 going to -- for the polymer that goes over months and
13 years, or are you measuring a property that is just an
14 hour, or are we measuring properties that is impact or
15 crash, which is -- where the time scale is really small.
16 And all of those require different test methods.

17 So one test method doesn't -- doesn't cover
18 the whole territory of material characterization,
19 neither in rheology nor in solid mechanics.

20 MR. OAKS: Phillip, when you get to a break,
21 we've been going about an hour.

22 MR. BROWN: Yeah, I was just looking. I think
23 now is a fine time to break, so why don't we go off the
24 record.

25 (Recess.)

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1 BY MR. BROWN:

2 Q. Okay. Dr. Osswald, what types of polymers are
3 commonly used for 3D printing?

4 A. There are all kinds of polymers. There are --
5 they go all the way from polycaprolactone to PLA,
6 polylactic acid, ABS, Acrylonitrile Butadiene Styrene.
7 And other polymers like polyamides or nylons. I mean,
8 there's all kinds of -- this -- in 3D printing using
9 PEEK, P-E-E-K.

10 Q. Are there any few in particular that are most
11 common?

12 A. Yeah. I would say most common to date is PLA
13 and ABS.

14 Q. Can you look up the modulus for PLA?

15 MR. OAKS: Objection.

16 THE WITNESS: Yes. Yeah. Yes. You could. I
17 mean, you could look up properties for PLA. And there
18 are different grades. The same with ABS, but they are
19 differing grades, and that's one problem with 3D
20 printing materials where they use whatever grade or
21 molecular weight is available to make filaments. And so
22 there is significant variability between one ABS and
23 another ABS with 3D printing materials.

24 BY MR. BROWN:

25 Q. But it is something that you can typically

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1 look up, even if it's not perfectly representative of
2 the exact specimen you're using?

3 A. In general, ABS and PLA are materials that you
4 can find in databanks, et cetera. But if you want a
5 full rheological or mechanical characterization, you
6 probably need to measure them.

7 Q. Have you ever measured the modulus for PLA or
8 ABS?

9 A. Yes. I mean, I don't think I personally
10 pushed the buttons on the machine, but I have either
11 asked my undergraduates or graduate students to perform
12 those measurements.

13 Q. So that's something that you would do or
14 oversee in a lab?

15 A. Yes. I would oversee that in a lab, yes.

16 Q. Okay. So it's fairly -- is it something that
17 you would do regularly, or was it for a specific
18 project?

19 A. For a specific project, I mean, I -- research
20 projects, we were printing with ABS, and we wanted to
21 measure the properties. We did the whole project on
22 failure criteria of FFF parts and selectively the
23 centering parts. And there we would print specimens,
24 and those specimens we would do the measurements to
25 determine the strength and the modulus of the material.

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1 Q. For those particular projects you are
2 interested in a more precise characteristics of the
3 materials?

4 A. Yes, to know how those materials fail. If you
5 design a product with them, we developed the model that
6 predicted the failure. So it's a failure criteria we
7 developed for composites, but we extended for 3D printed
8 parts.

9 Q. Would your research or process testing have
10 been part of what was published from that research, or
11 is that an ancillary part of the project?

12 A. No. We published data of FFF printed parts or
13 extrusion-based manufacturing parts and develop the
14 whole failure criteria for those. In fact, we did it
15 for -- I believe we did it for ABS.

16 Q. Okay. Earlier before our break you mentioned
17 creep data and creep tests.

18 Could you explain kind of what those creep
19 tests look like?

20 A. Yeah. So you make a specimen, a dog-bone
21 specimen, that starts wide and has a central portion
22 that is constant length. You put a transducer in the
23 constant length, an extensometer, to measure how much it
24 stretches. And then you clamp one side of the specimen,
25 and then the other end. You'd hang a weight from it so

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1 you have a constant stress.

2 And with that constant stress you measure the
3 strain over time. So it starts stretching, very slowly
4 starts flowing. So if you take stress over strain, the
5 strain starts increasing, so that means the modulus
6 starts decreasing over time.

7 Q. What is a normal time scale for this kind of
8 test?

9 A. The creep test -- one, I mean typical, because
10 it's very expensive because each -- each test occupies
11 about a square meter, about 10 square feet in your lab.

12 And they don't -- ideally you would have those
13 tests run for three years, four years. But too
14 expensive to do that.

15 And so what they do is they do a thousand
16 hours, which is about six weeks. And then you have
17 relationships that exist in those tests that one can
18 extrapolate them in two years -- two years. Whereas to
19 predict modulus as a function of time over years, but it
20 doesn't catch the failure, the creep rupture that would
21 occur.

22 Q. Okay. What kind of materials is the -- where
23 are these creep tests most relevant to?

24 A. Thermoplastics.

25 Q. And is there a specific use case for

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1 thermoplastics that the creep data is needed for?

2 A. Yeah. It's for long-term mechanical behavior.

3 Q. Is creep data relevant to the polymers and
4 their characteristics for use in 3D printing?

5 A. If you're going to do a design analysis of 3D
6 printed parts -- so if you're 3D -- printing some
7 bracket, for example, if that bracket is going to be
8 under stress over time, you want to know how it deforms
9 over time. So, yeah, it would be relevant to any design
10 part, be it manufactured by any method, including
11 additive manufacturing.

12 Q. So it's helpful to understand, I guess, how
13 the printed part will behave over the long-term; is that
14 right?

15 A. Yes.

16 Q. But that test data isn't really useful for the
17 characteristics of actually extruding the part, is it?

18 A. No. The characteristics for extruding the
19 part are more rheological characteristics, viscosity,
20 et cetera.

21 Q. Okay. So based on your experience in this
22 field that we went through already, you would meet the
23 limitations or definition of a POSITA in this space,
24 right?

25 A. Yes.

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1 Q. And in your declarations, you analyzed the
2 patents and the prior art from the perspective of a
3 person of ordinary skill in the art, right?

4 A. Yes.

5 Q. Okay. It also looks like on your -- from your
6 declarations that you served as an advisory to the
7 Colombian president.

8 Are you still in that role today?

9 A. Well, right now the government is a little bit
10 funky, and so I am still supposedly in part of this
11 advisory board, but we haven't been asked by him to do
12 anything. But I am still on the advisory board.

13 Q. How did you use your background in polymers
14 for this position?

15 A. Well, I was asked by the president of the
16 national university if I wanted to be part of this
17 commission, and I said I would. And I was in the -- in
18 the group that dealt with materials and manufacturing.

19 Q. Did you do any work specific with 3D printers?

20 A. Yes. One of my advice -- our group had
21 several things that actually were implemented by the
22 Colombian government. But for one, there is now a
23 ministry of science and education in Colombia, which is
24 good.

25 But one of the -- one of the areas that we

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1 suggested is to have a digital ID to end corruption in
2 the country so that people couldn't hide their taxes and
3 their sales and whatever.

4 And the other one, and one that was
5 particularly close to my heart, was the democratization
6 of 3D printing because 3D printing can be used
7 throughout the country in the rural areas in order to
8 manufacture parts and to educate people.

9 And for that, we needed the whole country to
10 have access to internet. And so that was our other
11 suggestion. And so we found a first solution to have
12 phone antennas, which are throughout the country, to use
13 as also an internet access source for Colombians in the
14 rural area.

15 But that way, by having the Internet, having
16 their digital ID, one could democratized 3D printing and
17 have 3D printing at differing communities, either
18 community houses in rural areas and schools, et cetera,
19 or people could make, like, replacement for some parts
20 like items that break, like the handle of a machete, for
21 example, that you could 3D print.

22 And so that -- and the other one aspect that I
23 really -- was close to my heart is -- is to expand the
24 usage of natural rubber plantations in Colombia.

25 Q. So you're using 3D printers as a way to spread

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1 more widespread internet access, it sounds like?

2 A. In a way, yes. They go hand in hand.

3 Q. That's -- that's very interesting.

4 So when was the first time that you personally
5 used a 3D printer?

6 A. Probably in the early -- late 1990s, early
7 2000s. There was, I think, an old Stratasys machine in
8 the labs at UW Madison. I think that's when I first
9 used an FFF printer and SLS printer. I think I used it
10 for the first time, or played around with it. It was in
11 Erlangen in Germany in, like, 2000 -- maybe 1999, 2000.

12 Q. How frequently did you kind of end up using 3D
13 printers throughout the course of your career? Was this
14 something you were using a lot?

15 A. Well, I mean, I certainly didn't push buttons,
16 but I certainly -- with graduates I asked them to try
17 different powders, and how do we characterize those
18 powders. How do we make a filament? In fact, we made
19 a -- we developed a process at our labs here in Madison
20 to actually extrude our own filament because we wanted
21 repeatability between materials.

22 And so ABS was the material that we were going
23 to do a lot of experiments with, but we found from batch
24 to batch there were too many differences.

25 And so we decided to buy, like, a whole

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1 gaylord of ABS from SABIC. Actually, they gave it to us
2 for free. And with that then we made filament that
3 always had the same properties, the same diameter, the
4 same behavior to be able to do a more in-depth analysis.

5 Q. Was -- was your -- your own kind of research
6 interest generally more related to the actual materials
7 that were being used by the 3D printers, generally
8 speaking?

9 A. No. I think -- I mean, by the materials,
10 which is the polymer, right? but also by the additive
11 manufacturing technique, so the process. And then what
12 products -- the P for products and the performance.
13 That was -- so literally it was all across the polymer
14 engineering field.

15 Q. Okay. And you said you didn't literally press
16 the buttons.

17 Is that you're having your grad students and
18 things -- grad students run the actual tests; is that
19 what you're referring to?

20 A. Yeah. I mean, I have ran the machines and
21 played with machines throughout, but my graduate
22 students always wanted to keep me away from the machines
23 because I knew I -- they knew I would do something that
24 would break it. I would push it to the limits and break
25 the machines.

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1 And so -- and that's with everything. With an
2 extruder and injection molding machine, I've broken many
3 machines by just doing something that I shouldn't.

4 Q. So leave it into the hands of your trusted
5 researchers?

6 A. Yes. Yeah.

7 Q. When would you say the last time you used a 3D
8 printer was, personally?

9 A. The last time was in this case playing around
10 with machines at the law firm offices.

11 Q. Was that at Stratasys's law firm offices?

12 A. Yes.

13 Q. Do you personally own any 3D printers?

14 A. No, I don't. I don't.

15 Q. Have you -- have you ever personally purchased
16 a 3D printer?

17 A. No, I haven't. I mean, I've purchased several
18 of them in my lab, but no, I have not.

19 Q. Okay. I think you mentioned that you're now
20 retired as a professor from Wisconsin but your current
21 title is professor emeritus; is that right?

22 A. Yes. I still have graduate students working
23 with me, so I still go to the lab. I still work there,
24 et cetera.

25 Q. Are there 3D printers in your lab currently?

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1 A. Yes.

2 Q. What -- what brand 3D printers do you have?

3 A. I think until recently we had a Markforged.
4 It's like a fiber -- a continuous fiber printer. We
5 have -- in the other side of the lab with all the
6 professors, Stratasys's machines. We have a Cosine
7 printer, which is for making larger parts. And we have
8 also some Fused Form printers, which is a startup
9 company in Colombia that makes printers.

10 Q. Have you -- have you ever worked as an expert
11 in a 3D printer case before?

12 A. Yes.

13 Q. And what was the -- what was that case?

14 A. It's a case -- lawsuit between Continuous
15 Composites and Markforged.

16 Q. And who were you working for?

17 A. Continuous Composites.

18 Q. And was that a patent case?

19 A. Yes.

20 Q. And any other 3D printing cases that you
21 worked on?

22 A. I can't think of any right now. Yeah, no.
23 No.

24 Q. Have you ever personally built or designed a
25 3D printer before?

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1 A. Yes.

2 Q. When?

3 A. The project with the students where we
4 designed a 3D printer that would print in different
5 colors. Then we designed a 3D printer with an actual
6 screw extruder that was built for us, Fused Form in
7 Colombia. We designed and patented the spinning nozzle,
8 FFF printer, and that was manufactured also by Fused
9 Form. So several times, yes.

10 Q. Have any of those projects -- have you ever --
11 strike that.

12 During any of those projects, have you ever
13 designed a sensor for a 3D printer before?

14 A. No.

15 Q. So when you've used sensors, they've been
16 aftermarket or commercially available sensors; is that
17 right?

18 A. Correct.

19 Q. Did any of those printers use a -- any sort of
20 a force sensor?

21 A. Yes.

22 Q. Which project would that have been for?

23 A. The FFF printers that what we developed for a
24 lab in our class to be able to measure the force that
25 the filament exerts on the nozzle that I was talking

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1 about earlier. But also the force sensor and encoders
2 that were used in the rotating nozzle printer.

3 Q. And when was the rotating nozzle printer
4 project?

5 A. I think that was built for us in maybe 2022.
6 The Ph.D. thesis on that work was defended in September
7 of 2023. About three years ago.

8 Q. Do you have any -- outside of these printers
9 that were designed in your lab, do you have any
10 experience using printers that use a force sensor?

11 A. Not that I can think of right now.

12 Q. So none of the printers, for instance, that
13 are in your lab right now that you recall having a force
14 sensor on them?

15 A. Well, the ones that I said that we developed
16 for the course, they have it in that. We did play
17 around with the force sensors of the Bambu printers in
18 Austin.

19 Q. Okay. But none of the -- I guess maybe -- let
20 me clarify.

21 None of the commercial printers that you have
22 in your lab have a force sensor, to your knowledge?

23 A. I don't think so. I don't know.

24 Q. Okay. Have you ever worked with a 3D printing
25 company in more of a business relationship as opposed to

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1 your expert role before?

2 A. I mean, the students that I worked with
3 negotiated the patent with MakerBot, but I don't know if
4 that's a business type of relationship.

5 Q. Okay. When you say they "negotiated the
6 patent," did they negotiate a sale of the patent for
7 their invention; is that what you're referring to?

8 A. Yes.

9 Q. And that was developed in your lab?

10 A. Yes.

11 Q. And did MakerBot just buy the patent rights
12 for that patent?

13 A. Correct.

14 Q. Okay. Were you involved in that transaction?

15 A. I was the technical advisor. They also had a
16 business advisor, but, yes, I was involved with it so --
17 peripherally.

18 Q. Did you receive any compensation as part of
19 that sale?

20 A. Yes.

21 Q. Do you remember what that compensation was?

22 A. I remember -- what was it? I think it was one
23 percent -- one percent of the patent. So maybe I got --
24 we never received a second payment for some -- I
25 remember there were some issues with it, but I think I

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1 received \$15,000 for one percent.

2 Q. Okay. So you received a percentage of the
3 sale of the patent rights to MakerBot; is that right?

4 A. Yes.

5 Q. Okay. And Stratasyys now owns MakerBot; is
6 that right?

7 A. That's my understanding, yes.

8 Q. Okay. And before this case, have you ever
9 worked directly with Stratasyys?

10 A. No. I mean, I -- I met once with research --
11 I don't remember what year it was. He was in Madison.
12 I think he was recruiting. He came to my office, and we
13 chatted a little bit about maybe possibilities of doing
14 researching or consulting, but it never went anywhere.

15 Q. Okay. And approximately what -- what, like,
16 timeframe would that have been?

17 A. I don't know. Maybe eight, nine years ago,
18 ten years ago.

19 Q. Okay. When you were preparing your
20 declaration, how much time would you say you spent
21 reviewing the '381 patent?

22 A. I don't remember. Probably less time than I
23 spent reviewing the '698 patent.

24 Q. Okay. Do you remember approximately how much
25 time you spent on '698?

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1 A. No, I don't remember. I mean, I read the
2 patent. I looked it over again, and I studied it, but I
3 don't remember how many hours.

4 Q. Okay. Do you think it would have been, you
5 know, on the order of ten or more hours?

6 A. I don't know. Probably more. But I don't
7 know how many hours.

8 Q. And so as part of that process, did you read
9 the entire patent?

10 A. Yes.

11 Q. And that includes all of the claims?

12 A. Yes.

13 Q. Do you think you've read the entire patent
14 more than one time?

15 A. Well, I mean, I think one time I read the
16 whole patent, and then I looked at pieces here and there
17 and claims and all of that, but, yeah, I've read many
18 parts of the patent. I read several times.

19 Q. Okay. I think we talked about this earlier,
20 but you mentioned earlier that you have not, to your
21 knowledge, ever spoken with any of the named inventors
22 of these patents; is that right?

23 A. That's -- that's what my memory tells me.
24 Yeah, I don't think I've talked to the inventors.

25 Q. Okay. Do you remember the inventors of these

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1 patents? I'm not trying to do a memory test here.

2 A. I don't remember.

3 Q. Okay. Let me just drop them into the -- the
4 patents into the chat so you can refresh your memory.

5 Okay. I just dropped in the chat the '698
6 patent, if you want to go ahead and download it and open
7 it. Let me know when you have it open.

8 Were you able to open that?

9 A. I'm trying to find it, where I saved it.
10 Yeah. I've got it now. I have it here. Yes.

11 Q. Okay. Do you see that there is three named
12 inventors?

13 A. Yes.

14 Q. And so just ask my question again.

15 Do you remember ever speaking with any of
16 these individuals?

17 A. No, I don't remember.

18 Q. Okay. And have you ever heard of their names
19 before, before reviewing these patents?

20 A. I don't remember -- I mean, I -- yeah, no,
21 maybe. I don't know. I mean, I -- I'm not sure. I'm
22 not sure.

23 Q. Okay. So these patents talk about -- they
24 list quite a variety of different sensors.

25 Do you remember that?

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1 A. Yes.

2 Q. And just, if you would like to reference, I'm
3 referring -- I think one of the places they list on this
4 is on the bottom of Column 8 on to Column 9 of this '698
5 patent that we just put in the chat. So if you would
6 like to reference those.

7 Dr. Osswald, what is a strain gauge?

8 A. Yeah. The strain gauge is a flat device --
9 sorry, I can't see you now that I -- there we go. It's
10 easier if I see you when I answer my question.

11 A strain gauge is a flat wire system that
12 wraps around.

13 And when you glue that -- the strain gauge in
14 some substrate, very thin, and when you attach that
15 substrate to a metal, for example, the metal beam, and
16 you stretch the metal beam or you bend it, then the
17 resistor -- the resistance will change.

18 And the resistance changes because of the --
19 of the length change in the strain gauge. And so you
20 can calibrate that strain gauge to the -- to the strain.

21 So you calibrate the resistance to the strain
22 that the strain gauge experiences, and it measures the
23 strain in one direction. So if you want to measure the
24 strain in two directions, you need one strain gauge and
25 then one 90 degrees off from the other one, and you can

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1 measure the X and the Y strains.

2 Q. What -- what units of measurement does it
3 measure strain in typically?

4 A. The units of strain are units, so 100 percent
5 stretch, which is much too large, but just to give you
6 an example, 100 percent strain. So when you double the
7 length of something, it's a strain of one.

8 Q. Okay. What about capacitive sensors? What
9 are capacitive sensors?

10 A. I don't remember. Yeah.

11 Q. What about optical sensors?

12 A. I mean, if you -- you could measure, for
13 example, strain by looking at freckles on a surface and
14 then you can -- you can measure them. But I mean, there
15 are all kinds of different optical sensors. There is
16 also optical sensors that will detect a gap or a lack of
17 a gap. I think one of the references uses that.

18 Q. Have you seen or used any optical sensors that
19 measure force?

20 A. I've seen -- well, we've used optical sensors,
21 the ones with the freckles, to measure deformation, not
22 force.

23 Q. And so from the deformation or the strain, are
24 you able to calculate force?

25 A. If you have -- if you have the properties of

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1 the substrate where they are on, then, yes, the same
2 with the strain gauge. If you know what the properties
3 of the substrate are, then you can translate that into
4 force.

5 Q. So that goes back to with the modulus or
6 moduli that we were talking about earlier?

7 A. Yes, the modulus of the substrate.

8 Q. Right. Okay. Potentiometric sensors, what
9 are potentiometric sensors?

10 A. Potentiometers they are similar. I mean,
11 there are different potentiometers. Some of them will
12 measure the displacement at certain force systems. And,
13 look, I -- I don't really want to start -- if you'd
14 point me in my report where I write about all of those,
15 I'd be happy to answer.

16 Q. I'm just trying to understand -- you know, get
17 your understanding of these sensors that are used in the
18 patent.

19 So have you ever -- have you used a
20 potentiometric sensor to measure force before, if you
21 recall?

22 A. Yeah, I mean, I think they are -- as some of
23 them are present, for example, in the -- in the MTS,
24 stress-strain testers, they have potentiometers. But
25 there are also some sensors that -- if I can go -- what

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1 column is it? So let me go look. Column 8, you said,
2 right, the bottom of it?

3 Q. Yes.

4 A. Yeah, there we go. Yeah. Potentiometric,
5 yes. P as electric, electromechanical. Yeah,
6 electromagnetic eddy currents. Acoustic and other
7 sensors. Yeah, strain gauges. Yeah. I see where
8 you're getting that, yeah. I remember that.

9 Q. Okay. So do you recall ever using a
10 potentiometric sensor to measure force in your work?

11 A. They may have been inside of -- inside of load
12 cells.

13 Q. Okay. What about an electromagnetic eddy
14 current sensor? What is that kind of sensor?

15 A. It's similar. It measures -- it measures a
16 gap. It measures -- well, if you have the two areas
17 that associate with it and the gap between those two
18 areas changes -- it changes the frequency.

19 Q. And I'm sorry, what was that?

20 A. The signal.

21 Q. So that -- that sensor uses a frequency
22 measurement to change or to measure a displacement; is
23 that right?

24 A. So, I mean, all those stress or force sensors,
25 they make use of some form of displacement, just like a

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1 strain gauge. You stretch the part. The strain gauge
2 measures, so can you translate the signal to strain.

3 And the strain, if you know the property or
4 the substrate, can be translated to stress, and the
5 stress can be translated to load.

6 The same with the eddy current system, if you
7 apply a load, a gap will -- depending where the load
8 comes from, the gap becomes smaller. And that will
9 change the frequency signal.

10 So the frequency is obviously related to the
11 gap, and the gap change is related to some force. So
12 that's calibrated then, and you can then translate
13 frequency to force.

14 Q. Okay. And that's -- again, we're talking
15 about doing a lookup or testing for the modulus and then
16 using that to calibrate?

17 A. No, or the general -- general compliance of
18 the system. So if the system -- when you apply a load,
19 I mean, we're talking about -- right now we're talking
20 about the Bambu Labs, printers. If you push on the
21 nozzle -- there is a certain compliance on there. And
22 if you push on the nozzle, the gap where the sensors --
23 or the sensors gap will change.

24 So that general compliance is particular to
25 the system. And so you can translate the change in gap

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1 to the amount of force that is applied on the nozzle.
2 And that amount of force is then related because the gap
3 is related to the frequency, so you can have a direct
4 relationship between frequency and load.

5 Q. Okay. How do you -- how do you determine that
6 relationship?

7 A. Experimentally.

8 Q. Okay. So would that be like applying a known
9 force and monitoring the displacement or the re -- the
10 frequency change?

11 A. Correct.

12 Q. Okay. And then based on that, you would know
13 how that particular system reacts; is that right?

14 A. Yes, you would know what force is being
15 applied to on the nozzle.

16 Q. Okay. And so you could kind of use that to
17 work your way backwards and figure out, in some way,
18 something like a modulus factor or some sort of
19 proportional factor and then use that kind of going
20 forward to calculate force from the change in frequency;
21 is that how that would work?

22 A. No, not necessarily.

23 Q. Why not necessarily? What did I get wrong
24 there?

25 A. You're not really -- you don't care what

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1 the -- what the system's stiffness is. I mean, you care
2 what the compliance is.

3 So you push on the nozzle. You have a force
4 that you know that changes the gap, and so you can
5 relate the force to the change in gap. Or the change in
6 gap changes the frequency. So you apply a force, and
7 you see what the frequency is. You apply another force;
8 you see what the frequency is.

9 And you have now a direct relationship between
10 frequency and force without having to compute any moduli
11 or anything for the system.

12 Q. Okay. I understand. And when you say the
13 term "compliance," what do you mean by that?

14 A. So a system that has a high compliance --
15 compliance is -- is the opposite of stiffness. So it's
16 the ability of the system to deform. So in other words,
17 the ability of the gap to become smaller or larger
18 depending on where -- how you apply the force.

19 Q. So in your opinion what does it require to
20 calculate a contact force?

21 A. Well, have a signal that changes as you apply
22 force. If we're talking about the nozzle and about
23 these patents, you apply a force on the nozzle, and you
24 have a signal, which you can use to compute a force.

25 Q. And so you have to -- one of the steps there

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1 is you have to understand what that relationship is
2 between the signal and the force; is that right?

3 A. Well, you, as the user, don't. But the
4 manufacturer of the system would then internally, in the
5 system, know what force you have. If you know the
6 relationship between the change in gap and force or
7 the -- or the frequency change and the force.

8 Q. Okay. And so in order to calculate a contact
9 force as these patents describe, you would need to know
10 that, if you -- generally speaking, the system would
11 need to know that relationship; is that fair?

12 A. Yeah, the system would have to have a
13 conversion between hertz per newton or newton per hertz.

14 Q. Okay. I think we quickly touched on this
15 before. But before you were asked to work on these
16 IPRs, were you aware of the Warren reference?

17 A. No. I may have come across it, but I did not
18 remember it. It's such a long reference, that -- yeah.

19 Q. What about the Calderon reference?

20 A. I don't remember. Yeah.

21 Q. And so you reviewed both of those references
22 in detail when you're preparing your declarations,
23 right?

24 A. Yes.

25 Q. Okay. Just generally speaking at a very high

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1 level, what is the Warren reference about?

2 A. Well, I can read you what I wrote in my
3 report.

4 Q. Do you have a -- do you have a recollection of
5 just, generally speaking, what it was without reading
6 from your report?

7 A. Yeah. I mean it's additive and subtractive
8 manufacturing in the field of biomaterials.

9 Q. Okay. Have you worked in the field of
10 biomaterials before?

11 A. I have, yes.

12 Q. Is that overlapping with kind of the field of
13 polymers generally?

14 A. It is because they are complex fluids, complex
15 materials.

16 Q. Okay. So maybe they are not polymers, but
17 they are, you know, similar in many ways; is that -- is
18 that kind of the gist of that?

19 A. Yeah. I mean, tissue and bone and -- are
20 complex fluids, are complex materials. So I advised a
21 couple of Ph.D. theses in those areas. Those were kind
22 of hobby projects, but I did get into physiological
23 flows and behavior of physiological materials.

24 Q. Have you ever used a system like what's
25 described in Warren?

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1 A. No.

2 Q. No.

3 Any aspects of Warren, as you mentioned this,
4 that you've used or something similar to what you've
5 used?

6 A. No.

7 Q. Let's look at -- let's flip over to your
8 expert declaration.

9 I'm going to have open the '381, just so we
10 can be consistent on numbering.

11 Do you want to go ahead and open that and let
12 me know when you have it open?

13 A. Yep, I have it open.

14 Q. Okay. And if we look -- let's flip to your
15 paragraph number 163. It's on page 74 of the PDF, if
16 that helps.

17 A. 163, yes.

18 Q. So you would agree that Warren teaches a
19 system that senses a change in amplitude of vibration,
20 right?

21 A. Yes.

22 Q. And it's your opinion that that system does
23 not sense a contact force, right?

24 A. That's correct.

25 Q. Okay. And you would agree that Warren

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1 explains that a change in amplitude is proportional to
2 the force of contact, right?

3 A. I disagree with that.

4 Q. You disagree that Warren teaches an amplitude
5 that's proportional to contact force?

6 A. Yeah. There is no -- there is no way that the
7 amplitude change can be translated into a contact force.

8 Q. Okay. If you look at -- I think maybe I'm
9 asking a slightly different question.

10 If you look at paragraph 165, do you see the
11 second or third sentence there that starts with
12 "Although"?

13 A. Yes.

14 Q. So part of that you quote that Warren states,
15 "change in amplitude is proportional to the force of
16 contact between the dispenser and the substrate," right?

17 A. That's -- that's what he says --

18 Q. Okay.

19 A. -- in paragraph 313.

20 Q. Right. So Warren does say that it's -- that
21 this proportionality exists, right?

22 A. Well, Warren says that, but he doesn't -- as a
23 writer, he doesn't provide any guidance, and he can't,
24 because it's not possible to translate the shift in
25 frequency that leads to a change in amplitude to a

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1 force.

2 At best you would know that the material or
3 that the quill has contacted some complex fluid that --
4 I think in this case it was hydrogels, that would create
5 some damping that would switch the frequency.

6 So it's not even that the amplitude of the
7 vibration changes. It's the whole frequency spectrum
8 shifts like it does because of the -- of the damping
9 that occurs in the system.

10 So it's not possible from a materials and from
11 a complex fluid perspective to actually measure a force
12 or to translate that into force.

13 Q. Okay. And from what I just heard -- and I
14 think your report says the main thing that's missing is
15 it doesn't -- I think you used the term "proportionality
16 constants"; is that right? That's kind of what's
17 missing?

18 A. It's more than that. I mean, I write about I
19 think the whole system -- first of all, there's no way
20 that you can characterize the material because typically
21 materials are characterized with low frequency as you
22 apply vibration, so it's a dynamic mechanical analyzer
23 or a rheometer that has a certain frequency.

24 And it can go from really low frequencies like
25 .001 hertz, which is like a thousand seconds per cycle,

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1 to at most maybe 100 -- maybe -- or so, or maybe a
2 thousand if you go up, but -- but the Warren system
3 isn't a kilohertz, and there's no way that you can
4 characterize a material with that.

5 And the thing is you need to know the
6 properties of the substrate to even do any type of
7 translation. So there is no guidance. I mean, I write
8 extensively about it and why it wouldn't work.

9 Q. And so is it your opinion that Warren requires
10 frequencies in the kilohertz, I think is what you used?

11 A. No, he uses his system, and I don't know where
12 I write about that. Let me see. Yeah. So Warren's
13 system -- I don't remember where I -- I think it's on
14 the next page somewhere. Yeah, so Warren's system goes
15 between 90 and a hundred kilohertz, which is 90,000 to
16 100,000 hertz where typical systems go between .01,
17 maybe a little bit lower, to a hundred.

18 And so there's no way we can find a system
19 that characterizes the material that he's measuring at
20 those high frequencies.

21 But also things change from material to
22 material. You have temperature dependences. You have
23 frequency dependences. And his graphs or his curves --
24 and I don't remember which figure they are located at,
25 and his -- his figures, it's not really a change.

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1 Sure. He talks about a change in amplitude,
2 but what he sees is a slight shift to the -- to the
3 right, I think, of the curve of the spectrum. And that
4 shift is due to a damping. And so it's a damping that
5 comes as a result of contacting a fluid, but it's not
6 related to a force. It's related to a damping process.

7 And so at best he can say, yes, we've touched
8 the material, but you can't -- if you move deeper or --
9 into this fluid that he's doing or this gel, it's not
10 going to change that -- that -- that shift.

11 So the delta A will stay very similar because
12 it's a material. It's a damping that is generated. So
13 he cannot translate that into force.

14 But I think I explain that in my report.

15 Q. Okay. Let's look at paragraph 169.

16 You use the term "contact-detection
17 device" there.

18 Do you see that --

19 A. Yes.

20 Q. -- the bottom of the page?

21 What is a contact-detection device?

22 A. Well, it detects that it has contacted some --
23 which paragraph, 169, right?

24 Q. Yes.

25 A. Yes. "Warren's sensor cannot provide a

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1 quantitative measurement of contact force and functions,
2 instead as a contact-detection device."

3 As I said, at best, it knows, oh, okay, I
4 touched one of those fluids. That's all. But -- so
5 it's, yes, it has contact; and, no, it doesn't have
6 contact. And that's really what Warren does.

7 I mean, sure, he does mention forces in all of
8 that, but he doesn't explain it. And he doesn't explain
9 it because he can't. There is no way of doing it.

10 Q. Okay. Is -- is a contact-detection device, is
11 that a term that you use in the industry?

12 A. Yeah. I mean, I think you can -- I mean,
13 sure, that's used in industry. I mean, a
14 contact-detection device. If you contact something
15 either by opening and closing a switch -- in this case
16 here, it's by seeing a little shift in the -- in the
17 frequency spectrum.

18 Q. So you can measure in different ways, but it's
19 more or less just a yes/no kind of device; is that what
20 you're saying?

21 A. Yes.

22 Q. Okay. So that's -- the contact-detection
23 device is just measuring, yes, there's contact or, no,
24 there's no contact; it doesn't measure force?

25 A. Yes, that's what Warren does.

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1 Q. And you said a switch. So, I mean, to take a
2 general example, it's kind of a light switch; on or off
3 kind of thing?

4 A. Yes.

5 Q. In paragraph -- a little bit later on in those
6 paragraph you include two charts, in that same
7 paragraph, 169. These are from books that you wrote,
8 right?

9 A. Yes.

10 Q. Published?

11 A. Yes.

12 Q. And so for these charts, is this data that you
13 collected as part of your research, or is this a figure
14 that you would have obtained the data from somewhere
15 else?

16 A. Yeah. The first one is one that was measured
17 years ago, and I believe that was measured at BASF, and
18 I've had that -- or by Bayer, one of the two, and I've
19 had that in my books.

20 And it simply shows the effect of frequency on
21 the -- on the storage modulus up above. In this case
22 think it's PVC. And the lower one is something that we
23 measured in the lab when we were writing the book on
24 rheology.

25 Q. Okay. Just out of curiosity, is that

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1 something that you would have published as part of your
2 research and then would have included a book, or is that
3 something you've collected just for this book?

4 A. Something that came from teaching the class on
5 rheology and the students' measurements. So it's data
6 that we collected while teaching and then eventually
7 included it in the textbook of rheology.

8 Q. Okay. I see we're just under an hour. I'm
9 getting close to wrapping up. I think a quick break
10 would be helpful, unless you'd rather take lunch, but I
11 think I'll be relatively quick after this. So why don't
12 we take a -- go off the record.

13 (Recess.)

14 BY MR. BROWN:

15 Q. Dr. Osswald, you cite to an Ashby reference or
16 book that is Exhibit 2024 in your report.

17 Do you remember that exhibit?

18 A. I have to go back and look.

19 Q. Paragraph 188.

20 A. Okay. Yes.

21 Q. And is -- you cited to Figure 4.1 in your
22 report.

23 Is this a textbook reference that you are
24 citing?

25 A. Yeah. It's a book.

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1 Q. And do you know, is this a textbook that
2 you've used before?

3 A. Not this, but, I mean, I've had drafts similar
4 in other textbooks. This is a very common draft to
5 compare moduli of different materials.

6 Q. Okay. And did you find this particular
7 reference that you cited, the Ashby book?

8 A. I don't remember where I got this. I think
9 that graph was in maybe Dr. Wolfe's report. I don't
10 remember where that graph comes from. I'm drawing a
11 blank, actually.

12 Q. We don't need to, but would it be helpful to
13 look at the document, or do you think you're just not
14 going to remember where that's from?

15 A. I can look at the document, yeah. And I'm --
16 I'm drawing a blank where that came from.

17 Q. Sure. I'll drop it in the chat, and you can
18 take a look at it and see if that helps.

19 A. Yeah, I see it. I've seen that book -- that
20 first diagram, I remember. This is a very common --
21 common diagrams, and it's just one of many textbooks.

22 I don't remember where that came from, but
23 it's a very common -- common type of graph. It just
24 illustrates different moduli between different
25 materials.

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1 I don't remember where that came from
2 actually.

3 Q. Okay. Would that have been -- is that a
4 common figure for, again, more of a basic level of
5 mechanical engineering class talking about Young's
6 modulus?

7 A. Yes, mostly material science class. So it's
8 the material science class that people take when they
9 are taking mechanical engineering and other courses.

10 Q. Okay. And so you don't -- you don't remember
11 if this is a book that you searched for for this case or
12 not?

13 A. Yeah, I don't remember. I don't remember the
14 province of it. I'm drawing a blank right now, but
15 it's -- it's a very typical graph that would have been
16 available to anybody of ordinary skill in the art.

17 Q. Okay. While we were on breaks today, did you
18 talk to anyone during any of your breaks?

19 A. No, I didn't.

20 Q. Okay.

21 MR. BROWN: That's all I have. I don't know
22 if Brian has anything else?

23 MR. OAKS: I'd like to take a short break
24 before any further questioning, so let's go off the
25 record.

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(Recess.)

MR. OAKS: Thank you for your time today,
Dr. Osswald. I don't have any questions for you, so I
think we can be done.

COURT REPORTER: Counsel, may I get transcript
requests, please?

MR. GRISWOLD: We need the final by Friday,
Tamara, if you can do that.

MR. OAKS: No, thanks.

(Whereupon the proceedings concluded at
10:20 a.m.)

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ERRATA SHEET

NAME OF CASE: SHENZHEN TUOZHU TECHNOLOGY CO., LTD v. STRATASYS, INC.

DATE OF DEPOSITION: MAY 6, 2026

NAME OF WITNESS: Dr. Tim A. Osswald

Reason Codes:

- 1: To clarify the record.
- 2: To conform to the facts.
- 3: To correct transcription error.

Page _____ Line _____ Reason _____

From _____ to _____

Page _____ Line _____ Reason _____

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Deponent's Signature _____

Date _____

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DECLARATION UNDER PENALTY OF PERJURY

I, Dr. Tim A. Osswald, do hereby certify under penalty of perjury that I have read the foregoing transcript of my deposition taken on May 6, 2026; that I have made such corrections as appear noted on the Deposition Errata Page(s), attached hereto, signed by me; that my testimony as contained herein, as corrected, is true and correct.

This Declaration is executed this _____ day of _____, 20____, at _____, California.

Dr. Tim A. Osswald

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STATE OF CALIFORNIA) ss.
)

I, Tamara Houston, RPR, CCRR, CSR No. 7244, a
Certified Shorthand Reporter in the State of California,
duly empowered to administer oaths, do hereby certify:

That, prior to being examined, the witness
named in the foregoing deposition was by me duly sworn
to testify to the truth, the whole truth, and nothing
but the truth;

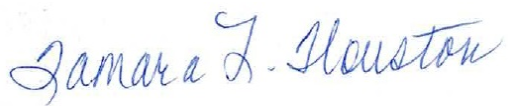
That said deposition was taken down by me in
shorthand at the time and place therein named, and
thereafter reduced to typewriting by computer-aided
transcription under my direction;

That the dismantling, unsealing, or unbinding of
the original transcript will render the reporter's
certification null and void.

I further certify that I am not interested in the
event of the action.

In witness whereof, I have hereunto subscribed my
name.

Dated: 8th of May, 2026.



TAMARA L. HOUSTON
CSR 7244, RPR, CCRR 140, CRG

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