

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 IPR2025-00532
Patent 10,556,381

PETITIONER'S REPLY TO
PATENT OWNER'S RESPONSE TO PETITION

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- EX1017 US20080195353A1 to Igasaki et al (“Igasaki”)
- EX1018 J.E. Carryer, R.M. Ohline, and T.W. Kenny, Introduction to Mechatronic Design, ISBN-13: 978-0-13-143356-4, Pearson Education, Inc., Upper Saddle River, New Jersey 07458 (2011)
- EX1019 J. Srihohi, I. Chopra, Fundamental Understanding of Piezoelectric Strain Sensors, Journal of Intelligent Material Systems and Structures, Vol. 11, P. 246-257, April 2000
- EX1020 https://web.archive.org/web/20060615115221/http://www.allelectronics.com/cgi-bin/item/PE-49/466/PIEZO_ELEMENT_.html (piezoelectric element product discussed in <https://reprap.org/forum/read.php?1,8028,8276#msg-8276>)
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In re Wands, 858 F.2d 731 (Fed. Cir. 1988)

In re Morsa, 803 F.3d 1374 (Fed. Cir. 2015)

Raytheon Techs. Corp. v. GE, 993 F.3d 1374 (Fed. Cir. 2021)

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I. INTRODUCTION

Patent Owner defends its patent by the simple expedient of ignoring the record. To avoid Warren, Patent Owner asks the Board to disregard the plain text of Warren's own claims. Those claims explicitly recite the exact vibrating sensor applied to the through-nozzle dispenser that Patent Owner insists is missing. Patent Owner then invents technical hurdles to calculating force from vibration amplitude, flatly ignoring Warren's express teaching that the two are proportional. Their defense against the Calderon grounds are equally detached from the evidence. Rather than confront the record, Patent Owner baselessly asserts that Calderon requires no improvement and a strain gauge offers no benefit—arguments the Petition preemptively dismantled. Reading the prior art as it is actually written, rather than as Patent Owner wishes it were written, renders the claims unpatentable.

II. WARREN'S THROUGH-NOZZLE DISPENSER USES VIBRATING SENSING

The Petition advanced both Warren's through-nozzle and capillary dispensers as rendering the claims of the '381 patent unpatentable. Petition, 15-17. The POR does not dispute that Warren's capillary dispensers use vibrating force sensing. And indeed, PO admits as much in its Response. POR, 24 ("the dispensers in Warren that need vibrating sensor capabilities, such as the capillary dispenser"); ID, 6-7 (recognizing Warren's teachings of capillary vibro-sensor dispensers).

Instead, PO vigorously argues that Warren's through-nozzle dispenser does not use vibrating force sensing and that it would not have been obvious to do so. POR, 16-25.

PO overlooks Warren's claims, however, that recite "a vibration imparting device for imparting vibration of a particular amplitude to the at least one dispenser...a position controller for varying the position of the at least one dispenser...to obtain a desired force of contact...wherein the at least one dispenser includes at least one of a **through-nozzle**, a needle valve, a capillary pen, or a quill pen." Warren, claims 54→59 & 65→70 (corresponding method claims). Thus, Warren expressly refutes PO's response, supporting the Petition's position advancing vibrating force sensing in Warren's through-nozzle dispenser. *E.g.*, Petition, 11-14, 17-22; EX1003 ¶¶85-86; *Thereasense* 593 F. 3d at 1295 ("The claims of a prior art patent are part of its disclosure.").

Warren's claims support the position that "Warren invites the use of the vibrating force sensor concepts with other configurations of dispenser" and "a POSITA would have recognized the benefits of providing the through-nozzle dispenser with vibrating force sensor capabilities." Petition, 12-14; EX1003 ¶¶68-72 (benefits include improvements over inconsistent volumes and inaccurate start times). PO mischaracterizes Warren's through-nozzle design as lacking precise deposition because Warren expressly teaches precise rate (speed) control resulting

in “smooth, seamless, and very reproducible” start times. *E.g.*, EX1003 ¶69; EX1004 ¶¶[0234], [0243].

III. WARREN’S VIBRATION SENSOR SATISFIES 1[b]

As admitted by the POR, the ’381 patent describes its sensors broadly to sense anything, “so long as the contact force(s)...may be calculated from the sensed physical characteristics.” EX1001, 8:49-61; EX1003 ¶¶90-91; POR, 34; Petition, 21. Thus, Warren’s vibration sensors, which sense a change in amplitude (ΔA) of the vibration, satisfy the claims because Warren teaches that the contact force is calculable from the sensed ΔA physical characteristic. *E.g.*, EX1004 ¶[0302], [0313]; Petition, 20-21; EX1003 ¶¶90-91. Specifically, Warren teaches that the contact force is proportional to ΔA . *E.g.*, EX1004 ¶[0302], [0313]; Petition, 20-21; EX1003 ¶¶90-91. Moreover, Warren teaches calculating the force from the ΔA . *E.g.*, Warren ¶¶[0287], [0313]-[0316]; *see also infra* §IV. Thus, a POSITA would have immediately recognized that Warren teaches a sensor from which “the contact force...may be calculated from sensed physical characteristics,” consistent with the ’381 patent and claims. EX1003 ¶¶90-91.

IV. WARREN CALCULATES FORCE

Despite PO's arguments to the contrary, Warren teaches, and renders obvious, calculating contact force and using calculated force for control. *E.g.*, POR 26-27, 34, 37-38.

As PO correctly points out, Warren teaches varying the position of one or more elements of the dispenser “to maintain a desired force of contact between the dispenser and the substrate.” POR, 26 (citing Warren ¶[0289]); *see also* Warren ¶[0283] (introducing the section on controlling the position of Elements of the dispensing system using force feedback”), [0313]-[0316], FIG. 22A, claims 54-56, 61, 65-67 and 72. Warren varies the position based on a comparison between a detected contact force and a desired contact force. *E.g.*, EX1004 ¶[0313], FIG. 22A.

More specifically, Warren explains that its system addresses a need for “a depositing system **that accurately determines the intensity of the contact force** between a dispensing tip and a substrate surface.” Warren ¶[0287]. Warren explains that its system controls “the contact force between the dispensing structure and the substrate surface,” to “maintain contact of a desirable **intensity**, accurate to a precision of **micronewtons of force, if not smaller units of force.**” Warren ¶[0316]; Petition, 23, 25-27, 33.¹ Warren has “demonstrated” that the system is

¹ All emphases added, unless otherwise state.

“sufficiently sensitive to allow for the **sensing of the contact force** as a dispenser contacts a substrate surface.” Warren ¶[0316]. Contrary to PO’s arguments, these passages expressly support the conclusion that Warren does indeed convert the change in amplitude in its vibrating sensor “into a calculated or quantitative contact force.” POR, 27 (citing EX2027 ¶185).

Warren also explains that “[c]ontrol applied in this manner allows for dispensing to be accomplished onto conformal surfaces as the **force feedback control** continuously corrects the dispensing structure’s Z-height position as the Z height of the substrate surface changes, either by modifying the dispenser’s position, the substrate’s position, or both.” Warren ¶[0316], Petition, 23, 25-27, 33. Warren compares the calculated contact force intensity to a desired value when determining whether or not to reposition the dispenser or substrate.

The necessity of calculating contract force from the vibrating sensor output is built directly into Warren’s operating principles. In order for Warren “to maintain a desired force of contact between the dispenser and the substrate,” Warren must compare the vibrating force sensor’s reading against the desired force. Warren ¶[0289]. To do so, the system must either convert the desired force into vibration amplitude units or convert the sensor’s amplitude output into units of force. And Warren consistently teaches comparing the detected contact force intensity to a desired value when determining whether or not to reposition the

dispenser or substrate. Specifically, Warren teaches that if “the **contact force is** that which is **desired**,” the process may stop; and if “it is determined that **the contact force is not as desired**, the position(s) of the dispenser and/or the substrate are varied.” Warren ¶[0313]. So, not only does Warren teach calculating the contact force (*e.g.*, to micronewton precision), Warren teaches controlling the position of the dispenser by comparing the calculated contact force to a desired intensity. Petition, 23, 25-27, 33 (citing Warren ¶¶[0301]-[0316], [0322], [0324]).

V. CALCULATING FORCE IS OBVIOUS

Beyond demonstrating that Warren detects contact force, the Petition further demonstrates that it was obvious that Warren calculates a contact force from ΔA . *E.g.*, Petition, 19-24; EX1004, [0313], [0301]-[0307]; EX1003, ¶¶89-91 (explaining additional details of Warren’s sensing operations). Consistent with the discussion of Warren in §IV, *supra*, a POSITA would have understood that to control to a desired force intensity, one would need to know the difference between the desired force and a detected force. *E.g.*, EX1004 ¶[0313]-[0316]; Petition, 19-24; EX1003 ¶¶89-91.

Warren provides express motivation for calculating the contact force. Warren begins by stating plainly that “for proper deposition some knowledge is **required of the intensity of the contact force** between the dispenser tip and the surface where deposition is desired.” Warren ¶[0285]. Warren recognizes the

quantitative (proportional) relationship between contact force and sensor output.

E.g., EX1004 ¶[0302]; Petition, 19-21; EX1003 ¶89. Warren concludes by identifying the need to accurately determine “the **intensity of the contact force** between a dispensing tip and a substrate surface to maintain a desired contact force.” Warren ¶[0287]. And as discussed above, Warren compares a calculated contact force intensity with a desired value for determining whether to reposition the dispenser/substrate, the force intensity being a magnitude component of the force vector quantity measured in Newtons. *E.g.*, Warren ¶¶[0313]-[0316] (micronewton precision). Thus, as pointed out in the Petition, a POSITA would have made such a comparison using the same units to obtain an accurate result. Petition, 23-24 (citing EX1003, ¶93). It would have been obvious to a POSITA to calculate force.

That Warren expresses a desire (and even demonstrates) sensing force to a high-degree of precision suggests that Warren does not rely solely on the measurement of ΔA in making the contact force comparison to determine whether to reposition the nozzle. *E.g.*, Warren ¶[0316]. Warren teaches that the contact force is “proportional” to ΔA , not equal or equivalent to it. *E.g.*, Warren ¶[0313]. And as discussed in the Petition, the proportional relationship means that the contact force can be readily calculated from the detected ΔA . Petition, 20-21 (citing Warren, [0313], [0301]-[0307]; EX1003, ¶¶86-90); *see also* Petition, 23;

EX1003, ¶95 (“Calculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012.”).

PO’s extended discussion of Young’s Modulus and frequency selection to suggest that it is infeasible to calculate force from Warren’s vibrating force sensor is a red herring, particularly given Warren’s express teaching that the contact force is “proportional” to ΔA and the necessity to compare the “desired force” to the force measured by the vibrating force sensor. “Prior art disclosures are presumed enabling.” *Agilent*, 139 F.4th at 1327; *Apple*, 861 F. App’x at 449-50; *Amgen*, 314 F.3d at 1355. The patentee’s burden requires evidence that “undue experimentation,” *In re Wands*, 858 F.2d at 737, was necessary to practice even “a single embodiment,” *In re Morsa*, 803 F.3d 1377, *Raytheon*, 993 F.3d at 1380. Patent Owner fails to surmount this high hurdle.

Even still, PO’s infeasibility arguments support, rather than detract from, feasibility. POR, 32 (citing EX2024, FIG. 4.1). PO’s own evidence demonstrates that the properties that it says are relevant to calculating force, such as Young’s Modulus, were well-known for a wide variety of materials. EX2024, 6-8 (showing Young’s Modulus displayed in three different styles of graphical representation to show how material properties can be displayed); EX1042, 80:2-81:6 (can look up modulus for commonly printed materials). A POSITA would simply look up those

properties, which reinforces Dr. Wolfe’s testimony that “[c]alculating contact force from...a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012.” EX1003, ¶95; Petition, 23. Warren teaches that ΔA is proportional to contact force, and PO’s expert acquiesces that Warren so teaches. EX2027 ¶0185. Moreover, PO’s arguments assume calculating force from first principle calculations, wholly ignoring that the proportionality could be established by measurement and calibration. *See, e.g.*, EX1042, 102:7-103-11 (testifying a force-frequency relationship is obtainable experimentally); 100:13-104:14.

Also contrary to PO’s arguments, the evidence shows that calculating contact force from ΔA was common at that time. For example, Igasaki describes a vibrating force sensor that determines the contact force. *E.g.*, EX1017 ¶¶[0006]-[0007] (“135 μN is obtained as measurement force F ”). Matsumiya likewise teaches calculating a “measuring force based on the **change in the vibration level**.” EX1012 ¶[0034], [0078]; Petition, 23.

VI. GROUND 1A RENDERS CLAIMS 2-6 AND 9-16 UNPATENTABLE

The Petition explains how Ground 1A renders claims 2-6 and 9-16 unpatentable, and the POR's incorrect complaints about claim 1 fail to save these dependent claims. Petition, 24-39.

A. Ground 1A Renders Claims 2, 3, and 6 Unpatentable

Dr. Wolfe explains that when the substrate is aligned in the x-y plane, “there is a **force component** directed along the dispenser/extrusion axis and this force component is a contact force.” EX1003 ¶¶99-100; Petition, 25. Force, a vector with constituent components in orthogonal directions, can include both a z-axis component and an orthogonal component (e.g., a vector quantity defined by x-axis and/or y-axis components). *See, e.g.*, EX1003, ¶¶99-100. Dr. Wolfe explained that in Warren the “contact force at the tip of dispenser 3700 acts along the z-axis, and therefore normal to the surface.” EX1003, ¶114; Petition, 28-29. Claims 2 and 6 are not mutually exclusive. When the extruder is orthogonal to the substrate, the force along the extruder axis can be normal to the substrate. *E.g.*, EX1003, ¶114; Petition, 28-29. PO's arguments pertaining to claim 3 fail to appreciate that force can have components in orthogonal directions. Warren discusses how the nozzle might not be normal to the substrate, such as for conformal or curved surfaces. *E.g.*, EX1004, ¶¶[0316], FIG. 22; EX1003, ¶¶101-103. And, as Dr. Wolfe explained, Warren includes a deflection force “due to friction from contact of the

moving dispenser against the surface of the material,” referring again to Warren’s reference to curved surfaces. EX1003 ¶¶101-103; EX1004 ¶[0316], [0322];
Petition, 25.

B. Ground 1A Renders Claim 4 Unpatentable

Warren teaches claim 4. First, Warren does not restrict the surface to be a substrate. *E.g.*, EX1004, ¶[0316] (“Control applied in this manner also enables the dispenser to seek and find contact with a surface....”); EX1003 ¶106.

Additionally, Warren expressly teaches control based on contact force “allows for dispensing to be accomplished onto conformal surfaces” by continuously correcting the dispenser’s z-height position. Warren ¶[0316]; Petition, 26-27.

Moreover, Warren teaches sensing a force between a surface and the material being extruded from the nozzle as it contacts a surface. Warren ¶[0316]. A POSITA would have at least found it obvious that Warren’s surface included the object being fabricated because Warren controls for dispensing over conformal or curved surfaces by continuously considering changes in z-height that occur during a build. EX1003 ¶¶106-107; EX1004 ¶¶[0316], *see also id.*, [0295].

C. Ground 1A Renders Claim 11 Unpatentable

Warren compares the calculated contact force intensity to a desired value when determining whether or not to reposition the dispenser or substrate. *E.g.*, Warren ¶¶[0313]-[0316] (discussing comparing calculated force with a desired

force). Warren teaches that “a determination is made whether the contact force is that which is desired.” Warren ¶[0313]. If so, the process may stop; if the contact force is not as desired, “the position(s) of the dispenser and/or substrate are varied.” Warren ¶[0313]; EX1003 ¶¶122-128. Thus, in Warren, the control of the dispenser/substrate achieves a specified (“desired”) contact force. EX1003 ¶¶122-128.

D. Ground 1A Renders Claims 13, 15, and 16 Unpatentable

The Petition maps each of feed rate, speed of extruder, and temperature in the claim 12 mapping. *E.g.*, Petition, 35-37. Generally, Warren teaches that the “valving mechanism” for extruding material “maybe synchronized with the xyz motion of the dispenser,” and teaches modifying the z height based on surface changes detected by changes in force intensity.” EX1004 ¶¶[0234], [0316]. Likewise, temperature of the extruder can control flow rate by changing viscosity. Petition, 37-38. Specifically, Warren teaches “temperature control...to enable the user to adjust viscosity of the constituent materials, to accelerate or decelerate setting of a scaffold material, or otherwise to provide a suitable environment for delicate or temperature-sensitive constituent materials.” EX1004, [0212]; Petition, 37. And extruder speed also controls the amount of material deposited. Petition, 35-36. Thus, a POSITA would have understood Warren as teaching adjusting the feed rate (through the valving mechanism or by temperature control) with changes

in z-height (synchronized with xyz motion, related to extruder speed) based on changes in calculated contact force. Petition, 33-38.

VII. GROUND 1B RENDERS CLAIM 3 OBVIOUS

A. The Warren-Dunn Combination Is Predictable

First, PO's requirement that the combination involve bodily incorporation of Dunn's structural elements into Warren is legally unsound. Warren already teaches calculating force from a vibrating sensor. As Dr. Wolfe explained, a POSITA would have found it obvious to "expand Warren's single-axis example into a multi-axis configuration for contact force sensing along two or more non-parallel axes," pointing to Dunn as having taught multi-axes configurations. EX1003 ¶148; Petition, 40. As discussed elsewhere, Warren supports deposition onto conformal surfaces, and would have benefited from multi-axis sensing capability to accommodate the xyz motion of its dispenser. EX1004 ¶[0316]; EX1003 ¶¶147-148; Petition, 40-41. Additionally, Dunn broadly teaches other multi-axis configurations "that can be driven a predetermined distance by force of contact with a surface such as a cam, pawl, cantilever, screw, or membrane, or other mechanical structure." EX1007 ¶[0096]. Thus, Dunn evidences that multi-axis configurations of different implementations were well-known in the art. And expanding Warren's single-axis example to include multiple axes would have

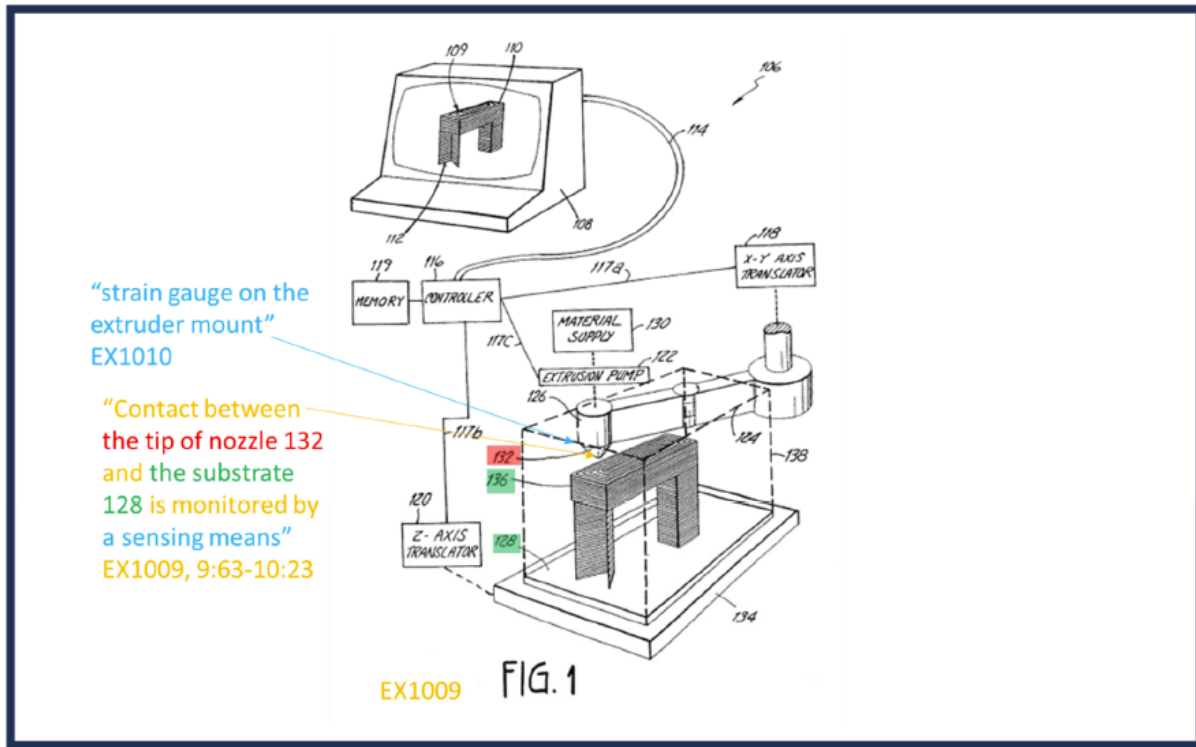
achieved predictable improvements without detracting from Warren's intended operation. EX1003 ¶148; Petition, 41.

B. Warren-Dunn Renders Claim 3 Unpatentable

As mentioned above, Warren's vibration sensor senses a contact force, and in the combination, is expanded to include a multi-axis configuration. In the combination, the multi-axis configuration is collectively operation to sense force due to deflection caused by friction. EX1003 ¶¶149-151; Petition 41.

VIII. GROUND 2A/2B USING A STRAIN GAUGE WITH CALDERON IS OBVIOUS

PO argues that "Calderon already has his own technique for auto-initialization and collision detection to determine contact with a nozzle by 'monitoring a change in the servo drive current.'" POR 46; EX1009, 10:5-8. But Calderon monitors a change in servo drive current only in the specific use-case of "an apparatus that uses servo drive motors." EX1009, 10:5-8 (the only discussion of servos). That is, Calderon predominantly teaches embodiments that do not implement servos. *E.g.*, EX1009, 4:34-5:10, 5:10-24 6:16-18; Petition, 42-46, 49-57. For the combination, the Petition points to Calderon FIG. 1, which does not illustrate an apparatus with servo drive motors:



Petition, 60

Calderon explains that its method for determination Z-height is applicable to the three-dimensional modeling system “shown in FIG. 1.” *See* EX1009, 4:66-5:3.

Before introducing the servo use-case, Calderon explains that, generally, “[c]ontact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means and the controller 116 electrically records the Z-axis position of platform 134 at the time contact is detected.” EX1009, 9:63-10:5 (introducing Example 3 before mentioning servos); *Petition*, 54. Calderon does not restrict the type of sensor it uses, and RepRap20208’s discussion of strain gauges fits with Calderon’s nozzle implementation. EX1009, 6:38-7:5, 9:63-10:23; EX1010, 20 (contact force on the head). Dr. Wolfe explained that a POSITA would understand Calderon as

suggesting that the mechanism for force measurement can include “any known sensing mechanism” using a conventional sensor such as a strain gauge, which was known as “a common sensor.” EX1003, ¶¶54-60 (citing EX1001, 9:17-23); Petition, 45.

RepRap20208 also links the strain gauge to determining Z-height, which is the same problem Calderon is trying to solve using sensors with the nozzle tip. *E.g.*, EX1009, 9:63-10:23; EX1010, 18-19 (describing that “the frame itself warps over time, so I’d like to measure the important variable – nozzle to bed height – directly”); *see also id.*, 20 (expressing a desire for “knowing exactly when the head touches, which is what I’m really interested in”); Petition, 51-52, 62.

Additionally, Wade introduces the discussion of strain gauges by sharing that he experienced “catastrophic failure” involving “an all-night long series of head collisions,” remarking on the advantages of strain gauges to prevent this problem. EX1010, 13 (also remarking that a strain gauge could also find “bed height automatically”); *see also id.*, 14 (“A single head collision would be more difficult to detect without a strain gauge.”). A POSITA reading RepRap20208 would have immediately recognized the advantages of using a strain gauge to prevent damage to the extruder and substrate by avoiding collisions and other catastrophic failure events. Petition, 53; EX1009, 2:36-53; EX1003 ¶165. Note that, despite PO’s argument to the contrary, Calderon does not limit its use case to

being below the top surface of some substrates. POR, 55. Calderon expressly teaches use cases where the nozzle tip depth is zero or even above the top surface, explaining that these specifications “can easily be accommodated by the algorithm.” EX1009, 8:45-52.

That strain gauges were commonly used for force sensing at that time is directly supported by the '381 patent. *E.g.*, EX1001, 9:17-23 (“Strain gauges are one common sensor used for such [contact force] measurements.”); Petition, 53-54; EX1003 ¶¶165-168. And while RepRap20208 poster Larry Pfeffer recognizes potential labor costs, in the same post, he describes a solution to implementing strain gauges:

However, there may be a way to skin this cat.... I did some preliminary experiments (read, played around with) some conductive-plastic fiber I got a sample of, and it serves as a pretty good strain gage, and well matched to plastic, because it is plastic. Since it has high intrinsic resistance (compared to foil gauges), it develops a larger signal, with minimal resistive heating. (The mfr. didn't seem very interested in this aspect -- may have been too far out of their area of expertise....)

EX1010, 16 (annotated)

Indeed, RepRap20208 presents a solution to the so-called “thermal problems” argued by the POR. *Id.* (this post also signifies that POSITA were knowledgeable about the variety in strain gauge options available at that time); POR, 57. The concern of “work[ing] well over long periods of time” refers to a specific force sensor, not strain gauges in general. EX1010, 19. RepRap20208 also recognizes

that strain gauges offer advantages over other sensors, such as addressing problems associated with heating, warping, or catastrophic failure:

edit - the neat thing about strain gauge vs optical measurements is that the strain gauge will tell you how much your extruder has elongated due to heating, warping, or in my special case, catastrophic failure.
--

EX1010, 14

Thus, certainly for implementations that do not include servos, a POSITA implementing Calderon would have turned to common sensors, one of which was a strain gauge. Petition, 53, EX1003 ¶165, EX1001, 9:17-23. Moreover, the '381 patent describes strain gauges as a common sensor for producing a contact force without identifying or curing any issues associated with their implementation, including issues concerning costs.

Even in the context of servo drive motors, however, the Petition addresses why it would have been obvious to modify Calderon with a strain gauge, like that described in RepRap20208, for detecting extrusion head collisions and Z-axis calibration. Petition, 46-54. For example, the Petition points out the “slop/backlash” problem that would make it difficult to accurately and precisely identify when the nozzle contacted the substrate, as is needed for Calderon’s Find-Z program. Petition, 50 (citing EX1010, 20; EX1003, ¶161). RepRap20208 corroborates the Petition’s reasoning when discussing the motivation for using a strain gauge:

 **Wade**

Re: Genetic Algorithms
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

EX1010, 20 (annotated)

Despite PO's assertion that the post concerned "some other sensor," RepRap20208 (red underline) points to "backlash" in the "entire system" as a motivation for using strain gauges for "knowing exactly when the head touches." EX1010, 20, Petition, 50-51; POR, 48. Dr. Wolfe affirms that such backlash would have been present in the system when using sensors that monitor servo current. Petition, 50-51 (citing EX1003 ¶¶161-163). By contrast, a strain gauge between the head and its mount will not measure arm joint and Z-drive slop/backlash, because the joints and Z-drive are outside the gauge's force path. *Id.* In the same post (blue underline), RepRap20208 recognizes the utility of strain gauges for providing a "constant measurement of force on the head," providing express corroboration for Petitioner's assertion that a strain gauge would "produce more accurate and consistent force measurements by which to sense contact of the nozzle 132 to the substrate 128." EX1010, 20; Petition, 51; POR 49. Thus, as stated in the Petition, RepRap20208 contribution to Calderon results in a system that can perform Z-height calibration, while also performing collision detection. Petition, 46; EX1010,

13, 18-19 (discussing how a strain gauge provides Z-height calibration, with collision detection as a nice side effect). And, it would have improved Calderon's collision detection by enabling collision detection after initialization. Petition, 70-71.

IX. GROUND 2A/2B CALCULATING THE FORCE IS OBVIOUS FROM CALDERON-REPRAP20208

The Petition explains why a POSITA would have calculated contact force from the strain gauge in Calderon-RepRap20208. *E.g.*, Petition, 54-57. First, as mentioned above, RepRap20208 expressly discusses strain gauges can provide a “constant measurement of the force” in the context of Z-height calibration and collision detection, and not just a sensor signal. EX1010, 19-20:

Hi Wade

My idea was that it would measure upwards pressure from a calibration touch down or abort if it had run into the bed.

 **Wade**
Re: Genetic Algorithms
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

EX1010, 19-20

Petition, 55; *see also* EX1009, 8:14-20 (teaching that contact can be sensed at initial contact). Thus, in the combination, RepRap20208 teaches a POSITA to use

the strain gauges to calculate a current contact force. Petition, 55; EX1003 ¶170.

And calculating contact force from a strain gauge was rudimentary engineering, commonplace and typical long before 2012. EX1003, ¶171-173; Petition, 57; EX1042, 67:24-68:20 (sophomore engineers learn and have “hands-on experience” with strain gauges) and 60:1-63:7 (describing a commercial sensor “with strain gauges inside” that “measures the strain” which is translated to force). A POSITA would not be stymied by the simple math to account for the weight of the head. EX1003, ¶171-173.

Second, the Petition explains that “a POSITA would have configured Calderon-RepRap20208 to control the contact force to prevent damaging the substrate 128 **or the nozzle 132.**” Petition 55. PO’s arguments about damaging the substrate are addressed below, but notably, PO did not address the motivation in Calderon-RepRap20208 of protecting the nozzle from damage caused by collisions. Dr. Wolfe explained that collision detection matters whenever the extrusion head is being moved, including when depositing material during the build. *E.g.*, EX1003 ¶216; Petition, 70-71. This understanding is wholly consistent with the disclosure in RepRep20208, which describes using strain gauges for collision detection during the build. *E.g.*, EX1010, 18-19 (describing shutting down the machine after detecting a collision).

Regarding protecting the substrate, PO fails to recognize several aspects of Calderon's teachings. First, Calderon describes use cases where the z-start position is not below the surface of the substrate. *E.g.*, EX1009, 2:49-53. Calderon explains that, generally, the appropriate z-start position of platform "is dependent upon the particular modeling system and substrate used." EX1009, 2:49-53. For example, in some cases, the "desired nozzle tip depth may be zero" and in other cases, it may be "above the top surface of the substrate." EX1009, 2:49-53 ("These specifications can easily be accommodated by the algorithm."). Thus, Calderon supports use-cases where damage to the foam substrate is not desirable, contrary to PO's arguments. POR, 49-50.

In the use-case the nozzle starts "below the top surface" of a foam substrate, the Petition explains why calculating the force is beneficial. Petition, 55-56. Calderon explains that the "porosity and compressibility" of the foam substrate allows foundation layers to be buried into the foam. EX1009, 2:27-34. The z-start position of the nozzle is not simply below the top surface of the foam, but starts at an "optimal" depth "so that the first two extruded layers of modeling material will be buried in the foam" to "provide a foundation to stabilize" the model. EX1009, 2:43-53. Calderon goes so far as to identify a z-axis accuracy for building on foam to be ± 5 -10 mils. *Id.* Thus, even in the situation where the starting z-height is

below the surface of the foam, a POSITA would have benefited from knowing the contact force so as to determine the “optimal” z-axis starting position.

Additionally, Calderon explains that the z-axis starting point is determined by the z-axis calibration routine. *E.g.*, EX1009, 8:10-37. Thus, in each use-case, the z-axis calibration must first be performed. As discussed above, and in the petition, supporting different substrate and nozzle materials benefits from calculating the contact force for that material. Petition, 55-56. A POSITA would have recognized that, among the advantages of calculating the contact force of the material in units of force from the strain gauge data when performing the z-axis calibration, included the ability to directly compare the strain gauge data to the compression strength of the substrate or nozzle. Petition, 55-56. Indeed, RepRap20208 similarly taught to “measure upwards pressure from a calibrated touchdown.” Petition, 56 (quoting EX1010, 19). As discussed at length, RepRap20208 links the use of a strain gauge to Z-height calibration, collision detection, and force sensing, and is directly applicable to Calderon. *E.g.*, EX1010, 18-20; Petition, 46-51.

X. GROUND 2A RENDERS DEPENDENT CLAIMS UNPATENTABLE

The Petition lays out the reasoning for how Ground 2A renders claims 2-6 and 9-16 unpatentable. Petition, 63-74. The Petition and this Reply point out how Ground 2A renders each and every element of claim 1 obvious, and POR cannot

rely on claim 1 to save the dependent claims. The POR only argues substantively against claim 11, however, which is unpatentable for at least the reasons provided in the Petition.

First, Dr. Wolfe explained that the controller sends control signals to the z-axis translator to achieve a contact force that is not damaging (force limit). EX1003 ¶¶204-207; Petition, 68, *see also* 55-56 (discussing “maximum contact pressure” and its relation to force). This contact force (sufficient for measurement, but not high enough to cause damage) is the claimed “specified contact force.”

Second, Calderon teaches that the z-axis starting position depends on the substrate, meaning that Calderon supports substrates of different materials. *See, e.g.*, EX1009, 2:50-53 (contrasting z-axis accuracy for foam versus rigid substrates), 8:43-52 (z-axis starting position is dependent on type of substrate). A POSITA would have recognized the advantages of calculating the contact force to support z-axis calibration for different materials without damaging either the substrate or the nozzle. As explained in the Petition, Calderon-RepRap20208 includes a maximum contact pressure related to the compression strength of the substrate. Petition, 55. By permitting the user to input a contact strength setpoint, z-axis calibration for substrates (and nozzles) of different materials can be supported, which is the intention of Calderon. *E.g.*, Petition, 55-56.

As mentioned above, Calderon is not limited to z-start positions below the surface of the substrate. But even in those scenarios, understanding contact force 1) enhances the accuracy of z-axis calibration for different substrate materials, 2) protects the nozzle from damage, and 3) permits controllable sub-surface z-start positions at the desired accuracy. EX1009, 2:27-53.

Last, also as mentioned, Calderon is not limited to implementations that involve servos. EX1009, 10:5-8. But even in those instances, the system experiences backlash/slop. Placing the strain gauge near the dispensing head at a position close to the nozzle tip permits accurate force sensing without having to address the backlash/slop exhibited by the other parts of the system. EX1010, 20; EX1003 ¶¶161-163; Petition, 50-51.

XI. GROUND 2B RENDERS CLAIM 3 UNPATENTABLE

A. The Calderon-RepRap20208-Dunn Is Predictable

In Calderon-RepRap20208-Dunn, the extrusion head of Calderon, which defines a lateral range for its z-axis calibration, benefits from a strain gauge for force sensing, like that taught by RepRap20208, and would have further benefitted from force sensing in multiple axes, for reasons analogous to the advantages provided by Dunn's multi-axis configuration. Petition, 75. RepRap20208 teaches force sensing using strain gauges. Calderon-RepRap20208-Dunn enhances Calderon-RepRap20208 with the advantages of multiple strain gauges for force

sensing in multiple (orthogonal) axes. The RepRap20208 does not teach away from using strain gauges. In the post about labor costs, the same poster provided explained how strain gauges could be implemented. EX1010, 16-17. The “heat flow” comment was for a specific implementation involving metal bars, and was not directed at strain gauges in general. EX1010, 19.

A POSITA would have found it obvious to provide multiple strain gauges in the extrusion head mount of Calderon-RepRap20208 oriented to measure in multiple axis so that the three-dimensional printer of Calderon-RepRap20208-Dunn has “the capability of sensing surfaces in the X and Y directions” in addition to “sensing surfaces in the Z-direction.” EX1007, [0069-0070]; EX1003, ¶¶233-235.

B. Calderon-RepRap20208-Dunn Renders Claims 3, 7, and 8 Unpatentable

In Calderon-RepRap20208-Dunn, sensors are collectively operable to sense a deflection force acting in the x-y axes (claim 3), two or more non-parallel axes (claim 7), and three or more non-parallel axes (claim 8). Petition, 76-77; EX1003, ¶¶237-242. As discussed above, Calderon-RepRap20208 provides force sensing using a strain gauge. Dr. Wolfe explains a POSITA would have found it obvious that Calderon-RepRap20208 benefits from identifying the surfaces of first and second stationary blocks in the x- and y-directions, thereby improving the

efficiency of Calderon's z-axis initialization routine. EX1003 ¶235; Petition, 75-76.

The Petition does not argue bodily incorporation of Dunn. But Dunn broadly teaches other multi-axis configurations "that can be driven a predetermined distance by force of contact with a surface such as a cam, pawl, cantilever, screw, or membrane, or other mechanical structure." EX1007 ¶[0096]. So Dunn is not limited to a plunger implementation. Instead, Calderon-RepRap20208 benefits from Dunn's stated advantages of implementing a multi-axis design with the "capability of sensing surfaces in the X and Y directions" in addition to "sensing surfaces in the Z-direction." EX1007 ¶[0069].

XII. REPRAP20208 IS A PRINTED PUBLICATION

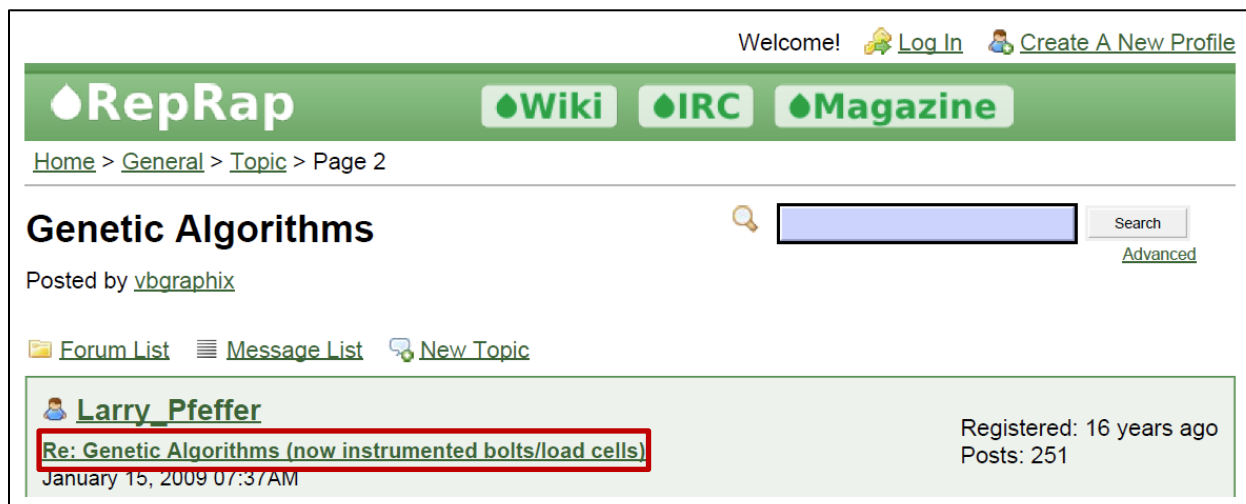
The Board invited the parties to further develop the record concerning RepRap20208's status as a printed publication. ID, 15. It is undisputed that the RepRap forum was a text-searchable, and visited by, professionals, hobbyists, and others, to "share knowledge and information regarding development of RepRap machines and 3D printing in general." EX1014 ¶4.

Mr. Bowyer testified that "the forums were (and still are) fully keyword searchable, allowing users to search for and readily identify relevant discussion threads." EX1014 ¶6. Bowyer added that the "search functionality allowed users to search for posts based on...the content of the posts." EX1014 ¶6. RepRap20208,

including Wade's posts, contain many relevant keywords, including "collision," "collision detection," "calibration," "sensor," "force," and "measurement."

EX1010, 13-21. In addition, the thread title "Genetic Algorithms" undoubtedly pertained to *algorithms* for 3D printers, like RepRap. *E.g.*, EX1010, 1; EX1014, ¶2 (RepRap project is for 3D printer development). Thus, a POSITA interested in 3D printer design and control would have readily accessed RepRap20208.

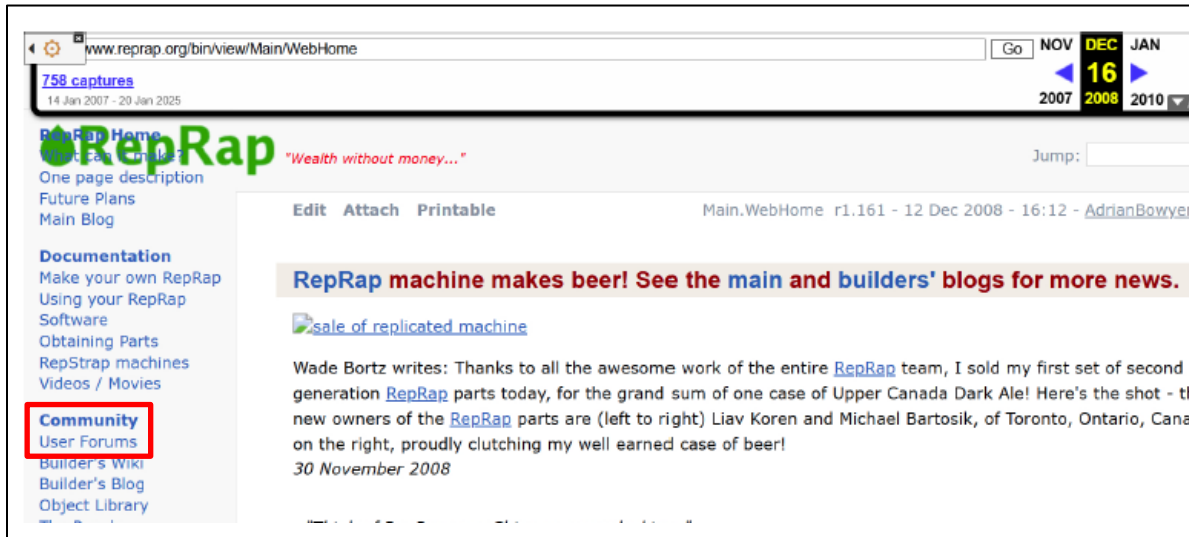
RepRap20208 also discusses strain gauges as force sensors for z-axis calibration and collision detection. EX1010, 13-21. The discussion included contributions from 9 different participants. *E.g.*, EX1010, 13-21. Some of these participants, including Wade, were not involved in earlier discussions about Genetic Algorithms, but still found and contributed to the discussion about force sensing. EX1010. Moreover, the title of the thread was adjusted as the topics evolved, as shown below:



EX1010, 16 (annotated)

The POPR argues that EX1013 only references the RepRap wiki. POPR, 30.

But Bowyer testified that the “RepRap forums were (and still are) linked to the main page,” and provided a screenshot of the RepRap landing page from December 16, 2008 that shows a link to “User Forums” front-and-center:



EX1014, ¶6, page 33 (showing exhibit B-1) (annotated)

PO provides no evidence that contradicts Bowyer’s testimony.

XIII. CONCLUSION

Petitioner has established that the Challenged Claims are unpatentable and respectfully requests that the Board find the same.

Respectfully submitted,

Dated: May 11, 2026

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CERTIFICATION UNDER 37 CFR §42.24

Under the provisions of 37 CFR § 42.24(d), the undersigned hereby certifies that the word count for the foregoing Petitioner's Reply to Patent Owner's Response totals 5,564 words, which is less than the 5,600 allowed under 37 CFR § 42.24(c)(4).

Dated: May 11, 2026

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CERTIFICATE OF SERVICE

Pursuant to 37 CFR § 42.6(e)(4), the undersigned certifies that on May 11, 2026, a complete and entire copy of this Petitioner's Reply to Patent Owner's Response to Petition and Accompanying Exhibit was provided by email to the Patent Owner by serving the email correspondence address of record as follows:

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