

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CARLISLE FOODSERVICE PRODUCTS, INC.,
Petitioner,

v.

GHT GLOBAL HEATING TECHNOLOGIES AG,
Patent Owner.

Case IPR2016-01770
Patent 7,708,553 B2

Before JAMES A. TARTAL, GEORGE R. HOSKINS, and
FRANCES L. IPPOLITO, *Administrative Patent Judges*.

HOSKINS, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

I. INTRODUCTION

On September 9, 2016, Carlisle FoodService Products, Inc. (“Petitioner”) filed a Petition (Paper 1, “Pet.”) pursuant to 35 U.S.C. §§ 311–319 to institute an *inter partes* review of claims 1–39 in U.S. Patent No. 7,708,553 B2 (“the ’553 patent”). On December 9, 2016, Patent Owner filed a Preliminary Response (Paper 6, “Prelim. Resp.”). After consideration of the Petition and the Preliminary Response, on March 6, 2017, we instituted an *inter partes* review to determine whether claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in the ’553 patent are unpatentable. *See* Paper 7 (“Inst. Dec.”), 36. Review of all other claims was denied. *See id.*

During the trial, Patent Owner filed a Response (Paper 9, “PO Resp.”). Petitioner filed a Reply (Paper 12, “Pet. Reply”). An oral hearing was held on November 29, 2017, and a copy of the transcript has been entered into the record (Paper 18, “Tr.”).

We have jurisdiction under 35 U.S.C. § 6. This Decision is a Final Written Decision under 35 U.S.C. § 318(a) as to the patentability of the claims for which trial proceeded. Based on the record before us, Petitioner has shown, by a preponderance of the evidence, that claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in the ’553 patent are unpatentable.

II. BACKGROUND

A. *Related Proceedings*

Neither party is aware of any matter that would affect, or be affected by, a decision in this proceeding. Pet. 1; Paper 5, 2; Paper 14, 2.

B. The '553 Patent

The '553 patent concerns a catalytic combustion heater, in which fuel vapor is combined with oxygen (such as from an ambient air supply) in the presence of a catalyst, to promote the flameless combustion of the fuel vapor and release of heat. Ex. 1001, Abstract, 1:9–14. Figure 1 of the '553 patent is reproduced below:

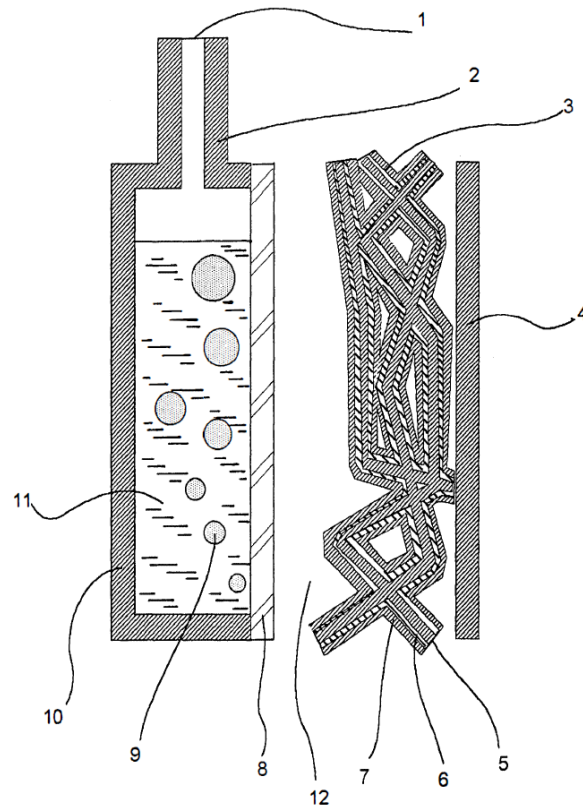


Fig. 1

Figure 1 is a cross-sectional view of tank 10 for storing liquid fuel 11 such as methanol, fiber 5 with catalyst coating 6, and cover wall 4. *Id.* at 4:14–15, 4:47–63, 5:44–47. Tank 10 incorporates membrane 8, which is “selectively permeable . . . such that only the fuel vapors diffuse through the membrane” to catalyst 6. *Id.* at 1:48–51, 4:47–63. The fuel vapors are exposed to air 12 in the presence of catalyst 6 to initiate flameless

combustion and heat generated by the combustion is carried by the walls of tank 10 and cover wall 4 to be applied outside of the heater. *Id.* at 5:32–47. Figure 2 of the '553 patent is reproduced below:

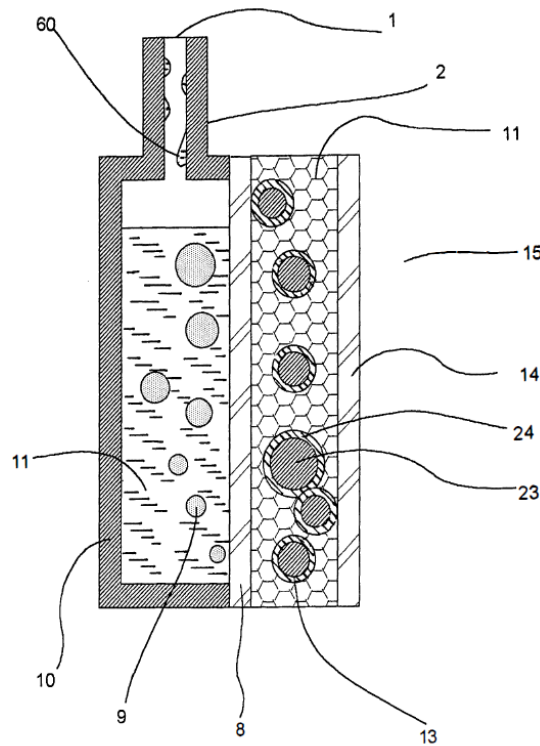


Fig. 2

Figure 2 illustrates a separate membrane 14 which filters the air before it reaches the catalyst, which in Figure 2 is structured as catalyst particles 13 dispersed in an embalming material. *Id.* at Fig. 2, 5:61–6:6.

C. The Instituted Claims

Trial was instituted as to independent claim 1, and claims 13, 14, 16–18, 23, 28, 34, and 35 depending from claim 1. Claim 1 is thus illustrative:

1. A heat-generating device comprising
a fuel source,
a fuel delivery connected to the fuel source,
a catalyst dispersed over a porous substrate, the catalyst
being in diffusive contact with an oxidizing gas, and
a molecular selectively permeable membrane for selective
molecular delivery of fuel by diffusion to the catalyst,
wherein the fuel diffuses to the catalyst through the
molecular selectively permeable membrane and the oxidizing
gas diffuses to the catalyst through a different membrane or
mechanical mechanism,
further comprising an upper temperature limit setting on a
thermal output caused by boiling the fuel.

Ex. 1001, 15:28–39 (line breaks added).

D. Instituted Ground of Unpatentability

We instituted trial to determine whether claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in the '553 patent are unpatentable under 35 U.S.C. § 102(b) as anticipated by Welles '665¹, as further evidenced by Rice². See Pet. 2–3; Inst. Dec. 36.

III. ANALYSIS

A. Claim Construction

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. See 37 C.F.R. § 42.100(b); *Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2144–46 (2016) (upholding the broadest reasonable

¹ Ex. 1006 (U.S. Patent No. 6,138,665, iss. Oct. 31, 2000).

² Ex. 1007 (U.S. Patent No. 4,140,247, iss. Feb. 20, 1979).

construction standard); Office Patent Trial Practice Guide, 77 Fed. Reg. 48,756, 48,764 (Aug. 14, 2012).

1. “*fuel delivery*” (claim 1)

In the Decision to Institute, we construed “a fuel delivery” in claim 1 to require, at the least, a structure for the delivery of fuel. Inst. Dec. 4–5. Neither Petitioner nor Patent Owner contests that construction. PO Resp. 11; Pet. Reply *passim*. Having considered our previous construction in light of the evidence introduced during trial, we are not persuaded any modification is necessary.

2. “*molecular selectively permeable membrane*” (claim 1)

In the Decision to Institute, we construed “a molecular selectively permeable membrane” in claim 1 to be “a membrane that allows fuel molecules in the vapor phase to permeate but does not allow the passage of liquid fuel.” Inst. Dec. 5–6. Neither Petitioner nor Patent Owner contests that construction. PO Resp. 11–12; Pet. Reply *passim*. Having considered our previous construction in light of the evidence introduced during trial, we are not persuaded any modification is necessary.

3. “*boiling the fuel*” (claim 1)

Although not presented by the parties as a claim construction issue *per se*, testimony offered by Robert G. Hockaday in support of Patent Owner’s case, and Petitioner’s response to that testimony, both consider the meaning of “boiling” in claim 1. We, therefore, address that meaning here as a matter of claim construction.

Mr. Hockaday³ testifies that the liquid fuel in Welles '665 “is not expected to boil but rather [will] evaporate.” Ex. 2001 ¶¶ 19–20; PO Resp. 21. That is, Mr. Hockaday draws a distinction between boiling of liquid fuel and evaporation of liquid fuel. More specifically, in Mr. Hockaday’s view, the term “boiling” in claim 1 of the ’553 patent is limited to nucleate boiling, in which bubbles form in the liquid. Ex. 2001 ¶¶ 21–22; PO Resp. 22–24; Ex. 1018, 48:5–16, 100:22–101:9, 103:16–105:21. Mr. Hockaday therefore testifies that the term “boiling” in claim 1 of the ’553 patent does not encompass the Leidenfrost effect, which produces via evaporation “*an insulating vapor layer keeping that liquid from boiling rapidly.*” Ex. 2001 ¶ 20 (emphasis added); PO Resp. 21.

Petitioner responds that Patent Owner’s definition of “boiling” as requiring bubble generation is overly narrow in light of the ’553 patent specification and prosecution history. Pet. Reply 1–2, 7–11; Tr. 9:3–10:14, 16:18–26. Petitioner contends Mr. Hockaday, in particular, agrees that the dictionary definition of “boiling point” as “bubble point” (Ex. 1016) is “not the only definition for boiling,” and that “there are varying definitions” of “boiling.” Pet. Reply 10–11; see Ex. 1018, 103:16–105:21. Petitioner contends the ’553 patent specification “is silent with respect to the particular

³ Mr. Hockaday is the lead inventor named in the ’553 patent. Ex. 1001, (75); Ex. 2001 ¶ 3. Petitioner attacks the credibility of Mr. Hockaday’s testimony in this proceeding. Pet. Reply 2–3. In particular, Petitioner asserts that Mr. Hockaday is a “paid consultant of Patent Owner” on engineering projects. *Id.* (citing Ex. 1018, 113:15–116:10). Further, Mr. Hockaday “is entitled to 20% of any profit obtained by Patent Owner as a result of commercializing the ’553 patent.” *Id.* (citing Ex. 1018, 15:7–21, 116:11–117:4, 118:1–7). We have taken account of these facts in weighing Mr. Hockaday’s testimony.

type of boiling or the speed at which boiling occurs.” Pet. Reply 10. Petitioner moreover contends a person of ordinary skill in the art would understand that the Leidenfrost effect, which results in the *heat-induced vaporization* of liquid fuel if not *bubble formation* in liquid fuel, is one form of “boiling.” Pet. Reply 11–13 (citing Ex. 1001, 8:41–46; Ex. 1020, 4–5; Ex. 1019 ¶ 11); Tr. 16:18–26. In support, Dr. James F. Klausner testifies that “the Leidenfrost effect is commonly referred to as Leidenfrost boiling” and “is a type of film boiling.” Ex. 1019 ¶¶ 10–15.

The parties, largely, do not address specific disclosure(s) in the ’553 patent specification relating to the meaning of “boiling.” Our own review leads us to the ’553 patent’s disclosure that “liquid fuel” is advantageously placed “in proximity to the catalytic heater” so that “when the [liquid] fuel reaches its boiling point” it results in “vaporized fuel.” Ex. 1001, 2:20–29. The ’553 patent further discloses that “[w]hen the heater is running, the temperature can get above the boiling point of the fuel and it will boil,” which results in “fuel vapor go[ing] up the vent line 2” such that “[t]his boiling of the fuel acts to limit the temperature of the heater 3 by heat removal with the vaporized fuel 9.” *Id.* at 5:47–60 (describing Figure 1); *see also id.* at 6:34–51 (substantially similar disclosure in relation to Figure 2). These disclosures support a broad interpretation of the term “boiling” as including the heat-induced vaporization of liquid fuel.

The ’553 patent disclosure does, however, in some instances refer specifically to bubbling of liquid fuel. For example, Figures 1 and 2 of the ’553 patent illustrate vaporized fuel 9 appearing within liquid fuel 11 in the form of bubbles. *Id.* at 5:53–60; *see also id.* at 12:51–54 (describing Figure 10 as illustrating “[t]he fuel will boil 198”). Further, the ’553 patent

describes Figure 5 as illustrating: “When the temperature of the fuel hits its boiling point the fuel boils and creates bubbles 68 in the fuel,” which “rise up to an aluminum heat exchanger 60.” *Id.* at 8:8–12; *see also id.* at 9:24–28 (substantially similar disclosure in relation to Figure 6).

Despite these disclosures of the ’553 patent which refer to bubbling of liquid fuel, we determine the broadest reasonable interpretation of “boiling” that is consistent with the ’553 patent specification includes heat-induced vaporization. The vaporization may occur in the form of bubbles, or not. This determination is consistent with the ’553 patent’s disclosure that the purpose of boiling the liquid fuel is to “remove[] heat from the catalytic reaction site and subsequently limit[] the maximum temperature” via repeated vaporization and condensation cycles. *Id.* at 2:20–29, 5:47–60, 6:34–51, 8:8–12, 9:24–28, 12:51–54. That function will be achieved regardless of whether the heat-induced vaporization arises in the specific form of bubbling within the liquid fuel.

Our construction of “boiling” is further consistent with the prosecution history of the ’553 patent, during which the applicant argued the claimed invention “essentially separat[es] the liquid from the membrane surface by a gas” so that “when the fuel boils on a hot membrane it can hover over the molecularly selective membrane, reducing the concentration (liquid vs vapor) and hence the diffusion rate.” Ex. 1020, 4; *see also id.* at 4–5 (“The present invention has a non-obvious and novel auto-thermal regulation effect of reducing the fuel delivery by removing liquid from the membrane surface or mechanically blocking areas of the membrane.”). These statements, as with the ’553 patent specification described above,

focus on the vaporization of liquid fuel rather than the specific bubbling form of vaporization.

Our construction is also supported by the dictionary definitions of “boiling point” as “1. The temperature at which the transition from the liquid to the gaseous phase occurs in a pure substance at fixed pressure” and “2. See bubble point.” Ex. 1016. The ’553 patent specification, as discussed above, is consistent with both dictionary definitions.

Our construction is further consistent with Dr. Klausner’s testimony that “the Leidenfrost effect is commonly referred to as Leidenfrost boiling” and is one “type of film boiling.” Ex. 1019 ¶¶ 10–11. Dr. Klausner and Mr. Hockaday agree that the Leidenfrost effect produces vaporized fuel, if not bubbling fuel. *Id.* ¶¶ 10–15; Ex. 2001 ¶ 20. Mr. Hockaday’s testimony that the Leidenfrost effect vaporization is different from the claimed “boiling” is not supported by the ’553 patent specification and prosecution history, as discussed above.

Thus, for the foregoing reasons, we construe the term “boiling” in claim 1 of the ’553 patent to include heat-induced vaporization of liquid fuel, whether or not the vaporization forms bubbles.

4. “*upper temperature limit setting on a thermal output caused by*” fuel boiling (claim 1)

Petitioner contends this limitation “should be construed as *the cooling effect on the catalytic reaction area* by boiling of fuel, which serves to limit the maximum temperature of the thermal output obtained at the surface of the heater, dependent on the boiling point of the fuel.” Pet. 15–20 (emphasis added) (citing Ex. 1001, 2:20–29, 5:57, 11:64–66, 12:57–60, 14:54–58, dependent claims 14, 34, and 35); Ex. 1013 ¶ 18. Petitioner contends a

“more restrictive” interpretation requiring “the maximum thermal output is *limited by the availability of liquid fuel*, as determined by boiling” would improperly import a limitation into claim 1 from the ’553 patent specification. Pet. 19–20 (emphasis added) (citing Ex. 1001, 8:41–43).

Patent Owner contends this limitation means that “when the fuel reaches its boiling point it *removes heat from the catalytic reaction site* and subsequently limits the maximum temperature.” PO Resp. 12–13 (emphasis added). Patent Owner argues claim 1 requires that this heat removal is performed via “*reduc[ing] fuel delivery* [through the membrane] in a diffusion driven process.” *Id.* at 13 (emphasis added); *see also id.* at 7–9 (discussing ’553 patent disclosure without citations). In other words, Patent Owner’s view is that claim 1 is limited to the more restrictive interpretation rejected by Petitioner, which would require that the availability of fuel to diffuse through the membrane is limited by the conversion of some of the liquid fuel to vapor, as a result of boiling. *Id.* Patent Owner’s counsel explained the proposed claim construction during the oral hearing as “when [the liquid fuel] boils, it then creates a vapor pushing liquid fuel away from the surface of the membrane, the membrane being -- transmitting fuel by diffusion,” and “[o]nce you’ve pushed that liquid fuel away, it decreases the diffusion.” Tr. 18:14–19:11 (referring to Patent Owner’s demonstrative exhibit slide 8, in turn citing Ex. 1001, 1:55–2:2).

As discussed in more detail below, we determine that under either party’s proposed claim construction, a preponderance of the evidence supports Petitioner’s contention that Welles ’665 inherently discloses the claimed subject matter. Therefore, we need not expressly construe the final limitation of claim 1 in this regard, because regardless of which claim

construction is applied, Petitioner prevails. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co. Ltd.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (per curiam) (claim terms need to be construed “only to the extent necessary to resolve the controversy”) (quoting *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999)).

However, Patent Owner additionally contends the fuel delivery rate in claim 1 “is dominated by . . . concentration gradient across the membrane rather than pressure across them membrane.” PO Resp. 17. Patent Owner made a similar contention in the Preliminary Response, in connection with the “membrane” limitation. *See* Prelim. Resp. 44–46; Inst. Dec. 11–12. Now, Patent Owner makes the contention in connection with the “upper temperature limit setting” limitation. PO Resp. 15–17.

Patent Owner’s contention is not persuasive, because it relies on limitations not recited in claim 1. Claim 1 simply recites a membrane for “delivery of fuel by diffusion” through the membrane, and “an upper temperature limit setting on a thermal output caused by boiling the fuel.” Ex. 1001, 15:28–39. Patent Owner has not established that a person of ordinary skill in the art would consider the upper temperature limit to be controlled *solely* by the concentration of a liquid fuel against the membrane, without regard to pressure.

We appreciate that the ’553 patent indicates, in at least some embodiments, the diffusion rate “will not be changed if the system is inverted causing a low or high hydraulic pressure on the selectively permeable membrane,” so the ’553 patent “invention . . . does not depend on the use of pumps which add complexity and cost of the heater.” *Id.* at 2:52–59; *see also id.* at 5:39–44 (“selective diffusion through membranes is

dominated by the concentration gradient across them” and “fuel delivery is therefore independent of the *vapor pressure* of the fuel when the selective membrane is immersed in fuel” (emphases added)). Nonetheless, under a broadest reasonable construction, the present record fails to establish that claim 1 *excludes* using a pump *as part of* regulating the diffusion rate of fuel vapor through the membrane. Construing claim 1 to exclude the use of a pump would improperly read a limitation into the claim from the ’553 patent specification.

5. *Remaining Claim Terms*

No further explicit constructions of any claim terms are needed to resolve the issues presented by the arguments and evidence of record. *See Nidec v. Zhongshan*, 868 F.3d at 1017 (claim terms need to be construed “only to the extent necessary to resolve the controversy”).

B. *Anticipation by Welles ’665 as further evidenced by Rice*

Petitioner asserts claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in the ’553 patent are unpatentable under 35 U.S.C. § 102(b) as anticipated by Welles ’665, as further evidenced by Rice. *See* Pet. 2–3, 7–9, 21–35. Petitioner cites the testimony of Dr. Klausner in support. Ex. 1013; Ex. 1019. Patent Owner opposes Petitioner’s assertions. Patent Owner cites the testimony of Mr. Hockaday in support. Ex. 2001; Ex. 1018.

We have reviewed the arguments and evidence of record. Based on our review, and for the following reasons, we determine a preponderance of the evidence demonstrates claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in the ’553 patent are unpatentable as anticipated by Welles ’665, as further evidenced by Rice. We first briefly summarize the law of anticipation, then

we summarize the respective disclosures of Welles '665 and Rice, and we finally address Petitioner's and Patent Owner's contentions.

1. *Law of Anticipation*

“A patent [claim] is invalid for anticipation under 35 U.S.C. § 102 if a single prior art reference discloses each and every limitation of the claimed invention.” *Purdue Pharma L.P. v. Epic Pharma, LLC*, 811 F.3d 1345, 1351 (Fed. Cir. 2016) (citing *Schering Corp. v. Geneva Pharm., Inc.*, 339 F.3d 1373, 1377 (Fed. Cir. 2003)). “A reference may anticipate inherently if a claim limitation that is not expressly disclosed ‘is necessarily present, or inherent, in the single anticipating reference.’” *In re Montgomery*, 677 F.3d 1375, 1379–80 (Fed. Cir. 2012) (quoting *Verizon Servs. Corp. v. Cox Fibernet Va., Inc.*, 602 F.3d 1325, 1337 (Fed. Cir. 2010) and *Schering v. Geneva*, 339 F.3d at 1377). “[I]nherency . . . may not be established by probabilities or possibilities.” *Id.* at 1380 (citing *Bettcher Indus., Inc. v. Bunzl USA, Inc.*, 661 F.3d 629, 639 (Fed. Cir. 2011) and *In re Oelrich*, 666 F.2d 578, 581 (CCPA 1981)).

2. *Welles '665*

Welles '665 discloses a heat generating device. Ex. 1006, Title. Figure 1 of Welles '665 is reproduced below:

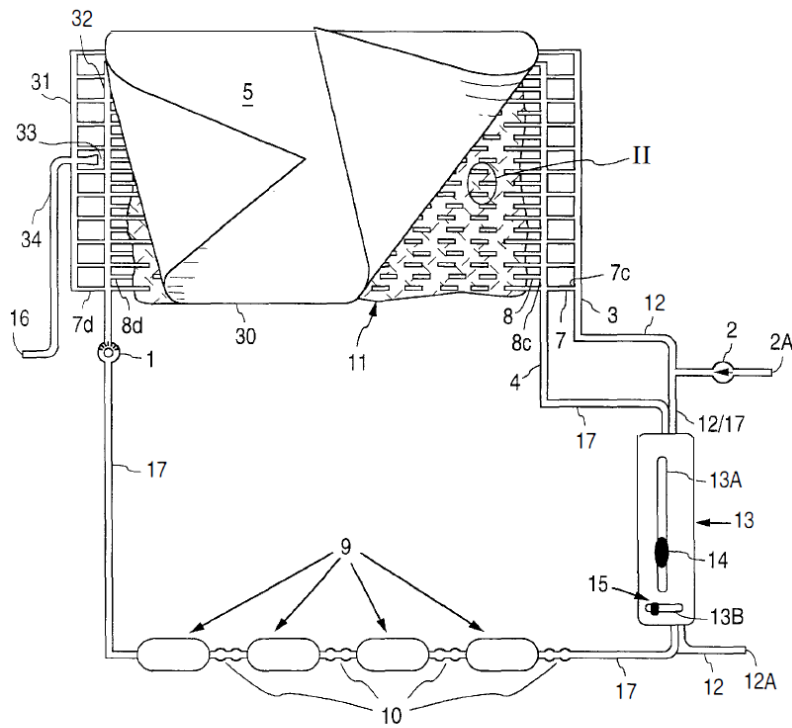


FIG. 1

Figure 1 illustrates a heat generating device including peristaltic pump 13 that supplies liquid fuel, such as methanol, from storage vessels 9 to woven (fabric-like) structure 5, via fuel line 17. Ex. 1006, Fig. 1, 2:35–38, 3:66–4:3. Pump 13 also supplies air, including oxygen, to woven structure 5 via air inlet tube 12. *Id.* at 5:38–47.

Figure 2 of Welles '665, reproduced below, is a cross-sectional view of woven structure 5 shown in perspective. *Id.* at 3:53–54, 4:6–10.

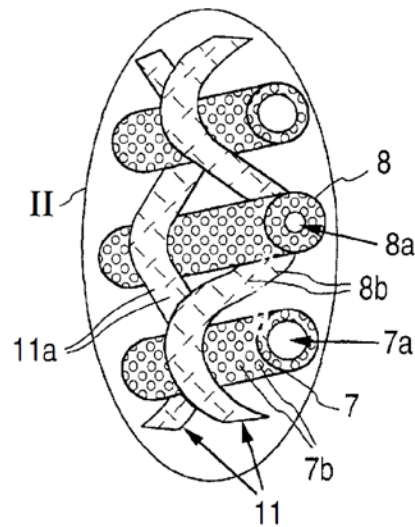


FIG. 2

Figure 2 illustrates that woven structure 5 is constructed of glass filaments 11, air-carrying microbore tubes 7, and fuel-carrying microbore tubes 8. *Id.* at 4:6–10, 4:49–55. Air exits pores 7b of tubes 7, and fuel vapor exits pores 8b of tubes 8⁴, so that the fuel vapor reacts with oxygen in the air in the presence of catalyst material 11a on filaments 11 to generate heat by flameless combustion. *Id.* at Abstract, 4:3–5, 4:24–25, 4:49–55.

3. *Rice*

Rice discloses a catalytic fuel combustion apparatus. Ex. 1007, Title. Figure 1 of Rice is reproduced below:

⁴ It is apparent from the cited written description of Figure 2 that the lead lines from “8b” in Figure 2 should extend to tube 8, not filament 11.

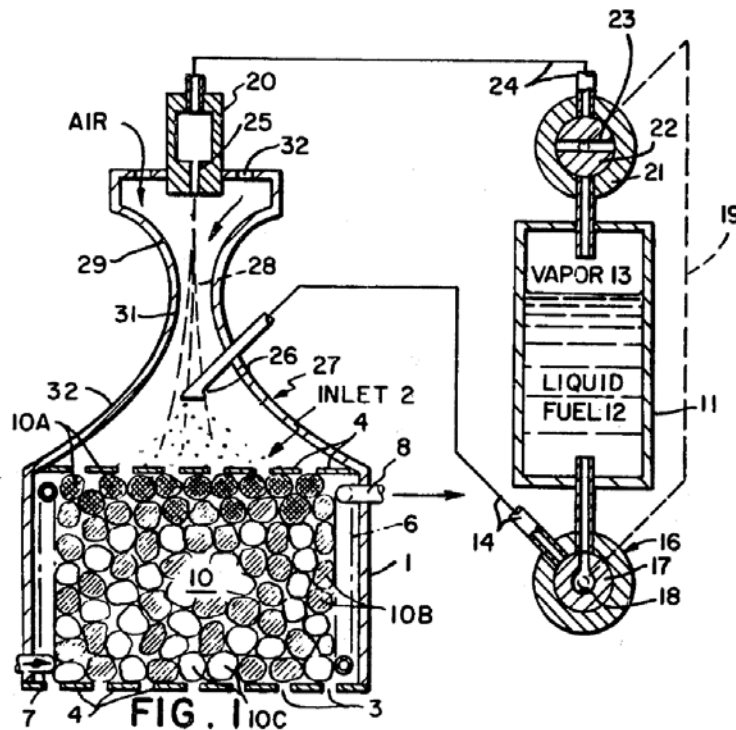


Figure 1 illustrates a catalytic combustion apparatus in which vaporized fuel from conduit 24 and atomized liquid fuel from conduit 14 mix with air in aspirator 27 before reaching catalyst pellets 10 to be combusted. *Id.* at 3:1–38. In describing the apparatus shown in Figure 1, Rice states:

Although the loss of pressure and waste of alcohol could be avoided by withdrawing fuel from the liquid volume 12 of the container 11, the liquid fuel *would be evaporated* in the aspirator 27 or in the mass 10 of catalyst pellets. *Such fuel evaporation produces a refrigeration effect which will reduce or inhibit ignition or continued combustion.* However, according to one aspect of the invention, metering only a small amount of alcohol-rich liquid fuel does not inhibit spontaneous ignition, and subsequently *supplying fuel pre-evaporated in the fuel container 11 [via conduit 24] isolates the combustion chamber 27 from the refrigeration effect. The fuel container [11] can absorb and dissipate the refrigeration remotely from the combustion chamber [containing catalysts 10].*

Ex. 1007, 4:45–58 (emphases added).

4. *Independent Claim 1*

Petitioner contends Welles '665 discloses each and every limitation of claim 1 in the '553 patent. *See* Pet. 7–9, 21–29.

a. *Limitations Preceding Final Limitation*

For each limitation preceding the final limitation of claim 1 (i.e., preceding “further comprising . . .”), Petitioner relies on Welles '665 as applied in the Board of Patent Appeals and Interferences (“BPAI”) decision (Ex. 1003, the “BPAI Decision”) entered during prosecution of U.S. Patent Application No. 10/492,018 (“the '018 application”), which issued as the '553 patent. *See* Pet. 21–22, 28. In particular, during prosecution, the BPAI considered claim 1 in the '018 application, which at the time recited (hereafter “Application Claim 1”):

Claim 1: A heat-generating device comprising
a fuel source,
a fuel delivery connected to the fuel source,
a catalyst dispersed over a porous substrate, the catalyst
being in diffusive contact with an oxidizing gas, and
a molecular selectively permeable membrane for selective
molecular delivery of fuel by diffusion to the catalyst,
wherein the fuel diffuses to the catalyst through the
molecular selectively permeable membrane and the oxidizing
gas diffuses to the catalyst through a different membrane or
mechanical mechanism.

BPAI Decision 2. Thus, Application Claim 1 as considered in the BPAI Decision was identical to claim 1 in the '553 patent, except Application Claim 1 did not include the final limitation of claim 1 in the '553 patent.

The BPAI Decision found that Welles '665 discloses each and every limitation of Application Claim 1, which corresponds to all of the limitations

of claim 1 in the '553 patent preceding the final limitation. *See* Ex. 1003, 5–6 (Finding of Fact Nos. 7–10 concerning Welles '665 disclosure), 7–9 (comparing Welles '665 disclosure with the limitations of Application Claim 1). Based on those findings, the BPAI Decision affirmed the Examiner's rejection of Application Claim 1.⁵

In the Petition, for the challenge presently before us, Petitioner relies on the findings and conclusions in the BPAI Decision. In short, we understand Petitioner has adopted the findings and conclusions in the BPAI Decision as its own position in this proceeding. *See* Pet. 21–22, 28. Based on the record in this case, we determine that Petitioner's position is sufficiently supported by the disclosure in Welles '665. *See* Ex. 1006, 1:11–13, 2:48–62, 4:55–63. Further, while not necessarily dispositive of our review in this proceeding, we note that the findings in the BPAI Decision are also supported by and consistent with the disclosure in Welles '665. *See id.*; Ex. 1003, 7–9.

Patent Owner's Response in the present proceeding does not present argument or evidence to dispute that Welles '665 discloses each and every limitation of claim 1 in the '553 patent preceding the final limitation. *See* PO Resp. 15–28 (addressing only the final limitation of claim 1 in the '553 patent); Ex. 2001 ¶¶ 9–17 (discussing scope of claimed “molecular selectively permeable membrane,” but not opining that Welles '665 fails to disclose that claim limitation), ¶¶ 18–26 (addressing final limitation of

⁵ Although the BPAI Decision affirmed the Examiner's determination that Application Claim 1 would have been obvious over a combination of Welles '665 and additional prior art, the Board expressly explained that the rejection was affirmed because Welles '665 anticipated Application Claim 1, rendering the additional prior art unnecessary to the rejection.

claim 1 in the '553 patent); Ex. 1018, 95:9–20. Accordingly, we determine a preponderance of the evidence presented in this proceeding establishes that Welles '665 discloses each and every limitation of claim 1 in the '553 patent preceding the final limitation.

We further note that both Application Claim 1 and claim 1 of the '553 patent recite a “molecular selectively permeable membrane,” and that during the oral argument in this case, Patent Owner’s counsel asserted microbore tubes 8 of Welles '665 are not a “molecular selectively permeable membrane.” Tr. 20:4–20. When asked where that argument was made in the Patent Owner Response, Patent Owner’s counsel cited page 21. *Id.* at 20:21–21:1. We can discern no such argument at page 21, or anywhere else, in the Patent Owner Response. *See* Paper 8, 6 (“The patent owner is cautioned that any arguments for patentability not raised in the response will be deemed waived.”); *see also In re NuVasive, Inc.*, 842 F.3d 1376, 1380–81 (Fed. Cir. 2016) (argument waived when not presented during trial phase of IPR proceeding). Furthermore, the BPAI Decision determined that microbore tubes 8 of Welles '665 corresponded to a “molecular selectively permeable membrane,” and the Applicant did not appeal that decision.⁶ Because this argument was not raised by Patent Owner in this proceeding prior to the oral argument, we determine it was waived.

⁶ We need not resolve whether Patent Owner waived its argument by not appealing the BPAI Decision. Rather, we determine the record before us does not support Patent Owner’s suggestion that it previously presented this argument and *continued* to rely on it in this *inter partes* review proceeding.

A preponderance of the evidence supports Petitioner's contention that Welles '665 expressly discloses each and every limitation of claim 1 in the '553 patent preceding the final limitation.

b. "boiling the fuel"

Petitioner contends Welles '665 discloses, inherently, that the liquid fuel within tubes 8 will boil as a result of the heat generated around catalyst material 11a. Pet. 22–25; Ex. 1013 ¶¶ 11, 19–20. Petitioner relies on the testimony of Dr. Klausner, who states the “close proximity” between tubes 8 and the heat-generating area surrounding catalyst material 11a, including the “direct physical contact” between tubes 8 and filaments 11 illustrated in Figure 2 of Welles '665, “will necessarily lead to boiling” of the liquid fuel within tubes 8. Ex. 1013 ¶ 20; *see* Pet. 23–24. In Dr. Klausner's opinion, the “relatively low pressure[s] obtained in the porous tubing [8]” with pump 13 and the “thin elastomeric materials” of tubes 8 “would not be sufficient to prevent boiling of methanol at temperatures achieved adjacent to the catalytic reaction area.” Ex. 1013 ¶ 20; *see* Pet. 24–25. Dr. Klausner relies on unspecified “[c]alculations according to Antoine's Equation” as indicating the liquid methanol fuel of Welles '665 will boil at a temperature of 95°C even at a pressure of 3 atmospheres. Ex. 1013 ¶ 20; *see* Pet. 25. Thus, in Dr. Klausner's opinion:

To achieve pressures high enough to prevent boiling at temperatures achieved by the device [of Welles '665] would be inconsistent with the design using thin elastomeric materials as disclosed in Welles '665, such as 3 to 5 mm diameter elastomeric material with a wall thickness of 1 to 2 mm (Ex. 1006, 5:34–37). Such an elastomeric material would stretch excessively or rupture in response to high pressures and would not withstand high temperatures.

Ex. 1013 ¶ 20; *see* Pet. 25.

Patent Owner contends Petitioner has not established Welles '665 inherently discloses that the liquid fuel inside tubes 8 will boil in response to the heat generated around catalyst material 11a. PO Resp. 21–24; Ex. 2001 ¶¶ 19–22. In support, Mr. Hockaday testifies that liquid fuel inside the “small diameter hydrophobic porous tubes [8]” of Welles '665 “is not expected to boil but rather [will] evaporate at the outer liquid/porous surface interface.” Ex. 2001 ¶ 20; PO Resp. 21. Mr. Hockaday points out that the heat in Welles '665 is generated near catalyst material 11a, outside of tubes 8. Ex. 2001 ¶ 20; PO Resp. 21. That configuration, in Mr. Hockaday’s opinion, leads to a situation “akin to the Leidenfrost effect,” which “is a phenomenon in which a liquid, in near contact with a mass significantly hotter than the liquid’s boiling point, produces *an insulating vapor layer keeping that liquid from boiling rapidly.*” Ex. 2001 ¶ 20 (emphasis added); PO Resp. 21. Given the small size and porosity of tubes 8, and the Leidenfrost effect, Mr. Hockaday concludes “it is *not* possible to cause the liquid fuel to boil inside this tube [8] with exterior heating.” Ex. 2001 ¶ 20 (emphasis added); PO Resp. 21.

In support of that conclusion, Mr. Hockaday cites the disclosure of Sachar (Ex. 2003, US 4,381,818, iss. May 3, 1983). Ex. 2001 ¶ 21; PO Resp. 22–24. Mr. Hockaday cites Sachar’s Equation 3 as giving “the equilibrium temperature to *maintain a bubble.*” Ex. 2001 ¶ 21 (emphasis added); PO Resp. 22. Mr. Hockaday opines Equation 3 establishes “that to form a bubble and grow a bubble inside a liquid (that is, to boil) the temperature must be higher on the inside of a liquid than the surface of the liquid.” Ex. 2001 ¶ 22; PO Resp. 23. According to Mr. Hockaday, given

the small size of tubes 8 in Welles '665, and with the heat being delivered to the liquid fuel inside tubes 8 from the exterior of tubes 8, “*only evaporation* can occur on the outside surface of the liquid because it would take a higher temperature inside the liquid to form a *bubble*” as required for boiling, pursuant to Sachar’s Equation 3. Ex. 2001 ¶ 22 (emphases added); PO Resp. 23–24.

As set forth above, the broadest reasonable construction of the “boiling” limitation of claim 1 includes heat-induced vaporization of liquid fuel, and does not require bubble generation. *See supra* Section III.A.3. Dr. Klausner and Mr. Hockaday agree that the heat generated around catalyst material 11a in Welles '665 will induce vaporization of liquid fuel inside tubes 8. Ex. 1013 ¶¶ 11, 19–20; Ex. 2001 ¶ 20; Ex. 1019 ¶¶ 5–6, 10–15. Mr. Hockaday’s testimony that the heat generated around catalyst material 11a will not generate bubbling of the induced vapor within the liquid fuel, even if correct, relies on an overly narrow understanding of the “boiling” term in claim 1 when seeking to distinguish Welles '665. Ex. 2001 ¶¶ 20–22. Bubbling in the liquid fuel is not required by the broadest reasonable construction of “boiling” in light of the '553 patent specification. *See supra* Section III.A.3.

For the foregoing reasons, we conclude a preponderance of the evidence supports Petitioner’s contention that Welles '665 inherently discloses boiling of the liquid fuel within tubes 8.

c. “*an upper temperature limit setting on a thermal output caused by fuel boiling*”

Petitioner contends Welles '665 discloses that the boiling of liquid fuel within tubes 8 causes, inherently, an upper temperature limit setting on

a thermal output. This contention is based on two alternative theories, corresponding to the competing claim constructions of the upper temperature limitation in claim 1 proposed by Petitioner and Patent Owner, discussed above. For the following reasons, we determine that under either claim construction, a preponderance of the evidence supports Petitioner's contention that Welles '665 inherently discloses the upper temperature limitation.

i. upper temperature limit via refrigeration caused by fuel vaporization

Petitioner firstly applies its own construction of the final limitation in claim 1 as corresponding to “*the cooling effect on the catalytic reaction area by boiling of fuel, which serves to limit the maximum temperature of the thermal output obtained at the surface of the heater.*” See Pet. 15–20 (emphasis added); Ex. 1013 ¶ 18.

Petitioner relies on Dr. Klausner's testimony that boiling of liquid fuel in tubes 8 of Welles '665 inherently provides such a cooling effect and upper temperature limit setting, because the vaporization of liquid fuel “will remove heat from the [catalytic combustion] reaction area by virtue of the energy absorbed in supplying heat of vaporization.” Ex. 1013 ¶ 20; Pet. 23–28; Pet. Reply 16–17. Dr. Klausner cites Rice as “evidence of the inherent aspect of cooling by fuel vaporization (establishing an upper temperature limit setting on a thermal output)” in Welles '665. Ex. 1013 ¶ 21; Pet. 8–9, 25–26. Dr. Klausner particularly cites Rice's disclosure that its liquid fuel might “be evaporated,” and that “[s]uch fuel evaporation produces a refrigeration effect which will reduce or inhibit ignition or continued combustion.” Ex. 1013 ¶ 21 (quoting Ex. 1007, 4:47–51); Pet. 25–26;

Tr. 16:6–21. Dr. Klausner also relies on Rice’s disclosure that “supplying the fuel pre-evaporated in the fuel container 11 isolates the combustion chamber 27 from the refrigeration effect,” and “[t]he fuel container can absorb and dissipate the refrigeration remotely from the combustion chamber.” Ex. 1013 ¶ 22 (quoting Ex. 1007, 4:54–58); Pet. 26.

Dr. Klausner concludes “[s]uch statements . . . support common knowledge that cooling by evaporation will inherently occur in” Welles ’665, caused by boiling of the liquid fuel in tubes 8. Ex. 1013 ¶ 22; Pet. 26.

Patent Owner contends Petitioner has not established Welles ’665 inherently discloses that boiling of liquid fuel within tubes 8 causes an upper temperature limit setting on a thermal output. PO Resp. 15–28; Ex. 2001 ¶¶ 18, 23–26. Patent Owner asserts Welles ’665 “does not mention . . . heat exchange from the fuel,” and instead provides variable pressure relief valve 1 “as the heat rate regulating mechanism.” PO Resp. 16–17 (citing Ex. 1006, 3:8–21); Tr. 23:19–23. In that regard, Welles ’665 indicates a user can adjust valve 1 to limit the pressure generated within tubes 8 by pump 13, and thereby adjust the rate of fuel vapor production exiting tubes 8, which is “the primary mechanism for controlling the rate of heat generation.” Ex. 1006, 3:5–13, 8:33–38.

Addressing Rice, Patent Owner contends claim 1 in the ’553 patent recites a “negative” feedback system, wherein “more heating and boiling of the fuel” *decreases* the thermal output of the device. PO Resp. 18–19; Ex. 2001 ¶ 18. Patent Owner asserts Rice, by contrast, discloses a “positive” feedback system, wherein “more heating ‘evaporation’” *increases* the thermal output of the device. PO Resp. 18–19; Ex. 2001 ¶ 18. In support, Patent Owner notes Rice stores liquid fuel 12 in container 11, which is

“placed away” and “not . . . thermally coupled to” catalysts 10 within combustion chamber 1. PO Resp. 19; Ex. 2001 ¶ 18. Patent Owner cites Rice’s disclosure that this arrangement advantageously “isolates the combustion chamber [1] from the refrigeration effect” caused by evaporation of liquid fuel 12 within container 11. PO Resp. 19–20 (quoting Ex. 1007, 4:45–60); Ex. 2001 ¶ 18. Thus, Patent Owner concludes Rice “is not setting a thermal output limit tied to the heater temperature,” because heat is not transferred from combustion chamber 1 to liquid fuel 12 within storage container 11 to boil the fuel. PO Resp. 19–20; Ex. 2001 ¶ 18. Further, according to Mr. Hockaday, the refrigeration effect described in Rice is “a transient effect” which “cools initially and then heats when the combustion occurs,” so Rice does not disclose setting an upper temperature limit on thermal output by boiling fuel. Ex. 2001 ¶¶ 24–26; PO Resp. 25–28.

We determine a preponderance of the evidence supports Petitioner’s contention that the vaporization of liquid fuel in tubes 8 of Welles ’665 inherently cools, or refrigerates, the combustion area surrounding catalyst material 11a. We credit Dr. Klausner’s testimony that vaporization of liquid fuel will inherently absorb energy in the form of the “heat of vaporization,” which will cool the surrounding environment. Ex. 1013 ¶ 20.

Mr. Hockaday does not materially dispute, and indeed appears to agree with, that basic scientific principle. See Ex. 2001 ¶ 24. Further, Figures 1 and 2 of Welles ’665 illustrate the close proximity of the liquid within tubes 8 to catalyst material 11a, due to the interweaving of tubes 8 and filaments 11 to form fabric-like structure 5. See Ex. 1006, 4:6–10. Indeed, as Dr. Klausner points out, in some embodiments, the catalyst material may be disposed on tubes 8 themselves. See Ex. 1013 ¶ 20 (citing Ex. 1006, 4:46–47). The

close proximity between the catalyst material and the liquid fuel in Welles '665 means that the cooling effect produced by vaporization of the liquid fuel will extend to the reaction area surrounding the catalytic material, and consequently cause an upper temperature limit setting on thermal output.

That finding is supported by the disclosure in Rice. Rice discloses that *if* its liquid fuel 12 *were to be allowed* to evaporate near its catalysts 10, this would “produce[] a refrigeration effect which will reduce or inhibit ignition or continued combustion.” Ex. 1007, 4:45–51. Rice chooses to avoid such refrigeration by supplying most of the fuel to catalysts 10 in “pre-evaporated” form, such that vaporization of liquid fuel 12 in container 11 “isolates” catalysts 10 from the refrigeration effect. *Id.* at 4:51–58. Welles '665, by contrast, does not have the pre-evaporation isolation provided by Rice, given the close proximity of liquid fuel within tubes 8 to catalyst material 11a.

We agree with Patent Owner’s characterization of claim 1 in the '553 patent as reciting a negative feedback system. However, the issue we must decide is whether a preponderance of the evidence supports Petitioner’s contention that Welles '665 (not Rice) inherently discloses a negative feedback system. *See, e.g.*, Inst. Dec. 14–15. We conclude that it does, for the reasons just provided. It is true, as Patent Owner contends, that Rice avoids refrigerating its catalytic combustion in the Rice device by pre-evaporating liquid fuel 12 in container 11, far away from catalysts 10. *See* Rice, Fig. 1, 4:45–58. However, that fact is irrelevant to whether Welles '665 inherently refrigerates its catalytic combustion due to the close proximity of liquid fuel within tubes 8 to catalyst material 11a.

We also agree with Patent Owner’s position that Welles ’665 discloses that valve 1 is the “primary mechanism for controlling the rate of heat generation.” Ex. 1006, 3:5–13. However, Welles ’665 goes on to state that “[i]n addition to” the hydraulic pressure regulating valve 1, “the *bounding limits for lower and upper reaction rates* can be selected by choosing specific component characteristics,” including various characteristics of tubes 8. *Id.* at 3:13–20 (emphases added). Thus, Welles ’665 discloses that valve 1 is the primary, but not the sole, means of regulating heat generation. Welles ’665 is not inconsistent with Dr. Klausner’s testimony that boiling of liquid fuel within tubes 8 will set an upper temperature limit on thermal output of the device — or, in the words of Welles ’665, set a “bounding limit[] for . . . upper reaction rate[.]” *Id.* at 3:15–16.

This is particularly true once the user has adjusted valve 1 to set the maximum pressure achievable in tubes 8 using pump 13. That is, at any given maximum pressure setting, the boiling of liquid fuel within tubes 8 causes the fuel to vaporize, which inherently cools, or refrigerates, the combustion area surrounding catalyst material 11a. This will consequently cause an upper temperature limit setting on thermal output, at the set maximum pressure, according to Dr. Klausner’s testimony which we find to be persuasive. *See* Ex. 1013 ¶ 20.

For the foregoing reasons, we conclude a preponderance of the evidence supports Petitioner’s contention that Welles ’665 inherently discloses that boiling of liquid fuel within tubes 8 causes an upper temperature limit setting on thermal output, in the event Petitioner’s claim construction of that limitation is adopted.

ii. *upper temperature limit via reducing fuel delivery*

Petitioner secondly applies Patent Owner's construction of the final limitation in claim 1, as requiring "*reduc[ing] fuel delivery* [through the membrane] in a diffusion driven process," when the vaporized liquid "push[es] liquid fuel away from the surface of the membrane" to "decrease[] the diffusion." PO Resp. 7–9, 13 (emphasis added); Tr. 18:20–24, 19:6–8.

Petitioner relies on Dr. Klausner's testimony that the boiling of liquid fuel within tubes 8 "would serve to remove liquid fuel from the porous tubing region by vaporization," in relation to dependent claim 13 of the '553 patent. Ex. 1013 ¶ 24; Ex. 1019 ¶ 4; Pet. 29–30; Pet. Reply 12–14, 17–19. This removal of fuel from the reaction area, in Dr. Klausner's opinion, "would reduce the quantity of fuel reaching the catalytic area via diffusion, as vapor movement is faster than diffusion on this timescale." Ex. 1013 ¶ 24. In particular, Dr. Klausner concludes the vaporized fuel which results from the boiling of liquid fuel will cover the pores of tubes 8 and push liquid away from those pores. Ex. 1019 ¶¶ 25–26. As a consequence, "a large fraction of pores will no longer be able [to] deliver fuel to the catalyst bed at the same rate as would occur in the absence of boiling, and the heat rate will diminish due to the diminishing fuel delivery rate." *Id.* ¶ 25. Dr. Klausner believes this second theory of setting an upper temperature limit on thermal output caused by fuel boiling is consistent with the mechanism described in the '553 patent. Ex. 1013 ¶ 24 (citing Ex. 1001, 2:46–49, 5:42–44); Ex. 1019 ¶¶ 25–26; Pet. 30; Pet. Reply 11, 13 (further citing Ex. 1001, 8:41–46, Ex. 1020, 4–5).

Patent Owner's witness, Mr. Hockaday, does not materially dispute that testimony from Dr. Klausner. Indeed, Mr. Hockaday agrees at least that

the liquid fuel in Welles '665 “evaporate[s] at the outer liquid / porous surface interface,” which “produce[s] an insulating vapor layer keeping that liquid from boiling rapidly” by forming bubbles. Ex. 2001 ¶¶ 20–22. That testimony is generally consistent with Dr. Klausner’s opinion that the vaporization of liquid fuel in Welles '665 will cover the pores of tubes 8 and push liquid away from those pores.

We determine a preponderance of the evidence supports Petitioner’s contention that the vaporization of liquid fuel in tubes 8 of Welles '665 inherently removes fuel from the catalytic reaction area by covering the pores of tubes 8 and pushing liquid away from those pores. Ex. 1019 ¶¶ 25–26. As a result, a large fraction of the pores will not be able to deliver fuel to the catalyst bed at the same rate as would occur in the absence of boiling, thereby diminishing the heat rate, and causing an upper temperature limit setting on a thermal output, as required by Patent Owner’s claim construction. *Id.*

Patent Owner’s contention that it is valve 1 in Welles '665, and not fuel boiling, which causes an upper temperature limit setting on thermal output, is not persuasive for essentially the same reasons provided above. That is, Welles '665 discloses that valve 1 is the primary, but not the sole, means for controlling the rate of heat generation. Ex. 1006, 3:5–20. Welles '665 is not inconsistent with Dr. Klausner’s testimony that boiling of liquid fuel within tubes 8 will set an upper temperature limit on thermal output of the device via pushing liquid fuel away from the pores of tubes 8. This is particularly true once the user has adjusted valve 1 to set the maximum pressure achievable in tubes 8 using pump 13. That is, at any given maximum pressure setting, the boiling of liquid fuel within tubes 8

pushes liquid fuel away from the pores of tubes 8. This will consequently cause an upper temperature limit setting on thermal output, at the set maximum pressure, according to Dr. Klausner's testimony which we find to be persuasive. *See* Ex. 1013 ¶ 24; Ex. 1019 ¶¶ 4, 25–26.

For the foregoing reasons, we conclude a preponderance of the evidence supports Petitioner's contention that Welles '665 inherently discloses that boiling of liquid fuel within tubes 8 causes an upper temperature limit setting on thermal output, in the event Patent Owner's interpretation of that limitation is adopted.

d. Conclusion as to Independent Claim 1

A preponderance of the evidence supports Petitioner's contention that Welles '665 discloses, expressly or inherently, each and every limitation of claim 1 in the '553 patent. Therefore, claim 1 is anticipated by Welles '665, as evidenced by Rice, and is not patentable under 35 U.S.C. § 102(b).

5. Dependent Claims 13, 14, 16–18, 23, 28, 34, and 35

Petitioner contends the Welles '665 heating device expressly or inherently incorporates each and every limitation of dependent claims 13, 14, 16–18, 23, 28, 34, and 35. Pet. 29–35; Ex. 1013 ¶¶ 19, 23–29 & Appx. B. Patent Owner's Response relies solely on arguments as to claim 1 in relation to the challenged dependent claims, and does not address Petitioner's arguments and supporting evidence as to the subject matter added by the challenged dependent claims. *See, e.g.*, PO Resp. 4, 15.

We adopt Petitioner's above-identified and unopposed contentions as our findings with regard to the anticipation of claims 13, 14, 16–18, 23, 28, 34, and 35 because, upon review of the full record in this proceeding, the

cited portions of Welles '665 and Dr. Klausner's testimony sufficiently support Petitioner's assertions. We, therefore, determine a preponderance of the evidence establishes that these claims in the '553 patent are unpatentable as having been anticipated by Welles '665, as evidenced by Rice.

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that claims 1, 13, 14, 16–18, 23, 28, 34, and 35 in U.S. Patent No. 7,708,553 B2 have been shown, by a preponderance of the evidence, to be unpatentable; and

FURTHER ORDERED that, because this is a Final Written Decision, the parties to the proceeding seeking judicial review of this decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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