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Paper 46
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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

BUTAMAX™ ADVANCED BIOFUELS LLC,
Petitioner,

v.

GEVO, INC.,
Patent Owner.

Case IPR2013-00214
Patent 8,304,588 B2

Before RAMA G. ELLURU, CHRISTOPHER L. CRUMBLEY, and ZHENYU YANG, *Administrative Patent Judges*.

YANG, *Administrative Patent Judge*.

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

I. INTRODUCTION

Butamax™ Advanced Biofuels LLC ("Butamax") petitioned for an *inter partes* review of claims 1–28 of U.S. Patent No. 8,304,588 B2 ("the '588 patent"). Paper 2 ("Pet."). On September 30, 2013, the Board instituted trial to review all challenged claims. Paper 11 ("Dec."). Thereafter, Patent Owner, Gevo, Inc. ("Gevo"), filed a Response (Paper 23 ("PO Resp.")) and Butamax filed a Reply (Paper 32 ("Reply")). Oral hearing was held on April 30, 2014. *See* Paper 45 ("Tr.").

The Board has jurisdiction under 35 U.S.C. § 6(c) and issues this final written decision pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons provided below, we conclude that Butamax has proved by a preponderance of the evidence that claims 1–28 of the '588 patent are unpatentable.

A. Related Proceedings

Concurrent with the present *inter partes* review, Butamax also petitioned for review of, and the Board instituted trial on, claims 1–18 of U.S. Patent No. 8,283,505, a patent in the same family as the '588 patent. *See Butamax™ Advanced Biofuels LLC v. Gevo, Inc.*, Case IPR2013-000215 (PTAB Sept. 30, 2013) (Paper 10). Because of overlapping issues between the two proceedings, we consolidated the oral hearings for IPR2013-00214 and IPR2013-00215. *See* Tr. 2:17–18.

B. The '588 Patent

The '588 patent relates to a method for recovering C3–C6 alcohols, specifically isobutanol, from dilute aqueous solutions, such as fermentation

broths. Ex. 1001, Abstract; 8:25–27. In one embodiment, the Specification teaches a method to produce isobutanol in a retrofit ethanol production plant that includes a pretreatment unit, fermentation units, and a beer still. *Id.* at 5:29–33. The method includes culturing a microorganism in a fermentation medium to produce the alcohol. *Id.* at 4:63–65. The Specification discloses embodiments in which "[f]ermentation and recovery may be conducted simultaneously." *Id.* at 8:27–28. For example, the method includes distilling a portion of the fermentation medium to produce a vapor phase that includes water and the alcohol, and returning the liquid phase to the fermentor. *Id.* at 4:67–5:12. The method further includes condensing the vapor phase to form an alcohol-rich liquid phase and a water-rich liquid phase, and then separating the liquid phases. *Id.* at 5:12–23. Recovery during fermentation, according to the '588 patent, improves fermentation volumetric productivity and reduces energy required. *Id.* at 8:28–33.

Claims 1 and 14 are the independent claims in this trial. They are reproduced below:

> 1. A method for producing isobutanol in a retrofit ethanol production plant comprising:
> a. pretreating a feedstock to form fermentable sugars in a pretreatment unit;
> b. culturing a microorganism capable of producing isobutanol in a fermentation medium comprising the fermentable sugars in a fermentation unit to produce isobutanol;
> c. distilling a portion of the fermentation medium comprising isobutanol and viable microorganisms, thereby removing at least some of the isobutanol therefrom;
> d. returning the isobutanol-depleted portion of the fermentation medium from step (c) comprising viable microorganisms to the fermentation unit; and

e. transferring the fermentation medium from the fermentation unit to a beer still;

wherein said distilling forms a vapor phase comprising isobutanol and water, and said method further comprises:

i. condensing the vapor phase to form an isobutanol-rich liquid phase and a water-rich liquid phase; and

ii. separating the isobutanol-rich liquid phase from the water-rich liquid phase; and

iii. returning said water-rich liquid phase to the fermentation unit.

14. A method for producing isobutanol in a retrofit ethanol production plant comprising:

a. pretreating a feedstock to form fermentable sugars in a pretreatment unit;

b. culturing a microorganism capable of producing isobutanol in a fermentation medium comprising the fermentable sugars in a fermentation unit to produce isobutanol;

c. extracting the fermentation medium with an alcohol-selective extractant, thereby forming a isobutanol-rich portion of the fermentation medium comprising alcohol-selective extractant and isobutanol and an isobutanol-depleted portion of the fermentation medium;

d. returning the isobutanol-depleted portion of the fermentation medium from step (c) to the fermentation unit;

e. distilling the isobutanol-rich portion of the fermentation medium from step (c), thereby forming a vapor phase comprising isobutanol;

f. condensing said vapor phase to form an isobutanol-rich liquid phase and a water-rich liquid phase;

g. separating the isobutanol-rich liquid phase from the water-rich liquid phase; and

h. transferring the fermentation medium from the fermentation unit to a beer still.

C. Reviewed Grounds of Unpatentability

The Board instituted trial on the following two grounds, each of which challenges the patentability of claims 1–28: (1) obviousness over the combination of English,[1] Hess,[2] and D'Amore;[3] and (2) obviousness over the combination of Maiorella,[4] Hess, and D'Amore. Dec. 21.

II. ANALYSIS

A. Real-Party-in-Interest Analysis

In the Decision to Institute, the Board found that Gevo had not set forth persuasive evidence to establish E.I. Dupont de Nemours and Co. as a real party in interest. Dec. 3–4. In the Patent Owner's Response, Gevo "renews its arguments" on this issue because it believes the Board erred in its conclusion "for the reasons stated previously." PO Resp. 29. Our Rules do not permit incorporating arguments from one document into another document. 37 C.F.R. § 42.6(a)(3). We, therefore, do not revisit the real-party-in-interest issue in this Decision.

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[1] English et al., U.S. Patent No. 4,349,628 (Ex. 1002) ("English").
[2] Glenn Hess, *BP and DuPont Plan 'Biobutanol,'* CHEMICAL & ENGINEERING NEWS June 26, 2006, at 9 (Ex. 1003) ("Hess").
[3] D'Amore et al., U.S. Patent Pub. No. 2008/0132741 Al (Ex. 1004) ("D'Amore").
[4] B. L. Maiorella et al., *Biotechnology Report Economic Evaluation of Alternative Ethanol Fermentation Processes*, 26 BIOTECHNOLOGY AND BIOENGINEERING, 1003 (1984) (Ex. 1005) ("Maiorella").

B. Claim Construction

In an *inter partes* review, the Board interprets a claim term in an unexpired patent according to its broadest reasonable construction in light of the specification of the patent in which it appears. 37 C.F.R. § 42.100(b). Under this standard, we assign claim terms their ordinary and customary meaning, as understood by a person of ordinary skill in the art, in the context of the entire patent disclosure. *See In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007).

In the Decision to Institute, the Board construed three claim terms: "fermentation medium," "retrofit ethanol production plant," and "pretreatment unit." Dec. 9–12. In its Response, Gevo challenges the Board's interpretation of the first two terms. PO Resp. 29–32. As explained below, Gevo's arguments are unconvincing, and thus, we do not change the constructions stated in the Decision to Institute.

fermentation medium

Step (e) of claim 1 and step (h) of claim 14 each recites "transferring the fermentation medium from the fermentation unit to a beer still." In the Decision to Institute, the Board concluded the fermentation medium in these two steps refers to fermentation medium that contains, as well as fermentation medium that does not contain, microorganisms. Dec. 12. Gevo contends that the fermentation medium in these two steps must include microorganisms. PO Resp. 31. We disagree.

Both claims 1 and 14 use the open-ended transition "comprising" and allow for additional method steps. *See Invitrogen Corp. v. Biocrest Mfg., L.P.*, 327 F.3d 1364, 1368 (Fed. Cir. 2003). Thus, when construing the claim term "fermentation medium" under the broadest reasonable

interpretation standard, we may consider an additional step between steps (d) and (e) of claim 1 (as well as between steps (d) and (h) of claim 14) to remove the microorganisms.

According to Gevo, the antecedent basis of "the" fermentation medium of step (e) in claim 1 is "a" fermentation medium of step (b). PO Resp. 30. Gevo argues that because "a fermentation medium" of step (b) includes a microorganism capable of producing isobutanol, "the fermentation medium" of step (e) also should be construed to contain microorganisms. *Id.* at 30–31. Gevo's argument is unpersuasive.

We note that the same "a fermentation medium" in step (b) also serves as the antecedent basis for "the fermentation medium" recited in steps (c) and (d). Yet, steps (c) and (d) specify that the fermentation medium comprises microorganisms. In contrast, the claim language in step (e) is silent in this regard. In other words, the applicants of the '588 patent knew how to limit the fermentation medium to include microorganisms, but chose not to do so in step (e). This approach appears consistent with the Specification, which defines the term "fermentation medium" as including fermentation medium both containing microorganisms and fermentation medium that does not contain microorganisms, "[u]nless explicitly noted." Ex. 1001, 8:62–65. Thus, we reiterate that the fermentation medium in step (e) of claim 1 and step (h) of claim 14 may, but is not required to, contain microorganisms.

Gevo also points to Figure 2 of the '588 patent, which shows a direct transfer of the fermentation medium from the fermentor to the beer still. *Id.* at 30. That the fermentation medium received in the beer still of Figure 2 contains microorganisms, Gevo contends, further supports its position. *Id.*

We disagree. Figure 2 merely illustrates "a specific embodiment" of the claimed invention. Ex. 1001, 25:1. We may not read a particular embodiment into a claim when the claim language is broader than the embodiment. *SuperGuide Corp. v. DirecTV Enters., Inc.*, 358 F.3d 870, 875 (Fed. Cir. 2004). Thus, Figure 2 does not change our analysis.

retrofit ethanol production plant

The preamble of claims 1 and 14 each recites a method for "producing isobutanol in a retrofit ethanol production plant." In the Decision to Institute, the Board determined that the term "retrofit ethanol production plant" is limiting and construed it to mean an ethanol production plant that is adapted to a new purpose or need. Dec. 9–11. Gevo argues that the term "denotes an existing, functioning ethanol plant reconfigured for producing isobutanol." PO Resp. 31. According to Gevo, the Specification supports its position. *Id.* at 31–32. We disagree.

Claims 11–13 and 21–23, which depend from claims 1 and 14, respectively, recite the output of the retrofit plant as a certain percentage of the isobutanol equivalent of the "ethanol maximum output of the plant before retrofit." The Specification explains that "[t]he term 'ethanol maximum output of the plant before retrofit' refers to the maximum amount of ethanol produced by a plant or *for which the plant was engineered* before it is retrofit to produce a C3–C6 alcohol." Ex. 1001, 28:64–67 (emphasis added). In other words, contrary to Gevo's assertion, the plant output before retrofit does not necessarily require an actual capacity. Instead, under the broadest reasonable interpretation, it also includes output designed for the plant. As a result, we conclude that the claims and the Specification do not support Gevo's narrow construction of "retrofit ethanol production plant."

C. Unpatentability Analysis

Obviousness is a question of law based on underlying facts. *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). The factual components include the scope and content of the prior art, the differences between the prior art and the claimed invention, the level of skill in the art, and any objective evidence of nonobviousness. *Id.* at 17.

1. Testimonial Evidence

Butamax relies on the declaration of Dr. Andrew J. Daugulis (Ex. 1006, "Daugulis Declaration") to support the Petition. Gevo relies on the declaration of Dr. Angelo Lucia (Ex. 2024) to support the Patent Owner's Response. The parties also cite excerpts of the deposition transcripts of Dr. Lucia (Ex. 1017) and Dr. Daugulis (Ex. 2023) to support their respective positions.

Gevo asserts that some opinions presented in the Daugulis Declaration are unsupported by underlying data. PO Resp. 6. Gevo also argues that portions of Dr. Daugulis's deposition testimony "reflect a misunderstanding of the fundamental differences in separation methodologies between homogeneous mixtures (*e.g.*, ethanol-water) and heterogeneous mixtures (*e.g.*, isobutanol-water)." *Id.* at 7. As a result, according to Gevo, Dr. Daugulis's analysis and opinions regarding the cited references are not credible. *Id.* at 11. Butamax disputes these allegations. Reply 12–14.

Despite challenging Dr. Daugulis's credibility, Gevo does not seek to disqualify Dr. Daugulis. Thus, we note Gevo's contentions, but shall

consider and assign appropriate weight to the Daugulis Declaration and his deposition testimony.

2. Technical Background

There are four isoforms of butanol: 1-butanol (also known as *n*-butanol), 2-butanol, isobutanol, and tert butyl alcohol. Ex. 2027 § 7.1. Almost a century ago, the ABE (acetone, butanol, and ethanol) fermentation process was developed to produce 1-butanol. *Id.* When used as a biofuel, 1-butanol has several advantages over ethanol. *Id.* For example, butanol has higher energy density than ethanol, which translates into more range for a given volume fuel tank on a vehicle. *Id.* Unlike ethanol, which forms a homogenous azeotrope with water, however, 1-butanol and water form a heterogeneous azeotrope at atmospheric pressure. *Id.* As a result, separating 1-butanol from water cannot be achieved in a single distillation column. *Id.*

Isobutanol, like 1-butanol, also forms a heterogeneous azeotrope with water. Ex. 1013 ¶ 183.[5] Hence, at the time of the '588 patent invention, it was known that distillation can only separate the isobutanol-water mixture up to its azeotropic composition. *Id.* To isolate and purify isobutanol, distillation may be used in combination with another separation method, such as decantation or liquid-liquid extraction. *Id.* Specifically:

> The isobutanol-water mixture forms a heterogeneous azeotrope so that distillation may be used in combination with decantation to isolate and purify the isobutanol. In this method, the isobutanol containing fermentation broth is distilled to near the

[5] Ex. 1013 (Donaldson et al., U.S. Patent Appl. Pub. No. 2007/0092957 A1) was published on Apr. 26, 2007, before the earliest priority date of the '588 patent.

> azeotropic composition. Then, the azeotropic mixture is condensed, and the isobutanol is separated from the fermentation medium by decantation.

Id. ¶ 184.

3. Prior Art

English (Ex. 1002)

English, entitled "Fermentation Process for the Manufacture of an Organic Compound," relates to "a process for the manufacture of ethanol or a similar volatile organic compound by the fermentation of a carbohydrate with a micro-organism." Ex. 1002, 1:6–9. According to English, the fermentation product, once it reaches certain concentration, "exhibits a toxic effect on the micro-organism which is responsible for its production." *Id.* at 1:19–22. To solve this issue, English teaches a process that includes, concurrent with fermentation, the steps of

> continuously transferring a portion of the fermentation medium to a separator where ethanol or the like volatile organic compound is evaporated from the fermentation medium at a temperature which is not deleterious to the micro-organism by subjecting the fermentation medium to a reduced pressure and recycling part or all of the remaining fermentation medium to the fermenter.

Id. at 1:63–2:2.

In one embodiment, English discloses: (1) a prepared feedstock containing fermentable sugars is fed into a continuous fermentor where the sugars are fermented to produce ethanol; (2) a stream of the contents of the fermentor, typically containing 6% wt/wt ethanol, is withdrawn and introduced into a separator or flash vessel; (3) a mixture of vapors, generally containing about 40% wt/wt ethanol, is evaporated under reduced pressure in

the separator and then subject to further recovery to reach 96–98% wt/wt ethanol; and (4) the remaining fluid in the separator is recycled to the fermentor. *Id.* at 7:33–8:36.

English states that its method can be used for manufacturing not only ethanol, but also other alcohols, including specifically, butanol, "from appropriate feedstocks using suitable micro-organisms." *Id.* at 3:66–4:4.

Hess (Ex. 1003)

According to Hess, 1-butanol, used as a biofuel, has several advantages over ethanol. Ex. 1003. Because "butanol is produced using a fermentation process very similar to that of ethanol," Hess announces a plan to convert an ethanol plant to produce 1-butanol. *Id.*

D'Amore (Ex. 1004)

D'Amore teaches that isobutanol can be produced fermentatively by recombinant microorganisms. Ex. 1004 ¶¶ 23, 56. It also discloses several methods of separating isobutanol and water, including distillation and liquid-liquid extraction. *See, e.g.*, *id.* ¶¶ 39–46. Figure 2 of D'Amore illustrates an embodiment of the distillation method:

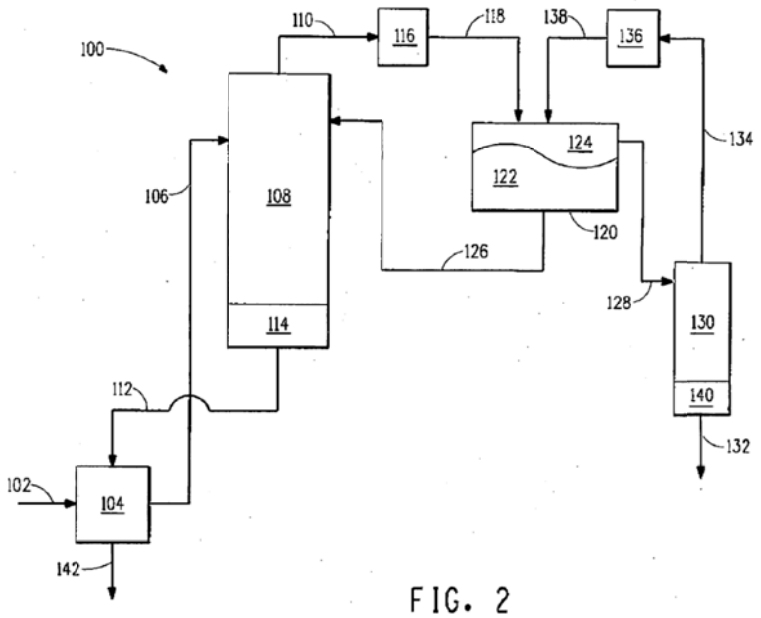

FIG. 2

Figure 2 shows fermentation broth stream 102 introduced into beer column 108, where an isobutanol-enriched vapor phase is separated from isobutanol-depleted hot water stream 112. *Id.* ¶ 57. In condenser 116, the isobutanol-enriched vapor phase, introduced as overhead stream 110, is condensed into biphasic liquid stream 118, conducted into decanter 120, and separated into isobutanol-rich phase 124 and water-rich phase 122. *Id.* Isobutanol-rich phase 124 is sent to distillation column 130 where isobutanol is recovered as product stream 132. *Id.* Water-rich phase 122, which contains 94% by weight water and 6% by weight isobutanol, is recycled to beer column 108. *Id.*

FIG. 4 of D'Amore illustrates an embodiment of the liquid-liquid extraction method:

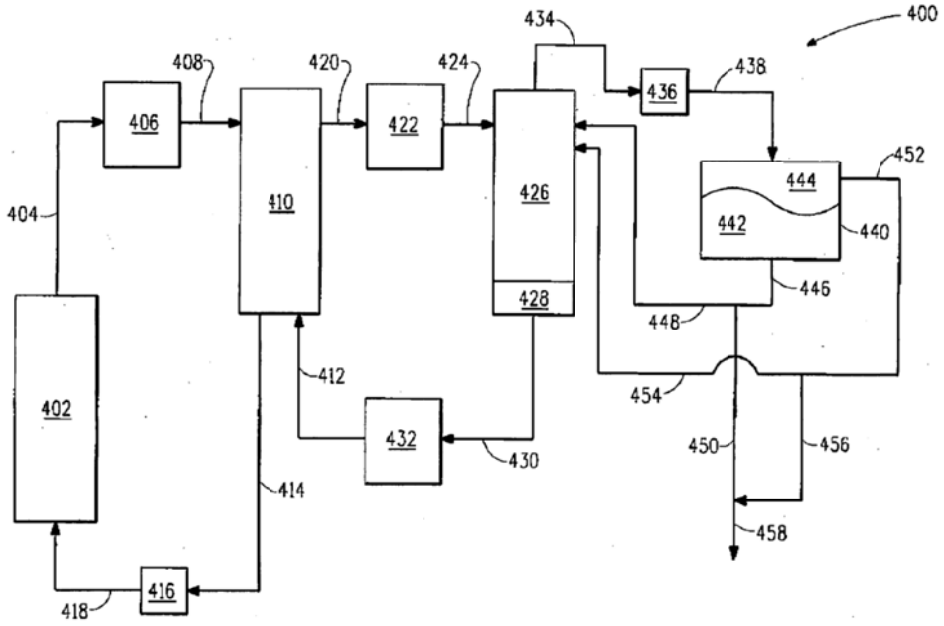

FIG. 4

FIG. 4 shows a stream of fermentation broth from fermentor 402 introduced into solvent extractor 410, where extract stream 420 containing solvent, isobutanol, and water is separated from isobutanol-depleted raffinate stream 414. *Id.* ¶ 59. Raffinate stream 414 is returned to fermentor 402 while extract stream 420 is introduced into solvent recovery distillation column 426, where solvent is separated from solvent overhead stream 434 containing an azeotropic mixture of isobutanol and water. *Id.* Vaporous solvent overhead stream 434 is condensed into biphasic liquid stream 438 in condenser 436 and introduced into decanter 440, where upper phase 444 with around 80% by weight isobutanol is separated from lower phase 442 with around 94% by weight water. *Id.*

Maiorella (Ex. 1005)

Maiorella describes several alternative fermentation schemes for ethanol production. Ex. 1005, Abstract. It discloses that "[f]or selective ethanol removal processes, the fermenting beer is cycled through a selective

ethanol recovery device (membrane separator, extractor, or flash vessel) to recover a concentrated ethanol product for distillation and an ethanol depleted beer for recycle to the fermentor." *Id.* at 1005 (citations omitted); *see also id.* at 1015, Fig. 17. Maiorella teaches sending clarified dilute beer to a stripper column to recover ethanol. *Id.* at 1005. According to Maiorella, recycling the microorganism cells to the fermentor "increases productivity and reduces costs." *Id.* at 1010. Maiorella further teaches ethanol purification using solvent extraction. *Id.* at 1019, Fig. 19.

4. Obviousness of Claims 1–28 over English, Hess, and D'Amore

Butamax argues that claims 1–28 would have been obvious over the combination of English, Hess, and D'Amore. Pet. 12–36.

Butamax asserts that one skilled in the art would have had a reason to combine the teachings of English, Hess, and D'Amore "because they are all directed to production and recovery of volatile alcohols such as ethanol or isobutanol from a fermentation medium." *Id.* at 14. According to Butamax, because D'Amore teaches producing isobutanol under culturing conditions similar to those disclosed in English, and Hess teaches that butanol can be produced in a retrofit ethanol plant, a skilled artisan "would have had a reasonable expectation of successfully culturing the microorganisms of D'Amore to produce isobutanol in the fermentation method of English." *Id.* at 15.

For claim 1, Butamax contends that the combination of English, Hess, and D'Amore teaches the preamble; English teaches steps (a)–(e) and (iii) of the wherein clause; and D'Amore teaches steps (b) and (i)–(iii) of the wherein clause. *Id.* at 12–20. According to Butamax, in view of the prior

art, one skilled in the art would have arrived at an isobutanol recovery process that includes every limitation of claim 1. *Id.* at 20. For claim 14, Butamax argues that the combination of English, Hess, and D'Amore teaches the preamble; English teaches steps (a), (b), (e), and (h); and D'Amore teaches steps (b)–(g). *Id.* at 21–25. In view of the prior art, Butamax asserts, one skilled in the art would have arrived at an isobutanol recovery process that includes every limitation of claim 14. *Id.* at 25. Butamax also refers to various disclosures in English and D'Amore for the teachings and suggestions of the additional limitations recited in claims 2–13 and 15–28. *Id.* at 26–36.

Gevo contends that the references fail to teach all the limitations of claims 1 and 14. PO Resp. 38. In addition, Gevo argues that one skilled in the art would have no reason to combine the references and no expectation of success in doing so, and that the combination of the references would render English unsuitable for its intended purposes. PO Resp. 46–58. We address each argument in turn.

Teaching or Suggestion of Each Claim Limitation

Claims 1 and 14, preamble

According to Gevo, the ethanol plant referenced in Hess was under construction and not operational when Hess was published. *Id.* Thus, Gevo argues, Hess only teaches design changes to a new, mid-construction plant, and does not teach a retrofit ethanol plant recited in the preambles of claims 1 and 14. *Id.* at 39. We reject this argument for the same reason we reject Gevo's narrow claim construction of "retrofit ethanol production plant," because Gevo has not pointed to persuasive evidence to demonstrate that the

'588 patents limits a retrofit ethanol plant to an existing and functioning one. *See* Section II.B.

Claims 1 and 14, step (a)

Gevo contends that English fails to teach a pretreatment unit recited in step (a) of claims 1 and 14. PO Resp. 39–40. Gevo points out that during his deposition, Dr. Daugulis admitted that Figure 2 of English is "missing the entire upstream" for "all of the steps involved in substrate pretreatment." *Id.* at 39 (citing Ex. 2023, 106:10–15). Gevo's argument is unpersuasive. In the Decision to Institute, the Board determined that "a person of ordinary skill in the art would understand 'pretreatment unit' as 'the location where the feedstock is pretreated to form fermentable sugars.'" Dec. 12. Under this construction, which Gevo does not challenge, the location where carbohydrate feedstock of starch, cellulose, or other polysaccharides is degraded to produce sugars is the pretreatment unit in English. *See* Ex. 1002, 2:58–3:3. This is so even though Figure 2, a specific embodiment of English, does not explicitly illustrate a pretreatment unit.

Claim 1, step (e); claim 14, step (h)

Gevo asserts that English fails to teach "transferring the fermentation medium from the fermentation unit to a beer still," as recited in step (e) of claim 1 and step (h) of claim 14. PO Resp. 40–41. Gevo emphasizes that English removes yeast from the fermentation medium before sending it to the stripping column. *Id.* According to Gevo, the fermentation medium recited in step (e) of claim 1 and step (h) of claim 14 is not clarified. *Id.* at 41. We disagree. As explained above, the fermentation medium in step (e) of claim 1 and step (h) of claim 14 may, but is not required to, contain

microorganisms. *See* Section II.B. Thus, we find English teaches step (e) of claim 1 and step (h) of claim 14.

Claim 1, step (iii)

The parties dispute whether the prior art teaches or suggests step (iii) in the wherein clause of claim 1, which requires returning the water-rich liquid phase to the fermentor. Pet. 19–20, PO Resp. 42–45. Referring to English's disclosure discarding a relatively smaller volume of water as effluent, Butamax asserts that one skilled in the art would have had a reason to recycle water for the same goal. Pet. 19 (citing Ex. 1002, 1:53–56). Gevo argues that English actually teaches removing water from the fermentor. PO Resp. 42. We find Butamax's arguments on this issue more persuasive.

English discloses a process with simultaneous fermentation and ethanol recovery, in which a stream of fermentation medium containing ethanol is withdrawn from the fermentor, ethanol is removed from the stream at a separator, and the remaining fluid is returned to the fermentor. Ex. 1002, 4:14–19; 7:42–47. English teaches tapping off "*some* of the fermentation medium issuing from the separator" in order to maintain the water balance in the fermentor. *Id.* at 6:11–14 (emphasis added); *see also id.* at 7:63–65. But drawing off a portion of the fluid confirms that the rest of the fluid is indeed recycled back to the fermentor. *See id.* at Fig. 1 (line 6); Fig. 2 (line 260). Thus, we are not persuaded by Gevo's argument that English contradicts Butamax's rationale for returning the water-rich phase to the fermentor, particularly given that Gevo does not argue, and we do not construe, step (iii) to limit "said water-rich liquid phase" to all of the water-rich liquid phase generated from the previous steps.

Butamax also refers to D'Amore's disclosure of sending a water-rich liquid phase to a beer column. Pet. 19 (citing Ex. 1004 ¶ 57, Fig. 2). Butamax argues that "a beer column is merely exemplary of the places to which water may be recycled." *Id.* According to Butamax, a skilled artisan would have had a reason to recycle water and would have understood that the water-rich liquid phase could be recycled to a finite number of places, including "the feedstock, the fermentor and the flash vessel." *Id.*; Tr. 22:9–16; *see also* Ex. 2023, 178:16–19.

Gevo counters that D'Amore sends the water-rich liquid phase to the beer column for a different reason, that is, to recover isobutanol, not to recycle water. PO Resp. 43. Gevo also points out the water-rich liquid phase of D'Amore contains 6% isobutanol. *Id.* According to Gevo, a skilled artisan intending to recover isobutanol would not have diluted the semi-concentrated phase by returning it to the fermentor. *Id.* Gevo further argues that one skilled in the art would not send the water-rich liquid phase of D'Amore to the fermentor, because 6% isobutanol is toxic to the microorganisms in the fermentor. *Id.* at 43–44. We are not convinced.

We first reject Gevo's argument that one skilled in the art would not return the water-rich liquid phase to the fermentor because of the toxicity from the 6% isobutanol. As explained in the Decision to Institute, the 6% isobutanol in the water-rich liquid phase does not equate to the same percentage of isobutanol in the fermentor. Dec. 16. Indeed, the experts for both parties agree that once mixed with, and thus diluted by, other contents in the fermentor, the isobutanol in the water-rich phase would not have a deleterious effect on the microorganisms. Ex. 2023, 224:8–227:5; Ex. 1017, 46:8–48:12.

We next note the '588 patent itself uses the term "recycle" to describe the transfer of water-rich liquid phase to a beer column. *See, e.g.*, Ex. 1001, 25:58–60; 26:9–10. Moreover, regardless of the purpose of sending water to a beer column, we agree with Butamax that there are a finite number of places to send the water-rich liquid phase, and the fermentor is a viable option. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 421 (2007) (explaining that when there is a design need to solve a problem and there are a finite number of predictable solutions, a person of ordinary skill has good reason to pursue these options). Gevo's assertion that the water-rich liquid phase contains isobutanol does not change our determination. Indeed, English teaches, after extracting ethanol from a portion of the fermentation medium, recycling the remaining fluid from the separator to the fermentor. The recycled fluid there necessarily contains a certain amount of ethanol. Similarly here, we are sufficiently persuaded the fact that the water-rich liquid phase contains isobutanol would not have precluded a skilled artisan from recycling it to the fermentor.

In sum, we find the combination of English and D'Amore teaches or suggests recycling the water-rich liquid phase to the fermentor, as recited in step (iii) of claim 1.

Claim 14, step (e)

In the claim chart, Butamax lists both English and D'Amore as disclosing step (e) of claim 14, but only D'Amore as disclosing step (c). Pet. 22. Gevo does not dispute D'Amore's teaching, but argues that English cannot disclose step (e) because the isobutanol-rich portion recited in that step comes from step (c). PO Resp. 45. We agree with Gevo on this issue.

Nevertheless, we find D'Amore sufficiently teaches both steps (c) and (e). *See* Ex. 1004 ¶ 59; Fig. 4.

Reason to Combine and Expectation of Success

Gevo argues that one skilled in the art would have had no reason to combine the references and no expectation of success in doing so, and that the combination of the references would render English unsuitable for its intended purposes. PO Resp. 46–58.

According to Gevo, "processes for obtaining high purity alcohol from homogeneous mixtures (ethanol-water) and heterogeneous mixtures (isobutanol-water) are fundamentally different." *Id.* at 47. Gevo's expert, Dr. Lucia, testified that the processes of English are "only suitable for separating homogeneous azeotropes like ethanol and water." Ex. 2024 ¶ 62; *see also* PO Resp. 48–49. Because isobutanol forms a heterogeneous azeotrope with water, Gevo asserts, one skilled in the art would not look to English as a starting point to produce isobutanol. PO Resp. 47–49, 55. Even if English was selected as a starting point, Gevo further argues, a skilled artisan would not disregard English's stated objective to save energy by modifying English's process with D'Amore. *Id.* at 49–50, 52, 56.

We find Gevo's argument unconvincing. First, the test for obviousness is whether the claimed invention is rendered obvious by the teachings of the prior art as a whole. *In re Etter*, 756 F.2d 852, 859 (Fed. Cir. 1985) (en banc). Here, we analyze the combined teachings of English and D'Amore; it matters not whether one skilled in the art would look to English as a starting point or to supplement the teachings of D'Amore. *See In re Bush*, 296 F.2d 491, 496 (CCPA 1961).

Second, as Butamax correctly points out, English never uses the terms "homogeneous" or "azeotrope." Reply 5. Instead, English specifically teaches that its method can be used for manufacturing butanol from fermentation. Ex. 1002, 3:47–52; 3:66–4:4. In his declaration, Dr. Lucia states that the butanol in English is t-butanol because it forms a homogeneous azeotrope with water. Ex. 2021 ¶ 50. During his deposition, however, Dr. Lucia testified that he was not certain which butanol is produced through the fermentation process. Ex. 1017, 12:4–24. In fact, the isoform of butanol produced by ABE fermentation is 1-butanol, which forms a heterogeneous azeotrope with water. Ex. 2027 § 7.1. Thus, contrary to Gevo's assertion, English does not limit "ethanol like volatile organic compounds" to only those that form homogeneous azeotropes with water.

Third, D'Amore teaches that "1-Butanol and isobutanol share many common features that allow the separation schemes devised for the separation of 1-butanol and water to be applicable to the isobutanol and water system." Ex. 1004 ¶ 37. During his deposition, Dr. Lucia confirmed that the separation processes for recovering isobutanol and 1-butanol from fermentation broth "would be roughly the same." Ex. 1017, 85:13–86:4. Thus, it appears to be reasonable for one skilled in the art, when designing a process to produce isobutanol, to consult prior art disclosing processes to produce 1-butanol. This is especially so here because D'Amore, while recognizing fermentation methodology as "well known in the art" (Ex. 1004 ¶ 34; *see also id.* ¶ 36), does not describe the fermentation process in detail. English, on the other hand, teaches fermentation processes that can be used to produce 1-butanol. *See e.g.*, Ex. 1002, 7:33–8:36. Thus, we are persuaded that one skilled in the art having the goal of fermenting biomass

to produce isobutanol would have had a reason to combine the teachings of English and D'Amore.

In addition, Gevo argues that Dr. Daugulis, Butamax's expert, conceded during his deposition that one skilled in the art would not combine English and D'Amore. PO Resp. 54 (citing Ex. 2023, 147:15–21). We do not find this argument persuasive. Even though he stated that it may be better to have additional equilibrium stages, Dr. Daugulis testified that "a simple isobutanol process could operate with [a] flash unit." Ex. 2023, 147:15–17; 148:6–7.

Gevo next argues that combining English and D'Amore would change the fundamental principles of operation of the English process. PO Resp. 50–53, 55. As explained above, we do not define the basic principle of operation of English so narrowly as limited to only homogeneous azeotrope production. Thus, we do not find that the combination of English and D'Amore would have changed the principle of operation of English.

Gevo also contends that combining English and D'Amore would render English unsuitable for its intended purpose of purifying ethanol to a purity of 96–98%. PO Resp. 50, 55–57. This argument also is inapposite. To analyze whether the challenged claims would have been obvious, we inquire whether one skilled in the art, combining the teachings of English and D'Amore, would have been successful in designing a method to produce isobutanol. It is irrelevant whether such a method can be used to purify ethanol.

Further, Dr. Lucia emphasizes the economic impact that would result from any modification of the English processes. Ex. 2024 ¶ 53. Relying on Dr. Lucia's opinion, Gevo asserts that without "significant simulation and

economic analysis," it would be "impossible" for a skilled artisan to conclude "whether such a modified process could be considered 'successful.'" PO Resp. 51–53 (citing Ex. 2024 ¶¶ 69, 70); *see also id.* at 34–35. Gevo's argument is unconvincing. Dr. Lucia's expressed skepticism is directed to the economic feasibility—whether the modified process could be considered *commercially* successful—not the technical merit of the claimed invention. But commercial viability does not control the obviousness determination:

> [T]he fact that the two [prior art disclosures] would not be combined by businessmen for economic reasons is not the same as saying that it could not be done because skilled persons in the art felt that there was some technological incompatibility that prevented their combination. Only the latter fact is telling on the issue of nonobviousness.

Orthopedic Equip. Co., Inc. v. United States, 702 F.2d 1005, 1013 (Fed. Cir. 1983). Therefore, we are not persuaded that economic analysis is required for the obviousness analysis.

Finally, Gevo contends that Butamax improperly relies on hindsight in asserting obviousness of the challenged claims. PO Resp. 57. D'Amore discloses, in addition to distillation, several other methods to purify isobutanol, including pervaporation, gas stripping, adsorption, and liquid-liquid extraction. Ex. 1004 ¶¶ 41–45. Gevo argues that none of those methods, when combined with English, could arrive at the claimed invention. PO Resp. 57; *see also* Tr. 49:9–51:22. According to Gevo, Butamax's selection of only distillation, while ignoring the other methods, for combination with English, is based on the hindsight knowledge of the claimed invention. PO Resp. 57. We disagree.

On this issue, the Federal Circuit's opinion in *In re Thomas* is informative. *See* 151 F. App'x 930 (Fed. Cir. 2005). In that case, one of the claims on appeal was directed to a computer implemented method for performing a survey, requiring email notification of registered participants as to research studies. *Id.* at 932. The Board affirmed an examiner's rejection of the claim for obviousness based on the combination of two prior art references. *Id.* at 934. On appeal to the Federal Circuit, the appellant argued that the Board erred in finding a motivation to combine because one of the references "suggests eight different methods of computer-based data collection, any one of which could be used to notify respondents, and that it does not suggest the particular desirability of email notification." *Id.* Rejecting this argument, the Federal Circuit pointed out: "for an obviousness analysis, even the fact that 'a specific embodiment is taught to be preferred is not controlling, since all disclosures of the prior art, including unpreferred embodiments, must be considered.'" *Id.* (quoting *Merck & Co., Inc. v. Biocraft Labs., Inc.*, 874 F.2d 804, 807 (Fed. Cir. 1989)).

Similarly in the present case, we must consider all disclosures of D'Amore, which explicitly teaches distillation to recover isobutanol from fermentation broth. Ex. 1004 ¶¶ 39, 40. D'Amore's teaching of other recovery methods does not render the combination of this method with the teaching of English not obvious. Indeed, during his deposition, Dr. Lucia testified that "the usual strategy" to purify a compound that forms a heterogeneous azeotrope with water would be to separate the condensed biphasic vapor with a decanter after distillation. Ex. 1017, 58:6–13.

In sum, we determine Butamax has shown that the combination of English, Hess, and D'Amore teaches or suggests all the limitations of claims

1–28. In addition, one skilled in the art would have had a reason to combine these references and would have had a reasonable expectation that the modified method be successful in producing isobutanol. Therefore, Butamax has shown by a preponderance of the evidence that claims 1–28 would have been obvious over the combination of English, Hess, and D'Amore.

5. Obviousness of Claims 1–28 over Maiorella, Hess, and D'Amore

Butamax argues that claims 1–28 would have been obvious over the combination of Maiorella, Hess, and D'Amore. Pet. 36–59.

Butamax's arguments supporting this ground are similar to those supporting the ground based on the combination of English, Hess, and D'Amore, with Maiorella's teachings replacing those supplied by English. *Id.* Specifically, Butamax contends Maiorella teaches manufacturing ethanol by culturing microorganisms in a fermentation process, and D'Amore teaches producing isobutanol under similar culturing conditions. *Id.* at 39. Because Hess teaches that butanol can be produced in a retrofit ethanol plant, according to Butamax, a skilled artisan would have had a reason to culture the microorganisms of D'Amore in the fermentation method of Maiorella, and would have had a reasonable expectation of success in producing isobutanol. *Id.* at 38–40.

For claim 1, Butamax contends that the combination of Maiorella, Hess, and D'Amore teaches the preamble; Maiorella teaches steps (a), (c)–(e) and (iii) of the wherein clause; and D'Amore teaches steps (b) and (i)–(iii) of the wherein clause. *Id.* at 37–43. According to Butamax, in view of

the prior art, one skilled in the art would have arrived at an isobutanol recovery process that includes every limitation of claim 1. *Id.* at 44. For claim 14, Butamax argues that the combination of Maiorella, Hess, and D'Amore teaches the preamble; Maiorella teaches steps (a), (c)–(e), and (h); and D'Amore teaches steps (b) and (e)–(g). *Id.* at 45–47. In view of the prior art, Butamax asserts, one skilled in the art would have arrived at an isobutanol recovery process that includes every limitation of claim 14. *Id.* at 48. Butamax also points to various teachings in Maiorella and D'Amore as teaching or suggesting the additional limitations recited in claims 2–13 and 15–28. *Id.* at 49–58.

Gevo's positions here parallel those countering the obviousness ground based on English, Hess, and D'Amore, discussed above. PO Resp. 38–47, 51, 59–60. Specifically, Gevo contends that the combination of Maiorella, Hess, and D'Amore fails to teach or suggest: (1) the preambles of claims 1 and 14, (2) step (a) of claims 1 and 14, (3) step (e) of claim 1 and step (h) of claim 14, and (4) step (iii) of claim 1. *Id.* at 38–45. We reject Gevo's assertions for the same reasons explained above in addressing the English, Hess, and D'Amore ground.

For example, step (a) of claims 1 and 14 requires "pretreating a feedstock to form fermentable sugars in a pretreatment unit." Maiorella does not explicitly recite a pretreatment unit. But, as Butamax correctly points out, Maiorella teaches producing glucose from corn stover residue by enzymatic hydrolysis and concentrating the sugar solution for fermentation. Pet. 37 (citing Ex. 1005, 1021). Under the Board's construction of "pretreatment unit" (*see* Dec. 12), which Gevo does not challenge, the location of the glucose production is the pretreatment unit in Maiorella.

Thus, we are satisfied that Maiorella teaches or suggests step (a) of claims 1 and 14.

Gevo correctly notes that steps (c) and (d) of claim 14 recite an isobutanol-rich portion and an isobutanol-depleted portion of the fermentation medium and that Butamax cites only Maiorella as suggesting these steps. PO Resp. 45; *see also* Pet. 45–46. According to Gevo, Maiorella only teaches ethanol-related processes and thus, cannot disclose steps (c) and (d). PO Resp. 45. We are not convinced.

In analyzing obviousness, we do not inquire whether Maiorella's ethanol-related processes may be incorporated bodily into D'Amore's isobutanol production method. "Rather, the test is what the combined teachings of the references would have suggested to those of ordinary skill in the art." *In re Keller*, 642 F.2d 413, 425 (CCPA 1981). Here, the parties agree that one skilled in the art would have a Ph.D. in chemical engineering and would have experience in distillation or fermentation and/or alcohol production. Ex. 1006 ¶ 16; Ex. 2024 ¶ 7. Such a skilled artisan would have understood that culturing the microorganisms of D'Amore in the fermentation method of Maiorella generates isobutanol, not ethanol, in the fermentation medium. Such a skilled artisan also would have understood that applying a solvent extractant, as disclosed in Maiorella, to the isobutanol-containing fermentation medium results in an isobutanol-rich portion and an isobutanol-depleted portion, as recited in steps (c) and (d).

Thus, we are persuaded that the prior art teaches or suggests all the limitations of claim 14.[6]

Gevo further asserts that Maiorella's processes are for producing ethanol (a homogeneous azeotrope) and would not be "commercially suitable" for purifying isobutanol (a heterogeneous azeotrope). PO Resp. 37, 59. We are not persuaded. As Butamax points out, Hess teaches modifying an ethanol plant to produce 1-butanol. Pet. 39 (citing Ex. 1003). D'Amore discloses, and Dr. Lucia confirms, that because 1-butanol and isobutanol share many common features, the separation schemes for the two are "roughly the same." Ex. 1017, 85:13–86:4; *see also* Ex. 1004 ¶ 37. Thus, one skilled in the art reading Maiorella, Hess, and D'Amore would have had a reason to modify Maiorella's process to produce isobutanol.

Gevo contends that the obviousness ground based on Maiorella, Hess, and D'Amore has the same flaws as the ground based on English, Hess, and D'Amore because Maiorella provides identical elements interchangeable with the disclosures of English. PO Resp. 59. For example, similar to its arguments presented in relation to the ground based on the combination of English, Hess, and D'Amore, Gevo again (1) emphasizes the lack of economic considerations; and (2) contends that modifying a process designed to purify ethanol to purify isobutanol would render the process inoperable and unsuitable for its intended purpose. PO Resp. 35–36, 59. We are unconvinced by either argument for the same reasons we explained

[6] Furthermore, we note that D'Amore discloses steps (c) and (d) of claim 14, as Butamax contends in its obviousness analysis based on English, Hess, and D'Amore, discussed above. *See* Pet. 22–24.

in addressing the ground based on the combination of English, Hess, and D'Amore.

In sum, we determine Butamax has shown by a preponderance of the evidence that claims 1–28 would have been obvious over the combination of Maiorella, Hess, and D'Amore.

III. CONCLUSION

Butamax has shown by a preponderance of the evidence that claims 1–28 of the '588 patent are unpatentable.

IV. ORDER

Accordingly, it is

ORDERED that claims 1–28 of the '588 patent are determined to be UNPATENTABLE;

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

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