

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

FORD MOTOR COMPANY,
Petitioner,

v.

ETHANOL BOOSTING SYSTEMS, LLC, and MASSACHUSETTS
INSTITUTE OF TECHNOLOGY,
Patent Owner.

IPR2021-00339
Patent 10,619,580 B2

Before LYNNE H. BROWNE, BARRY L. GROSSMAN, and
JAMES J. MAYBERRY, *Administrative Patent Judges*.

BROWNE, *Administrative Patent Judge*.

JUDGMENT
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)

ORDER
Dismissing Patent Owner's Motion to Exclude Evidence
37 C.F.R. § 42.64(c)

I. INTRODUCTION

We have authority to hear this *inter partes* review under 35 U.S.C. § 6. This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed below, we determine that Petitioner, Ford Motor Company, has shown by a preponderance of the evidence that claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, and 31 of U.S. Patent No. 10,619,580 B2 (Ex. 1001, “the ’580 patent”) are unpatentable. *See* 35 U.S.C. § 316(e) (2018); 37 C.F.R. § 42.1(d) (2019). We also dismiss as moot Patent Owner’s Motion to Exclude Evidence.

A. Procedural History

Petitioner requested *inter partes* review of claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, and 31 of the ’580 Patent (the “challenged claims”). Paper 2 (“Petition” or “Pet.”). Patent Owner, Ethanol Boosting Systems, LLC and Massachusetts Institute of Technology, filed a Preliminary Response. Paper 6. Based upon the record at that time, we denied institution of *inter partes* review of the ’580 patent. Paper 10 (“Decision Denying Institution” or “Dec. Deny. Inst.”). Petitioner filed a Request for Rehearing of our Decision Denying Institution, and also requested a Precedential Opinion Panel (“POP”) review of our Decision. Paper 11 (“Req. Reh’g” or “Rehearing Request”), Ex. 3002.

Central to our Decision Denying Institution, and Petitioner’s Rehearing Request, was a claim construction of the “fuel terms,” a construction originating in the parallel district court litigation and appealed to the U.S. Court of Appeals for the Federal Circuit. *See* Dec. Deny. Inst. 14–18; Req. Reh’g 1–2; *see also* Ex. 2014 (providing Notice of Appeal). In our Decision Denying Institution, we adopted the claim construction that

was adopted by the district court in *Ford II*¹, and that was consistent with a previous construction affirmed by the Federal Circuit for a set of related patents, which was the subject of prior litigation, in *Ford I*². *See* Dec. Deny. Inst. 18. The construction adopted in the Decision Denying Institution was consistent with the construction asserted by Petitioner in the district court in *Ford II*, and inconsistent with the construction asserted by Patent Owner in the district court and Petitioner in the Petition. *See id.*

Subsequent to our Decision Denying Institution, but before deciding Petitioner’s Request for Rehearing, the Federal Circuit vacated the district court’s claim construction in *Ford II*, and remanded that case to the district court, agreeing with Patent Owner that the claim construction of the “fuel terms” did not require two different fuels. Paper 16; *Ethanol Boosting Sys., LLC v. Ford Motor Co.*, No. 2021-1949, 2022 WL 2798395 (Fed. Cir. July 18, 2022) (hereinafter referred to as *EBS II* or “Ex. 1042”). In light of the Federal Circuit determining in *EBS II* that the construction of the “fuel terms” did not require two different fuels, we granted Petitioner’s Rehearing Request and instituted trial on all challenges in the Petition, applying the construction asserted by Petitioner in the Petition. Paper 17, 6 (“Institution Decision” or “Inst. Dec.”).

Patent Owner filed a request for rehearing (Paper 19), and a POP request (*see* Ex. 3003) of our Institution Decision. Both requests were denied. Papers 29, 32.

¹ *Ethanol Boosting Systems, LLC v. Ford Motor Company, LLC*, No. 1:20-cv-00706-CFC (Del.) (“*Ford IP*”). *See* § I.C.1, *infra*.

² *Ethanol Boosting Systems, LLC v. Ford Motor Company, LLC*, No. 1:19-cv-00196-CFC (D. Del.) (“*Ford I*”). *See* § I.C.2, *infra*.

After institution, Patent Owner filed a Response (Paper 33, “PO Resp.”), Petitioner filed a Reply (Paper 37, “Pet. Reply”), and Patent Owner filed a Sur-reply (Paper 41, “PO Sur-reply”).

Patent Owner filed a Motion Exclude Evidence. Paper 42 (“Motion”). Petitioner filed an Opposition to the Motion and Patent Owner filed a Reply to the Opposition. Papers 44, 46.

On September 6, 2023, an oral hearing was held. The transcript of the hearing (Paper 50) was entered in the record.

B. Real Parties in Interest

Petitioner states that it is the real party-in-interest. Pet. 77. Patent Owner states that it and Ethanol Boosting systems, LLC, the exclusive licensee of the ’580 patent, are the real parties-in-interest. Paper 5, 2.

C. Related Matters

Both parties identify *Ford I*, *Ford II*, and *Ethanol Boosting Systems, LLC et al v. Ford Motor Company, LLC*, No. 2020-1472 (Fed. Cir.) as judicial matters that may affect, or be affected by this proceeding. Pet. 77; Paper 5, 2.

Both parties identify IPR2019-01399, IPR2019-01401, IPR2019-01402, IPR2021-00340 and IPR2021-00341 as administrative matters that may affect, or be affected by this proceeding. *Id.*

D. The ’580 patent

The ’580 patent is titled “Optimized Fuel Management System for Direct Injection Ethanol Enhancement of Gasoline Engines.” Ex. 1001, code (54). Figure 3 of the ’580 patent is shown below.

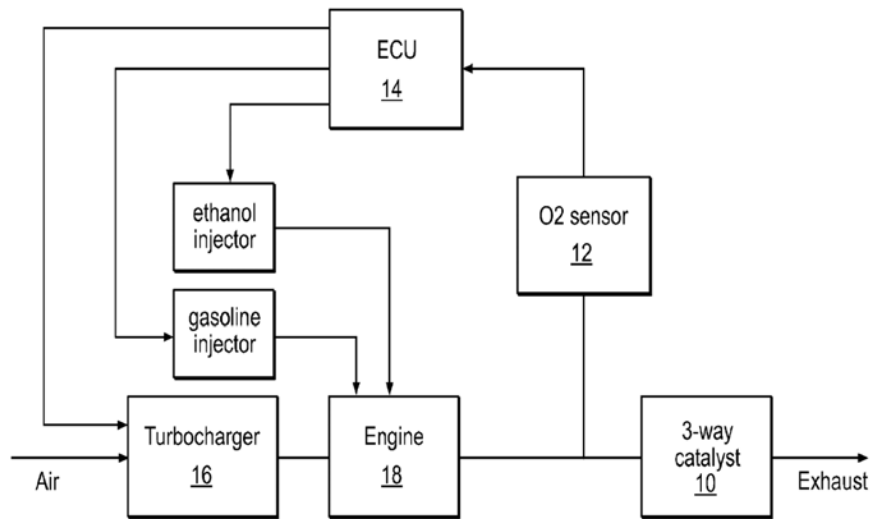


FIG. 3

Figure 3 shows a block diagram of an embodiment of the invention disclosed in the '580 patent. Ex. 1001, 2:48–49. In this figure a box at the top represents electronic control unit 14. Below this box are two boxes. The box on the left is labeled ethanol injector and the one on the right represents oxygen sensor 12. Below the ethanol injector box is another box labeled gasoline injector. At the bottom of the figure is a row of three boxes. The box on the bottom left represents turbocharger 16, the box in the bottom middle represents engine 18, and the box on the bottom right represents three-way catalyst 10. Three arrows originate on the left side of the electronic control unit box and lead to the ethanol injector box, the gasoline injector box, and turbocharger 16. An arrow originates on the right side of the ethanol injector box and leads to engine 18. Similarly, an arrow originates on the right side of the gasoline injector to engine 18. An arrow ending at turbocharger 16 represents air entering it and an arrow originating at the left side of three-way catalyst 10 pointing out of the diagram

represents exhaust. A line extends between the right side of turbocharger 16 and the left side of engine 18, a line extends between the right side of engine 18 and three-way catalyst 16, and a line extends between this latter line and oxygen sensor 12. A final arrow extends from the top of oxygen sensor 12 and electronic control unit 14.

In operation, “[t]he system uses an oxygen sensor 12 as an input to an electronic control unit (ECU) 14. The ECU 14 controls the amount of air into a turbocharger 16, the amount of 10 gasoline and the amount of ethanol so as to insure stoichiometric operation.” Ex. 1001, 9:8–12. “[W]hen variable ethanol octane enhancement is employed, the fuel management system needs to adjust the amounts of air, gasoline and ethanol such that the fuel/air ratio is substantially equal to 1.” *Id.* at 9:16–19. “The additional control is needed because, if the air/gasoline ratio determined by the fuel management were not [to] be corrected during the injection of ethanol, the mixture would no longer be stoichiometric.” *Id.* at 9:19–22.

E. Challenged Claims

Petitioner challenges claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, and 31 of the ’580 patent. Claims 1, 13, and 23 are independent. Claims 2 and 5–12 depend, directly or indirectly, from claim 1, claims 14, 15, 18, and 20, 21 depend, directly or indirectly, from claim 13, and claims 27–29 and 31 depend directly from claim 23. Claim 1, with Petitioner’s limitation numbering, is reproduced below:

[1.Pre] A fuel management system for a spark ignition engine, comprising:

- [1.A] a first fueling system that uses direct injection;
- [1.B] a second fueling system that uses port fuel injection; and
- [1.C] a three-way catalyst configured to reduce emissions from

the spark ignition engine,

[1.D] wherein the fuel management system is configured to provide fueling in a first torque range, the first torque range being a first range of torque values at which both the first fueling system and the second fueling system are operable throughout the first range of torque values,

[1.E] wherein the fuel management system is further configured such that a fraction of fueling provided by the first fueling system is higher at a highest value of torque in the first torque range than in a lowest value of torque in the first torque range,

[1.F] wherein the fuel management system is further configured to provide fueling in a second torque range, the second torque range being a second range of torque values at which the second fueling system is operable throughout the second range of torque values and the first fueling system is not operable throughout the second range of torque values,

[1.G] wherein the fuel management system is further configured such that when the system provides fueling at a torque value that exceeds the second range of torque values, the spark ignition engine is operated in the first torque range, and

[1.H] wherein the spark ignition engine is configured to operate at a stoichiometric air/fuel ratio in at least part of the first torque range and in at least part of the second torque range.

Ex. 1001, 16:62–17:26.

F. Asserted Grounds of Unpatentability

Petitioner asserts the following grounds of unpatentability:

Claim(s) Challenged	35 U.S.C. §	Reference(s)/Basis
1, 2, 5–15, 18, 21, 23, 25, 27–29, 31	103	Schray, ³ Miura ⁴

³ US 6,505,603 B1, issued January 14, 2003 (Ex. 1005, “Schray”).

⁴ JP 2003-13785 A, published January 15, 2003 (Ex. 1008, “Miura”).

Claim(s) Challenged	35 U.S.C. §	Reference(s)/Basis
1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, 31	103	Rubbert, ⁵ Yuushiro, ⁶ Bosch ⁷
1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, 31	103	Ohtani, ⁸ Zhao ⁹

Pet. 1–2.

G. Evidence

In support of its proposed grounds, Petitioner relies on the Declaration of Nigel N. Clark, Ph.D. Ex. 1003; Pet. 1. In support of its Response Patent Owner relies on the Declaration of Gregory M. Shaver, Ph.D. Ex. 2018; PO Resp. 59.

II. ANALYSIS

A. Principles of Law

A patent claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of skill in the art; and (4) any objective evidence of obviousness

⁵ DE 19853799 A1, published May 25, 2000 (Ex. 1007, “Rubbert”).

⁶ JP H10-252512, published September 22, 1998 (Ex. 1006, “Yuushiro”).

⁷ Automotive Handbook (3d Ed.), Bosch, published 1993 (Ex. 1011, “Bosch”).

⁸ US 2005/0098156 A1, published May 12, 2005 (Ex. 1009, “Ohtani”).

⁹ Automotive Gasoline Direct-Injection Engines, SAE R 315, 2002 (Ex. 1010, “Zhao”).

or non-obviousness.¹⁰ *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966).

B. Claim Construction

In *inter partes* reviews, we interpret a claim “using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b).” 37 C.F.R. § 42.100(b). Under this standard, we construe the claim “in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.” *Id.*

Petitioner proposes constructions for five terms: 1) “spark ignition engine,” 2) the “DI”¹¹ terms,”¹² 3) “range of torque,” 4) the “fuel terms,”¹³ and 5) “spark retard.” Pet. 3–6. We determine that we need discuss only the fuel terms. *See Realtime Data, LLC v. Iancu*, 912 F.3d 1368, 1375 (Fed. Cir. 2019) (“The Board is required to construe ‘only those terms . . . that are in controversy, and 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)).

In our Decision Granting Rehearing and Instituting *Inter Partes* Review, we construed the fuel terms consistent with the Federal Circuit’s construction of the terms “the fuel terms to encompass a configuration where the first fueling system and the second fueling system use the same fuel.”

¹⁰ The parties have not directed our attention to any objective evidence of obviousness or non-obviousness.

¹¹ Direct injection.

¹² As discussed on pages 5–6 of the Petition.

¹³ The “[f]irst fueling system that uses direct injection” / “[s]econd fueling system that uses port fuel injection.” Pet. 5.

Paper 17, 6. In response, Patent Owner argues that the directly injected fuel cannot be gasoline only. PO Resp. 16–17.

Patent Owner argues that, in the District Court, Petitioner prevailed in obtaining a construction for the fuel terms, and more precisely, the directly injected/first fuel system fuel to be a fuel that contains an anti-knock agent that is not gasoline and that is different from the fuel used in for port injection. PO Resp. 16 (referencing Ex. 1035, 1–2). Patent Owner then argues that the Federal Circuit reversed the portion of the construction requiring the port and direct injection fuels to be different, but kept intact the portion of the construction that the directly injected fuel contain a knock agent other than gasoline. *Id.* at 16–17.

We do not read the Federal Circuit’s decision to be so limiting. Instead, as Patent Owner argues, the appeal was directed to the two fuels issue only. We conclude that the decision is directed to that portion of the construction only. *See* Ex. 1042, 4.

Also, in the Petition, Petitioner applies the construction that Patent Owner advocated at the District Court. Pet. 5. Specifically, Petitioner proposes that the

“Second fueling system that injects fuel into a region outside of the cylinder” (or port injection) should be construed to mean “injection of fuel through a manifold,” and “first fueling system that directly injects fuel” (or direct injection) should be construed to mean “injection of fuel into the cylinder,” consistent with their respective ordinary and customary meanings.

Id. (citing Ex. 1003 ¶ 130); *see also* Ex. 1039, 11–17 (providing Patent Owner’s proposed construction), Tr. 42:19–21 (“So this anti-knock agent that is not gasoline, my question is did that -- was that part of Patent Owner’s construction at the District Court level? MR. COGSWELL: No, it

was not.”). We adopt this construction for the fuel terms, a construction not inconsistent with the Federal Circuit’s ruling in *Ford II*. Thus, we construe the fuel terms to mean that the first fueling system is not limited to using fuels different than the fuel in the second fueling system, nor limited to an anti-knock agent that is not gasoline.

To the extent that the scope of any particular claim term requires discussion, however, we provide it in our assessment of the challenges, which we turn to next.

C. Ground 1: Obviousness of Claims 1, 2, 5–15, 18, 21, 23, 25, 27–29, and 31 in View of the Combined Teachings of Schray and Miura

Petitioner asserts that claims 1, 2, 5–15, 18, 21, 23, 25, 27–29, and 31 are unpatentable over Schray and Miura. Pet. 1. We begin our analysis of this challenge with overviews of Schray and Miura.

1. Schray

Schray “relates to a fuel injection method for an internal combustion engine.” Ex. 1005, 1:6–7. Schray explains that high compression ratios are sought for internal combustion engines but such ratios lead to the problem of uncontrolled self-ignition of the engine’s air/fuel mixture (i.e., “knocking”). *Id.* at 1:10–15. Schray describes an object of improving the operation of an internal combustion engine at its operating limits without suffering a loss in torque due to knocking. *Id.* at 1:42–45.

Schray’s Figure 1 (reproduced below) shows a schematic illustration of an internal combustion engine with a control apparatus. Ex. 1005, 2:1–2.

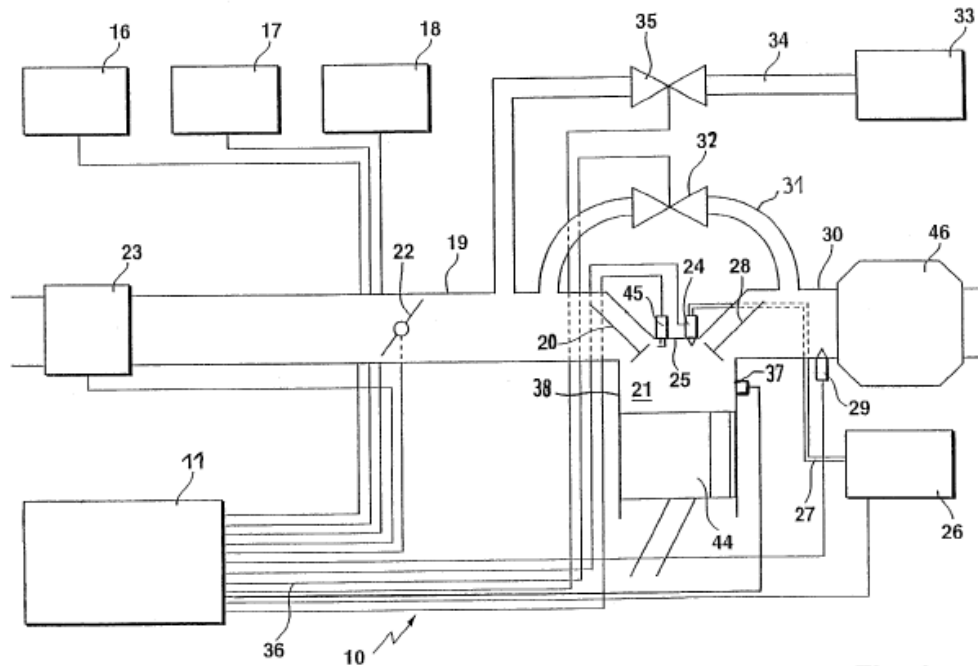


Fig. 1

Internal combustion engine having direct injection 10 operates by having fresh air supplied to cylinder 38 or combustion chamber 21 of cylinder 38 via intake manifold 19 and inlet valve 20. *Id.* at 2:9–12. Schray explains that “[a]n injection valve 24 and a spark plug 45 are mounted in the cylinder head 25” and that fuel “is injected into the combustion chamber 21 via a fuel line 27 and injection valves 24.” *Id.* at 2:16–20. Schray states that “[i]n homogeneous operation, the fuel is injected into the combustion chamber 21 by the injection valve 24 during an induction phase caused by the piston movement.” *Id.* at 3:1–3. The fuel is ignited via spark plug 45. *Id.* at 2:20–21.

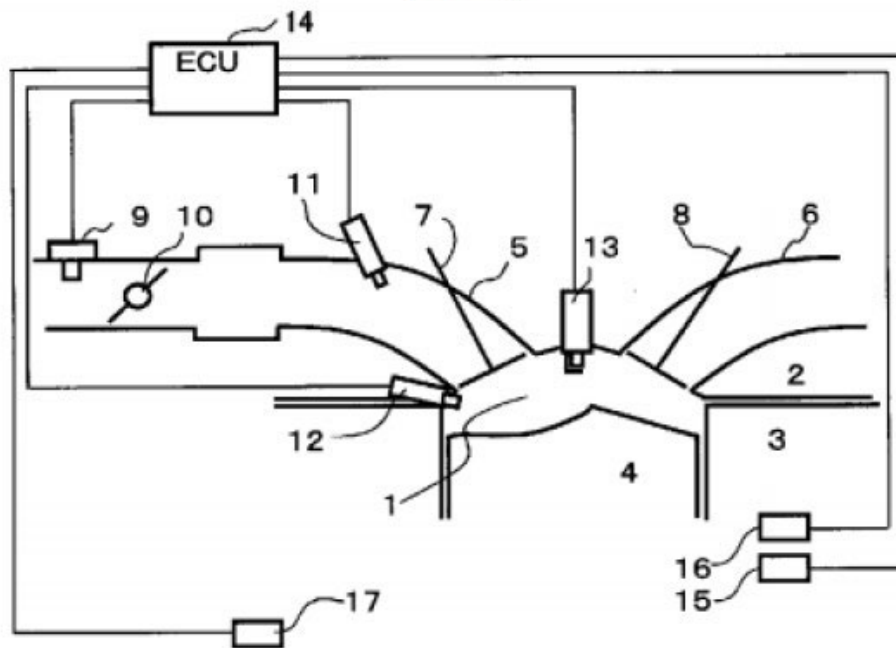
Schray describes determining a “tendency-to-knock signal” on the basis of a detected cylinder charge and the rpm N or on the basis of an injected fuel mass and the engine’s rpm and “[t]he tendency-to-knock signal is compared to a threshold value and double injections are initiated when this threshold value is exceeded.” Ex. 1005, 3:47–52. Schray explains that

“double injection means that the first injection takes place in the induction stroke and the second injection takes place in the compression stroke.” *Id.* at 3:53–55. According to Schray, “[t]he second injection causes the air/fuel mixture present in the combustion chamber 21 because of the first injection to be cooled whereby the danger of an uncontrolled ignition of the air/fuel mixture is reduced.” *Id.* at 3:55–60.

2. *Miura*

Miura “relates to a control device for a direct injection spark ignition internal combustion engine for suppressing generation of knocking by sub-stratifying an air-fuel mixture in a prescribed operation range.” Ex. 1008 ¶ 1. Miura explains that “in a high load range in which knocking regularly occurs, it is possible to suppress occurrence of knocking by injecting fuel after dividing into an intake stroke and a compression stroke.” *Id.* ¶ 3. More specifically, Miura describes “injecting an amount of fuel for the combustion chamber overall to become lean in the intake stroke and injecting the remaining fuel in the compression stroke to form a sub-stratified air-fuel mixture within the combustion chamber” so that “an end gas portion is made leaner to suppress and improve generation of knocking.” *Id.* Miura’s Figure 1 (reproduced below) shows a schematic illustration of Miura’s system. Ex. 1008 ¶ 37.

[FIG. 1]



Miura explains that combustion chamber 1 of an engine is defined by cylinder head 2, cylinder block 3, and piston 4. *Id.* ¶ 14. Intake path 5 includes throttle valve 10 for controlling the intake air volume and intake unit fuel injection valve 11 that “injects fuel into the intake path 5 in front of the combustion chamber 1.” *Id.* ¶ 15. Miura also describes “[a]n in-cylinder direct injection fuel injection valve 12 for injecting fuel into the combustion chamber 1.” *Id.* ¶ 16. Miura explains that, although the engine is described as including intake unit fuel injection valve 11 and in-cylinder direct injection fuel injection valve 12, “the present invention may be applied to an engine of a type for performing the intake stroke injection and compression stroke injection using only the in-cylinder direct injection fuel injection valve 12.” *Id.* ¶ 36.

3. *Rational for Combining the Teachings of Schray and Miura*

a) *Petitioner's Assertions*

Petitioner asserts that a person of ordinary skill in the art “would have modified Schray to include a port fuel injector as well as its disclosed direct fuel injector, as is taught by Miura, to provide the engine of Schray with additional benefits relating to mixing and stable combustion at low loads.” Pet. 10. According to Petitioner, “[b]oth the engine of Schray and the engine of Miura disclose similar operating conditions (e.g., homogeneous operations and stoichiometric combustion).” *Id.* at 11 (citing Ex. 1008 ¶¶ 17, 20; Ex. 1005, 3:16–18; Ex. 1003 ¶ 145). With this in mind, Petitioner asserts that a person of ordinary skill in the art “would have had a reasonable expectation of success given Miura’s explicit teachings that an engine can operate with either two injectors (port and direct) or a single direct injector providing two injections (early and late).” *Id.* (citing Ex. 1008 ¶ 36; Ex. 1003 ¶ 145).

Petitioner asserts further that a person of ordinary skill in the art “would have incorporated open loop control into Schray based on the teachings of Miura” because such a combination “would advantageously vary DI as a result of both load and speed. Pet. 11–12 (citing Ex. 1003 ¶¶ 147–150). Petitioner asserts further that “[s]uch a combined system would retain the benefits espoused by Schray; the ability to obtain high torque and low development of toxic substances while avoiding knock and the ability to vary the proportion of the first and second (or late) injections between 30 and 70%” and that “the combination of open and closed loop control would also provide for additional control over engine variables.” *Id.* at 12 (citing Ex. 1005, 4:5–10; Ex. 1003 ¶ 150).

b) Patent Owner's Response

First, Patent Owner responds that incorporating Miura's open loop control strategy into Schray would eviscerate the purpose of Schray to provide full range knock mitigation, particularly at high rpms, which Schray describes as being "*especially critical for the engine.*" PO Resp. 21–22 (citing Ex. 1005, 1:15–20; Ex. 2018 ¶ 89).

Second, Patent Owner responds that a person of ordinary skill in the art "would not have looked to Schray to supplement the knock mitigation routine of Miura," because "Schray and Miura describe different approaches to knock mitigation." *Id.* at 22 (citing Ex. 2018 ¶ 90).

Third, Patent Owner responds that the proposed combination lacks motivation because adding port fuel injection to Schray "would add complexity, without the ability to attain any clear offsetting benefit." PO Resp. 23. Specifically, Patent Owner contends that "Petitioner's mapping of Miura to Schray is not spelled out clearly, appears to be inconsistent, and it is unpersuasive." *Id.* (citing Ex. 2018 ¶ 91).

c) Petitioner's Reply

Petitioner replies that Patent Owner's first argument "relies on an alleged teaching in Miura of 'disabling' knock control at high speeds while Schray detects and prevents knock throughout the knock endangered operating range." "[h]owever, the combination does not rely on Miura's *high-speed* knocking control strategy." Pet. Reply. 9–10 (citing PO Resp. 21). Petitioner asserts that "Miura does not disable knock control at high speeds but prefers a different form of knock control—spark retard—at high speeds only" and that this "[a]lternative knock control does not teach away from knock control generally or DI." *Id.* at 10 (citing Ex. 2020,

130:16–133:2, 133:3–134:3; Ex. 1008, Fig. 6; Ex. 1003 ¶ 274; Ex. 1046, 466:11–467:2, 473:9–14; *Intel Corp. v. Qualcomm Inc.*, 21 F.4th 784, 800 (Fed. Cir. 2021); *ClassCo, Inc. v. Apple, Inc.*, 838 F.3d 1214, 1219 (Fed. Cir. 2016)). Petitioner asserts further that Dr. Clark’s unrebutted testimony is that “the **combination** would employ Schray’s late-DI injection in the knock endangered region using Miura’s implementation details to suppress knock—because additional cooling from Schray’s late-DI was needed to reduce the danger of uncontrolled ignition as load increased—allowing high torque and low development of toxic substances.” *Id.* (citing Ex. 1003 ¶¶ 143–155, 168–177).

Petitioner replies to Patent Owner’s second argument that it “ignores that Miura’s second injection provides vaporization cooling, like Schray.” Pet. Reply 11 (citing Ex. 1003 ¶¶ 143, 148). Petitioner asserts that “Miura’s late-DI mixes with the combination’s PI¹⁴ to become stoichiometric” and “allows PI to be leaner while resulting in an overall stoichiometric mixture, and provides vaporization cooling.” *Id.* (citing Ex. 1008 ¶ 20; Ex. 1046, 203:16–23; Ex. 1003 ¶¶ 145–131; Ex. 2020, 125:14–127:11). According to Petitioner, “[e]ither way, Miura’s late-DI prevents knock.” *Id.* (citing Ex. 2020, 123:23–125:13; Ex. 1008 ¶ 27).

Petitioner replies to Patent Owner’s third argument that it “relies on Schray’s ‘stratified mode’ to argue against adding PI,” “[b]ut the Petition **does not rely on the ‘stratified mode’ embodiment.**” Pet. Reply 11 (citing PO Resp. 23; Pet. 10; Ex. 1003 ¶ 144). Petitioner also asserts that “Patent Owner ignores Schray’s homogenous operation throughout the operating

¹⁴ Port injection.

range.” *Id.* at 12 (citing Ex. 1005, 3:16–19; Ex. 1046, 373:21–374:6, 366:23–373:20; Ex. 1003 ¶ 145; Pet. 11).

d) *Patent Owner’s Sur-Reply*

Patent Owner replies that “Petitioner should not be permitted to belatedly provide critical details for its argument.” PO Sur-reply 9–10.

Patent Owner replies further that

Petitioner erroneously takes Schray’s vague teaching that “[t]he homogeneous operation is preferably adjusted in the full load range of the engine but can also be adjusted over the entire operating range of the engine” (Ex. 1005 at 3:17-19) as somehow trumping the plain and unambiguous exhortation that the stratified (*i.e.*, inhomogeneous) and homogeneous modes are “essential” (Ex. 1005 at 2:65-67) -- to contend that Schray teaches homogeneous operation throughout the entire operating load range *at low rpms*. It does not.

Id. at 10 (Ex. 1046, 368–379). According to Patent Owner, “this vague passage, if interpreted as Petitioner urges, would be brazenly inconsistent with the fundamental teaching of Schray: to use a stratified (inhomogeneous) charge from a second late direct injection (DI) in part of the operating range in order to prevent knock. *Id.*

e) *Discussion*

Having considered the full record before us, we determine that Petitioner articulated sufficient reasoning with rational underpinning to show that it would have been obvious to a person of ordinary skill in the art to combined the teachings of Schray and Miura in the manner proposed in Ground 1. Considering each of Patent Owner’s arguments we do not find them to demonstrate a deficiency in Petitioner’s contentions.

First, we do not agree with Patent Owner that the proposed modification of Schray would result in the elimination of knock control as

argued by Patent Owner. PO Resp. 21–22. Rather, we understand the proposed combination to “employ Schray’s late-DI injection in the knock endangered region using Miura’s implementation details to suppress knock—because additional cooling from Schray’s late-DI was needed to reduce the danger of uncontrolled ignition as load increased—allowing high torque and low development of toxic substances” as discussed in Dr. Clark’s testimony provided in support of the Petition. Pet. Reply 10; Ex. 1003 ¶¶ 143–151, 168–177.

Second, Patent Owner’s argument that a person of ordinary skill in the art would not have looked to Schray to supplement the knock mitigation routine of Miura because Schray and Miura describe different approaches to knock mitigation misstates the proposed combination, as the challenge proposes supplementing Schray by including Miura’s port fuel injectors to provide the benefits of port fuel injection. Pet. 10–11. Rather than discourage the proposed modification, the fact that “Schray and Miura describe different approaches to knock mitigation” bolster’s Petitioner’s reasoning that Schray would reap additional benefits as a result of the proposed combination (i.e., the benefits “relating to mixing and stable combustion at low loads”). [I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.” *KSR*, 550 U.S. at 417.

In addition, Patent Owner’s argument that adding an intake port fuel injection valve (“PFI”) to Schray does not provide reasons with rational underpinning for the proposed combination because “the addition of PFI would add complexity, without the ability to attain any clear offsetting

benefit” is unconvincing. PO Resp. 23. “The fact that the motivating benefit comes at the expense of another benefit, however, should not nullify its use as a basis to modify the disclosure of one reference with the teachings of another. Instead, the benefits, both lost and gained, should be weighed against one another.” *Winner Int’l Royalty Corp. v. Wang*, 202 F.3d 1340, 1349 n.8. (Fed. Cir. 2000). We determine based on the record before us the benefits relating to mixing and stable combustion at low loads outweigh any alleged complexity. Further, we credit Dr. Clark’s testimony about the benefits of the proposed combination and determine that his testimony adequately maps Miura to Schray. *See* Ex. 1003 ¶¶ 143–151.

For these reasons, we determine that Petitioner has articulated adequate reasons with rationale underpinning to show, by a preponderance of the evidence, that a person of ordinary skill in the art would have been motivated to modify Schray in view of the teachings of Miura in the manner outlined in the Petition. Pet. 10–12.

4. *Claim 1*

Petitioner asserts that claim 1 is unpatentable over the combined teachings of Schray and Miura. Pet. 12–19.

a) *Uncontested Limitations*

Patent Owner does not contest Petitioner’s assertions regarding limitations [1.Pre], [1.A], [1.B], [1.D], and [1.G]. *See* PO Resp. 21–41. We summarize Petitioner’s assertions regarding these limitations below.

The preamble [1.Pre] recites, “[a] fuel management system for a spark ignition engine, comprising.” Ex. 1001, 16:62–63. Petitioner asserts that “[t]o the extent the preamble of Claim 1 is limiting, Miura and Schray discloses an engine having a spark plug.” Pet. 12 (citing Ex. 1005, 2:20–21; Ex. 1008 ¶ 16; Ex. 1003 ¶¶ 152–154).

The first limitation [1.A] requires, “a first fueling system that uses direct injection.” Ex. 1001, 16:64. Petitioner asserts that “Schray discloses an engine, controlled by control apparatus 11, and having an injection valve 24 for DI.” Pet. 13 (citing Ex. 1005, 2:16–17, 2:55–56; Ex. 1003 ¶¶ 155, 158).

The second limitation [1.B] requires, “a second fueling system that uses portion fuel injection.” Ex. 1001, 16:65. Petitioner asserts that “Miura discloses an ECU,¹⁵ PI, and DI.” Pet. 13 (citing Ex. 1008 ¶¶ 15–16; Ex. 1003 ¶¶ 156, 160).

The fourth limitation [1.D] requires a fuel management system “configured to provide fueling in a first torque range, the first torque range being a first range of torque values at which both the first fueling system and the second fueling system are operable throughout the first range of torque values.” Ex. 1001, 17:1–5. Petitioner asserts that “Miura discloses a high load range as well as low and medium load ranges.” Pet 15 (citing Ex. 1008 ¶¶ 20–21; *id.* at 10–12; Ex. 1003 ¶ 169). According to Petitioner, “[i]n the high load range, and thus the first range of torque values, Miura discloses that the required fuel is injected via PI and DI.” *Id.* (citing Ex. 1008 ¶ 21; Ex. 1003 ¶ 170).

The seventh limitation [1.G] requires a fuel management system “further configured such that when the system provides fueling at a torque value that exceeds the second range of torque values the spark ignition engine is operated in the first torque range.” Ex. 1001, 17:18–22. Petitioner asserts the combined teachings of Schray and Miura disclose a “first torque

¹⁵ Engine control unit.

range [that] includes values of torque or load that are greater than those in the second torque range.” Pet. 19 (citing Pet. 15, 18; Ex. 1003 ¶¶ 182–183).

Having considered the full record in this proceeding including Petitioner’s assertions and the evidence in support thereof, we determine that a preponderance of the evidence supports Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered limitations [1.Pre], [1.A], [1.B], [1.D], and [1.G] obvious to one of ordinary skill in the art.

*b) Limitation [1.C]: a Three-way Catalyst
Configured to Reduce Emissions from the Spark Ignition
Engine*

(1) Petitioner’s Contentions

Petitioner asserts that “Schray teaches a three-way catalyst in the form of a catalytic converter 46 which is tasked with converting toxic exhaust-gas components such as CO, HC, and NO into CO₂, H₂O, and N₂, thereby reducing these emissions.” Pet. 14 (citing Ex. 1005, 2:39–42; Ex. 1003 ¶ 165; Ex. 1034, 2). Petitioner asserts further that “Schray discloses that the air/fuel mixture is adjusted to stoichiometric in order to obtain a high torque and a low development of toxic substances with the combustion.” *Id.* (citing Ex. 1005, 3:13–16; Ex. 1003 ¶¶ 163–165). Petitioner also asserts that “Miura discloses a stoichiometric ratio and inclusion of a catalyst.” *Id.* (citing Ex. 1008, ¶ 29; Ex. 1003 ¶ 166).

(2) Patent Owner’s Response

Patent Owner responds that “Schray is silent as to the type of catalyst used,” and that “Petitioner makes an inherency argument, as Miura does not explicitly refer to the catalyst as being ‘three-way.’” PO Resp. 24 (citing Ex. 2018 ¶ 93). Patent Owner responds further that “Petitioner fails to show

that Miura necessarily discloses a three-way catalyst as is required to show disclosure by inherency” and that Schray’s disclosure of a catalytic converter that has the task of converting toxic exhaust-gas components such as CO, HC, and NO into CO₂, H₂O, and N₂ “does not necessarily teach a three-way catalyst.” *Id.* (citing Ex. 2018 ¶ 93; *In re Robertson*, 169 F.3d 743, 745 (Fed. Cir. 1999); Ex. 1005, 2:28–42). In addition, Patent Owner responds that it is not “clear that Schray would reap benefit[s] from a three-way catalyst, because other methods would still be needed to address emissions in the regions where Schray is not stoichiometric.” *Id.* at 25.

(3) *Petitioner’s Reply*

Petitioner replies that “Patent Owner’s argument concerning the claimed three-way catalyst should be disregarded because it is founded on *Robertson*, which addressed anticipation.” Pet. Reply 12 (citing PO Resp. 24–26). According to Petitioner, “Dr. Clark evaluated the references’ teachings and determined that the limitation would have been obvious.” *Id.* (citing Ex. 1003 ¶¶ 163–167, 185–188).

Petitioner replies further that “Patent Owner’s challenge seems to be premised on a requirement that the phrase ‘three-way catalyst’ be explicitly recited (POR, 24), but the law considers what the disclosure teaches a POSITA.”¹⁶ *Id.* Petitioner asserts that “Dr. Clark explained Schray’s ‘catalytic converter 46 constitutes a three-way catalyst’ (Ex. 1003 ¶ 134) that satisfies emissions requirements, mitigates Schray’s three exhaust gases, and takes advantage of the combination’s stoichiometric operation to ‘obtain a high torque and a low development of toxic substances’” and that “Dr.

¹⁶ Person of ordinary skill in the art.

Shaver admits that three-way catalysts mitigate these gases.” Pet. Reply 12 (citing Ex. 1003 ¶¶ 163–165; Ex. 1046, 235:23–240:9, 452:23–453:8).

In reply to Patent Owner’s argument that Schray would not reap the benefits of a three-way catalyst, Petitioner asserts that “Patent Owner’s argument ignores the explicit disclosure of a catalytic converter and that Schray’s homogenous operating mode may be adjusted over the entire operating range.” Pet Reply 13 (citing Ex. 1005, 3:16–19). According to Petitioner, “Schray’s homogenous, stoichiometric operation ‘over the entire operating range’ would benefit from, and would have used, a three-way catalyst.” *Id.* (citing Ex. 1003 ¶¶ 164–165, 185). Petitioner replies further that “Patent Owner’s ‘stoichiometric’ arguments ignore that the claims require stoichiometric operation over *at least a part of* the range” and “Dr. Shaver admits that in the homogenous regime, Schray’s ‘intent is to operate stoichiometric *at least part of the time.*” *Id.* at 13–14 (citing PO Resp. 31; Ex. 1046, 352:17–353:19, 443:12–444:15). Petitioner also replies that “Dr. Clark’s opinion that Schray’s lambda sensor would be used to control the air/fuel ratio to enable a three-way catalyst is also un rebutted.” *Id.* at 14 (citing Ex. 1003 ¶ 185; Ex. 1046, 149:7–151:5).

(4) *Patent Owner’s Sur-reply*

Patent Owner replies that “Schray does not necessarily teach a three-way catalyst, and Petitioner has argued that Schray discloses this claim limitation—rather than arguing that a POSITA would have been motivated in view of Schray to modify or extend Schray to arrive at the missing limitation.” PO Resp. 10. According to Patent Owner, “[i]t is too late now for Petitioner to pivot and allege an additional reference or ground for modifying Schray to include the claim limitation not taught therein” and “Petitioner admits in its reply that a POSITA would have understood that a

three-way catalyst would require stoichiometric operation” and “Schray does not teach stoichiometric operation over its entire operating range. Nor does Miura.” PO Sur-reply 11 (citing Pet. Reply 21).

(5) *Discussion of Limitation [1.C]*

For limitation [1.C], the Petition asserts that “Schray *teaches* a three-way catalyst in the form of a catalytic converter 46 which is tasked with converting toxic exhaust-gas components such as CO, HC, and NO into CO₂, H₂O, and N₂, thereby reducing these emissions.” Pet. 14 (citing Ex. 1005, 2:39–42; Ex. 1003 ¶ 165; Ex. 1034, 2) (emphasis added). This is not an anticipation assertion nor does it rely on inherency. Accordingly, Patent Owner’s arguments that Schray does not disclose a three-way catalyst and such a catalyst is not necessarily present in Schray or Miura are inapposite.

We credit Dr. Clark’s testimony that “[a] person of ordinary skill in the art would have understood that [Schray’s] catalytic converter 46 constitutes a three-way catalyst” and that “[s]ince Miura presents the option of stoichiometric combustion and a catalyst, a person of ordinary skill in the art would have understood that a three-way catalyst was operable with the engine in Miura.” Ex. 1003 ¶¶ 165–166 (citing Ex. 1008 ¶ 20). We therefore determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered limitation [1.C] obvious to one of ordinary skill.

c) *Limitation [1.E]: Wherein the Fuel Management System is Further Configured Such That a Fraction of Fueling Provided by the First Fueling System is Higher at a Highest Value of Torque in the First Torque Range*

Than in a Lowest Value of Torque in the First Torque Range

(1) Petitioner's Assertions

Petitioner asserts “that Miura discloses that the fraction of DI increases from no DI in the low and medium load ranges to at least some DI in the high load range.” Pet. 16 (citing Ex. 1008 ¶¶ 20–21; Ex. 1003 ¶ 175). Petitioner asserts further that “[e]ven if Limitation 1.E is interpreted to require an increase/decrease in the fraction of DI fuel for each increase/decrease in torque or load, this is also taught by the combination” because “[s]uch an increase is taught by Schray, which discloses that the proportion of the first and second injections (or late) varies between 30% and 70% depending on the operating state of the engine 10 and based on the tendency-to-knock signal.” *Id.* (citing Ex. 1003 ¶¶ 172–176; Ex. 1005, 3:46–48). According to Petitioner, a person of ordinary skill in the art “would understand that a higher cooling action is predicated on a higher ratio of directly injected fuel” and “that an engine operating at higher loads would operate at higher temperatures and pressures, and therefore demand a higher ratio of fuel from the second injection to provide cooling.” *Id.* at 16–17 (citing Ex. 1005, 4:1–10; Ex. 1003 ¶¶ 173–174).

In addition, Petitioner asserts that “Miura also discloses varying the portion of directly injected fuel based on engine operating conditions (*e.g.*, engine rpm).” Pet. 17 (citing Ex. 1008 ¶ 30; Ex. 1003 ¶ 175). Petitioner asserts that “Miura illustrates that the fraction of direct injection is not constant (*e.g.*, changes with respect to rpm).” *Id.* Petitioner then asserts that “Schray teaches setting DI fueling amounts based on both cylinder charge RL and the rpm N in determining the amount of fuel to be directly injected”

and that in Schray “the tendency to knock signal is used to set the fuel injection ratio.” *Id.* (citing Ex. 1008 ¶ 19; Ex. 1005, 3:43–45, 4:1–10; Ex. 1003 ¶ 176). Based on these teachings in Schray and Miura, Petitioner asserts that a person of ordinary skill in the art “would have understood the ratio of fuel from the second injection would have targeted increases as pressure increases so as to achieve the increase in output torque disclosed by Schray” and “that when Miura’s open loop control strategy is added to the control strategy of Schray, the resulting fuel management strategy would vary direct injection as a result of engine operating conditions that include both load and speed for each increase in torque or load.” *Id.* at 17–18 (citing Ex. 1003 ¶¶ 173, 176 (footnote omitted)).

(2) *Patent Owner’s Response*

Patent Owner responds that Petitioner’s “assertion about ‘low and medium load ranges,’ even if correct, says *nothing* about whether the DI fraction ‘is higher at a highest value of torque *in the first torque range* than in a lowest value of torque *in the first torque range*.” PO Resp. 27 (citing Ex. 2018 ¶ 103). Patent Owner responds further that “Petitioner’s statement is not only irrelevant but incorrect. Far from teaching ‘no DI in the low and medium ranges,’ Miura teaches the use of stratified combustion . . . which a POSITA would understand to be achieved by direct injection.” *Id.* (citing Ex. 1008 ¶ 20; Ex. 2018 ¶ 103).

In addition, Patent Owner responds that Petitioner’s alternative reliance on Schray to satisfy limitation [1.E] fails because “Schray has no port fuel injector.” PO Resp. 27. Patent Owner responds further that “Schray does not necessarily disclose that the fraction of fuel supplied by the first and the second DI pulses changes with load,” because “[a]ll that Schray says is that the proportion of fuel injected in the first and second pulse varies

from 30% to 70% ‘depending on the operating state of the engine and in dependence upon the extent of the tendency-to-knock signal.’” *Id.* at 27–28 (citing Ex. 2018 ¶ 105; Ex. 1005, 4:5–8).

Finally, Patent Owner asserts that “there would have been no motivation to combine the references to arrive at the recited limitation.” PO Resp. 29 (citing Ex. 2018 ¶¶ 87–92). According to Patent Owner, “Petitioner does not explain how this claim limitation is possibly satisfied.” *Id.*

(3) *Petitioner’s Reply*

Petitioner replies that “Patent Owner critiques Schray because it ‘has no port fuel injector,’ which entirely ignores the proposed combination with Miura.” Pet. Reply 14 (citing PO Resp. 27; Pet. 10–14, 16–18). Petitioner asserts further that “Patent Owner compounds its flawed analysis because it only analyzes Miura’s single-injector embodiment to the exclusion of the double-injector embodiment” and ignores Dr. Clark’s testimony “that PI confers additional mixing and low-load stable combustion benefits.” *Id.* at 14–15 (citing PO Resp. 27; Ex. 1046, 506:19–512:4; Ex. 1003 ¶¶ 144, 159 (internal citations omitted)).

In reply to Patent Owner’s argument that Schray does not inherently disclose or require increasing DI with increasing torque, Petitioner quotes Dr. Clark’s testimony that a person of ordinary skill in the art “‘would have understood that the proportion of the second or late injection increases as torque increases from, for example, 30%-70%’” and asserts that “Patent Owner admits Schray teaches the ‘proportion of the fuel injected’ by the first and second fueling systems ‘varies from 30% to 70% depending on the operating state of the engine.’” Pet. Reply 15 (quoting Ex. 1003 ¶ 173;

PO Resp. 27–28). Petitioner replies further that “[i]t is undisputed that knock is more likely at higher torques . . . and that late (i.e., Schray’s second) injection confers knock mitigation through charge cooling.” *Id.* (citing Ex. 1003 ¶¶ 173–174; Ex. 1046, 184:18–185:18, 388:14–390:13, 482:17–21). Thus, according to Petitioner, “Schray’s instruction to vary ‘[t]he proportion of the first and second injections’ between 30 and 70% renders the claim unpatentable.” *Id.* at 16 (citing Ex. 1003 ¶¶ 173–177).

(4) *Patent Owner’s Sur-reply*

Patent Owner replies that “Petitioner’s inherency argument fails. Petitioner specifically stated that ‘such an increase is taught by Schray’ which is clear invocation of inherency.” PO Sur-reply 11–12 (citing Pet. 16). Patent Owner replies further that “[i]t is too late now for Petitioner to include an additional reference to try to plug the hole in its combination or to try to transform its clear invocation of inherent disclosure into an argument that a *missing* claim limitation would have been obvious.” *Id.* at 12.

(5) *Discussion of Limitation [1.E]*

For limitation [1.E], the Petition relies on the combined teachings of Miura and Schray to meet this limitation as discussed in Section II.C.4.b above. Pet. 16–18. Patent Owner’s arguments do not consider the combined teachings of these references and assert that the challenge relies on inherency, when this is clearly not the case (see for example, the statement in the Petition that Schray *teaches* “an increase/decrease in the fraction of DI fuel for each increase/decrease in torque or load” is a clear indication that the challenge is based on obviousness not inherency). Pet. 16 (citing Ex. 1003 ¶¶ 172–176).

We credit Dr. Clark's testimony that a person of ordinary skill in the art "would have understood that a higher cooling action is predicated on a higher ratio of directly injected fuel during the compression stroke (second injection) and, thus, would have understood that the proportion of the second or late injection increases as torque increases from, for example, 30% - 70%." Ex. 1003 ¶ 173. We further credit Dr. Clark's testimony that

A person of ordinary skill in the art would have also recognized the necessity of empirical calibration in establishing the Schray injection ratio, and would recognize that, starting with the "lowest value of torque in the first torque range," an engine operating at higher loads would operate at higher temperatures and pressures, and therefore demand a higher ratio of fuel from the second injection to provide cooling and, thus, allow the engine to operate without knocking. Moreover, the person of ordinary skill in the art would have understood that the ratio of fuel from the second injection would have targeted increases as pressure increases so as to achieve the increase in output torque disclosed by Schray.

Id. ¶ 174. In addition, we agree with Dr. Clark that "Miura confirms this understanding" and "also discloses varying the portion of directly injected fuel based on engine operating conditions (e.g., engine rpm)." *Id.*

¶¶ 175–176.

For these reasons, we credit Dr. Clark's testimony that a person of ordinary skill in the art "would have understood that when Miura's open loop control strategy is added to the control strategy of Schray, the resulting fuel management strategy would advantageously vary direct injection as a result of engine operating conditions that include both load and speed." *Id.* ¶ 176. We therefore determine that the preponderance of the evidence supports Petitioner's assertion that the combined teachings of Schray and

Miura would have rendered limitation [1.E] obvious to one of ordinary skill in the art.

d) Limitation [1.F]: Wherein the Fuel Management System is Further Configured to Provide Fueling in a Second Torque Range, the Second Torque Range Being a Second Range of Torque Values at Which the Second Fueling System is Operable Throughout the Second range of Torque Values and the First Fueling System is not Operable Throughout the Second Range of Torque Values

(1) Petitioner's Assertions

Petitioner asserts that Miura discloses that “when the engine is not in the high load range, normal control is performed (e.g., fueled by the second fueling system or the port fueling system).” Pet. 18 (citing Ex. 1008 ¶¶ 4, 25; Ex. 1003 ¶ 180).

(2) Patent Owner's Response

Patent Owner responds that “Petitioner does not explain how Miura satisfies the condition that the ‘first fueling system is not operable throughout the second range of torque values,’” because a person of ordinary skill in the art “would recognize that stratified combustion would require injection by the direct injector.” PO Resp. 30 (citing Ex. 2018 ¶ 111). Patent Owner responds further that

Even if Schray were modified by substituting port fuel injection for Schray's *induction* stroke direct injection, this combination fails, because Schray teaches that double injections – whether by induction stroke injection or compression stroke injection – can be entered into at any region in the operating map (whether from a region of stratified or homogeneous operation, Cf. FIG. 2, regions “A” and “B”), and because in the stratified operating range “A” direct injection during the compression stroke is always used.

Id. at 30–31 (citing PO Resp. 8–10; Ex. 2018 ¶ 111). Thus, according to Patent Owner, “there is no second torque range that doesn’t also use the same type of injection used in the first torque range.” *Id.* at 31.

(3) *Petitioner’s Reply*

Noting that Patent Owner does not dispute the obviousness of limitation [1.b], Petitioner replies “Patent Owner addresses Miura’s direct injection embodiment alone, but Petitioner alleges that Miura’s *port injector*, combined with Schray, is the claimed second fueling system.” Pet. Reply 16 (citing Pet. 18; Ex. 1003 ¶¶ 178–181). Petitioner replies further that “[n]ext, Patent Owner mispresents Miura (POR, 30), inferring that stratified lean combustion is *required* at low loads, using an ellipsis to omit that Miura teaches ‘homogenous stoichiometric combustion’ at low and medium load ranges” and “Patent Owner then fails to address Schray’s homogenous mode.” *Id.* (citing Ex. 1008 ¶ 20; Ex. 1046, 457:3–10).

In addition, Petitioner replies that “because Patent Owner has not rebutted Petitioner’s construction of ‘torque range,’ its allegation that Schray can enter into double injections ‘at any region’ is inapposite.” Pet. Reply 16 (citing Pet. 4–5). According to Petitioner, “[w]hen the combination begins double-injections, it is in the first torque range” and “[w]hen the combination operates with Miura’s port injector only, it is in the second torque range.” *Id.* (citing Ex. 1003 ¶¶ 178–180).

(4) *Patent Owner’s Sur-reply*

Patent Owner replies that “Schray teaches making [direct] injection when the tendency-to-knock signal exceeds a threshold value, which can be at virtually any point in the operating map” such that “Schray’s alleged ‘first fueling system’ (early DI) is emphatically *not* inoperable throughout the second range of torque values in FIG. 2 of Schray.” PO Sur-reply 12 (citing

Ex. 1005, 3:49–52). Patent Owner replies further that “the alleged ‘interchangeability’ of Schray’s early DI with Miura’s port injection is inconsistent with Dr. Clark’s testimony about the difference between DI and port injection (such as that better combustion stability and mixing is obtained with port injection).” *Id.* at 13. According to Patent Owner, “[t]hese differences, along with the greater vaporization cooling of early DI in comparison with port injection, would clearly lead a POSITA to conclude that Miura’s port injection and Schray’s early DI are not interchangeable.” *Id.*

(5) *Discussion of Limitation [1.F]*

Patent Owner’s arguments are not responsive to the challenge set forth in the Petition and do not address the combined teachings of Schray and Miura. Further, the Petition does not treat Schray’s DI as interchangeable with Miura’s PI. Rather, the Petition relies on Miura’s teaching that PI is only used in the second (or high) torque range. Pet. 18; Ex. 1008 ¶ 21. We therefore determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered limitation [1.F] obvious to one of ordinary skill in the art.

e) *Limitation [1.H]: Wherein the Spark Ignition Engine is Configured to Operate at a Stoichiometric Air/Fuel Ratio in at Least Part of the First Torque Range and in at Least Part of the Second Torque Range*

(1) *Petitioner’s Assertions*

The eight, and final, limitation [1.H] requires a spark ignition engine “configured to operate at a stoichiometric air/fuel ratio in at least part of the first torque range and in at least part of the second torque range.” Ex. 1001, 17:23–26. Petitioner asserts that “the disclosure of a three-way catalyst (*see*

Limitation (1.C) indicates that an engine is operating at a stoichiometric fuel/air ratio.” Pet. 19 (citing Ex. 1034, 10–11).

(2) *Patent Owner’s Response*

Patent Owner responds that “Petitioner’s argument rests on its flawed premise that the cited references necessarily disclose a three-way catalyst.” PO Resp. 31. Patent Owner responds further that “Schray teaches lean operation at low loads, such as range ‘A’ in FIG. 2” and “Miura teaches lean combustion at low loads.” *Id.* (citing Ex. 1005, 3:19–31, Fig. 2; Ex. 1008 ¶ 20).

(3) *Petitioner’s Reply*

Petitioner addresses limitations [1.C] and [1.H] together in its Reply. Pet. Reply 12–14. As Petitioner’s reply for this limitation is addressed in Section II.C.4.b.3 above, we do not reproduce it here.

(4) *Patent Owner’s Sur-reply*

Patent Owner also addresses limitations [1.C] and [1.H] together in its Sur-reply. PO Sur-reply 10–11. As Patent Owner’s reply for this limitation is addressed in Section II.C.4.b.4 above, we do not reproduce it here.

(5) *Discussion*

For the reasons discussed in Section II.C.4.b.5 above, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered limitation [1.H] obvious to one of ordinary skill in the art.

f) *Conclusion Re Claim 1*

Having considered the full record in this proceeding, including the evidence, testimony, and arguments presented by both parties, and for the reasons discussed above, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of

Schray and Miura would have rendered claim 1 obvious to one of ordinary skill in the art.

5. *Claim 5*

Claim 5 requires “[t]he fuel management system of claim 1, wherein the second torque range extends from a zero value of torque to a highest value of torque in the second torque range.” Ex. 1001, 17:38–40. Petitioner asserts that “[c]laim 5 is interpreted to mean that the second torque range is in use at low loads. The combination discloses operation in the second torque range (e.g., PI only) at low loads.” Pet. 20 (citing Ex. 1001, 17:1–6; 17:11–17; Ex. 1034, 18–19; Ex. 1003 ¶¶ 195–196).

Patent Owner responds that “Petitioner fails to explain how Miura’s operation in low to medium loads excludes DI operation.” PO Resp. 32. Patent Owner responds further that “Petitioner additionally fails to explain how Miura teaches *not* using DI at the very low end of the torque curve.” *Id.* In addition, Patent Owner contends that “Petitioner does not set forth any argument for how any purported combination of Miura with Schray would result in a modification of Schray satisfying the limitation that any form of direct injection is inoperable down to the lowest torques.” *Id.*

Petitioner replies that “[t]he combination discloses PI-only operation at low loads” and that “Patent Owner critiques Petitioner for not explaining how Miura alone ‘excludes DI’ at low loads, but no such showing is required.” Pet. Reply 17 (citing Ex. 1003 ¶¶ 195–200; PO Resp. 32). Petitioner asserts that Patent Owner addresses Schray’s DI alone, ignoring that the combination is based on the modification of Schray to include Miura’s PI. *Id.* According to Petitioner “[i]n the combination PI alone is used during Schray’s homogenous operation before the tendency-to-knock

signal exceeds the threshold value” and “[t]his is the second torque range.” *Id.* (citing Ex. 1003 ¶¶ 195–196; Ex. 1046, 382:4–12, 402:17–25).

Petitioner replies further that “Patent Owner does not refute Petitioner’s ‘torque range’ construction: the claims define ‘torque range’ based on whether the engine utilizes (1) PI only or (2) PI and DI.” Pet. Reply 17 (citing Pet. 5; Ex. 1003 ¶¶ 126–129; Ex. 1046, 336:22–338:15, 342:10–17, 345:16–24, 348:23–352:3). In addition, Petitioner replies that “Patent Owner’s allegation that double injections could hypothetically start in advance of knock endangered regions is irrelevant: when double injections begin, the system operates in the first torque range” and that “[a]rguments about Schray’s stratified operation embodiment are similarly irrelevant.” Pet. Reply 18 (citing Ex. 1003 ¶¶ 195–200; Ex. 1045, 336:22–338:15; *id.* at 26).

Patent Owner replies that “nowhere does Schray teach any threshold value of torque.” PO Sur-reply 13 (citing Pet. Reply 17). Patent Owner replies further that “[t]o the contrary, at low rpms—the region that Petitioner belatedly states that it is relying upon for its combination—Schray’s FIG. 2 shows stratified (inhomogeneous) DI operation at low loads. Thus there would be DI use at low loads.” *Id.* at 13–14. According to Patent Owner, “[e]ven if Schray taught homogeneous operation at all loads and rpms—which it does not and would conflict with the statement that stratified operation is ‘essential’—Petitioner fails to persuade that Schray would **disable** double direct injection everywhere below the engine operating limit line ‘I’ in FIG. 2 of Schray.” *Id.* at 14.

We agree with Petitioner that Patent Owner’s arguments are not on point. The challenge to claim 5 is based on the combined teachings of Schray and Miura, but Patent Owner’s arguments are directed to the

references separately and do not consider what the combined teachings of Schray and Miura would have *suggested* to one of ordinary skill in the art. For example, Patent Owner argues that “there is no inherent disclosure” of a second torque range that extends from a zero value of torque. PO Resp. 32. The challenge does not rely on an inherent disclosure of a second torque range that extends from a zero value of torque. Rather, the challenge asserts that the references suggest such a range. *See* Pet. 10–12, 15–18.

We credit Dr. Clark’s testimony that “Schray represents that double injections equivalent to the first torque range are implemented only when knocking would occur” such that a person of ordinary skill in the art “would appreciate that zero torque operation would not imply knocking and that the engine would operate in the second torque range from zero torque to a highest value in the second torque range, which is the highest value of torque before the tendency-to-knock signal exceeds the threshold value.” Ex. 1003 ¶ 195 (citing Ex. 1005, 4:17–23). We further credit Dr. Clark’s testimony that “[a]s is disclosed by Miura, when the engine is not in the high load range, the use of compression stroke injection is terminated and normal control of combustion is performed” and that normal control includes zero torque operation. *Id.* ¶ 196 (citing Ex. 1008 ¶¶ 4, 25, Fig. 2).

Having considered the full record in this proceeding and for the reasons discussed above, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered claim 5 obvious to one of ordinary skill in the art.

6. *Claim 6*

Claim 6 requires “[t]he fuel management system of claim 1, wherein a highest value of torque in the second torque range is a highest value of

torque at which the spark ignition engine is operable without fueling from the first fueling system being provided to prevent knock.” Ex. 1001, 17:41–45. Petitioner asserts that the Petition’s discussion of limitation [1.E] and claims 2, 5, and 8 shows that this limitation is met by the combined teachings of Schray and Miura. *See* Pet. 20 (citing Ex. 1003 ¶¶ 195–196).

Patent Owner’s response for claim 6 is similar to its response for claim 5. *See* PO Resp. 33–34; PO Sur-reply 14 (stating “dependent Claim 6 is not taught by the references for similar reasons to those given above for Claim 5”). Patent Owner’s arguments are unconvincing for the reasons discussed above.

Further, we credit the testimony of Dr. Clark that Schray and Miura discloses this limitation because “Schray employs the equivalent of the second torque range when a tendency-to-knock signal is below a threshold value, and the highest value in the second torque range is the highest value of torque before the tendency-to-knock signal exceeds the threshold value” and that “[a]s is disclosed by Miura, when the engine is not in the high load range, the use of compression stroke injection is terminated and normal control of combustion is performed.” Ex. 1003 ¶¶ 198–199.

Having considered the full record in this proceeding, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered claim 6 obvious to one of ordinary skill in the art.

7. Claim 7

Claim 7 requires

The fuel management system of claim 1, wherein the fuel management system is further configured to increase the fraction of fueling provided by the first fueling system in the first torque

range to prevent knock in at least part of the first torque range that begins at a lowest value of torque in the first torque range.

Ex. 1001, 17:46–51. Petitioner asserts that the Petition’s discussion of limitation [1.E] and claims 2 and 8 show that this limitation is met by the combined teachings of Schray and Miura. Pet. 21.

Patent Owner responds by referring to its arguments for claim 1. We did not find those arguments convincing for the reasons discussed in Section II.C.4 above.

Further, we credit Dr. Clark this limitation is met by the combined teachings of Schray and Miura because

A person of ordinary skill in the art would have also recognized the necessity of empirical calibration in establishing the Schray injection ratio, and would recognize that, starting with the “lowest value of torque in the first torque range,” an engine operating at higher loads would operate at higher temperatures and pressures, and therefore demand a higher ratio of fuel from the second injection to provide cooling and, thus, allow the engine to operate without knocking.

Ex. 1003 ¶ 203. We further agree that “Miura confirms this understanding.” For these reasons, we determine that the preponderance of the evidence support’s Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claim 7 obvious to one of ordinary skill in the art.

8. *Claim 8*

Claim 8 requires

The fuel management system of claim 7, wherein the fuel management system is further configured to increase the fraction of fueling provided by the first fueling system in the first torque range as torque increases so as to minimize the amount of fueling provided by the first fueling system that is used while still preventing knock.

Ex. 1001, 17:52–57.

Petitioner asserts that the “combination of Schray and Miura confirms that the quantity DI fuel must be the minimum needed to prevent knock.” Pet. 21 (citing Ex. 1003 ¶ 212). Specifically, Petitioner asserts that “[a]s is disclosed by Miura, latent heat of vaporization may result in diminishing torque and thus any fueling strategy must control the amount of DI to prevent diminishing torque” and that Miura gives three optimum values for the ration of PI to DI with operation at higher or lower values being less desirable. *Id.* at 21–22 (citing Ex. 1008 ¶¶ 27, 30; Ex. 1003 ¶ 212). Petitioner asserts further that “Schray confirms that the double injections are targeted to achieve an increase in output torque” and that a person of ordinary skill in the art “would have understood the directly injected fuel amount should be minimized to achieve efficient operation in the form of an increase in output torque while preventing knock.” *Id.* at 22 (citing Ex. 1005, 3:61–64; Ex. 1003 ¶ 212).

Patent Owner responds that Petitioner’s statement that “[a]s is disclosed by Miura, latent heat of vaporization may result in diminishing torque and thus any fueling strategy must control the amount of DI to prevent diminishing torque” is not true. PO Resp. 35 (quoting Pet. 21 (internal citations omitted); Ex. 2018 ¶ 123). Patent Owner contends that “[f]ar from teaching that latent heat of vaporization causes torque reduction during in cylinder injection, Miura teaches ‘improving intake density by effectively utilizing [latent] heat of vaporization.’” *Id.* (citing Ex. 1008 ¶ 5).

Patent Owner responds further that “Petitioner fails to explain why Miura’s ‘optimum’ values are ones at which DI is kept to a minimum as required by the claim language.” PO Resp. 35 (citing Ex. 2018 ¶ 124). According to Patent Owner, “Miura teaches that a variety of factors go into

setting the ‘optimum value,’ *none of which* is the desire to minimize use of DI” and that “Miura *actually* states that “[t]he optimum fuel ratio differs depending on specification and the like and is a value that varies depending on the piston shape, the strength of gas flow, or the like.”” *Id.* (citing Ex. 1008 ¶ 30; Ex. 2018 ¶ 125).

In addition, Patent Owner responds that “instead of teaching minimizing DI, Miura teaches using more DI than necessary to prevent knock. For example, Miura clearly states at [0027] that DI is used in order to allow *advancement of ignition timing*.” PO Resp. 36 (citing Ex. 1008 ¶ 27; Ex. 2018 ¶ 127). According to Patent Owner, “[i]t follows that less DI could necessarily be used to prevent knock if ignition timing were not so advanced.” *Id.* (citing Ex. 2018 ¶ 127). Further, Patent Owner responds that “Schray teaches not using a minimum amount of DI to prevent knock, but rather using extra fuel *before* reaching knocking limits for the purpose of improving torque.” *Id.* at 36–37 (citing Ex. 2018 ¶ 128).

Petitioner replies that a person of ordinary skill in the art “would have understood from Schray and Miura that DI fuel should be minimized to achieve efficient operation by increasing output torque while preventing knock.” Pet. Reply 18 (citing Ex. 1003 ¶¶ 207–220). Petitioner asserts that “[t]his is minimization, as the claims again only require an increase of DI fuel between two values of torque and knock prevention.” *Id.* (citing Pet. 3–4, 21–22; Ex. 1003 ¶¶ 124–125, 207–212).

Petitioner replies further that “Dr. Shaver could not coherently explain his view of ‘minimize’” and he ultimately read “minimize” as “reduce” admitting that “the claim requires ‘the intent of minimizing the amount of DI . . . it doesn’t require that they do that a certain way.’” Pet. Reply 18 (citing Ex. 1046, 279:2–311:19, 313:25–333:10). According to Petitioner,

“[c]alibrators can ‘choose to’ employ additional strategies to ‘further minimize the DI amount,’” “the strategy is going to include all these factors at once,” and “Miura’s exemplary ‘optimum values’ confirm these considerations were known.” *Id.* at 18–19 (citing Ex. 1040, 288:7–289:6, 324:3–23; Pet. 21–22; Ex. 1003 ¶ 212; Ex 1008 ¶ 30).

Patent Owner replies that “Schray teaches not using a minimum or substantially equal amount of DI to prevent knock, but rather using extra fuel before reaching knocking limits for the purpose of improving torque.” PO Sur-reply 15.

It appears that Patent Owner does not maintain its arguments regarding Miura as they are not mentioned in its response. If, however, Patent Owner intended to maintain those arguments, we note that they do not address the proposed combination. Patent Owner’s argument that Schray “use[s] extra fuel before reaching knocking limits” is based on its understanding of Schray’s disclosure that “in knock endangered operating regions and before reaching the engine operating limits, the knocking limit of the engine 10 is reduced and/or the knocking behavior is improved by the double injections.” PO Sur-reply 15; Ex. 1005, 3:61–64. We do not agree with Patent Owner that this disclosure implies that Schray uses “extra” fuel before reaching knocking limits, and thus, does not teach minimization as claimed.

Rather, we credit Dr. Clark’s testimony that in view of the combined teachings of Schray and Miura, a person of ordinary skill in the art “would have understood that the directly injected fuel amount should be minimized to achieve efficient operation in the form of an increase in output torque while still preventing knock.” Ex. 1003 ¶ 212.

For these reasons, we determine that the preponderance of the evidence support’s Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claim 8 obvious to one of ordinary skill in the art.

9. *Claim 9*

Claim 9 requires “[t]he fuel management system of claim 7, wherein as torque increases the fraction of fueling provided by the first fueling system is increased to be substantially equal to an amount of fueling sufficient to prevent knock.” Ex. 1001, 17:58–61. Petitioner asserts that “Patent Owner has not differentiated terms ‘substantially equal’ and ‘minimized.’” Pet. 22 (citing *id.* at 3–4; Ex. 1034, 31–34). Thus, according to Petitioner, “the combination of Schray and Miura disclose the limitations of Claim 9.” *Id.* (citing *id.* 21–22; Ex. 1003 ¶¶ 214–219).

Patent Owner responds that “[t]he recitation in Claim 9 of the fraction of fueling provided by the first fueling system being increased ‘to be substantially equal to an amount of fueling sufficient to prevent knock’ is not taught by Schray and Miura for similar reasons to those given for Claim 8.” PO Resp. 37.

For the reasons discussed above, Patent Owner’s arguments are unconvincing. Further, we credit Dr. Clark’s testimony regarding this claim. Ex. 1003 ¶¶ 214–220. We determine that the preponderance of the evidence supports Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claim 9 obvious to one of ordinary skill in the art.

10. *Claim 11*

Claim 11 requires “[t]he fuel management system of claim 1, wherein the fuel management system is further configured to reduce the fraction of

fuel that is provided by the first fueling system as torque decreases while still preventing knock.” Ex. 1001, 18:3–6. Petitioner asserts that a person of ordinary skill in the art “would have understood Schray’s components to represent fuel vapor recovery that is common for gasoline engines.” Pet. 24 (citing Ex. 1003 ¶¶ 234–235).

Patent Owner asserts that for claim 11 “Petitioner repeats its arguments for Claims 1.E and 2” and responds that it does the same. PO Resp. 37. We note that Patent Owner did not present any arguments for claim 2. Further, as discussed in Section II.C.4.c above, Patent Owner’s arguments regarding limitation [1.E] are unconvincing.

For these reasons, we determine that the preponderance of the evidence supports Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claim 11 obvious to one of ordinary skill in the art.

11. Claim 13

Claim 13 is similar to claim 1. *Compare* Ex. 1001, 16:62–17:26 *with id.* at 18:1–46. Given these similarities, we do not reproduce claim 13 in its entirety. For limitations [13Pre]–[13G], Petitioner refers back to its assertions for corresponding limitations [1Pre]–[1.G]. Pet. 24–26. For limitation [13.H] Petitioner asserts that “Schray discloses use of spark retard in that it discloses that ‘the ignition time point is, as a rule, shifted so far in the direction “retard” until there is again a drop below the knock limit.’” *Id.* at 27 (citing Ex. 1005, 1:37–39; Ex. 1003 ¶ 273). Petitioner asserts further that a person of ordinary skill in the art “would understand that use of more retarded ignition would increase knock prevention and reduce the need for as much direct injection to control knock” and “that both direct injection during the compression stroke and retarded timing would reduce the high

temperatures and pressures in the cylinder that engender knock, and hence would serve as interchangeable control parameters to reduce knock.” *Id.* (citing Ex. 1003 ¶ 273).

In addition, Petitioner asserts that “Miura presents that ‘knocking improvement control enables advancement of the ignition timing,’ thereby teaching the interchangeability of control by timing retard and by use of knocking improvement control (e.g. use of both port and direct injection).” Pet. 27 (citing Ex. 1008 ¶ 4; Ex. 1003 ¶ 274). Therefore, according to Petitioner, “in the combined system, a POSITA would be motivated to apply the spark control of Schray to the engine of Miura to effect knock reduction and reduce the quantity of directly injected fuel.” *Id.* (citing Ex. 1003 ¶ 274).

For limitations [13Pre]–[13.G] Patent Owner responds that Petitioner repeats its asserts for limitations [1.Pre]–1.G] and it “does the same.” PO Resp. 37–39. For limitation [13.H] Patent Owner responds that Petitioner’s reasoning in support of the proposed combination is based on hindsight bias. PO Resp. 38 (citing Ex. 2018 ¶¶ 129–131). According to Patent Owner, “Schray teaches the exact opposite of using spark retard to reduce a DI fraction used to control knock. It teaches using DI to *reduce ignition control depth*. Schray thus teaches *using more DI than would otherwise be required* to prevent knock” and “Schray teaches using DI even when not needed to prevent knock . . . such as in advance of knock endangered regions.” *Id.* (citing Ex. 1005, 3:60–67, 4:17–24; Ex. 2018 ¶ 129). Patent Owner responds further that “Petitioner’s citation to Miura is also unavailing” because “Miura teaches that ‘knocking improvement control enables advancement of the ignition timing’ and “does not teach the use of

spark timing to allow higher fraction of port injection.” *Id.* at 38–39 (citing *id.* at 27; Ex. 2018 ¶ 130).

Petitioner replies that “Patent Owner alleges Schray uses too much DI, but Patent Owner is wrong: Schray’s additional spark retard ‘leads to an improved control result, **a reduction of consumption**, and an increase of torque.’” Pet. Reply 19 (citing Ex. 1005, 4:17–23). Petitioner replies further that “Patent Owner’s refrain that there is a certain amount of DI that ‘would otherwise be required to prevent knock’ is wrong” as “[t]here is no such amount—the Challenged Patent fails to disclose **any specific amount or even a method to determine such an amount.**” *Id.* at 20 (citing PO Resp. 38; Ex. 1046, 275:9–276:6, 287:21–294:25, 296:23–297:4, 317:14–23, 336:22–338:15, 272:18–273:16).

Patent Owner replies by repeating its arguments that “Schray teaches the opposite of using spark retard to reduce a DI fraction that is employed in an engine with both DI and PI fueling systems,” “Schray teaches the opposite: using double injection of DI to reduce spark retard (to reduce ‘ignition control depth’),” and “Schray teaches using more DI than would otherwise be required to prevent knock.” PO Sur-reply 15 (citing Ex. 1005, 4:17–24).

Patent Owner cites the following passage from Schray to support its arguments that Schray teaches the opposite of what is claimed:

When detecting a “knocking” combustion, double injections are carried out in addition to the knock control by shifting the ignition angle in a direction of retard. In this way, the ignition angle control depth of the knock control is reduced which leads to an improved control result, a reduction of consumption and an increase of the torque.

Ex. 1005, 4:17–22. However, this passage does not support Patent Owner’s argument that Schray teaches using more DI than would otherwise be required to prevent knock. Rather, as noted by Petitioner, this passage teaches reduction of consumption of DI. *See id.* Further, the fact that Schray teaches the use of spark retard to reduce ignition control depth does not demonstrate that the reasoning in support of the proposed combination is based on hindsight bias as it is not necessary for the prior art to serve the same purpose as that disclosed in the ’580 Patent in order to support the conclusion that the claimed subject matter would have been obvious. “Under the correct analysis, any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.” *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 420 (2007).

Given that Schray provides sufficient rational in support of the proposed combination, Patent Owner arguments that Miura doesn’t teach this limitation are unconvincing. On the record before us, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered limitation [13.H] obvious to one of ordinary skill in the art. For the reasons discussed above, the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Schray and Miura would have rendered claim 13 obvious to one of ordinary skill in the art.

12. *Claims 15, 18, 23, and 25*

We do not reproduce the language of claims 15, 18, 23, and 25 as the parties agree that it is similar to the language of claims or limitations discussed above. *See* Pet. 28–32; *see also* PO Resp. 39–40. For each of these claims Patent Owner does not provide separate arguments referring

instead to its previous arguments. PO Resp. 39–40. We have determined that these arguments are unconvincing for the reasons discussed above. On the record before us, we determine that the preponderance of the evidence supports Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claims 15, 18, 23, and 25 obvious to one of ordinary skill in the art.

13. Claim 28

Claim 28 requires “[t]he fuel management system of claim 23, wherein the fuel management system is further configured such that both the first and second fueling systems are used at the highest torque value at which the engine is operated in a drive cycle.” Ex. 1001, 20:36–39.

Petitioner asserts that “[t]he 580 Patent reviews a driving cycle in terms of ethanol use and presents that the ‘maximum fraction of ethanol used during a drive cycle will depend upon the engine system design and the desired level of maximum torque at different engine speeds.’” Pet. 33 (quoting Ex. 1001, 3:28–31). Petitioner asserts further that a person of ordinary skill in the art “constrained to consider the limitation of a driving cycle, would review a typical driving cycle used for emissions certification such as the EPA Federal Test Procedure for light duty vehicles (FTP-75) defined in 40 CFR 86.1.” *Id.* (citing Ex. 1003 ¶ 370). According to Petitioner, “[s]uch a cycle is known to have low power demand and would require operation in the low, medium, and high load ranges of Miura.” *Id.* at 33–34 (citing Ex. 1008 ¶¶ 20–21; Ex. 1003 ¶¶ 372–373).

Petitioner also asserts that “Schray discloses that the first and second injections, albeit from the same direct injector, occur in knock endangered operating regions and before reaching the engine operating limits, the

knocking limit of the engine 10 is reduced and/or the knocking behavior is improved by the double injections.” Pet. 34 (citing Ex. 1005, 3:61–64; Ex. 1003 ¶ 371). According to Petitioner, a person of ordinary skill in the art “would have understood a knock endangered operating region (e.g., an area where the engine has a tendency to knock) would occur when the engine is operating at high load.” *Id.* (citing Ex. 1003 ¶ 371). In addition, Petitioner asserts that “[i]n the high load range, Miura discloses that the required fuel is injected via DI and PI” and that “[a]ny torque higher than the highest torque in the medium load range of Miura would fall into the high load range and require knock control by direct injection.” *Id.* (citing Ex. 1008 ¶ 21, Fig. 2; Ex. 1003 ¶ 373).

Patent Owner responds that “Miura teaches that **all** of the fuel can be directly injected.” PO Resp. 40 (citing Ex. 1008 ¶ 37). According to Patent Owner a person of ordinary skill in the art “would not consider this claim limitation to be satisfactorily taught or suggested by the references in view of the facts, the references themselves, and Petitioner’s argument.” *Id.* at 41 (citing Ex. 2018 ¶¶ 132–133).

Petitioner responds that “Patent Owner addresses Miura alone, not the combination, and cites the single-injector embodiment rather than the relied-upon PI embodiment.” Pet. Reply 20 (citing PO Resp. 40–41; Ex. 1008 ¶ 37; Ex. 1046, 506:19–512:4). Patent Owner does not respond. *See* PO Resp. 9–15.

We agree with Petitioner that Patent Owner’s argument is unconvincing as it addresses Miura alone, and not the proposed combination. Pet. Reply 20. Having considered the full record before us, we determine that the preponderance of the evidence support’s Petitioner’s

assertions that the combined teachings of Schray and Miura would have rendered claim 28 obvious to one of ordinary skill in the art.

14. Claims 2, 10, 12, 14, 21, 29, and 31

Patent Owner does not separately address Petitioner’s assertions regarding claims 2, 10, 12, 14, 21, 29, and 31. *See* PO Resp. 9–15. We reproduce these claims and Petitioner’s assertions regarding the patentability of each claim below.

Claim 2 requires “[t]he fuel management system of claim 1, wherein the first fueling system is configured to prevent knock when torque increases.” Ex. 1001, 17:27–29. Petitioner asserts that “[t]he combination discloses use of DI to prevent knock. Indeed, Schray discloses that ‘[t]he second injection causes the air/fuel mixture [] to be cooled’ to prevent knock.” Pet. 20 (citing Ex. 1005, 3:55–60; Ex. 1003 ¶ 190). Petitioner asserts further that “Miura discloses knock suppression by evaporative cooling, which is a characteristic of in-cylinder direct injection.” *Id.* (citing Ex. 1008 ¶ 27; Ex. 1003 ¶ 192). Petitioner also refers to the discussion of limitation [1.E]. *Id.* (citing Ex. 1003 ¶¶ 189–193).

Claim 10 requires

The fuel management system of claim 1, wherein the fuel management system is further configured to use a knock detector for closed loop control, and wherein a signal from the knock detector is configured to determine at least one of when to provide fueling or how much fueling to provide from the first fueling system to prevent knock at various times during a drive cycle of the spark ignition engine.

Ex. 1001, 17:62–18:2. Petitioner asserts that “Schray discloses that when detecting a ‘knocking’ combustion, double injections are carried out in addition to the knock control by shifting the ignition angle in a direction of retard, which the POSITA would understand as changing the fraction of fuel

used in the second injection of Schray.” Pet. 23 (citing Ex. 1005, 4:18–20; Ex. 1003 ¶¶ 221, 225). According to Petitioner, a person of ordinary skill in the art “would employ the detection of ‘knocking’ combustion by a knock sensor as taught by Schray to control the engine of Miura.” *Id.* (citing Ex. 1003 ¶¶ 222, 224–226).

Claim 12 requires “[t]he fuel management system of claim 1, wherein the first fueling system is configured to introduce gasoline into the engine and the second fueling system is configured to introduce gasoline into the engine.” Ex. 1001, 18:7–10. Petitioner asserts that “Miura presents the use of gasoline.” Pet. 24 (citing Ex. 1008, Fig. 2). Petitioner asserts further that “Miura states: ‘In this case, for example, the rotational speed is set higher when using regular gasoline than when using high-octane gasoline.’” *Id.* (Ex. 1008 ¶ 28; Ex. 1003 ¶ 237).

Claim 14 requires “[t]he fuel management system of claim 13, wherein the first fueling system is configured to introduce gasoline into the engine and the second fueling system is configured to introduce gasoline into the engine.” Ex. 1001, 18:47–50. Petitioner asserts that “[t]he combination discloses use of spark retard to reduce the fraction of DI fuel.” Pet. 28 (citing *id.* at 26–27; Ex. 1003 ¶¶ 285–288). Petitioner asserts further that “Schray discloses that when detecting a ‘knocking’ combustion using its knock sensor 37, double injections are carried out in addition to the knock control by shifting the ignition angle in a direction of retard.” *Id.* (citing Ex. 1003 ¶ 285). In addition, Petitioner asserts that “[a]n additional sensed parameter measured by Schray and used in the tendency-to-knock signal is the engine speed.” *Id.* (citing Ex. 1003 ¶ 287).

Claim 29 requires “[t]he fuel management system of claim 23, wherein the fuel management system is further configured to use spark

retard to reduce an amount of fuel that is provided by the first fueling system.” Ex. 1001, 20:40–43. For limitation 29, Petitioner refers to its assertions for limitation [13.H]. Pet. 34 (citing Ex. 1003 ¶¶ 375–376).

Claim 31 requires “[t]he fuel management system of claim 23, wherein the first fueling system is configured to introduce gasoline into the engine and the second fueling system is configured to introduce gasoline into the engine.” Ex. 1001, 20:48–51.

Having considered the full record in this proceeding including Petitioner’s assertions and the evidence in support thereof, we determine that a preponderance of the evidence supports Petitioner’s assertions that the combined teachings of Schray and Miura would have rendered claims 2, 10, 12, 14, 21, 29, and 31 obvious to one of ordinary skill in the art.

D. Ground 2: Obviousness of Claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, and 31 in View of the Combined Teachings of Rubbert, Yuushiro, and Bosch

Petitioner asserts that claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, and 31 are unpatentable over Rubbert, Yuushiro, and Bosch. Pet. 35–57. In the previous section of this Decision discussing Ground 1, we determined that claims 1, 2, 5–15, 18, 21, 23, 25, 27–29, and 31 are unpatentable. Ground 1, however, does not challenge claim 20. Accordingly, we consider Ground 2. However, in the interest of brevity, we do not reproduce the limitations of the claims addressed above, nor do we reproduce Petitioner’s assertions regarding each of them under this ground.

For claims 1, 2, 5–7, 10–12, 14, 15, 20, 21, 23, 25, 27, 28, and 31, Patent Owner does not contest Petitioner’s assertions that the prior art discloses each and every element claimed. PO Resp. 41–46. We have reviewed Petitioner’s assertions and the evidence in support thereof and

determine that Petitioner has demonstrated by a preponderance of the evidence that Rubbert, Yuushiro, and Bosch disclose the elements recited in claims 1, 2, 5–7, 10–12, 14, 15, 20, 21, 23, 25, 27–29, and 31.

For all of the claims challenged in Ground Two, Patent Owner contends that “there would have been no motivation to combine Rubbert with Yuushiro and Bosch to obtain the subject matter of independent [c]laims 1, 13, and 23, nor of their dependent claims.” PO Resp. 41. This argument is addressed in Section II.D.4 below. For claims 8, 9, 13, 18, and 29 Patent Owner contends that “Yuushiro does not teach minimizing the amount of DI fuel to prevent knock.” PO Resp. 46. This argument is addressed in Section II.D.5 below.

We beginning our analysis of this challenge with overviews of Rubbert, Yuushiro, and Bosch.

1. Rubbert

Rubbert “relates to a method for mixture formation in a mixture-compressing, external-ignition internal combustion engine with fuel injection.” Ex. 1007, 1:1–3. Specifically, Rubbert is directed to an air-fuel mixture that “is formed by a combination of induction pipe injection and direct injection through partial injection amounts controlled or regulated depending on the load. *Id.* at 1:30–32. In Rubbert’s method “in the idling and partial load ranges, the greater portion of fuel in the mixture is injected by induction pipe injection than by direct injection,” whereas “the fuel portion in the mixture can be mostly or completely injected by direct injection in the full-load range.” *Id.* at 1:47–49, 2:4–6.

2. Yuushiro

Yuushiro “relates to a compression ignition type internal combustion engine that compresses premixed gas at high pressure, and causes

compression ignition.” Ex. 1006 ¶ 1. Specifically, Yuushiro is directed to a “compression ignition type internal combustion engine, comprising a cylinder, a reciprocating piston in the cylinder, a combustion chamber formed divided by the cylinder and the piston” *Id.* ¶ 12. Yuushiro’s internal combustion engine further includes an intake valve, an exhaust valve, and “an open and close timing variable means for changing, among the intake the exhaust valves, the open and close time for only the intake valve or for both the intake valve and exhaust valve.” *Id.* Yuushiro’s internal combustion engine also includes “a port injection valve for injecting fuel to the intake port, and an in-cylinder injection valve for directly injecting fuel to the combustion chamber, wherein the open and close timing variable means is controlled so that when fuel is injected from the port injection valve only.” *Id.* In Yuushiro’s internal combustion engine “a maximum injection amount at which knocking does not occur is set as a reference injection amount, a load amount corresponding to this is set as a reference load amount.” *Id.* “[I]n a load zone of the reference load amount or less, the total amount of fuel of a required injection amount is injected from the port injection valve during intake stroke after top dead center of the piston, and moreover, the smaller the load, the greater the open valve polymerization time of the intake valve and the exhaust valve.” *Id.*

3. *Bosch*

Bosch is an automotive handbook. Ex. 1011, 1. It discusses spark retard and closed loop control in fuel management systems. *Id.* at 360, 372–374, 441, 464–65.

4. *Rational for Combining the Teachings of Rubbert,
Yuushiro, and Bosch*
a) *Petitioner's Assertions*

Petitioner asserts that “[b]ecause Rubbert states its fuel injection strategy is based on load, a POSITA would have been motivated to select a known fuel map that provided specific quantities of PI and DI fuel based on load” and “would have implemented Yuushiro’s fuel map in Rubbert.” Pet. 37 (citing Ex. 1003 ¶¶ 391–394, 401–402; Ex. 1006 ¶ 39). According to Petitioner, “Yuushiro supplements the teachings of Rubbert” and a person of ordinary skill in the art “would have understood [that] Yuushiro’s fuel map is designed to rely on an increasing amount of DI to prevent knock as engine load increases. *Id.* Such a map not only allows for the advantages of DI with respect to cylinder filling, but also enables the knock limit to be fully utilized.” Ex. 1003 ¶¶ 394, 401. Petitioner asserts further that a person of ordinary skill in the art “would have had a reasonable expectation of success of achieving the predictable result of an engine that reduces knock based on both PI and DI based on a known fuel map.” *Id.* (citing Ex. 1003 ¶ 402 (footnote omitted)).

Petitioner asserts that “[e]ven though Rubbert suggests use of DI at low loads and mostly DI at high loads, the POSITA would still have been motivated to modify Rubbert with Yuushiro’s map to achieve the benefits of Yuushiro, including operating at a stoichiometric ratio and using a three-way catalyst” because a person of ordinary skill in the art would understand that Rubbert ‘wouldn’t need the additional DI’ at low loads if it operated at a stoichiometric ratio.” Pet 38–39 (citing Ex. 1003 ¶¶ 394–400; Ex. 1030, 175:4–7; Ex. 1007, 1:49–2:3; Ex. 1006 ¶¶ 4, 56). In footnote 8, Petitioner notes that “Yuushiro discloses use of a catalytic converter” and that a person

of ordinary skill in the art “would have understood use of a catalytic converter requires a stoichiometric ratio.” *Id.* n.8 (citing Ex. 1006 ¶ 56; Ex. 1011, 428). In footnote 8, Petitioner further notes that “[t]o the extent it is argued that Rubbert teaches lean PI operation, a POSITA would be motivated to modify Rubbert to be overall stoichiometric as taught by Yuushiro and confirmed by Bosch at least because of the need to meet emissions standards.” *Id.* (citing Ex. 1011, 478, 471, 484–85; Ex. 1003 ¶¶ 395–398).

Petitioner asserts further that a person of ordinary skill in the art “would have understood engines employ various strategies at low loads (e.g., rich fuel mixture (Ex. 1011, 356, 358, 428), increase intake heating to prevent ignition failure” and that “Rubbert does not require that the port injection amount is zero at high loads and Yuushiro does not require that more port injection is used than direct injection at high loads.” *Id.* at 39 (citing Ex. 1006 ¶¶ 10, 13; Ex. 1011, 416). According to Petitioner, “Rubbert and Yuushiro agree that the general fueling strategy relies on the fact that the port injected and directly injected fuel amounts are regulated depending on load, and the amount of directly injected fuel increases as load increases.” *Id.* (citing Ex. 1003 ¶ 400).

Petitioner admits that Rubbert and Yuushiro are “silent with respect to closed loop control.” Pet. 39 (citing Ex. 1003 ¶ 407). Petitioner asserts that a person of ordinary skill in the art “would have been motivated to identify those additional implementation details and would have understood these details were well-known in the art at the time” and, for example, “would have been motivated to improve fuel economy and reduce emissions.” *Id.* at 39–40 (citing Ex. 1031, 3; Ex. 1003 ¶ 407).

b) Patent Owner's Response

Patent Owner responds that Rubbert “teaches away from substantially stoichiometric operation” because it “teaches that ‘[i]n currently used direct fuel injection methods, the fuel is exclusively injected directly into the combustion chamber. ... [S]table combustion is achieved even at high air ratios,’” but “[t]his disadvantageously results in higher HC, CO, and soot emissions.” PO Resp. 41–42 (citing Ex. 1007, 1:4–5, 1:9–10, 1:19–20). According to Patent Owner, Rubbert “sought ‘an improved method of mixture formation,’ which is achieved by using ‘a combination of induction pipe injection and direct injection through partial injection amounts controlled or regulated depending on the load.’” *Id.* (citing Ex. 1007, 1:26–27, 1:30–32; Ex. 2018 ¶ 135).

Patent Owner responds further that “[a]ccording to Rubbert, this combination allowed ‘avoid[ing] the disadvantages of direct injection in stratified operation with its relatively high emission[s]’ while providing ‘good efficiency and low emissions of harmful substances even at **higher air ratios**.’” PO Resp. 42 (citing Ex. 1007, 1:34–35, 1:38–39; Ex. 2018 ¶ 13). Thus, according to Patent Owner, Rubbert “relies on lean operation using combined DI and PFI fuel injection to achieve improved emissions and efficiency, and there would thus be no motivation to adopt a distinct strategy of employing stoichiometric operation and using a three-way catalytic converter.” *Id.* Patent Owner responds that “[i]n fact, doing so would vitiate the operating principle of Rubbert regarding capacity for lean operation, which was a central premise of Rubbert’s motivation for a dual injection system.” *Id.* at 42–43 (citing Ex. 2018 ¶ 237).

Patent Owner also responds that “[t]his Board has previously rejected Petitioner’s argument for modifying Rubbert to make it stoichiometric” and quotes a portion of the decision in IPR2019-01400. PO Resp. 43 (citing Ex. 2012, 24). According to Patent Owner,

This Board held, in denying institution based on Rubbert in view of Bosch: “We determine that Petitioner fails to supply adequate and persuasive reasoning with rational underpinning why a person of ordinary skill in the art would have modified Rubbert’s carefully crafted system of regulating DI fuel and PI fuel in order to utilize ‘the lean mixture in the entire combustion chamber’ to a system utilizing a stoichiometric ratio.”

Id. (citing Ex. 2012, 25). Patent Owner responds further that “Petitioner attempts to augment its failed Rubbert/Bosch combination by adding Yuushiro as proof of motivation to ‘achieve the benefits of Yuushiro, including operating at a stoichiometric ratio and using a three-way catalyst,” but “[t]he addition of Yuushiro fails to salvage the combination for at least the reason that it teaches neither a three-way catalyst nor stoichiometric operation. *Id.* at 44 (citing Pet. 38).

In addition, Patent Owner responds that “Yuushiro does not teach stoichiometric operation but instead clearly teaches the advantages of lean operating compression ignition engines” and quotes paragraph 3 of Yuushiro in support of its position. PO Resp.44. Patent Owner asserts that a person of ordinary skill in the art “would recognize the ‘predetermined’ air-fuel ratio range of Yuushiro’s engine (AFR of 34 to 44) is *lean*” and that the fact that Yuushiro lacks a throttle indicates that its operation is lean. *Id.* (citing Ex. 2018 ¶¶ 139–140). Patent Owner also responds that a person of ordinary skill in the art “would have further understood that the catalytic converter referred to in [0062] is not a three-way catalyst.” *Id.* at 45 (citing Ex. 2018 ¶ 142).

Finally, Patent Owner responds that “[b]oth because Yuushiro lacks a throttle, and because of the nature of its engine, a POSITA would understand that lean burn operation is an essential feature of operation throughout a major portion of the operating map.” PO Resp. 45 (citing Ex. 2018 ¶ 143). In support of this position, Patent Owner quotes a passage from Zhao, relied upon in the Petition’s third ground, but not relied upon in this ground, for the proposition that “a distinct feature of HCCI¹⁷ engines like Yuushiro is lean burn operation.” *Id.* Patent Owner responds further that “there is no motivation to combine the features of spark ignition engine with a compression ignition engine such Yuushiro’s. These are two fundamentally different engines.” *Id.* at 46 (citing Ex. 2018 ¶ 146).

c) Petitioner’s Reply

Petitioner replies that Patent Owner does not “address the combination of Rubbert in view of Yuushiro and Bosch.” Pet. Reply 20 (citing PO Resp. 41–48). Addressing Patent Owner’s arguments, Petitioner first asserts that “Rubbert does not teach lean operation as “an essential feature.” *Id.* at 21 (citing PO Resp. 41). According to Petitioner, Rubbert explains operation ‘even at higher air ratios ***and with residual gas portions***’” which suggests that Rubbert is operating stoichiometrically at light load and at high load.” *Id.* (citing Ex. 1007, 1:39; Ex. 2020, 151:8–152:9; Ex. 1003 ¶¶ 394–398, 401, 422–425, 444–448; Pet. 37–39, 41, 46). Petitioner reiterates its position that a person of ordinary skill in the art would be motivated to modify Rubbert to be stoichiometric as taught by Yuushiro and Bosch. *Id.* (citing Ex. 1003 ¶¶ 394–398, 422–425, 444–448; Pet. 1, 37–39, 41, 46).

¹⁷ Homogeneous Charge Compression Ignition. Ex. 1010, 55.

Replying to Patent Owner’s second argument, Petitioner asserts that “the Board’s earlier decision does not bear on Ground 2, at least because it did not consider Yuushiro and Dr. Clark’s testimony regarding the same.” Pet. Reply 21 (citing Pet. 1–2).¹⁸

Petitioner replies further that “Patent Owner mischaracterizes Yuushiro” in that the “[l]ack of a throttle does not preclude stoichiometric operation.” Pet. Reply 21 (citing PO Resp. 44–46). Petitioner asserts that “Dr. Shaver agreed that Variable Valve Timing, which Yuushiro employs, can be used to regulate air intake like a throttle.” *Id.* (citing Ex. 1046, 194:5–196:8; Ex. 1006, Abstract, ¶¶ 12, 15, 60–61, Figure 1; Ex. 1001, 8:31–42; Ex. 2020, 138:13–142:1, 143:22–144:9). According to Petitioner, “Yuushiro discloses a catalytic converter to mitigate NO_x (Ex. 1006 ¶ 56), which POSITA would have understood requires stoichiometric operation.” *Id.* (citing Ex. 1003 ¶¶ 395, 421–426; Ex. 2020, 144:10–17).

In addition, Petitioner replies that “Patent Owner cites Yuushiro’s discussion of prior art (not Yuushiro’s teachings), where Yuushiro discourages *both operation on the lean side and operation on the rich side*” which suggest stoichiometric operation. Pet. Reply 22 (citing Ex. 1006 ¶ 4; PO Resp. 44–45; Ex. 1003 ¶¶ 444–449). Petitioner also asserts that “Dr. Shaver admits three-way catalysts would reduce emissions during lean or rich operation (Ex. 1046, 256:15–257:5), which the art confirms (Exs. 1023; 2020, 94:16–96:2)” such that “[t]he argument that Yuushiro would not employ a three-way catalyst with reasonable success fails.” *Id.* (citing Ex. 1003 ¶¶ 394–398, 421–426).

¹⁸ We note that Petitioner cites Section III.C of the Petition, but Section III of the Petition does not include a sub-part C. It appears that Petitioner may have intended to cite Section V.C.

d) *Patent Owner's Sur-reply*

In reply, Patent Owner reiterates its arguments that “to achieve good efficiency and emissions reductions in engines that could operate with lean (higher than stoichiometric) air/fuel ratios” and that Rubbert teaches away from the proposed combination. PO Sur-reply 16 (citing Ex. 1007, 1:35–36). Patent Owner further reiterates its argument that Yuushiro teaches lean operation and does not disclose a three-way catalyst. *Id.* at 16 (citing PO Resp 41–46; Ex. 2018 ¶¶ 135–145; Ex. 1007, 1:38–39; Ex. 1006 ¶¶ 3–4, 62; Ex. 1010, 179), 19. Thus, according to Patent Owner, Petitioner’s failed Rubbert/Bosch combination “is not remedied by Yuushiro’s *lean burn HCCI engine*.” *Id.* at 17 (citing Ex. 2012, 24–25; Ex. 1060, 11–12). In addition, Patent Owner reiterates its argument that “[t]his Board agrees, having previously decided that ‘Rubbert is not silent as to its fuel/air ratio,’ and describes ‘Rubbert’s carefully crafted system’ that regulates fuel to utilize a ‘lean mixture in the entire combustion chamber’ that would need *modifying* to become a ‘system utilizing a stoichiometric ratio.’” *Id.* Patent Owner also reiterates its argument that “there is no motivation to combine the features of the spark ignition engine of Rubbert with a compression ignition engine such Yuushiro’s” because “[t]hese are two fundamentally different engines.” *Id.* at 19 (citing Ex. 2018 ¶ 146).

Patent Owner replies further that “Petitioner incorrectly argues that Rubbert’s statement referring to ‘even at higher air ratios’ implies stoichiometric operation” is wrong because “[t]he phrase ‘**even** at higher air ratios’ in fact implies even higher, *leaner* air ratios than the high air ratios used in lean operation. It does not imply stoichiometric operation.” PO Sur-reply 17 (citing Pet. Reply 21; Ex. 1007, 1:39; Ex. 2018 ¶¶ 135–137).

In addition, Patent Owner replies that “Petitioner’s statement that ‘the Board’s earlier decision does not bear on Ground 2’ . . . is clearly incorrect in that the denial of institution in IPR2019-01400 clearly shows that the Rubbert/Bosch combination fails to teach stoichiometric operation” “which for the reasons given above is not remedied by Yuushiro’s *lean burn HCCI engine*.” PO Sur-reply 18 (citing PO Resp. 44–46; Ex. 2018 ¶¶ 138–146; Ex. 1006 ¶¶ 3–4, 62; Ex. 1010, 179).

e) *Discussion*

Having considered the full record before us, we determine that Petitioner articulated sufficient reasoning with rational underpinning to show that it would have been obvious to a person of ordinary skill in the art to combine the teachings of Rubbert, Yuushiro, and Bosch in the manner proposed in Ground 2. Considering each of Patent Owner’s arguments we do not find them to demonstrate a deficiency in Petitioner’s contentions.

First, we do not agree with Patent Owner “that an essential feature of Rubbert is lean operation.” PO Resp. 41 (citing Ex. 2018 ¶ 135). We do not credit Dr. Shaver’s testimony because although Rubbert discusses lean operation in idling and partial load ranges, this discussion does not indicate that lean operation is an essential feature of Rubbert’s method. Ex. 1007, 1:47–2:3). Dr. Shaver identifies no portion of Rubbert that states that lean operation is an essential feature, nor does Dr. Shaver even identify another portion of Rubbert’s disclosure that discusses lean operation, because Rubbert does not do so. Given that we do not agree with Patent Owner that lean operation is an essential feature of Rubbert, it follows that we do not agree that Rubbert teaches away from stoichiometric operation because it relies on lean operation. PO Resp. 41–42.

Second, we agree with Petitioner that the Board’s earlier decision in another proceeding “does not bear on Ground 2, at least because [the earlier decision] did not consider Yuushiro and Dr. Clark’s testimony regarding the same.” Pet. Reply 21.

Third, we agree with Petitioner that “Patent Owner mischaracterizes Yuushiro” because the “[l]ack of a throttle does not preclude stoichiometric operation.” Pet. Reply 21. We credit Dr. Clark’s testimony that “Yuushiro discloses the use of a catalytic converter” and [a] person of ordinary skill in the art would have understood that the use of a catalytic converter requires a stoichiometric ratio” which is also supported by Dr. Shaver’s testimony. Ex. 1003 ¶ 395 (citing Ex. 1006 ¶ 56; Ex. 1011, 428; Ex. 1040, 194:5–196:8).

Finally, we agree with Petitioner that Patent Owner’s argument that Yuushiro would not employ a three-way catalyst is unconvincing. First, Patent Owner’s argument based on teachings in Zhao is unavailing because Patent Owner presumes that Yuushiro’s engine is a HCCI engine without showing that it is a HCCI engine. Second, Patent Owner’s citation to Yuushiro’s discussion of the prior art does not apprise us of Yuushiro’s teachings. PO Resp. 44–45.

5. *Claims 8, 9, 13, 18, and 29:¹⁹ Allegation That Yuushiro Does Not Teach Minimizing the Amount of Fuel Needed to Prevent Knock*

a) *Petitioner’s Assertions*

Claim 8 requires

The fuel management system of claim 7, wherein the fuel management system is further configured to increase the fraction

¹⁹ In its heading for this argument, Patent Owner refers to claims 8, 9, 13, and 18. PO Resp. 46. However, its argument is also directed to claim 29. *See id.* at 47.

of fueling provided by the first fueling system in the first torque range as torque increases so as to minimize the amount of fueling provided by the first fueling system that is used while still preventing knock.

Ex. 1001, 17:52–57.

For claim 8 Petitioner refers back to its assertions for limitation [1.E] and claim 2. For limitation [1.E] Petitioner asserts that “Rubbert discloses under idle conditions and part (low) load range, the larger (*i.e.*, increased) proportion of fuel in the mixture is injected via PI whereas in full load ranges, DI is used” and that “Yuushiro discloses transitioning from PI alone (no DI) to the combination of PI and DI (at least some DI) above the reference load amount.” Pet. 43 (citing Ex. 1007, 1:49–2:8; Ex. 1006 ¶ 39; Ex. 1003 ¶¶ 432–443). Petitioner asserts further that “[e]ven if Limitation 1.E is interpreted to require an increase in the fraction of DI fuel for each increase in load, this is also taught by Yuushiro” in that “Yuushiro discloses that the amount of DI fuel is changed as load increases based the formula $Q_d = Q_q - Q_b$.” *Id.* at 44 (citing Ex. 1003 ¶ 433; Ex. 1006 ¶ 39). According to Petitioner, “[t]he amount of fuel Q_d changes in the same direction as the load changes with respect to the reference load Q_b , where Q_b is the port injected fuel quantity that avoids knocking” and that “Yuushiro discloses that DI cools premix gas to prevent knock.” *Id.* (citing Ex. 1006 ¶ 53, Fig. 3). Petitioner asserts further that “Figure 3 of Yuushiro explicitly demonstrates an increase in the fraction of DI as load increases. Yuushiro therefore teaches use of the amount of fuel Q_d needed so as to fuel the engine while avoiding knock.” *Id.* (citing Ex. 1003 ¶ 433)

For claim 2 Petitioner refers to its assertions regarding limitation [1.E] and asserts again that “the combination discloses the use of DI to prevent knock.” Pet. 47 (citing Ex. 1003 ¶¶ 450–451). According to Petitioner,

“Yuushiro discloses preventing knock via direct injection, which cools the cylinder: ‘fuel injected from the in-cylinder injection valve 16 evaporates near compression top dead center, and the *latent heat of vaporization thereof cools the premixed gas.*’” Ex. 1006 ¶ 53).

In addition to referring to its assertions for limitation [I.E] and claim 2, Petitioner asserts that “Patent Owner equates increasing DI with mitigating knock at elevated loads and admits that limiting DI is related to ‘efficiency’ and nothing more” and “previously used the terms ‘matches’ and ‘minimizes’ interchangeably.” Pet. 48 (citing Ex. 1034, 21–22; IPR2019–01401, Paper 18, at 25).

Petitioner asserts further that “Yuushiro illustrates in FIG. 3 that as load increases in the reference load zone, the quantity of DI fuel (Q_d) increases in line with the amount that is needed to prevent knock and no more” and that “Yuushiro teaches directly injecting only the amount of fuel necessary to obtain the required power output while maintaining knock free operation at the desired torque, *e.g.*, according to $Q_d = Q_q - Q_b$.” Pet. 48–49 (citing Ex. 1006 ¶¶ 466–467; Ex. 1006 ¶ 39).

Claim 9 requires “[t]he fuel management system of claim 7, wherein as torque increases the fraction of fueling provided by the first fueling system is increased to be substantially equal to an amount of fueling sufficient to prevent knock.” Ex. 1001, 17:58–61. Petitioner asserts that “Patent Owner has not differentiated terms ‘substantially equal’ and ‘minimized’” “and as demonstrated with respect to Claim 8, the combination

of Rubbert, Yuushiro, and Bosch disclose the limitations of Claim 9.” Pet. 49 (citing *id.* at 48–49; Ex. 1304, 31–34; Ex. 1003 ¶¶ 469–470).²⁰

Limitation [13.H] requires “wherein the fuel management system is further configured to use spark retard to reduce the fraction of fueling provided by first fueling system.” Ex. 1001, 18:40–42. Petitioner asserts that “[w]hile Rubbert does not explicitly address spark retard, Bosch teaches that ‘internal combustion engines are damaged by combustion knock’ and that ‘higher combustion ratios . . . increase the engine’s tendency to knock.’” Pet. 52. Petitioner asserts further that “Bosch discloses that it was ‘customary’ as of 1993 to use spark retard to eliminate combustion knock” and that “Bosch further discloses determining the optimum parameters for ignition timing, *e.g.*, whether or not to employ spark retard, based on a sensed parameter, including intake-manifold pressure.” *Id.* (citing Ex. 1011, 360, 472; Ex. 1003 ¶¶ 522–523). According to Petitioner “[i]n a spark ignition engine, when considering the fuel map of Yuushiro, retarding the spark would increase the value of Hb because the mixture would experience later ignition, as taught by Bosch, and, hence, lower temperature and pressures that are the causes of autoignition” and “this would increase the value of Qb and reduce Qd.” *Id.* (citing Ex. 1003 ¶¶ 524–525).

Claim 18 requires “[t]he fuel management system of claim 17, wherein the fraction of fueling provided by the first fueling system in at least part of the first torque range is substantially equal to a fraction sufficient to prevent knock as torque increases.” Ex. 1001, 19:1–4.

²⁰ We note that the Petition also cites Section IV.C.2; however, the Petition contains no such section.

For claim 18, Petitioner refers to its asserts for claim 9 and limitations [10.A] and [10.B] (i.e. claim 10). Pet. 53 (citing Ex. 1003 ¶¶545–546). We have discussed Petitioner’s assertions for claim 8 above. For claim 10 Petitioner asserts that “Bosch discloses that knock detectors are used to prevent knock in internal-combustion engines by adjusting the engine by means of an actuator.” Pet. 49–50 (citing Ex. 1011, 464–465; Ex. 1003 ¶ 473). Petitioner asserts further that “Bosch provides that one such actuator may include ignition timing, but was not limited to such, and a POSITA would have understood that the actuator could have been used with any anti-knock measure, including the direct fuel injection of Rubbert and Yuushiro.” *Id.* at 50 (citing Ex. 1003 ¶¶ 472–478; *id.* at 37–40).

Claim 29 requires “The fuel management system of claim 23, wherein the fuel management system is further configured to use spark retard to reduce an amount of fuel that is provided by the first fueling system.” Ex. 1001, 20:40–43. For claim 29 Petitioner refers to its discussion of limitation [13.H]. Pet. 57.

b) Patent Owner’s Response

Patent Owner responds to Petitioner’s challenge to claims 8, 9, 18, 29, and limitation [13.H] together. PO Resp. 46–48. According to Patent Owner, Yuushiro teaches that in the high load regime, it uses a maximum port fuel charge with the remainder of the required fuel coming from direct injection” and that “Yuushiro teaches that the DI amount increases with torque, while the PFI amount remains constant with torque.” *Id.* at 47 (citing Ex. 1006 ¶¶ 38–39; Ex. 2018 ¶ 148).

Referring to Zhao (which is not relied upon for this ground), Patent Owner responds that it “teaches that the gas temperature in HCCI engines is a critical parameter for determining combustion timing, and further teaches

that evaporation of injected fuel can cool the gas charge.” PO Resp. 47 (citing Ex. 2018 ¶149). According to Patent Owner, “[i]t follows that Zhao teaches that DI fuel injection during high load will cool the PFI charge.” *Id.* (citing Ex. 1010, 180). Patent Owner responds further that “Yuushiro itself teaches that DI injection occurs before the PFI charge self-ignites, resulting in charge cooling” and that “Zhao reinforces that this DI-induced charge cooling will affect the start of ignition, by delaying it.” *Id.* (citing Ex. 1006 ¶ 53; Ex. 2018 ¶¶ 150–152). Patent Owner asserts that “[b]ased off this ignition delay induced by the DI charge itself, a POSITA would recognize that the maximum amount of PFI that could be added before knock occurs will actually increase once DI is added, *i.e.*, that the knock critical maximum PFI amount increases with increasing torque.” *Id.* at 47–48 (citing Ex. 2018 ¶ 153).

With respect to the requirement for spark retard, Patent Owner responds that “Yuushiro teaches nothing, because it lacks a spark plug. Rubbert is likewise silent about ignition timing. While Bosch teaches the general concept, it does not teach or suggest the use of spark retard in the manner recited in the claims to reduce the recited fueling fraction.” PO Resp. 48.

c) Petitioner’s Reply

Petitioner replies that Patent Owner’s Response “reiterates its view that Yuushiro does not ‘minimize’ because DI increases to meet load while PI is constant.” Pet Reply 22–23 (citing PO Resp. 12, 46–48). According to Petitioner “[t]he Board denied this argument” and “[n]othing has changed. Dr. Shaver agreed that Yuushiro does not inject more DI than is taught for a given load, *i.e.*, no more DI than necessary.” *Id.* at 23 (citing Ex. 1047, 31–34; 1046, 534:18–535:21).

Petitioner replies further that “Patent Owner attempts to distinguish Yuushiro on the basis that ‘more PFI than necessary to control knock in the high load range’ is used because DI will cool the PI charge after mixing,” but “Yuushiro does not use PI to control knock—it uses DI.” Pet. Reply 23 (citing PO Resp. 47–48; Ex. 1046, 524:3–10, 526:17–528:2, 531:24–532:9, 533:16–535:21 (footnotes omitted)). Petitioner also replies that “Dr. Shaver admits calibrators can practice Claim 8 ‘with the intent of minimizing the amount of DI’ and the claim ‘doesn’t require that they do that a certain way.’” *Id.* at 23–24 (citing Ex. 1046, 332:10–333:10, 328:5–331:11).

According to Petitioner,

The Board recognized Yuushiro minimizes DI because it “proportionally increases the amount of [DI] so that the amount of fuel that is [PI] is maintained at the maximum level (Qb) to prevent engine knock” and “then only the minimum amount of [DI] necessary is used—the amount that makes of the difference between the total amount required (Qq) and the amount of [PI] (Qb) to satisfy the load demand.”

Id. at 24 (quoting Ex. 1047, 33–34; citing Ex. 1006 ¶¶ 38–39, Fig. 3).

For spark retard, Petitioner replies that “Patent Owner ignores the combination.” Pet. Reply 24 (citing PO Resp. 48). Petitioner replies further by quoting Dr. Clark’s testimony that

In a spark ignition engine, when considering the fuel map of Yuushiro, retarding the spark would increase the value of Hb because the mixture would experience later ignition, as taught by Bosch, and, hence, lower temperature and pressures that are the causes of autoignition . . . would increase the value of Qb . . . [and] Qd would be reduced when the spark is retarded.

Pet. Reply 24; Ex. 1003 ¶ 524.

d) *Patent Owner's Sur-reply*

Patent Owner replies “Petitioner is wrong to state that ‘nothing has changed’ in the argument regarding the ‘minimize’ and ‘substantially equal’ claim limitations.” PO Sur-reply 20 (citing Pet. Reply at 23). Patent Owner responds that it “has provided new evidence from Dr. Shaver of the effect produced by **evaporative cooling** induced by the DI charge itself, which changes completely the conclusions that should be drawn from the use of DI and PI fuel in the high load regime in the Yuushiro reference.” *Id.* (citing Ex. 2018 at ¶¶ 147–156).

Patent Owner replies further that “Petitioner’s analysis ignores the new evidence that DI fuel injection during high load will cool the PFI charge” such that a person of ordinary skill in the art would recognize that the maximum amount of PFI that could be added before knock occurs will actually increase once more DI is added at higher torques because the PFI charge will have been cooled, *i.e.*, that the ***knock critical maximum PFI amount increases with increasing torque as more DI fuel is used – but Yuushiro has capped the amount of PFI used at a constant value.***

PO Sur-reply 20 (citing Ex. 2018 ¶¶ 149–153). Patent Owner replies that based on this evidence, “Yuushiro must then use more DI than would be necessary merely to prevent knock while it uses its added DI to meet the load – and accordingly is not ‘minimizing’ DI while still preventing knock or ‘substantially equal’ to an amount of DI sufficient to prevent knock.” *Id.* (citing Ex. 2018 ¶¶ 148, 153).

Turning to its arguments regarding spark retard, Patent Owner replies that “Petitioner’s argument on spark retard ignores the fact that even if combined, the references would not teach **reducing** the DI fueling fraction or amount in a two-fueling system engine by using spark retard, because

Yuushiro lacks a spark plug.” PO Sur-reply 21 (citing Ex. 2018 ¶¶ 154–156). Patent Owner replies further that “Rubbert is silent about ignition timing, and Bosch teaches nothing more than the general use of spark retard without any teaching or suggestion of using spark retard to reduce a fraction of DI fuel or amount of DI fuel in an engine that has both DI and PFI fuel injection as in Claims 13.H and 29.” *Id.*

e) *Discussion*

Considering both of Patent Owner’s arguments we do not find them to demonstrate a deficiency in Petitioner’s contentions. Patent Owner’s argument that Yuushiro must use more DI than would be necessary to prevent knock is unconvincing because does not consider the proposed combination. Rather, Patent Owner compares that amount of DI used in a system without PI to the amount of DI that would be used in a system that uses both DI and PI as the basis of its assertion that Yuushiro does not minimize DI. But, claims 8, 9, and 18 require minimization of DI in a system that uses both DI and PI. Even assuming that the proposed combination uses more DI than a system that uses DI alone because of the cooling effect described by Dr. Shaver, that does not indicate that the proposed combination does not minimize DI. Further, we credit Dr. Clark’s testimony that a “person of ordinary skill in the art would have understood that Yuushiro teaches directly injecting only the amount of fuel necessary to obtain the required power output while maintaining knock free operation at the desired torque (Qq–Qb) is provided.” Ex. 1003 ¶ 467.

Patent Owner’s argument that none of the references teach spark retard is unavailing because it does not consider the combined teachings of the references. We credit the testimony of Dr. Clark that “[i]n a spark ignition engine, when considering the fuel map of Yuushiro, retarding the

spark would increase the value of Hb because the mixture would experience later ignition, as taught by Bosch, and, hence, lower temperature and pressures that are the causes of autoignition” and that this “[i]n turn, this would increase the value of Qb. Yuushiro states that the directly injected fuel $Q_d = Q_q - Q_b$, where Q_q is the total fuel injected.” Ex. 1003 ¶ 525. We further credit Dr. Clark’s testimony that “[i]n this way, a person of ordinary skill in the art would have understood that Q_d would be reduced when the spark is retarded.”

6. *Conclusion Re Ground 2*

Having considered the full record in this proceeding, including the evidence, testimony, and arguments presented by both parties, and for the reasons discussed above, we determine that the preponderance of the evidence supports Petitioner’s assertion that the combined teachings of Rubbert, Yuushiro, and Bosch would have rendered claims 1, 2, 5–15, 18, 20, 21, 23, 25, 27–29, 31 obvious to one of ordinary skill in the art.

E. *Ground 3*

Because we determine that all of the Challenged Claims are unpatentable under Ground 1, Ground 2, or both Grounds, we need not reach Ground 3. *See SAS Inst. Inc. v. Iancu*, 138 S. Ct. 1348, 1359 (2018) (holding that a petitioner “is entitled to a final written decision addressing all of the *claims* it has challenged” (emphasis added)); *see also Boston Sci. Scimed, Inc. v. Cook Grp. Inc.*, 809 F. App’x 984, 990 (Fed. Cir. 2020) (nonprecedential) (stating that the “Board need not address issues that are not necessary to the resolution of the proceeding,” such as “alternative arguments with respect to claims [the Board] found unpatentable on other grounds”).

III. MOTION TO EXCLUDE EVIDENCE

Patent Owner moves to exclude certain of Petitioner's evidence. Paper 42. Petitioner opposes and Patent Owner replies to the opposition. Papers 44, 46. Specifically, Patent Owner moves to exclude Exhibits 1050 through 1056. Because we do not rely on these exhibits or the arguments for which the Exhibits were entered in this Final Written Decision, we dismiss Patent Owner's motion as moot.

IV. CONCLUSION

After considering all the evidence and arguments presently before us, we determine Petitioner has proven, by a preponderance of the evidence, that all of the Challenged Claims are unpatentable.²¹

²¹ Should Patent Owner wish to pursue amendment of the Challenged Claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner's attention to the April 2019 Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding, 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. *See* 37 C.F.R. §§ 42.8(a)(3), (b)(2).

Claims	35 U.S.C. §	Reference(s)/ Basis	Claims Shown Unpatentable	Claims Not Shown Unpatentable
1, 2, 5–15, 18, 21, 23, 25, 27–29, 31	103(a)	Schray, Miura	1, 2, 5–15, 18, 21, 23, 25, 27–29, 31	
1, 2, 5–15, 18, 20–21, 23, 25, 27– 29, 31	103(a)	Rubbert, Yuushiro, Bosch	1, 2, 5–15, 18, 20–21, 23, 25, 27–29, 31	
1, 2, 5–15, 18, 20–21, 23, 25, 27– 29, 31	103(a)	Ohtani, Zhao ²²		
Overall Outcome			1, 2, 5–15, 18, 20–21, 23, 25, 27–29, 31	

V. ORDER

In consideration of the foregoing, it is hereby

ORDERED that claims 1, 2, 5–15, 18, 20–21, 23, 25, 27–29, 31 of U.S. Patent No. 10,619,580 B2 are determined to be unpatentable; and

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.

²² We do not reach Ground 3, which alleges that claims 1, 2, 5–15, 18, 20–21, 23, 25, 27–29, and 31 are unpatentable under 35 U.S.C § 103(a) over Ohtani and Zhao.

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Patent 10,619,580 B2

FOR PETITIONER:

Christopher Douglas
Michael Connor
Lauren Burrow
ALSTON & BIRD LLP
christopher.douglas@alston.com
mike.connor@alston.com
lauren.burrow@alston.com

FOR PATENT OWNER:

Lawrence Cogswell
Keith Wood
HAMILTON, BROOK, SMITH, & REYNOLDS, P.C.
lawrence.cogswell@hbsr.com
keith.wood@hbsr.com