

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

FORD MOTOR COMPANY,
Petitioner,

v.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Patent Owner.

IPR2019-01399
Patent 9,810,166 B2

Before KEN B. BARRETT, LYNNE H. BROWNE, and
JAMES J. MAYBERRY, *Administrative Patent Judges*.

BARRETT, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)
ORDER
Dismissing Patent Owner's Motion to Exclude
37 C.F.R. § 42.64

I. INTRODUCTION

A. *Background and Summary*

Ford Motor Company (“Petitioner”)¹ filed a Petition requesting *inter partes* review of U.S. Patent No. 9,810,166 B2 (“the ’166 patent,” Ex. 1001). Paper 2 (“Pet.”). The Petition challenges the patentability of claims 1–5, 7, 8, 10–24, and 26–30 of the ’166 patent. Massachusetts Institute of Technology (“Patent Owner”)² filed a Response to the Petition. Paper 18 (“PO Resp.”). Petitioner filed a Reply (Paper 22, “Pet. Reply”) and Patent Owner filed a Sur-reply (Paper 28, “PO Sur-reply”).

Additionally, Patent Owner filed a Motion to Exclude Evidence (Paper 29), to which Petitioner filed an Opposition (Paper 30), and Patent Owner filed a Reply (Paper 33).

An oral hearing was held on November 19, 2020, and a transcript of the hearing is included in the record. Paper 36 (“Tr.”).

This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a). For the reasons discussed below, we determine that Petitioner has shown by a preponderance of the evidence that claims 1–5, 7, 8, 10–24, and 26–30 of the ’166 patent are unpatentable. We also *dismiss* Patent Owner’s Motion to Exclude.

B. *Related Proceedings*

One or both parties identify, as matters involving or related to the ’166 patent, *Ethanol Boosting Systems, LLC v. Ford Motor Company*,

¹ Petitioner identifies Ford Motor Company as the real party-in-interest. Pet. 79.

² Patent Owner identifies “Massachusetts Institute of Technology, the Patent Owner, and Ethanol Boosting Systems, LLC, the Exclusive Licensee,” as real parties-in-interest. Paper 8, 2.

Civil Action No. 1:19-cv-00196-CFC-SRF (D. Del.), *aff'd*, 831 F. App'x 505 (Fed. Cir. 2020) (rule 36 affirmance), *Ethanol Boosting Systems, LLC v. Ford Motor Company*, Civil Action No. 1:20-cv-00706-CFC (D. Del.), and Patent Trial and Appeal Board case IPR2020-00010. Pet. 79–81; Paper 6, 2–6. The parties also identify, as involving challenges to related patents, IPR2019-01400 and IPR2020-00013 (US 8,069,839), IPR2019-01401 and IPR2020-00011 (US 9,255,519), and IPR2019-01402 and IPR2020-00012 (US 10,138,826). Pet. 79; Paper 24, 2–3.

C. The '166 Patent

The '166 patent, titled “Fuel Management System for Variable Ethanol Octane Enhancement of Gasoline Engines,” issued November 7, 2017, from an application filed March 20, 2017, and ultimately claims priority to an application filed November 18, 2004. Ex. 1001, codes (54), (45), (22), (63). The '166 patent is directed “to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.” *Id.* at 1:35–38. Figure 1 of the '166 patent is reproduced below.

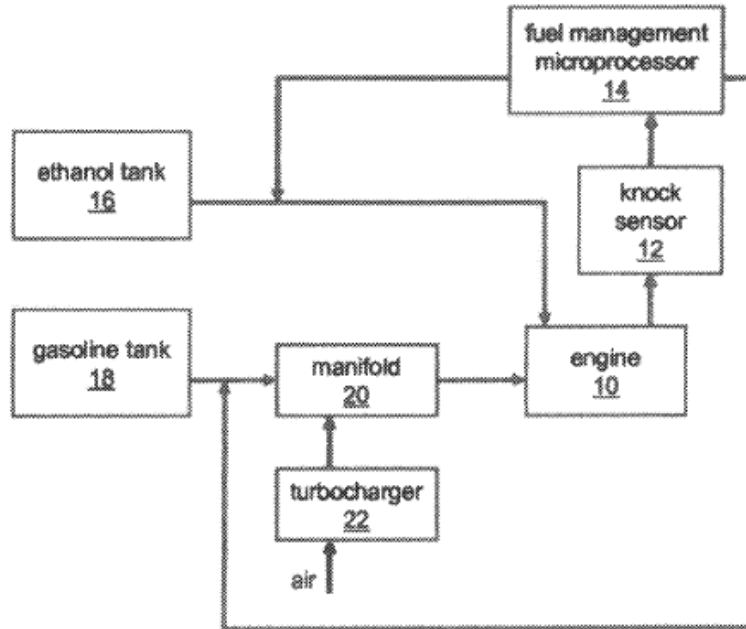


FIG. 1

Figure 1 depicts “a block diagram of one embodiment of the invention disclosed” in the ’166 patent. *Id.* at 3:3–4. Spark ignition gasoline engine 10 includes knock sensor 12, fuel management microprocessor system 14, engine manifold 20, and turbocharger 22. *Id.* at 3:20–28. Ethanol tank 16 contains an anti-knock agent, such as ethanol, and gasoline tank 18 contains the primary fuel, such as gasoline. *Id.* at 3:22–27. Fuel management microprocessor system 14 controls the direct injection of the anti-knock agent into engine 10 and the injection of gasoline into engine manifold 20. *Id.* “The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor 12 as an input to the fuel management [] microprocessor 14.” *Id.* at 3:28–34. The fuel management system minimizes the amount of ethanol directly injected into the cylinder while still preventing engine knock. *Id.* at 3:34–36.

“Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. . . . Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into [] the engine 10,” which “further increases knock resistance.” *Id.* at 3:41–49. The amount of octane enhancement needed from the ethanol to prevent knocking is a function of the torque level. *Id.* at 6:4–15. In the embodiment of Figure 1, “port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.” *Id.* at 3:49–54.

D. Illustrative Claims

Of the challenged claims of the '166 patent, claims 1, 19, and 22 are independent claims. The remaining challenged claims depend directly or indirectly from one of those independent claims. Independent claim 1, 19, and 22, reproduced below, are illustrative.

1. A fuel management system for a spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;
and where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque range
and where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knock-free operation is minimized.

19. A fuel management system for a turbocharged spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;
and where there is a first range of torque throughout which direct injection and port injection are used at the same value of torque;
and wherein as torque is increased the fraction of fuel that is directly injected is increased to a value that prevents knock;
and where there is a second range of torque where only port fuel injection is used;
and where when torque exceeds the highest torque in the second range of torque the engine operates in the first range of torque.
22. A spark ignition engine where port fuel injection and direct injection are used and the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur; and where spark retard is employed to enable reduction of the amount of direct injection that would otherwise be employed.

Ex. 1001, 7:38–48, 8:42–55, 62–67.

E. Evidence

Petitioner relies on the following references:

Reference		Dates	Exhibit No.
Kobayashi	US 7,188,607 B2	Filed June 27, 2003; Issued March 13, 2007	1005
Yuushiro	JP H10-252512	Filed March 13, 1997; Published Sept. 22, 1998	1006
Rubbert	DE 198 53 799 A1	Filed Nov. 21, 1998; Published May 25, 2000	1007

Reference		Dates	Exhibit No.
Kinjiro	JP 2002-227697	Filed Jan. 31, 2001; Published Aug. 14, 2002	1008
Bosch Automotive Handbook (Robert Bosch GmbH, 3rd ed. 1993) (“Bosch”)			1031

Petitioner also relies on the Declaration of Dr. Nigel N. Clark (Ex. 1003) in support of its arguments and Patent Owner relies on the Declaration of Neil E. Hannemann (Ex. 2002) in support of its arguments. The parties rely on other exhibits as discussed below.

F. Asserted Grounds of Unpatentability

Petitioner asserts that the challenged claims are unpatentable on the following grounds:

Claim(s) Challenged	35 U.S.C. §	Reference(s)/Basis
1–5, 7, 8, 10, 14–21	103(a)	Kobayashi, Yuushiro
1–5, 7, 8, 10–24, 26–30	103(a)	Rubbert, Yuushiro, Bosch
1–5, 7, 8, 10–24, 26–30	103(a)	Kinjiro, Bosch

II. ANALYSIS

A. Principles of Law

Petitioner bears the burden of persuasion to prove unpatentability of the claims challenged in the Petition, and that burden never shifts to Patent Owner. *Dynamic Drinkware, LLC v. Nat’l Graphics, Inc.*, 800 F.3d 1375, 1378 (Fed. Cir. 2015). To prevail, Petitioner must establish by a preponderance of the evidence that the challenged claims are unpatentable. 35 U.S.C. § 316(e) (2018); 37 C.F.R. § 42.1(d) (2019).

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 or non-obviousness.³ *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966).

B. The Level of Ordinary Skill in the Art

In determining the level of ordinary skill in the art, various factors may be considered, including the “type of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field.” *In re GPAC Inc.*, 57 F.3d 1573, 1579 (Fed. Cir. 1995) (internal quotation marks and citation omitted).

Petitioner’s declarant, Dr. Clark, opines that:

the person of ordinary skill in the field of the ’166 Patent would be expected to have at least a bachelor’s degree in engineering and at least five years of experience in the field of internal combustion engine design and controls. Individuals with different education and additional experience could still be of ordinary skill in the art if that additional experience compensates for a deficit in their education and experience stated above.

Ex. 1003 ¶ 10; *see* Pet. 9.

³ The parties have not directed our attention to any objective evidence of obviousness or non-obviousness.

Patent Owner does not dispute this characterization of the level of ordinary skill in the art. Patent Owner's declarant, Mr. Hannemann, opines that:

The relevant art is the general area of internal combustion engine design and controls. The person of ordinary skill in the art is a person with a bachelor's degree in mechanical engineering, or a related field, and at least five years of experience in the field of internal combustion engine design and controls. Individuals with different education and additional experience could still be of ordinary skill in the art if that additional experience compensates for a deficit in their education and experience stated above.

Ex. 2002 ¶ 40.

We find that Mr. Hannemann's definition of the level of ordinary skill in the art is substantially the same as Dr. Clark's characterization. We accept and adopt the parties' characterization of the level of ordinary skill in the art, which we find is consistent with the level of skill reflected in the '166 patent and the prior art of record. *Cf. Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001) (recognizing that the prior art itself may reflect an appropriate level of skill in the art).

C. Claim Construction

In an *inter partes* review requested in a petition filed on or after November 13, 2018, we apply the same claim construction standard used in district courts, namely that articulated in *Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005) (en banc). *See* 37 C.F.R. § 42.100(b) (2019).

In applying that standard, claim terms generally are given their ordinary and customary meaning as would have been understood by a person of ordinary skill in the art at the time of the invention and in the context of the entire patent disclosure. *Phillips*, 415 F.3d at 1312–13. “In determining

the meaning of the disputed claim limitation, we look principally to the intrinsic evidence of record, examining the claim language itself, the written description, and the prosecution history, if in evidence.” *DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 469 F.3d 1005, 1014 (Fed. Cir. 2006) (citing *Phillips*, 415 F.3d at 1312–17).

In parallel litigation in U.S. District Court for the District of Delaware, the District Court conducted a claim construction hearing on January 8, 2020. Ex. 1040, 1. The District Court issued a Claim Construction Order in which the Court construed certain terms disputed in that litigation. Ex. 1041. The Court’s reasoning is set forth in the transcript of the claim construction hearing. *Id.* at 1, *see* Ex. 1040. In the Order, the Court also identified and adopted the litigants’ agreed-upon constructions of certain terms. Ex. 1041, 3–4.

As a result of the District Court’s claim construction Order, the parties stipulated to non-infringement of the asserted claims of the ’166 patent, and Patent Owner appealed to the United States Court of Appeals for the Federal Circuit. *See* Pet. Reply 9–10; PO Resp. 30–31. The Federal Circuit affirmed the District Court’s decision. Ex. 1052 (Rule 36 affirmance). We have considered the District Court’s constructions in reaching a determination in this *inter partes* review. *See* 37 C.F.R. § 42.100(b) (providing that “[a]ny prior claim construction determination concerning a term of the claim in a civil action . . . that is timely made of record in the inter partes review proceeding will be considered”). The parties both assert, and we agree, that the District Court’s construction of the “fuel” terms, which apparently was the subject of the dispute in that forum, is not

implicated by the parties' disputes in this *inter partes* review.⁴ See Pet. Reply 9–10; PO Resp. 30–31.

As will be evident from our analysis below, we determine that we need not expressly construe any claim term to resolve the parties' disputes in this proceeding. We do, however, address here Patent Owner's argument that the claims require that the result of knock-free operation be caused by evaporation.

“So as to obtain knock-free operation” and similar phrases

Each of the challenged independent claims contains a recitation regarding the relationship of the amount of directly injected fuel to the prevention of knock. Independent claim 1, for example, recites that “the amount of fuel that is directly injected is changed so as to obtain knock-free operation.” Ex. 1001, 7:45–46; *see also id.* at 8:48–50 (claim 19: “the fraction of fuel that is directly injected is increased to a value that prevents knock”); 8:63–65 (claim 22: “the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur”).

Patent Owner argues that “[t]hese phrases . . . require, at a minimum, that the injection of the directly injected fuel *results in* obtaining knock-free operation (Claim 1), or *results in* preventing knock (Claims 19 and 22), as a *physical effect caused by the evaporation* of the directly injected fuel.” PO Resp. 23 (emphasis in original) (citing Ex. 2002 ¶ 88). In support, Patent Owner contends, “[t]hat follows from the plain language of those claim

⁴ The District Court construed “directly injected fuel” and similar phrases as “a fuel that contains an anti-knock agent that is not gasoline, and that is different from the fuel used for port injection/in the second fueling system.” Ex. 1041, 1.

phrases . . . as well as the description in the specification of the '166 Patent,” *id.* at 23–24, and “[t]hose requirements are common sense requirements in view of the specification,” PO Sur-reply 10.

Petitioner, in response, argues that Patent Owner’s proposed constructions would require the importation of requirements “that find no support in the '166 Patent.” Pet. Reply 5–6. According to Petitioner, the claims do not require that proposed by Patent Owner and, “instead, they merely require [direct injection] and knock prevention,” and that no further construction of the phrases is necessary. *Id.* at 6 (footnote and citations omitted).

We are not persuaded by Patent Owner’s arguments. As for Patent Owner’s argument that the claims should be read to require evaporation as the mechanism of knock-reduction, we disagree that such a requirement “follows from the plain language of those claim phrases” or is a “common sense requirement[.]” *See* PO Resp. 23; PO Sur-reply 10. The “evaporation” term is not, as Patent Owner implies, in the language of the challenged claims of the '166 patent and we decline to read it in as a matter of “common sense.”

Patent Owner’s reliance on the Specification also is not persuasive. Patent Owner quotes from a paragraph that begins with: “In one aspect, the invention is a fuel management system . . . including a source of an antiknock agent such as ethanol.” Ex. 1001, 2:23–25; *see* PO Resp. 24 (citing Ex. 1001, 2:27–32). Patent Owner then quotes, in support of its position, the statement that “[e]thanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine.” PO Resp. 24 (quoting Ex. 1001, 2:30–32).

Patent Owner’s quotation substitute’s ellipses for the phrase, with emphasis added, indicating that “[a] *preferred* antiknock agent is ethanol.” *Compare id.* 24 with Ex. 1001, 2:25–32. We decline to read a preferred embodiment into the claims.

Additionally, we note that Patent Owner has obtained claims in another patent that explicitly recite vaporization as a mechanism of knock-reduction. *See, e.g.*, IPR2019-01401, Ex. 1001, 7:25–29 (U.S. Patent No. 9,255,519 B2, claim 1: “where the fuel management system controls fueling from a first fueling system that directly injects fuel into at least one cylinder as a liquid and *increases knock suppression by vaporization cooling*” (emphasis added)). This supports our determination that Patent Owner’s proposed requirement of a “physical effect caused by the evaporation” should not be read into the claims of the ’166, where the drafter omitted such language.

We further address Patent Owner’s position as to the phrases “so as to obtain knock-free operation” and the like below in the context of Patent Owner’s arguments regarding the relied on prior art references.

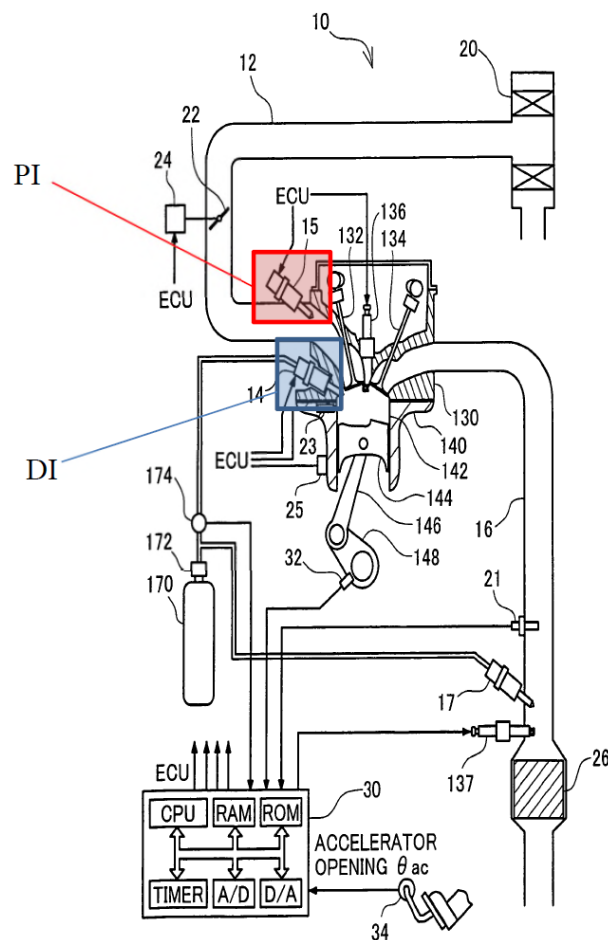
*D. The Alleged Obviousness of Claims 1–5, 7, 8, 10, and 14–21
Over Kobayashi and Yuushiro (Ground 1)*

Petitioner alleges that claims 1–5, 7, 8, 10, and 14–21 of the ’166 patent would have been obvious over Kobayashi and Yuushiro. *See* Pet. 11–24 (addressing claim 1). Patent Owner argues that a person of ordinary skill in the art would not have had a motivation to combine the references. Prelim. Resp. 37. For the reasons discussed below, we determine that Petitioner has not adequately explained why a person of ordinary skill in the art would have had a reason to modify Kobayashi by Yuushiro in the manner proposed by Petitioner.

1. *Kobayashi (Ex. 1005)*

Kobayashi “pertains to a technique of controlling auto ignition of the air-fuel mixture to take out power with a high efficiency, while effectively reducing emission of air pollutants through combustion.” Ex. 1005, 1:13–16. Petitioner’s annotated version of Kobayashi’s Figure 1 is reproduced below.

Fig.1



Pet. 12. Kobayashi's Figure 1 depicts "the structure of an engine . . . that adopts [Kobayashi's] premix compression ignition combustion system."

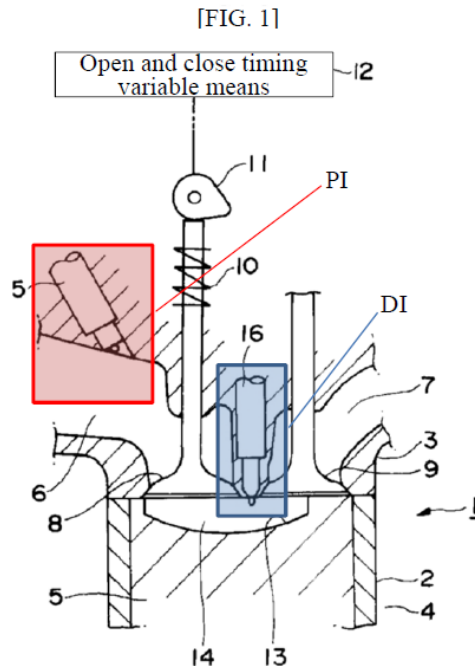
Ex. 1005, 7:39–41. Petitioner's annotations label the port injection ("PI") of gasoline (with the injector in red) and direct injection ("DI") of, for example,

hydrogen or ethanol (with the injector in blue). Engine 10 includes two fuel injection valves (valves 14, 15). *Id.* at 9:44–47. Gasoline is injected through valve 15 into intake conduit 12 and hydrogen gas is injected through valve 14 into the combustion chamber. *Id.* at 9:47–50. Kobayashi discloses that, in addition to hydrogen gas, liquid fuels with higher octane values than gasoline, such as methanol and ethanol, may be used. *Id.* at 9:58–63.

Engine control unit (ECU) 30 controls engine 10, including fuel injection valves 14, 15, and spark plug 136. *Id.* at 10:16–17, 27–29. ECU 30 also detects engine knocking using knocking sensor 25. *Id.* at 10:34–36. At low loads, the engine uses the air-fuel mixture injected by fuel injection valve 15, and which ignites via compression and combusts thereby forcing the piston downward and producing power. *Id.* at 13:39–14:3. Under the ECU’s control, when the engine is under a high load condition, hydrogen is injected into the cylinder to prevent knocking. *Id.* at 11:58–64, 12:7–12, 13:50–56. Kobayashi explains that, at high loading conditions, the air-fuel (gasoline) mixture is set to a high excess air ratio, which prevents knocking but also prevent auto-ignition of the mixture. *Id.* at 15:32–39. The hydrogen-air mixture is ignited by spark plug 136, which, in turn, results in combustion that raises the internal pressure in the cylinder thereby compressing the gasoline-air mixture and starting auto-ignition of that gasoline-air mixture. *Id.* at 16:16–27.

2. *Yuushiro (Ex. 1006)*

Yuushiro “relates to a compression ignition type internal combustion engine that compresses premixed gas at high pressure, and causes compression ignition.” Ex. 1006 ¶ 1. Petitioner’s annotated version of Yuushiro’s Figure 1 is reproduced below.



Pet. 14. Annotated Figure 1 depicts “a cross-section view . . . of [Yuushiro’s] compression ignition internal combustion engine,” and includes Petitioner’s labels “PI” (port injector,⁵ in red) and “DI” (direct injector, in blue). Ex. 1006, 10 (“Brief Description of the Drawings”); Pet. 14. Engine 1 includes cylinder 4 with cylinder head 3, intake port 6, combustion chamber 14, port injection valve 15, and in-cylinder injection valve 16. Ex. 1006 ¶¶ 21, 22, 25.

Yuushiro’s Figure 3 is reproduced below.

⁵ Yuushiro’s Figure 1 includes a reference number “5” for the port injection valve and for the piston. The port injection valve should be reference numeral “15.” See Ex. 1006 ¶¶ 21, 25.

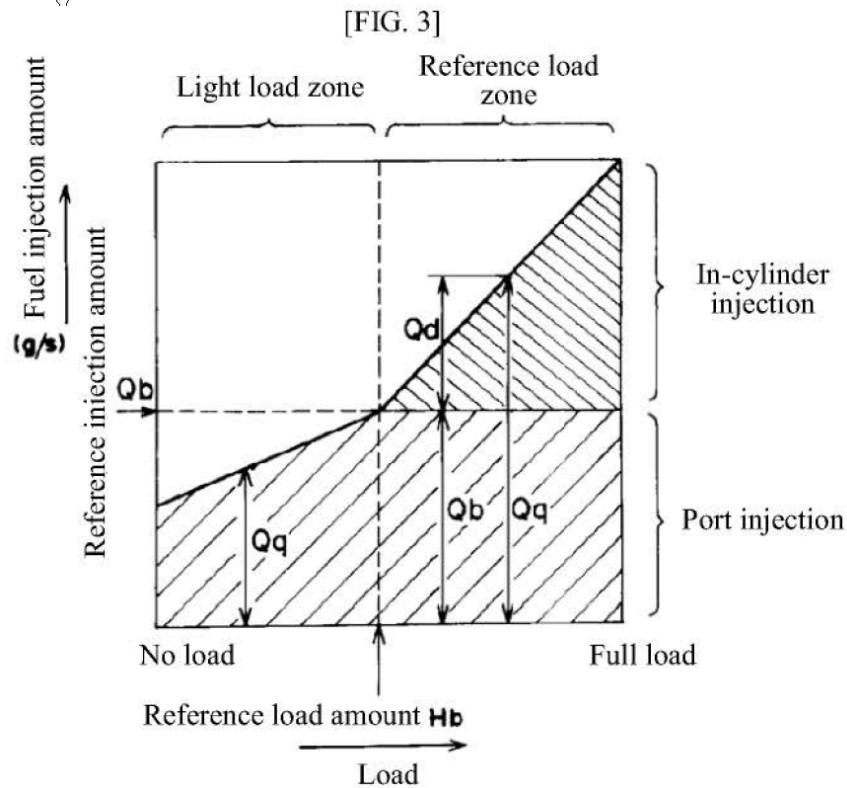


Figure 3 provides an exemplary fuel injection map. *Id.* at 10 (“Brief Description of the Drawings”). Yuushiro discloses that its system identifies a reference load amount (H_b), corresponding to a reference injection amount (Q_b), the maximum amount of fuel injected through port injection for which knocking does not occur. *Id.* ¶¶ 16, 38, 39. Loads that are equal to or less than H_b correspond to a light load zone and loads greater than H_b correspond to a high load zone. *Id.* ¶ 39. For loads in the light load zone, only port injection through valve 15 is used. *Id.* For loads in the high load zone, both port injection and direct injection are used. *Id.* As seen in Figure 3, in the high load zone, the amount of fuel directly injected into the cylinder through valve 16, Q_d , increases with increasing load, as the port injection amount, Q_b , remains the same, that is, at the maximum value for which knocking does not occur. *Id.* ¶ 39, Fig. 3; *see also id.* ¶¶ 41–50

(describing operations in the light load zone), ¶¶ 51–58 (describing operations in the high load zone).

3. Discussion

The challenged claims recite, in pertinent part, a fuel management system where both port fuel injection (PI) and direct fuel injection (DI) are used in the same torque range and where, along with increasing torque, the fraction of DI fuel is increased to a value that prevents knock. *See, e.g.*, Ex. 1001, 7:38–51, 8:42–55 (independent claims 1 and 19 and dependent claim 2). The increasing DI fuel is the subject of the parties’ dispute that we discuss here.

Petitioner asserts that “Kobayashi discloses an engine . . . that uses both PI and DI where the fuel quantity injected via the injection mechanisms is determined based on a fuel map.” Pet. 11 (citing Ex. 1005, 9:44–47, 12:14–21; Ex. 1003 ¶ 158). Petitioner further asserts that “Kobayashi uses PI fuel in both low and high loading conditions . . . [and] uses a second, spark-ignited DI fuel in high loading conditions to ignite the PI fuel and avoid knocking.” *Id.* at 13 (citing Ex. 1005, 9:44–50, 12:7–12, 15:65–16:27; Ex. 1003 ¶ 158).

Petitioner turns to Yuushiro, asserting that it discloses a fuel map where only PI fuel is used at a light load and both DI fuel and PI fuel are used at a higher load. *Id.* at 14. Petitioner’s proposed modification is the use of Yuushiro’s fuel map in Koboyashi’s engine. *See* Pet. Reply 11; Tr. 23:12–14 (“[T]he proposal that’s been advanced is that the person of skill in the art looking at Kobayashi would add the fuel map, look to the fuel map of the Yuushiro reference to fuel the engine.”). Petitioner argues that it would have been obvious to improve Koboyashi’s fuel map to include an increase in the DI fuel, and that Yuushiro discloses such a map. Pet.

Reply 13 (citing Ex. 1003 ¶¶ 158–166). According to Petitioner, Yuushiro “discloses DI fuel making a substantive contribution to engine torque under high loading conditions . . . [and] augments and improves the system of Kobayashi in that it supports a higher fuel to air ratio in the cylinder and allows for the amount of DI fuel to be increased as load is increased.” Pet. at 16 (citing Ex. 1003 ¶ 163).

We first consider Petitioner’s primary assertion of a motivation, which is as follows.

A POSITA [person of ordinary skill in the art] would have also understood that by relying on a lean air/fuel mixture, Kobayashi has a limit to its engine power output. Ex. 1003, ¶160. The POSITA would have looked to known techniques to increase engine power output, including increasing the ratio of fuel to air in the cylinder to be at or near a stoichiometric ratio. Ex. 1003, ¶¶160-61.

Pet. 15. Petitioner further argues that Kobayashi would be modified in accordance with Yuushiro’s teaching of the use of more DI fuel to provide “a substantive contribution to engine torque under high loading conditions.” *Id.* at 16. Thus, Petitioner argues that Kobayashi is underpowered due to the use of lean mixture, and that one of ordinary skill in the art would have been motivated to increase the DI fuel to generate more power, i.e. to provide a substantive contribution to torque, and to modify the air-fuel ratio to be stoichiometric. *Cf. id.* (“Yuushiro augments and improves the system of Kobayashi in that it supports a higher fuel to air ratio in the cylinder and allows for the amount of DI fuel to be increased as load is increased.”).

In opposition, Patent Owner, focusing on the sharp differences between the references’ teachings, argues that a person of ordinary skill in the art would not have been motivated to modify Kobayashi in the manner

proposed by Petitioner. *See* PO Resp. 31–37. Patent Owner argues, for example, that,

if Kobayashi’s engine is operated, as Petitioner suggests, with additional directly injected fuel at high loads (from Yuushiro) it would . . . eliminate the lean burn operating principles that are fundamental to Kobayashi and necessary for its stated objective of using lean air fuel mixtures to significantly reduce the emission of the air pollutants from the engine.

Id. at 36 (citations omitted).

We find Petitioner’s reasoning lacks an adequate explanation that connects the contention that Kobayashi has limited power with the critical contention that one would have looked to and applied another reference that teaches, as discussed below, increasing power via the use of a different air-fuel ratio and a different use of the DI fuel. *Cf.* PO Resp. 35 (Patent Owner arguing that Petitioner is incorrect in asserting that one would turn to Yuushiro’s fuel map because Kobayashi’s engine operation is too lean.). The Petition does not, for example, contain an explicit assertion that a person of ordinary skill in the art would view Kobayashi’s level of power production to be a problem in need of a solution. *See* Pet. 15. Similarly, Dr. Clark’s cited testimony, jumps from the assertion that Kobayashi has a limit on its power to the assertion that “[a]s a result, the person of ordinary skill in the art would have looked to known techniques to increase the power output of the engine.” Ex. 1003 ¶ 160 (emphasis added). Dr. Clark does not elaborate on the assertion that a limit on power results, as implied, in one desiring to greatly increase the power output of Kobayashi’s engine. *See id.* ¶¶ 160–161. Because of this lack in further support for this testimony, we give Dr. Clark’s opinion on this point little weight. *See* 37 C.F.R. 42.65(a)

(“Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.”).

Kobayashi’s engine utilizes an atypical combustion process and reflects a carefully balanced design having the advantages of high fuel efficiency, reduced emissions, and avoidance of knock. *See* Ex. 1005, 1:13–16, 11:53–64 (“[T]he engine adopting the premix compression ignition combustion system has the advantages of the less emission of the air pollutants and the less fuel consumption.”). Kobayashi explains the problem addressed as follows.

For protection of the global environment, reducing the emission of air pollutants from the internal combustion engine is highly demanded. Another strong demand is further reduction of the fuel consumption, in order to lower the emission of carbon dioxide as a cause of global warming and reduce the driving cost of the internal combustion engine.

Id. at 1:27–32. Kobayashi addresses these concerns by using a compression ignited port injected fuel (*e.g.*, gasoline) and air mixture containing an excess amount of air beyond that necessary to support combustion, *i.e.* a lean fuel mixture. *See, e.g., id.* at 23:5–9. Kobayashi explains that such a mixture avoids knock but does not self-ignite via compression when the engine is operated at high loads. *See id.* at 18:1–9. Kobayashi, therefore, at high loads, directly injects a relatively small amount of hydrogen or other high octane value fuel, the spark ignition of which creates a pressure spike in the cylinder thereby compressing and igniting the PI fuel mixture. *Id.* at 18:9–14, 32–34 (“The engine 10 of the embodiment ignites the hydrogen-air mixture to trigger auto ignition of the gasoline-air mixture under the high loading conditions.”); 20:15–32 (explaining that only a small quantity of hydrogen or the like is required). Thus, Kobayashi utilizes two

air-fuel mixtures and two successive combustions, with the latter producing the power to drive the engine. *See id.* at 2:35–65; Tr. 24:1–9.

Yuushiro, in contrast, mixes, in the high load range, a relatively greater amount of DI fuel with a PI fuel and ignites the mixture of DI fuel, PI fuel, and air by compression, thereby powering the engine. *See* Ex. 1006 ¶¶ 52–53 (“[F]uel injected in-cylinder [the DI fuel] is mixed with the premixed gas [the PI fuel] to become a combustible air-fuel ratio.”); *see, e.g.,* Ex. 2002 ¶ 107 (Mr. Hannemann: “Yuushiro uses direct injection to increase the amount of fuel during high load conditions; but Kobayashi has a *limit on how much fuel can be compressed and ignited* without experiencing severe knocking and uses direct injection of a small amount of fuel to auto-ignite the lean air-fuel mixture.”). Petitioner proposes a modification using a greater amount of DI fuel for the purpose of powering the engine (as opposed to merely igniting the PI power mix) and using a stoichiometric mix—where the air and fuel are balanced such that there is no excess air. *See* Pet. 15; *see also id.* at 16 (Petitioner relying on Yuushiro for the teachings of “DI fuel making a substantive contribution to engine torque under high loading conditions” and “support[ing] a higher fuel to air ratio in the cylinder and allow[ing] for the amount of DI fuel to be increased as load is increased.”); Ex. 1001, 4:2–3 (“stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel”).

Again, Kobayashi utilizes a very particular fueling and combustion scheme with the goal of creating a fuel efficient and low-emissions engine. As discussed above, Petitioner proposes jettisoning Kobayashi’s system utilizing two successive combustions of two air-fuel mixes where the DI fuel

is not used for power production and where a lean power producing mix—the air and PI fuel mix—is used, and replacing that with a power producing stoichiometric mix of DI fuel, PI fuel, and air, and where significantly more DI fuel is used. It may be true and not surprising that a person of ordinary skill in the art would have recognized that achieving Kobayashi’s low fuel consumption and low emissions goals yields an engine that could have more power, just like it would not be surprising to learn that an economy car does not have the acceleration of a sports car. However, it is not facially evident, and Petitioner does not explain adequately, why lower power in the fuel efficient, emissions-friendly engine of Kobayashi would have provided a reason for a person of ordinary skill in the art to perform the major design modifications required by Petitioner’s proposed modification. Accordingly, we do not find to be persuasive Petitioner’s reasoning to combine the references’ teachings based on Kobayashi’s lower power output.

Under the “Motivation to Combine” heading and after proposing to modify Kobayashi to utilize a stoichiometric air-fuel ratio, Petitioner makes the statement, “[o]perating at or near a stoichiometric ratio would enable conventional three-way catalysts and support emissions reduction.” Pet. 15 (citing Ex. 1025, 655; Ex. 1039, 3; Ex. 1003 ¶¶ 161–162). To the extent that Petitioner contends that emissions reduction through catalysis provides a reason to modify Kobayashi, we do not find this persuasive because Petitioner does not explain adequately why that would be so, particularly where, as unmodified, Kobayashi already utilizes the lean air-fuel mix to reduce emissions. *See* Ex. 1005, 23:5–9 (“The premix compression ignition combustion system combusts the air-fuel mixture having a large excess air ratio and thus significantly reduces the emission of air pollutants, such as

carbon monoxide and hydrocarbons, according to the mechanism discussed below.”). To the extent that Petitioner contends that catalysis-facilitated emissions reduction in the modification solves a problem, it appears that the problem is created by Petitioner’s proposed modification of the air-fuel ratio.

Petitioner also argues that a person of ordinary skill in the art “would have been further motivated to look to Yuushiro given the similarities in design between Kobayashi and Yuushiro.” Pet. 16–17 (citing Ex. 1003 ¶¶ 163–165). For the reasons discussed above, we do not find that Kobayashi and Yuushiro are as similar in design as Petitioner suggests, and therefore are not persuaded that “similarities in design” provide a “further motivation,” as Petitioner argues. *Accord* PO Resp. 31–36. We also note that, in the same paragraph directed to purported similarities, Petitioner highlights the important *differences* in the amounts of DI fuel and the uses thereof. *See* Pet. 16–17 (“While Kobayashi employs minimal fuel solely for knock management, Yuushiro improves Kobayashi, as it uses additional DI fuel that manages knock and provides for additional knock free torque production by the engine.”); *see also id.* at 17 (highlighting, in the very next paragraph, another important difference: “Whereas Yuushiro uses DI fuel that autoignites and ignites the PI fuel, Kobayashi uses a spark-ignited DI fuel that resists autoignition.”).

Petitioner’s arguments as to why a person of ordinary skill in the art purportedly would modify Kobayashi in light of Yuushiro apply to both of the independent claims that are the subject of this ground, claims 1 and 19. *See* Pet. 15–24, 33–34. Petitioner’s arguments for the dependent claims do not cure the underlying deficiencies in the challenges to the independent claims. *See id.* at 24–32, 34. For the reasons set forth above, we determine

that Petitioner has not demonstrated by a preponderance of the evidence that claims 1–5, 7, 8, 10, and 14–21 of the ’166 patent would have been obvious over Kobayashi and Yuushiro.

*E. The Alleged Obviousness of Claims 1–5, 7, 8, 10–24, and 26–30
Over Rubbert, Yuushiro, and Bosch (Ground 2)*

Petitioner alleges that claims 1–5, 7, 8, 10–24, and 26–30 of the ’166 patent would have been obvious over Rubbert, Yuushiro, and Bosch. *See* Pet. 34–42 (addressing claim 1). Patent Owner argues that a person of ordinary skill in the art would not have had a motivation to combine the references’ teachings and that the combination fails to teach certain recitations of the challenged claims. *See, e.g.*, PO Resp. 50–56. For the reasons given below, we determine that Petitioner has demonstrated that claims 1–5, 7, 8, 10–24, and 26–30 would have been obvious over Rubbert, Yuushiro, and Bosch.

1. Rubbert (Ex. 1007)

Rubbert “relates to a method for mixture formation in a mixture-compressing, external-ignition internal combustion engine with fuel injection.” Ex. 1007, 2, col. 1. Rubbert discloses a combination of induction pipe injection (that is, port injection) and direct injection of fuel.

Id. Rubbert describes that

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. The directly injected fuel in this load range results in an ignitable mixture near the spark plug and allows reliable ignition of the lean mixture in the entire combustion chamber.

In contrast, the fuel portion in the mixture can be mostly or completely injected by direct injection in the full-load range of the internal combustion engine, which means that the

advantages of direct injection with respect to cylinder filling and knock limit can be fully utilized.

Id. at 2, col. 1–col. 2.

2. *Bosch (Ex. 1031)*

Bosch is titled “Automotive Handbook.” Ex. 1031, 1–3. As seen in its table of contents, the Handbook covers a wide array of subjects directed to automotive engineering. *See id.* at 4–5. Exhibit 1031 includes excerpts from the handbook, covering sensors (pp. 102–15⁶), mathematics (pp. 136–42), quality (pp. 144–49), engineering statistics (pp. 150–57), reliability (pg. 158–59), data processing in motor vehicles (pp. 160–63), control engineering (pp. 164–67), internal-combustion engines (pp. 352–411), engine cooling (pp. 412–15), air filters (pp. 416–17), charging systems (pp. 418–23), exhaust systems (pp. 424–27), engine management (pp. 428–77), and exhaust emissions (pp. 478–89).

3. *The Alleged Obviousness of Independent Claim 1 Over Rubbert, Yuushiro, and Bosch*

As discussed below, Petitioner relies on Rubbert for the teachings of a spark ignition engine that utilizes a fuel map and both direct injection and port injection, relies on Yuushiro for the teachings of the specifics of a fuel map for DI and PI injection, and relies on Bosch for certain aspects characterized by Petitioner as “well-known in fuel management systems.” *See* Pet. 34–35.

⁶ For the specific technical topics, we, in this decision, refer to the page numbers of the underlying document rather than the pagination of the exhibit.

- a. “A fuel management system for a spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection”*

Petitioner contends that, “[t]o the extent the preamble of Claim 1 is limiting, Rubbert discloses a spark ignited engine relying on a ‘combination of a port injection with a direct injection through respective, load-dependent controlled / regulated partial injection quantities.’” Pet. 38 (citing Ex. 1007, 2, col. 1; Ex. 1003 ¶ 293).⁷ Patent Owner does not contest these assertions. Regardless as to whether this recitation is a preamble or is limiting, we find, based on the evidence cited by Petitioner, that it is disclosed in the asserted prior art.

- b. and where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque range*

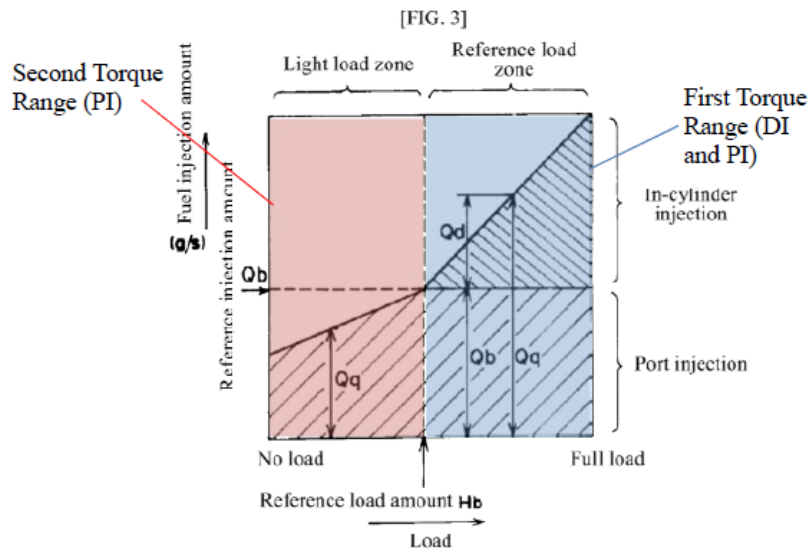
Claim 1 also recites, “where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque range.” Ex. 1001, 7:41–43 (the “torque range” recitation of claim 1). Petitioner, relying on the testimony of Dr. Clark and asserting that “torque range” never appears in the Specification of the ’166, argues persuasively that engine load is a proxy for “torque.” See Pet. 4–5 (citing, *inter alia*, Ex. 1003 ¶ 142); see also Ex. 1036, 2 (Patent Owner, stating in the District Court, that “[k]nock is a significant issue at moderate-to-high loads (also known as torques).”); Ex. 1003 ¶ 142 (“[A] person of

⁷ Petitioner characterizes this first recitation of claim 1 as the preamble. Pet. 18, 38. Petitioner notes that claim 1 does not have a traditional transitional phrase that separates a preamble from the main body of the claim. See *id.* at 18 n.7; see also Ex. 1001, 7:38–48.

ordinary skill in the art would have understood that a ‘torque range’ is a range of values representative of engine load.”).

Petitioner contends that Rubbert discloses an engine using different proportions of DI and PI fuel in two load (and, thus, torque) ranges, a part (low) load range and a full load range. Pet. 39. Petitioner also contends that “Yuushiro discloses and provides additional implementation details with respect to a first torque range where both DI and PI are used,” and that “Yuushiro relies on a calculated load to determine whether to use PI alone or the combination of PI and DI.” *Id.* at 40 (citing Ex. 1006 ¶ 39; Ex. 1003 ¶ 300).

Petitioner further asserts that, when the load is greater than the reference load (i.e. in the reference load zone), Yuushiro relies on both PI and DI at any torque value to provide the necessary fuel. *See id.* at 21 (citing Ex. 1006 ¶ 39; Ex. 1003 ¶ 181); *id.* at 40 (citing Ex. 1003 ¶ 301). Petitioner provides an annotated version of Yuushiro’s Figure 3 in support of its position, which we reproduce below.



Pet. 40. The annotated figure labels the “First Torque Range” as the reference load zone (in blue) and the “Second Torque Range” as the light load zone (in red). *See id.*

Patent Owner does not contest these assertions. We find, based on the evidence cited by Petitioner, that the combined teachings of Rubbert and Yuushiro disclose the subject matter of the “torque range” recitation of claim 1. We address Petitioner’s reasons to combine the references’ teachings below.

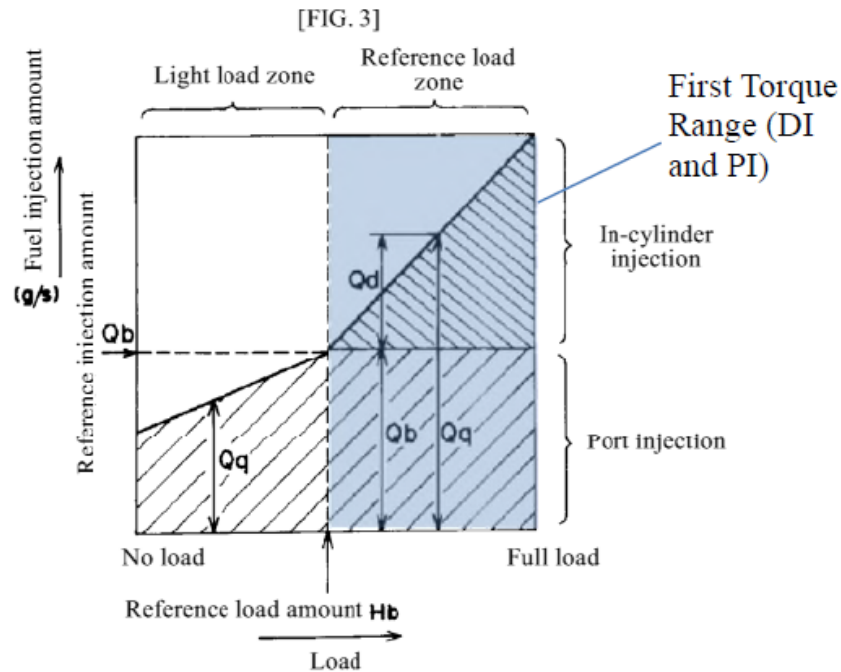
c. and where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knock-free operation is minimized.

Lastly, independent claim 1 recites: “where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knock-free operation is minimized.” Ex. 1001, 7:44–48.

Petitioner contends that Rubbert teaches a changing DI-to-PI fuel ratio in high load conditions, and that a person of ordinary skill in the art “would rely on the disclosure of Yuushiro that demonstrates that as load increases in the reference load zone, the quantity of DI fuel likewise increases.” Pet. 41 (citing Ex. 1003 ¶ 303). Petitioner argues that a person of ordinary skill in the art would have implemented Yuushiro’s fuel map with Rubbert’s engine. *See id.* at 35–36. According to Petitioner, applying Yuushiro’s fuel map teachings results in knock-free operation. *See id.* at 41; *see also id.* at 24.

Petitioner asserts that Yuushiro’s Figure 3 shows “that as load increases in the reference load zone [which Petitioner identifies as the first

torque range], the quantity of DI fuel (Q_d) increases.” *Id.* at 23 (citing Ex. 1003 ¶¶ 185–186); *see id.* at 41 (citing Ex. 1003 ¶¶ 304–305, and referring to its arguments made in the context of the first ground). Petitioner provides another annotated version of Yuushiro’s Figure 3 in support of its position, which we reproduce below.



Id. at 23. This annotated version of Yuushiro’s Figure 3 shows the fuel map, with the first torque range identified and colored in blue. Yuushiro’s figure shows that the amount of direct injected fuel (Q_d) increases with increasing load in what Petitioner maps to the recited first torque range, namely the zone between the reference load amount (H_b) and the full load amount. *See* Ex. 1006 ¶¶ 51–55 (describing operations in the high load zone).

Petitioner contends that:

In the reference load zone, the minimum amount of fuel is directly injected because 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 $Q_d = Q_q - Q_b$, where Q_d is the DI fuel

injected, Q_q is the total fuel injected, and Q_b is the reference load injection.

Id. at 24 (citing Ex. 1006 ¶ 39; Ex. 1003 ¶ 187).

Petitioner also contends that, “[l]ike Yuushiro, Bosch confirms that it was well-known not only to rely on fuel maps but also on knock detectors to detect knock and actuate a system to eliminate knock (e.g., the DI system of Rubbert and Yuushiro).” *Id.* at 42 (citing Ex. 1031, 465; Ex. 1003 ¶ 310).

Patent Owner argues that none of the relied on references or their combination teaches or suggests changing the amount of directly injected (DI) fuel “so as to obtain knock-free operation” or that “the amount of directly injected fuel used to provide knock-free operation is minimized” as recited in independent claim 1. PO Resp. 55–56; *see id.* at 54 (arguing that Yuushiro does not teach the “so as to obtain knock-free operation” recitation for the reasons addressed in the context of the first ground).

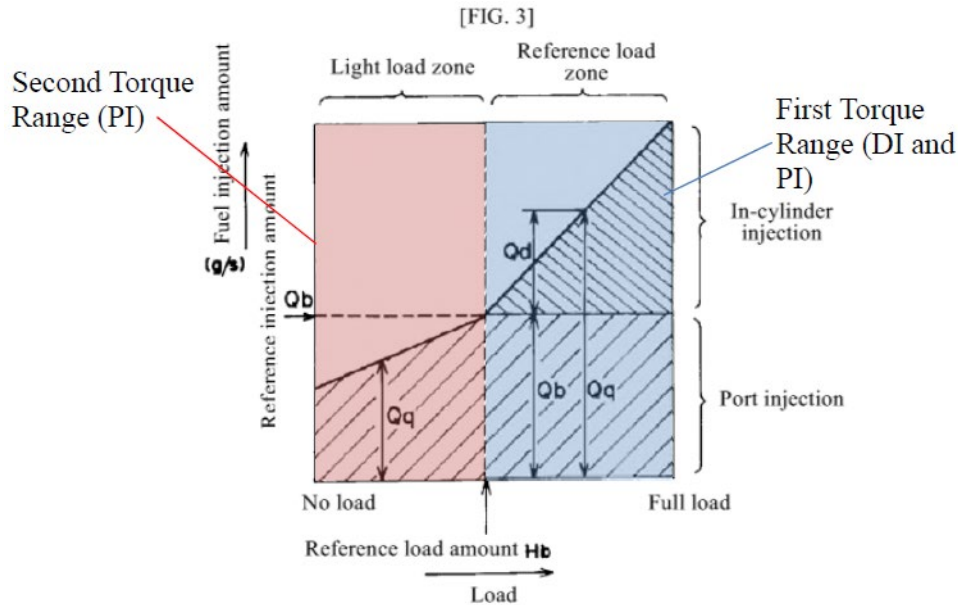
Patent Owner first reiterates its position that the claims require the resulting knock-free operation to be caused directly by evaporation. *Id.* at 40, 44–45. For the reasons discussed above in the claim construction section, we decline to read in to the claim an evaporation mechanism limitation.

Patent Owner also argues that Yuushiro limits the amount of *port* fuel injection to prevent knock, such that the amount of fuel directly injected does not prevent knock. PO Resp. 42–43. Building on that argument, Patent Owner argues that, because Yuushiro’s DI fuel does not prevent knock, it also cannot be minimized for knock-free operation. *See id.* at 46. Petitioner replies that “Yuushiro limits the [direct injection] fuel amount (Q_d) to the fuel amount needed to power the engine without knocking.” Pet. Reply 14. Petitioner explains that “Yuushiro’s fuel map teaches only one

way to meet the load requirements in the reference load zone—increase the amount of DI *to prevent engine knock* such that the maximum amount of fuel that is port injected (Q_b) is maintained.” *Id.* In sur-reply, Patent Owner argues that knock cannot be prevented by direct injection fuel if it is already being prevented by Yuushiro’s limiting port injection. PO Sur-reply 18.

Patent Owner does not demonstrate a deficiency in Petitioner’s position. We find, on the complete record and as discussed below, that Petitioner has demonstrated by a preponderance of the evidence that the combination of Rubbert, Yuushiro, and Bosch discloses: 1) that, as torque is increased, the amount of directly injected fuel is changed so as to obtain knock-free operation, and 2) the amount of DI fuel used to provide knock-free operation is minimized. Patent Owner’s arguments ignore the simple fact that, in the reference load region (mapped to the first torque range), the required engine power must come from somewhere—either from port injected fuel, direct injected fuel, or a combination of both.

Yuushiro discloses using only port injection in the region from no load to the reference load amount, H_b . *See* Ex. 1006 ¶¶ 38–39, Fig. 3; Ex. 1003 ¶¶ 300, 304. If additional power is required above the reference load amount, the power requirement, Q_q , must be met by either port injection only, direct injection only, or a combination of port injection and direct injection, with this third option illustrated in Yuushiro’s Figure 3 (Petitioner’s annotated version of which is reproduced below).



Pet. 41. The annotated figure provides an exemplary fuel injection map with labels identifying a first torque range (colored in blue) and a second torque range (colored in pink). *See* Ex. 1006, 10. As illustrated, if the engine uses port injection alone to satisfy the load requirement in the reference load zone, then knocking would occur, because, in the reference load zone, Q_q is greater than Q_b , the maximum amount of port-injected fuel before knocking occurs. *See id.* ¶ 38; Ex. 1003 ¶ 301. So, to prevent knock as torque (load) increases from the reference load amount into the reference zone, port injection alone cannot be used.

Accordingly, because Yuushiro limits the amount of port-injected fuel to Q_b , the direct injection amount (Q_d) must satisfy the remaining fuel requirement ($Q_q - Q_b$). *See* Ex. 1003 ¶ 301. Also, with an increasing power requirement, Q_q , in the reference load zone, the amount of DI fuel represented by Q_d increases. That is to say, to meet increasing load requirements in the reference load zone, the fuel management system proportionally increases the amount of directly injected fuel so that the amount of fuel that is port injected is maintained at the maximum level (Q_b)

to prevent engine knock (again, knock is prevented by this direct injection fuel because, but for this direct injection fuel, the engine would need to rely on port injection to satisfy the load demand, and knocking would result). *See* Ex. 1003 ¶ 304. In this way, the amount of directly injected fuel prevents knocking while meeting the power requirements in the reference load zone. And, because port fuel injection at a level of PI fuel (Q_b) is maintained, then only the minimum amount of direct injection fuel necessary is used—the amount that makes of the difference between the total amount required (Q_q) and the amount of port injection fuel (Q_b) to satisfy the load demand. *Accord* Ex. 1006 ¶¶ 38–39, Fig. 3; Ex. 1003 ¶¶ 301, 304–305; Ex. 1050, 183:19–22 (Mr. Hannemann’s deposition: “Q. And is it your opinion that if Yuushiro added additional PI fuel above the line QB that the engine would knock? A. Yes.”); PO Sur-reply 19 (“Yuushiro must use its directly injected fuel to meet an *increasing* load while at the same time it must keep the port injected fuel amount *constant*.”). We credit Dr. Clark’s testimony as it is consistent with our understanding of Yuushiro.

d. Reasons to Combine Rubbert, Yuushiro, and Bosch

Petitioner contends that Rubbert discloses a spark ignition engine utilizing both port injection and direct injection with the injection quantities based on load, but does not disclose the actual quantity of DI fuel. Pet. 34–35 (citing Ex. 1007, 2, col. 1–2; Ex. 1003 ¶ 283). Petitioner asserts that a person of ordinary skill in the art would have known of many of the details that would be required to implement Rubbert’s invention including, for example, the fuel quantities based on defined fuel maps. *Id.* at 35 (citing Ex. 1003 ¶ 283). Petitioner relies on Yuushiro for the disclosure of the use of such fuel maps. *Id.* Petitioner contends that “[s]park retard, turbocharging, and closed loop control were well-known in fuel

management systems,” and relies on Bosch as support. *Id.* (citing Ex. 1031, 360, 372–74, 441, 464–65; Ex. 1003 ¶ 291).

Petitioner contends that, “[b]ecause Rubbert states its fuel injection strategy is based on load, a [person of ordinary skill in the art] would have been motivated to select a known fuel map [such as Yuushiro’s] that provided specific quantities of [port injection] and [direct injection] fuel based on load.” *Id.* at 35–36 (citing Ex. 1003 ¶ 284; Ex. 1006 ¶ 39). Petitioner asserts that 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,” and also “not only allows for the advantages of DI with respect to cylinder filling, but also enables the knock limit to be fully utilized.” *Id.* at 36 (emphasis omitted) (citing Ex. 1003 ¶¶ 286–87). Petitioner argues 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 ¶ 287). Petitioner adds that an artisan of ordinary skill “would have recognized that Yuushiro’s DI strategy could be applied to extend the DI fuel quantity of Rubbert.” *Id.* (citing Ex. 1003 ¶ 288).

Petitioner acknowledges that Rubbert discloses a spark ignition engine and, relying on the testimony of Dr. Clark, argues that a person of ordinary skill in the art would turn to Yuushiro even though it discloses a compression ignition engine. *Id.* (citing Ex. 1003 ¶ 288). Petitioner argues that this is so because “Rubbert and Yuushiro both seek to create an ignition source for the same purpose” and that a person of ordinary skill in the art “would have recognized that Yuushiro’s DI strategy could be applied to

extend the DI fuel quantity of Rubbert.” *Id.* (citing Ex. 1003 ¶ 288).

According to Petitioner, a person of ordinary skill in the art “would consider the implementation details of Yuushiro to be standard and would have understood they could likewise be implemented in Rubbert’s engine.” *Id.* at 36–37 (citing Ex. 1003 ¶ 288).

Petitioner also contends that Bosch is “a widely relied-upon reference” that discloses certain techniques and engine components that were “well-known in fuel management systems.” *Id.* at 35, 37; *see also* PO Resp. 14 (“Bosch is a general-purpose automotive handbook.”). Petitioner, relying on the testimony of Dr. Clark, persuasively reasons that a person of ordinary skill in the art “would have been motivated to reduce knock using well-understood methods [such as those taught by Bosch]” and “would have had a reasonable expectation of success and would have expected a predic[t]able result.” Pet. 37–38 (citing Ex. 1003 ¶¶ 289–291). Patent Owner does not contest Petitioner’s reasoning as to why a person of ordinary skill in the art would have combined Bosch’s teachings with that of Rubbert and Yuushiro.

Patent Owner focuses its opposition to Petitioner’s reasoning on the motivation to combine Rubbert and Yuushiro. PO Resp. 50. Specifically, Patent Owner argues that “[t]here would have been no motivation to combine the fuel map of Yuushiro, a compression ignition engine, with Rubbert, a spark ignition engine.” *Id.* (citing Ex. 2002 ¶ 169). Patent Owner argues that Yuushiro “would not be considered by one skilled in the art for any teaching of how to prevent knock in a spark ignition system,” as Yuushiro is directed to a compression ignition engine. *Id.* at 51 (citing Ex. 2002 ¶ 171).

Patent Owner also argues that Rubbert’s teachings are inconsistent with Yuushiro’s fuel map. *Id.* at 50–51. Patent Owner argues that, for light engine loads, Rubbert teaches using both port injection and direct injection, and Yuushiro teaches using port injection only. *Id.* at 51. Patent Owner further argues that, for heavy engine loads, Rubbert teaches using mostly direct injection while Yuushiro teaches “at least half the fuel in the heavy load regime is injected by port injection.” *Id.* (emphasis omitted).

Patent Owner argues that Rubbert refutes Petitioner’s reasoning that a person of ordinary skill in the art would have looked to Yuushiro to save direct injection fuel, as Rubbert teaches to use mostly or all direct injection fuel in the high load range. PO Resp. 53. Patent Owner argues that, as such, Rubbert teaches away from Yuushiro’s fuel map. *Id.* (citing Ex. 2002 ¶ 175). Patent Owner adds that, in the low load range, Rubbert expressly teaches a need for some directly injected fuel to achieve stable combustion. *Id.* at 53–54.

Petitioner replies that, as Patent Owner’s declarant testifies, Rubbert would not need directly injected fuel at low engine loads if the engine was operated at stoichiometric air-to-fuel ratios and that Yuushiro teaches using such stoichiometric ratios. Pet. Reply 16–17 (citing Ex. 1050, 175:4–7; Ex. 1003 ¶ 234; Ex. 1007, 2, col. 1–2). Petitioner adds that the combined teachings would result in an engine that would operate at low loads without the need for directly injected fuel. *Id.* at 17 (citing Ex. 1003 ¶¶ 286, 323).

Petitioner also replies that a person of ordinary skill in the art would have understood that different approaches can be used to achieve stable combustion at low loads, including intake heating (such as in Yuushiro) and

rich fuel mixtures. Pet. Reply 17 (citing Ex. 1031 (Bosch), 356, 358, 416, 428, 437; Ex. 1006 ¶¶ 10, 13).

Petitioner also replies that, in the full load range, Rubbert does not *require* zero port injection. Pet. Reply 18. Petitioner argues that Yuushiro’s fuel map is illustrative and that the key teaching from the map is that port injection and direct injection are regulated based on engine load and the amount of direct injected fuel increases with increasing load. *Id.*

In sur-reply, Patent Owner repeats its arguments that Rubbert teaches using mostly direct injection fuel in the high load regime and some direct injection fuel in the low load range to achieve stable combustion. PO Sur-reply 23. Patent Owner adds that, because Yuushiro is a compression ignition engine, it need not rely on direct injection fuel at low loads, unlike Rubbert, which teaches that using directly-injected fuel to achieve stable combustion. *Id.* at 23–24 (citing Ex. 1007, 2, col. 1; Ex. 2002 ¶ 178). Patent Owner also argues that Yuushiro does not rely on intake heating to achieve stable combustion in the low load range. *Id.* at 24.

We find, based on the complete record and weighing all of the related evidence, that Petitioner has demonstrated, by a preponderance of the evidence, that a person of ordinary skill in the art would have had reason to combine the teachings of Yuushiro’s fuel map with Rubbert’s engine. We credit Dr. Clark’s testimony that Yuushiro and Rubbert disclose comparable teachings and that Yuushiro’s fuel map provides additional details beyond Rubbert’s teachings. *See* Ex. 1003 ¶¶ 283–286; *see also id.* ¶ 328 (“Rubbert, however, does not explicitly teach a range in which only port injection is used, albeit Rubbert suggests that in lower loads the larger proportion of fuel is port injected.”). We credit this testimony, in part, based on the express

disclosures in Yuushiro and Rubbert. Both references disclose load-based fuel strategies and a concern for engine knock. Ex. 1006 ¶¶ 38–39; Ex. 1007, 2. Significant to our finding is that both Yuushiro and Rubbert disclose fuel strategies that rely on most or all port injected fuel at low engine loads and increasing amounts of direct injection fuel at high loads. *See, e.g.*, Ex. 1003 ¶ 287 (“While the specific details of fuel maps can change between each engine and engine types, the person of ordinary skill in the art would have understood that as load is increased, the amount of fuel is increased according to a lookup table or map.”); *cf. KSR Int’l Co.*, 550 U.S. at 418 (“[T]he [obviousness] analysis need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.”).

We also credit Dr. Clark’s testimony as it is supported by Mr. Hannemann’s testimony. For example, Mr. Hannemann testified that an engine designer would start with a pre-existing fuel map and then calibrate an engine using that map. *See* Ex. 1050, 116:18–117:12; *see also* Ex. 1003 ¶ 287 (“Indeed, fuel maps are a standard tool that are used by engine calibrators when calibrating an engine.”).

We have considered Patent Owner’s argument concerning the different ignition sources used for Yuushiro’s engine and Rubbert’s engine and find it unpersuasive of a deficiency in Petitioner’s reasoning. We credit Dr. Clark’s testimony, which provides, in part, that Yuushiro’s fuel “strategy would be applicable across internal combustion engines having an ECU and fuel injection.” Ex. 1003 ¶¶ 286–287. As Dr. Clark testifies, “Rubbert and Yuushiro both seek to create an ignition source for the same purpose.” *Id.* at

¶ 288. Dr. Clark testifies that a “person of ordinary skill in the art would consider the implementation details of Yuushiro to be standard and would have understood that because the implementations details were used to improve the Yuushiro engine, they could likewise implemented in the Rubbert engine.” *Id.* Dr. Clark bases this opinion, at least in part, on common teachings in Rubbert and Yuushiro of increasing direct injection fuel to avoid knock. *Id.* Mr. Hannemann’s testimony also supports our finding. Mr. Hannemann testified as to the similarities of a compression ignition engine and a spark ignition engine, and the similarities of fuel management systems for those engines. *See* Ex. 1050, 28:10–36:21.

We have also considered Patent Owner’s argument that Rubbert teaches away from the fueling strategy in Yuushiro, because Rubbert discloses a strategy using some direct injection at low engine loads and mostly or all direct injection at high engine loads, and find these teachings do not amount to a teaching away. “A reference may be said to teach away when a person of ordinary skill, upon reading the reference, . . . would be led in a direction divergent from the path that was taken by the applicant.” *In re Haruna*, 249 F.3d 1327, 1335 (Fed. Cir. 2001) (quoting *Tec Air, Inc. v. Denso Mfg. Mich. Inc.*, 192 F.3d 1353, 1360 (Fed. Cir. 1999)); *see, e.g., In re Fulton*, 391 F.3d 1195, 1201 (Fed. Cir. 2004) (holding that, to teach away, the prior art must “criticize, discredit, or otherwise discourage the solution claimed”). Patent Owner does not adequately explain how the teachings of a *different* strategy in Rubbert “criticize, discredit, or otherwise discourage” employing Yuushiro’s fuel injection map with Rubbert’s engine.

Although we find that Rubbert's differing strategy does not rise to a teaching away, we do weigh this evidence against a motivation to combine. However, in weighing all of the evidence concerning the motivation to combine Yuushiro's teachings with Rubbert, we find that the preponderance of the evidence weighs in favor of Petitioner's position. *See, e.g.*, Ex. 1003 ¶ 287 (discussing the advantages of port injection versus direct injection); Ex. 1031, 358, 416, 428, 429, 437 (discussing factors affecting combustion at different loads); Ex. 1050, 175:4–7 (“Q. So in your opinion if it was a stoichiometric ratio you wouldn't need the additional [direct injection fuel] that Rubbert discloses? A. Correct.”).

As mentioned above, Petitioner reasons that a person of ordinary skill in the art would have implemented Bosch's teachings regarding certain well-known aspects of engine design and Patent Owner does not dispute Petitioner's arguments as to a motivation to combine Bosch with Rubbert and Yuushiro. *See* Pet. 37–38 (citing Ex. 1003 ¶¶ 289–291); PO Resp. 50–56. We find, based on the complete record, that Petitioner has demonstrated, by a preponderance of the evidence, that a person of ordinary skill in the art would have had reason to combine the teachings of Bosch with those of Rubbert and Yuushiro.

In summary, we find, on the complete record, that Petitioner has demonstrated, by a preponderance of the evidence, that a person of ordinary skill in the art would have been motivated to combine the teachings of Rubbert, Yuushiro, and Bosch as Petitioner proposes. We find that Petitioner provides reasons for its proposed modifications and, as we discuss above, these reasons are supported by rational underpinnings. *See KSR Int'l Co.*, 550 U.S. at 418 (stating that, to facilitate the analysis of an obviousness

position, the proponent should provide “some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness”).

e. Conclusion as to Independent Claim 1

Based on the foregoing, Petitioner has established by a preponderance of the evidence that independent claim 1 is unpatentable over the combination of Rubbert, Yuushiro, and Bosch.

4. The Alleged Obviousness of Independent Claims 19 and 22 and Dependent Claims 2–5, 7, 8, 10–18, 20–24, and 26–30 Over Rubbert, Yuushiro, and Bosch

Independent Claim 19 is similar to independent claim 1. Claim 19 adds the modifier “turbocharged” to the recitation of a spark ignition engine and recites, in pertinent part, that “the fraction of fuel that is directly injected” rather than “the amount of fuel that is directly injected” of claim 1, and specifies that port injection alone is used in the second (lower) torque range. *See* Ex. 1001, 8:42, 8:48–50. Petitioner’s contentions regarding claim 19 are similar to those for independent claim 1. *See* Pet. 52–53; *see also id.* at 42 (addressing the “fraction” recitation), 44–45 (addressing the use of PI alone in the light load zone), 51–52 (arguing that “turbocharging was a well-known technique to reduce the displacement of engines while maintaining desired power.”).

Independent claim 22 recites, in its entirety:

A spark ignition engine where port fuel injection and direct injection are used and the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur; and where spark retard is employed to enable reduction of the amount of direct injection that would otherwise be employed.

Ex. 1001, 8:62–67. Thus, in contrast to independent claims 1 and 19, claim 22 does not refer to torque ranges and includes the concept of the use

of spark retard. Petitioner's contentions regarding claim 22 are again similar to those for independent claim. *See* Pet. 54–55. Petitioner, relying on the testimony of Dr. Clark, argues that a person of ordinary skill in the art “would have understood that adding spark retard to the engine of Rubbert and Yuushiro would result in reduced combustion knock” and that “Bosch discloses that it was ‘customary’ as of 1993 to use spark retard to eliminate combustion knock.” *Id.* at 47 (citing Ex. 1003 ¶¶ 338, 340; Ex. 1031, 360).

Patent Owner's arguments regarding independent claims 19 and 22 are the same as those for independent claim 1, and Patent Owner does not raise separate arguments regarding the dependent claims. *See* PO Resp. 50–56 (Patent Owner indicating that its arguments apply to most or all of the challenged claims); *see, e.g., id.* at 56 (“The ‘prevents knock’ phrase in Claim 19 . . . [is] not obvious . . . for at least the same reasons as given for the element of Claim 1, above, regarding ‘so as to obtain knock-free operation.’”). We have addressed those arguments above.

For independent claims 19 and 22 and dependent claims 2–5, 7, 8, 10–18, 20–24, and 26–30, Petitioner identifies teachings in the prior art references that teach or suggest the limitations of these claims and provides persuasive reasoning as to why the claimed subject matter would have been obvious to one of ordinary skill in the art. Pet. 42–57. Petitioner also supports its contentions for these claims with the testimony of Dr. Clark. Ex. 1003 ¶¶ 306–480. We have considered the evidence and arguments of record and determine that Petitioner has demonstrated by a preponderance of the evidence that independent claims 19 and 22 and dependent claims 2–5, 7, 8, 10–18, 20–24, and 26–30 would have been obvious based on Rubbert,

Yuushiro, and Bosch for the reasons discussed in the Petition as supported by the testimony of Dr. Clark.

F. The Alleged Obviousness of Claims 1–5, 7, 8, 10–24, and 26–30 Over Kinjiro and Bosch (Ground 3)

Petitioner alleges that claims 1–5, 7, 8, 10–24, and 26–30 of the ’166 patent would have been obvious over Kinjiro and Bosch. *See* Pet. 58–69 (addressing claim 1). Patent Owner argues that a person of ordinary skill in the art would not have had a motivation to combine the references’ teachings and that the combination fails to teach certain recitations of the challenged independent claims, claims 1, 19, and 22. PO Resp. 56–64. For the reasons given below, we determine that Petitioner has demonstrated that claims 22–24, 26, and 30 would have been obvious over Kinjiro and Bosch, but has *not* demonstrated that claims 1–5, 7, 8, 10–20, 21, and 27–29 would have been obvious over that same combination.

1. Kinjiro (Ex. 1008)

Kinjiro is titled “Fuel Injection Apparatus for Internal Combustion Engine,” published August 14, 2002. Ex. 1008, codes (54), (43). Kinjiro relates to a fuel injection apparatus where, “if knocking is detected by a knock detection means, fuel is injected from both fuel injection valves in a first fuel injection valve provided in an intake passage and a second fuel injection valve for injecting fuel directly into a combustion chamber.” *Id.*

¶ 7. Kinjiro’s Figure 1 is reproduced below.

[FIG. 1]

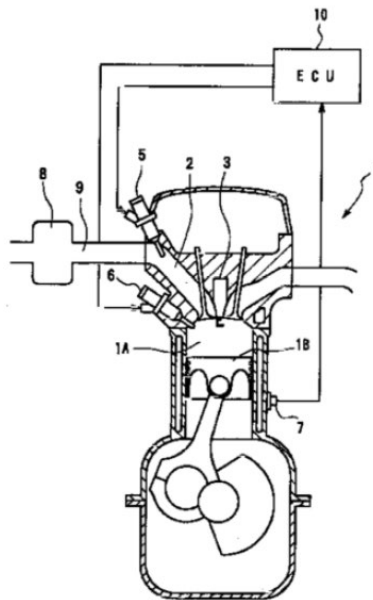


Figure 1 illustrates the main structures of Kinjiro's fuel injection apparatus. Ex. 1008, 8 (“Brief Description of the Drawings”). Kinjiro's engine 1, a “spark ignition type engine,” includes cylinder 1A, piston 1B, intake passage 2, and spark plug 3. *Id.* ¶¶ 10–11. The engine also includes injector 5, located in intake passage 2, and injector 6, located in cylinder 1A. *Id.* ¶¶ 11–13, Fig. 1. Engine 1 also includes knock sensor 7 and electronic control unit 10. *Id.* ¶¶ 12–13.

Kinjiro discloses that its engine operates in two states—a “normal operating state,” where knocking is not occurring, and a “specified operating state,” which is entered when knocking occurs. *Id.* ¶¶ 13, 14. During the normal operating state, fuel is injected using injector 5 only and during the specified operating state, fuel is injected using both injectors 5 and 6 (referred to as “split injection mode”). *Id.* ECU 10 initiates the specified operating state when knock sensor 7 indicates that engine knocking is occurring. *Id.* ¶¶ 13, 20.

2. *The Alleged Obviousness of Independent Claims 1 and 19 and Dependent Claims 2–5, 7, 8, 10–18, 20, and 21 Over Kinjiro and Bosch*

Claim 1 recites, in relevant part, “where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque range.” Ex. 1001, 7:41–43 (the “both fueling systems” limitation of claim 1). Petitioner contends that, in Kinjiro’s split injection mode, where engine knock has been detected, both port injection and direct injection are used. Pet. 64–65 (citing Ex. 1008 ¶¶ 14, 27; Ex. 1003 ¶ 409). Petitioner contends that split injection mode “is activated in response to detected knock, which occurs at or above *a specific engine load or output torque* (e.g., a first torque range).” *Id.* (citing Ex. 1008 ¶¶ 14, 27; Ex. 1003 ¶ 495) (emphasis added).

Dr. Clark testifies that “Kinjiro discloses a knock sensor 7 that is used to define a first torque range (e.g., *a range of torques* where knock would persist if direct injection was not used).” Ex. 1003 ¶ 495 (citing Ex. 1008 ¶ 12) (emphasis added).

Patent Owner argues that “Kinjiro does not teach that there is a ‘torque range’ throughout which both direct injection and port injection are used.” PO Resp. 57 (citing Ex. 2002 ¶ 202). Patent Owner, relying on the testimony of Mr. Hannemann, argues that

It does not follow that there is a “range” of torque in which the engine enters the specified state. Kinjiro could be in the specified state at only one torque value, or at discontinuous torque values, because the risk of knock can change over a torque range, as other engine variables change, and thus

Kinjiro's use of a knock detector could result in discontinuous use of the split injection mode.

Id. at 57–58 (emphasis omitted) (citing Ex. 2002 ¶ 202). Patent Owner adds that “Petitioner offers no argument based on inherency to suggest that Kinjiro necessarily teaches a ‘torque range’ throughout which both direct injection and port injection are used.” *Id.*

Petitioner replies that “[t]he term ‘first torque range’ as used in Claims 1, 19, and 22^[8] simply refers to a state where both [direct injection] and [port injection] are used,” and that “[t]he term has indeed been described as a ‘shorthand’ for which injection systems are being used.” Pet. Reply 21–22 (citing Ex. 1049, 14). Petitioner argues that “Kinjiro *by definition* discloses a ‘first torque range’ the instant it switches into its ‘split injection mode,’” and “[n]othing more is required.” *Id.* at 22. Petitioner argues that “Patent Owner’s exceedingly narrow construction is unwarranted.” *Id.*

In sur-reply, Patent Owner argues that Petitioner’s construction is contrary to the District Court’s construction of the term “torque range.” PO Sur-reply 27 (asserting that the term “was construed according to its plain and ordinary meaning, which clearly implies a ‘range’ of torque values”).

As an initial point, the Petitioner, in the Petition, proposes a construction of “torque range,” “range of torque,” or “region of torque” to mean “the region on a torque-speed map that lies between a first specified value of torque and a second specified value of torque.” Pet. 3–5. As Patent Owner argues, the District Court construed the term “torque range” to have its plain and ordinary meaning. Ex. 1041, 2.

⁸ Claim 22 does not contain the phrase “first torque range.” *See* Ex. 1001, 8:62–67.

Petitioner seems now to abandon the construction proposed in the Petition, in favor of a description of the operational mode of the fuel management system. Indeed, in addressing the “both fueling systems” limitation of claim 1, the Petition contains the argument that split injection mode “is activated in response to detected knock, which occurs at or above a *specific* engine load or output torque (*e.g., a first torque range*).” Pet. 64–65 (emphasis added). That is, Petitioner’s position is that the first torque range is defined at or above a specific load or output torque. Petitioner fails to demonstrate persuasively that split injection mode is activated *above a specific engine load*. Kinjiro discloses that split injection mode is activated when the knock sensor measures knock, not at a *specific* engine load. Ex. 1008 ¶¶ 13–14; Ex. 2002 ¶ 202. Petitioner’s claim construction position taken in the Reply seems to be a new position, contrary to what Petitioner asserts in the Petition.

In summary, we find that Petitioner fails to demonstrate that Kinjiro discloses that there is a range of torque where both fueling systems are used at the same value of torque, under the construction Petitioner proposes in the Petition. Accordingly, we conclude that the Petitioner fails to demonstrate, by a preponderance of the evidence, that Kinjiro discloses the “both fueling systems” limitation of claim 1.

Even if we were to apply the plain and ordinary meaning of the term “range of torque” to encompass discrete points within an overall range of torque values, which seems to be what Petitioner now argues, Petitioner’s obviousness position for claim 1 fails for another reason.

Claim 1 also recites “where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so

as to obtain knock-free operation.” Ex. 1001, 7:44–46. Thus, the increase in the amount of direct injection fuel is tied to an increase in torque.

Petitioner contends that the amount of fuel supplied by the first fuel system (direct injection) increases or decreases as Kinjiro’s system moves between the normal operating mode and split injection mode. Pet. 65. Petitioner explains that, in the normal operating mode, direct injection is not used, so its contribution would reduce (to zero) as the engine moves to normal operation mode from split injection mode. *Id.* Petitioner further argues that, “[t]herefore, the ratio of DI to PI increases (e.g., from no DI to some DI) as operation moves from the first operating state to the split injection mode.” *Id.* (citations omitted).

Petitioner further argues that cylinder temperature increases with increasing torque as engine torque is related to cylinder pressure, which is associated with cylinder temperatures (with increasing temperature associated with an increasing tendency to knock). Pet. 65–68. Petitioner concludes that “[b]ecause temperature increases with increasing torque, Kinjiro teaches in Figure 6A that a leaner mixture (higher air/fuel ratio) PI fuel mixture should be used at higher torque, requiring an increased ratio of DI fuel to compensate for the leaner PI fuel mixture.” *Id.* at 59 (citing Ex. 1003 ¶ 502); *see also* Ex. 1003 ¶¶ 497–502 (describing Kinjiro’s engine operations, and the relationship between cylinder temperature, pressure, and tendency for knock).

We find that Petitioner fails to demonstrate, by a preponderance of the evidence that the amount of fuel in the cylinder that is introduced by direct injection increases with increasing torque in Kinjiro’s fuel management system, or that Kinjiro discloses any relationship between torque and the

amount of fuel directly injected into the cylinder. Petitioner argues that there is a direct relationship between torque and cylinder temperature and pressure and, so, as torque increases, the amount of direct injection fuel will increase. *See* Pet. 57–59. Petitioner fails to explain persuasively how Kinjiro discloses that the *amount* of direct injection fuel changes with changing torque.

At best, the evidence demonstrates that, when Kinjiro’s system moves to split injection mode from normal operating mode, the amount of fuel that is directly injected increases from zero. *See* Pet. 65. As we explain below, Petitioner fails to explain persuasively that this change to split injection mode from normal operating mode *corresponds to an increase in torque*, as recited in claim 1.

Whether a reference inherently discloses a limitation is a question of fact. *PAR Pharm., Inc. v. TWI Pharm., Inc.*, 773 F.3d 1186, 1194 (Fed. Cir. 2014). “A party must . . . meet a *high* standard in order to rely on inherency to establish the existence of a claim limitation in the prior art in an obviousness analysis.” *Id.* at 1195–96 (emphasis added). In an obviousness challenge “the limitation at issue necessarily must be present, or the natural result of the combination of elements explicitly disclosed by the prior art.” *Id.* at 1196. Petitioner argues that “Kinjiro discloses that an increase in cylinder temperature during split injection mode would *necessarily* lead to an increase in the ratio of DI [direct injection] fuel to PI [port injection fuel].” Pet. 66 (citing Ex. 1003 ¶ 499) (emphasis added).

Petitioner’s evidence does not satisfy the high standard for inherency. Dr. Clark testifies that “[f]urthermore, Kinjiro discloses that an increase in cylinder temperature during the split injection mode would necessarily lead

to an increase in the ratio of direct injection to port injection. Such an increase in cylinder temperature would result, *for instance*, from an increase in torque.” Ex. 1003 ¶ 499 (emphasis added). As such, Dr. Clark testifies that an increase in torque *could be* the reason for increasing cylinder temperature. Also, we note that Dr. Clark offers no supporting evidence for his testimony—indeed, he does not even cite to Kinjiro when testifying as to what Kinjiro discloses regarding increasing temperature and increasing direct injection fuel. *See id.* ¶ 499. Such expert testimony is entitled to little weight. *See* 37 C.F.R. 42.65(a) (“Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.”).

In conclusion, we find that, even if Kinjiro’s disclosure of operating in split injection mode at discontinuous torque values constitutes a “range of torques,” Petitioner fails to explain persuasively a relationship between increasing torque and increasing values of direct injected fuel.

Accordingly, for the reasons above, we conclude that Petitioner does not demonstrate, by a preponderance of the evidence, that claim 1 is unpatentable under 35 U.S.C. § 103 over Kinjiro and Bosch.

Independent Claim 19 is similar to independent claim 1. Claim 19 also contains a torque range recitation, specifically providing that “there is a first range of torque throughout which direct injection and port injection are used at the same value of torque.” Ex. 1001, 8:45–47. Claim 19 also recites, in pertinent part, that “the fraction of fuel that is directly injected” rather than “the amount of fuel that is directly injected” of claim 1. *See id.* at 8:48–50. For claim 19, Petitioner relies on its arguments made for claim 1. *See* Pet. 75 (arguing that the recitations are similar to those in

claim 1 and dependent claim 2, and “[are] likewise disclosed.”); *id.* at 69 (arguing that dependent claim 2, which recites the “fraction” term, is disclosed “[a]s discussed with respect to Claim 1”). Thus, for the reasons set forth above for claim 1, we determine that Petitioner has not demonstrated by a preponderance of the evidence that independent claim 19 of the ’166 patent would have been obvious over Kinjiro and Bosch.

Claims 2–5, 7, 8, 10–18, 20, and 21 depend from either independent claim 1 or independent claim 19. Petitioner’s arguments for those dependent claims do not cure the underlying deficiencies in the challenges to independent claims 1 and 19. *See id.* at 69–76. For the reasons set forth above, we determine that Petitioner has not demonstrated by a preponderance of the evidence that claims 2–5, 7, 8, 10–18, 20, and 21 of the ’166 patent would have been obvious over Kinjiro and Bosch.

3. The Alleged Obviousness of Independent Claim 22 Over Kinjiro and Bosch

Independent claim 22, unlike independent claim 1, does not recite “a first torque range where direct injection and port injection are both used” or “as torque is increased the amount of fuel that is directly injected is changed.” Ex. 1001, 7:41–46. In contrast, independent claim 22 recites “direct injection is increased so as to prevent knock that would otherwise occur.” *Id.* at 8:64–65. As indicated below, claim 22 also recites the use of spark retard to enable the reduction of the amount of direct injection fuel that would otherwise be employed.

a. A spark ignition engine where port fuel injection and direct injection are used and

Petitioner contends that, “[t]o the extent the preamble of Claim 1 is limiting, Kinjiro discloses a spark ignition engine” that “comprises PI [port

injection] and DI [direct injection].” Pet. 63 (citing Ex. 1008 ¶¶ 10–11, Fig. 1; Ex. 1003 ¶ 492); *see also id.* at 76 (relying on the earlier arguments made for claim 1; citing Ex. 1003 ¶¶ 589–595).

Patent Owner does not contest these assertions. We find, based on the evidence cited by Petitioner that Kinjiro discloses a spark ignition engine where port fuel injection and direct injection are used.

b. the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur

Petitioner contends that, in Kinjiro:

Information detected by the knock sensor is input to an ECU, which sets an operation control signal for each of the DI and PI injectors. Ex. 1008, ¶ [0014]; Ex. 1003, ¶497. Kinjiro discloses two modes of operation. First, Kinjiro discloses a normal operating state. *Id.* In the normal operating state, Kinjiro discloses that when knock has not been detected, the engine is fueled by PI alone Second, Kinjiro discloses a split injection mode where the engine is fueled by DI and PI The engine enters the split injection mode when knock is detected in the normal operating state. Ex. 1008, ¶ [0014], FIG. 5; Ex. 1003, ¶497. Therefore, the ratio of DI to PI increases (e.g., from no DI to some DI) as operation moves from the first operating state to the split injection mode. *Id.*

Pet. 65; *see also id.* at 76 (referencing the earlier arguments made for claims 1 and 2; citing Ex. 1003 ¶¶ 589–595). Petitioner contends that the addition of direct injection fuel at the transition to the split injection mode discloses the recitation, “the fraction of fuel provided by direct injection is increased.” *See id.* at 69.

Petitioner contends that Kinjiro’s split injection mode, triggered by the knock sensor is “where knock would persist if DI was not used.” *See id.* at 64–65 (citing Ex. 1008 ¶ 12; Ex. 1003 ¶ 495).

Patent Owner argues that “no amount of directly injected fuel is being used, let alone changed or minimized, ‘so as to obtain knock-free operation’ in Kinjiro, and it would not make sense to do so.” PO Resp. 58–59; *see id.* at 60 (referring to earlier arguments). According to Patent Owner, Kinjiro’s lean mixture of the port injection fuel is that which prevents knock, and “changing the amount of fuel that is directly injected would have no effect on knock in Kinjiro’s engine because it is already operating with a lean fuel-air ratio from port injection.” *Id.* at 58.

Patent Owner does not demonstrate a deficiency in Petitioner’s position. We find, on the complete record, that Petitioner has demonstrated by a preponderance of the evidence that the Kinjiro discloses that, as recited in claim 22, “the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur.”

In the normal operating state, where knocking is not occurring, port injection fuel only is used. *See* Ex. 1008 ¶ 14. When knock occurs, the engine switches to the specified operating state where both port injection and direct injection are used. *See id.* ¶ 13. Thus, prior to knock, there is zero direct injection and, upon initiating the specified operating state at the detection of knock, the direct fuel is increased to a value greater than zero and the knocking is suppressed. *See id.* (“[I]f it is determined by the ECU 10 that knocking has occurred based on detection information from the knock sensor 7, fuel injection is performed from the two injectors 5 and 6 to suppress this knocking.”); *see also* Ex. 1003 ¶¶ 589–591. Accordingly, as recited in claim 22, Kinjiro discloses that “the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur.”

Patent Owner further argues that “[v]ariations among direct injection amounts *within the split injection mode* will have no effect on whether knock occurs.” PO Resp. 58 (emphasis added) (citing Ex. 1008 ¶ 9); *see also* PO Sur-reply 27 (repeating the argument regarding “variations among direct injection amounts within the split injection mode”). Even if this were correct, it does not address Petitioner’s argument that the recited increase in direct injection fuel is the change that occurs at the transition from the normal operating state to the split injection mode.

c. where spark retard is employed to enable reduction of the amount of direct injection that would otherwise be employed.

Petitioner’s proposed combination is the addition of Bosch’s spark retard to the engine of Kinjiro. Pet. 72; *see also id.* at 76 (referencing the earlier arguments made for dependent claim 11; citing Ex. 1003 ¶¶ 596–603). Petitioner argues that this would “would permit the engine of Kinjiro to operate with reduced DI (and therefore proportionally more PI) without altering the propensity of the engine to knock.” Pet. 72 (citing Ex. 1003 ¶ 535).

Petitioner recognizes that “Kinjiro does not explicitly disclose the use of spark retard in suppressing knock” but contends that “it is suggested throughout the disclosure.” *Id.* at 60. Petitioner contends that a person of ordinary skill in the art “would have understood that the use of spark retard would be beneficial to protect the engine and reduce the amount of fuel that is directly injected and, thus improve efficiency and reduce emissions.” *Id.* (citing Ex. 1003 ¶ 489). Petitioner contends that a person of ordinary skill in the art “would have looked to Bosch, which confirms that a [person of

ordinary skill in the art] would rely on spark retard to improve engine operation in a known way.” *Id.* (citing Ex. 1031, 360; Ex. 1003 ¶ 489).

Petitioner contends that “Bosch, like Kinjiro, also discloses the use of a knock sensor to adjust engine variables to eliminate knock, including but not limited to spark retard.” *Id.* (citing Ex. 1031, 464–65; Ex. 1003 ¶ 489). Petitioner contends that a person of ordinary skill in the art “would have understood from Bosch that Kinjiro’s knock sensor would have been applied to the management of other engine variables that influence knock, including [direct injection] quantity and spark retard.” *Id.* (citing Ex. 1003 ¶ 489). Petitioner contends that direct injection and spark retard perform in similar ways to avoid knock, so there would have been a reasonable expectation of success in the combination. *Id.*

Patent Owner agrees that Bosch “discloses that it was ‘customary’ as of 1993 to use spark retard to eliminate combustion knock,” but argues that Bosch does not teach using spark retard to reduce direct injection fuel as recited in claim 22. PO Resp. 61 (internal quotation marks omitted). This argument is not persuasive as Petitioner’s challenge is based on the combination of the references’ teachings and it is not necessary for a single reference to explicitly teach the claimed subject matter. *See KSR Int’l Co.*, 550 U.S. at 418 (An obviousness “analysis need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a [tribunal] can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.”).

Patent Owner argues that a person of ordinary skill in the art would not have modified Kinjiro with Bosch’s teachings of spark retard, as Kinjiro teaches spark advance. PO Resp. 26–57; *see also id.* at 60–61. Petitioner

replies that Kinjiro employs a knock sensor to increase direct injection fuel to increase its knock limit and eliminate knock and also “explains that it is conventional ‘to suppress the knocking by retarding the ignition timing.’” Pet. Reply 20 (citing Ex. 1008 ¶¶ 3, 20–21). Petitioner explains that “both increased [direct injection] and spark retard can be used for a few cycles to eliminate knock” and that there is a “ubiquitous nature of spark retard and DI in spark ignition engines.” *Id.* (citing Ex. 1050, 59:19–23; 123:21–124:4). Petitioner concludes that, because of this, a person of ordinary skill in the art “would have understood using spark retard as taught by Bosch would be beneficial to utilize in Kinjiro’s engine.” *Id.* (citing Ex. 1003 ¶ 489; Ex. 1050, 55:16–20). In sur-reply, Patent Owner repeats that “Kinjiro teaches advancing the ignition timing rather than retarding it.” PO Sur-reply 26 (emphasis omitted) (citing Ex. 1008 ¶ 37).

To the extent Patent Owner argues that Kinjiro teaches away from spark retard, we do not agree. *See* PO Resp. 56–57. “A reference may be said to teach away when a person of ordinary skill, upon reading the reference, . . . would be led in a direction divergent from the path that was taken by the applicant.” *In re Haruna*, 249 F.3d at 1335; *see, e.g., In re Fulton*, 391 F.3d at 1201 (holding that, to teach away, the prior art must “criticize, discredit, or otherwise discourage the solution claimed”). We find that Kinjiro’s statements about spark advance do not criticize, discredit, or otherwise discourage spark retard. Instead, we find that Kinjiro is stating that, for an engine that does not use direct injection (for example, in the normal operating mode of Kinjiro), the engine would rely on spark retard to reduce knock. *See* Ex. 1008 ¶ 37. However, *during the period of time that Kinjiro operates in split injection mode*, it can actually use spark advance to

improve engine output. *See id.* That is to say, Kinjiro’s disclosure about the benefits of spark *advance* are directed to operations during split injection mode only and are not directed to operations in the normal operating state. *See id.* ¶¶ 14, 37. Kinjiro’s statements are consistent with Dr. Clark’s testimony. Dr. Clark testifies the Kinjiro recognizes that spark retard can be used to reduce knock. *See, e.g.,* Ex. 1003 ¶ 489 (“Kinjiro . . . discloses the use of spark retard for mitigation of knock.”).

As mentioned, Petitioner contends that a person of ordinary skill in the art would have understood that spark retard would “reduce the amount of fuel that is directly injected and, thus improve efficiency and reduce emissions.” Pet. 60 (citing Ex. 1003 ¶ 489). Patent Owner disputes this, arguing that “spark retard would *reduce* efficiency – as taught by Bosch. PO Resp. 62 (citing Ex. 1031, 360); *see also* PO Sur-reply 27–28. Patent Owner’s argument is not persuasive as it appears that Patent Owner is not referring to the same type of efficiency as Petitioner. Petitioner indicates that Dr. Clark’s opinion is regarding the efficiency of the overall engine where both PI and DI are used. According to Petitioner:

Dr. Clark never disputes that, in the abstract, spark retard reduces efficiency at a very specific point. Ex. 1003, ¶290. Dr. Clark does, however, testify that a [person of ordinary skill in the art] would find it desirable to use spark retard along with DI to develop an engine that is *overall* more efficient. *Id.*; *see also*, Ex. 1050, 137:12-138:3 (discussing the interplay of the amounts of PI and DI fuel and spark retard as variables to increase efficiency).

Pet. Reply 9. Patent Owner’s reliance on Bosch for an efficiency teaching must be directed to something different because, according to Mr. Hannemann, “Bosch [in the context of spark retard] merely describes a

conventional spark-ignition engine that has a single (i.e., one) fuel-injection system.” Ex. 2002 ¶ 219.

We find, on the complete record, that Petitioner demonstrates, by a preponderance of the evidence, that a person of ordinary skill in the art would have had reason to incorporate spark retard into Kinjiro’s engine. We find that Petitioner’s reasoning is adequately supported by rational underpinnings, including that an artisan of ordinary skill would have had reason to employ spark retard to reduce knocking to improve engine performance. We also find that, in the proposed combination, “spark retard is employed to enable reduction of the amount of direct injection that would otherwise be employed,” as recited in claim 22. We credit Dr. Clark’s testimony, as it is consistent with our understanding of the disclosures in Kinjiro and Bosch. For example, Dr. Clark testifies that Kinjiro employs a knock sensor and that Bosch teaches using a knock sensor in conjunction with spark retard. Ex. 1003 ¶ 489; Ex. 1031, 360, 464–465. Dr. Clark also testifies that “a person of ordinary skill in the art would have understood that the use of spark retard would be beneficial to protect the engine and reduce the amount of fuel that is directly injected.” Ex. 1003 ¶ 489; *see also* Ex. 1031, 464 (“Internal-combustion engines are damaged by combustion knock.”).

d. Conclusion as to Independent Claim 22

Based on the foregoing, Petitioner has established by a preponderance of the evidence that independent claim 22 is unpatentable over the combination of Kinjiro and Bosch.

4. The Alleged Obviousness of Dependent Claims 23, 24, 26, and 30 Over Kinjiro and Bosch

Claims 23, 24, 26, and 30 depend from independent claim 22. Patent Owner does not raise separate arguments regarding these dependent claims beyond those addressed above. *See* PO Resp. 56–57, 60–64 (Patent Owner indicating that its arguments apply to all of the challenged claims).

For dependent claims 23, 24, 26, and 30, Petitioner identifies teachings in the prior art references that teach or suggest the limitations of these claims and provides persuasive reasoning as to why the claimed subject matter would have been obvious to one of ordinary skill in the art. Pet. 76–79. Petitioner also supports its contentions for these claims with the testimony of Dr. Clark. Ex. 1003 ¶¶ 604–649. We have considered the evidence and arguments of record and determine that Petitioner has demonstrated by a preponderance of the evidence that dependent claims 23, 24, 26, and 30 would have been obvious based on Kinjiro and Bosch for the reasons discussed in the Petition as supported by the testimony of Dr. Clark.

5. The Alleged Obviousness of Dependent Claims 27–29 Over Kinjiro and Bosch

Claims 27–29 depend from independent claim 22.

Claim 27 recites “the fraction of fuel provided by direct injection increases with increasing torque.” Ex. 1001, 9:14–17. Thus, claim 27 contains the recitation, discussed above in the context of independent claim 1 that ties increases in direct injection fuel to increases in torque.

Claim 28 recites “a first torque range throughout which port fuel injection and direct injection are used at the same torque and wherein the fraction of fuel provided by direct injection increases with increasing torque in such a way as to enable knock-free operation.” *Id.* at 10:1–9. Thus,

claim 28 contains the “both fueling systems” recitation discussed above in the context of claim 1 and the increasing DI/increasing torque recitation.

Claim 29 depends directly from claim 28 and, therefore, also contains these same recitations by virtue of its dependency.

Petitioner relies on its earlier arguments in challenging dependent claims 27–29. *See* Pet. 78–79.

For the reasons given above, we find that Petitioner fails to demonstrate that Kinjiro discloses that, as recited in claim 28, there is a range of torque where both fueling systems are used at the same value of torque, under the construction Petitioner proposes in the Petition. We also, for the reasons given above, find that Petitioner fails to demonstrate, by a preponderance of the evidence, that the amount or fraction of fuel in the cylinder that is introduced by direct injection increases with increasing torque in Kinjiro’s fuel management system, or that Kinjiro discloses any relationship between torque and the amount of fuel directly injected into the cylinder.

Accordingly, Petitioner has not demonstrated by a preponderance of the evidence that dependent claims 27–29 of the ’166 patent would have been obvious over Kinjiro and Bosch.

III. PATENT OWNER’S TAKINGS AND APPOINTMENTS CLAUSE ARGUMENTS

Patent Owner argues:

Applying IPRs retroactively to pre-AIA patents violates the Fifth Amendment. *Celgene v. Peter*, 931 F.3d 1342 (Fed. Cir. 2019) (certiorari pending) was wrongly decided. APJs remain unconstitutionally appointed after *Arthrex v. Smith & Nephew*, 941 F.3d 1320 (Fed. Cir. 2019) (certiorari pending);

and now lack removal protections (5 U.S.C. § 7521(a)), in violation of the Administrative Procedure Act.

PO Resp. 64.

As Patent Owner's argument indicates, the Federal Circuit has addressed Fifth Amendment and Appointments Clause challenges issues in, respectively, *Celgene Corp.*, 931 F.3d at 1362–63, *cert. denied*, 141 S.Ct. 132 (June 22, 2020), and *Arthrex*, 941 F.3d at 1325, 1337–38, *cert. granted*, 141 S.Ct. 551 (Oct. 13, 2020). We are bound by those decisions. Accordingly, we decline to consider further those issues.

IV. PATENT OWNER'S MOTION TO EXCLUDE

Patent Owner moved to exclude Exhibits 1034 and 1051 and portions of Exhibit 1050. Paper 29. Because we do not rely on Exhibits 1034 or 1051 or the identified portions of Exhibit 1050, we dismiss the motion as moot.

V. CONCLUSION⁹

Petitioner has shown by a preponderance of the evidence that claims 1–5, 7, 8, 10–24, and 26–30 of the '166 patent would have been obvious over Rubbert, Yuushiro, and Bosch. Petitioner also has shown by a

⁹ 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*. See 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).

preponderance of the evidence that claims 22–24, 26, and 30 of the '166 patent would have been obvious over Kinjiro and Bosch.

Petitioner has *not* shown by a preponderance of the evidence that claims 1–5, 7, 8, 10, and 14–21 of the '166 patent would have been obvious over Kobayashi and Yuushiro, or that claims 1–5, 7, 8, 10–20, 21, and 27–29 of the '166 patent would have been obvious over Kinjiro and Bosch.

We also dismiss Patent Owner's Motion to Exclude.

VI. ORDER

For the foregoing reasons, it is

ORDERED that claims 1–5, 7, 8, 10–24, and 26–30 of the '166 patent have been proven to be unpatentable;

FURTHER ORDERED that Patent Owner's Motion to Exclude is *dismissed*; 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.

In summary:

Claims	35 U.S.C. §	Reference(s)/Basis	Claims Shown Unpatentable	Claims Not shown Unpatentable
1–5, 7, 8, 10, 14–21	103(a)	Kobayashi, Yuushiro		1–5, 7, 8, 10, 14–21
1–5, 7, 8, 10–24, 26–30	103(a)	Rubbert, Yuushiro, Bosch	1–5, 7, 8, 10– 24, 26–30	
1–5, 7, 8, 10–24, 26–30	103(a)	Kinjiro, Bosch	22–24, 26, 30	1–5, 7, 8, 10– 20, 21, 27–29
Overall Outcome			1–5, 7, 8, 10– 24, 26–30	

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