

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

BMW OF NORTH AMERICA, LLC,

MERCEDES-BENZ USA, LLC

Petitioners

v.

MICHIGAN MOTOR TECHNOLOGIES, LLC,

Patent Owner

IPR2023-01233

U.S. Patent No. 6,581,574

**PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 6,581,574
UNDER 35 U.S.C. § 312 AND 37 C.F.R. § 42.104**

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EXHIBITS

Exhibit No.	Description
EX1001	U.S. Patent No. 6,581,574 (“the ’574 patent”)
EX1002	Prosecution History of the ’574 patent
EX1003	Declaration of Gerald J. Micklow, Ph.D
EX1004	U.S. Patent No. 5,505,180 (“Otterman”)
EX1005	U.S. Patent No. 5,806,497 (“Hosoya”)
EX1006	U.S. Patent No. 4,426,981 (“Greiner”)
EX1007	U.S. Patent No. 6,349,700 (“Buckland”)
EX1008	Federal Court Management Statistics, March 31, 2023, accessed at https://www.uscourts.gov/sites/default/files/data_tables/fcms_na_distprofile0331.2023.pdf

I. INTRODUCTION

BMW of North America, LLC and Mercedes-Benz USA, LLC (collectively, “Petitioners”) request *inter partes* review of claims 1-18 of U.S. Patent No. 6,581,574 (the “’574 patent”) (EX1001), owned by Michigan Motor Technologies, LLC (“PO”), pursuant to 35 U.S.C. §§ 311-19 and 37 C.F.R. § 42.100.

The ’574 patent and challenged claims relate generally to methods and systems for controlling fuel rail pressure. As explained below, all elements of the challenged claims were well-known in the prior art discussed herein.

II. MANDATORY NOTICES UNDER 37 C.F.R. § 42.8(b)(1)-(4)

A. Real Parties-In-Interest

BMW of North America, LLC and Bayerische Motoren Werke AG, as well as Mercedes-Benz USA, LLC, Mercedes-Benz Intellectual Property GmbH & Co. KG, Mercedes-Benz AG, and Mercedes-Benz Group AG, are the real parties-in-interest.

B. Related Matters

PO has asserted the ’574 patent in the following litigation against
Petitioners: *Michigan Motor Technologies, LLC V. Bayerische Motoren Werke AG et al.*, C.A. No. 22-3804 (N.D. Ill.); *Michigan Motor Technologies, LLC v. Mercedes-Benz USA, LLC*, C.A. No. 22-03957 (N.D. Ill.).

C. Counsel

Petitioners designate lead and back-up counsel as noted below. Powers of attorney pursuant to 37 C.F.R. § 42.10(b) accompany this Petition.

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D. Service Information

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III. CERTIFICATION OF STANDING – 37 C.F.R. § 42.104(a)

Pursuant to 37 C.F.R. § 42.104(a), Petitioners certify that the '574 patent is available for *inter partes* review and that Petitioners are not barred or estopped from requesting *inter partes* review.

IV. PAYMENT OF FEES – 37 C.F.R. § 42.103

The undersigned authorizes the Director to charge the fee specified by 37 C.F.R. §42.15(a) and any additional fees that might be due in connection with this Petition to Deposit Account No. 50-3266.

V. SUMMARY OF THE '574 PATENT

A. Brief Description

The '574 patent, entitled “Method For Controlling Fuel Rail Pressure,” was filed on March 27, 2002 and issued on June 24, 2003. EX1001. The patent relates to methods and systems of “controlling the fuel pressure within the fuel rail of an internal combustion engine” and purports to improve the prior art by “adapt[ing] to system variations such as part-to-part tolerance differences and wear” in closed loop control systems. *Id.*, 1:6-8, 1:17-23; EX1003, ¶36.

A fuel delivery system as disclosed in the '574 patent is shown in Figure 1.

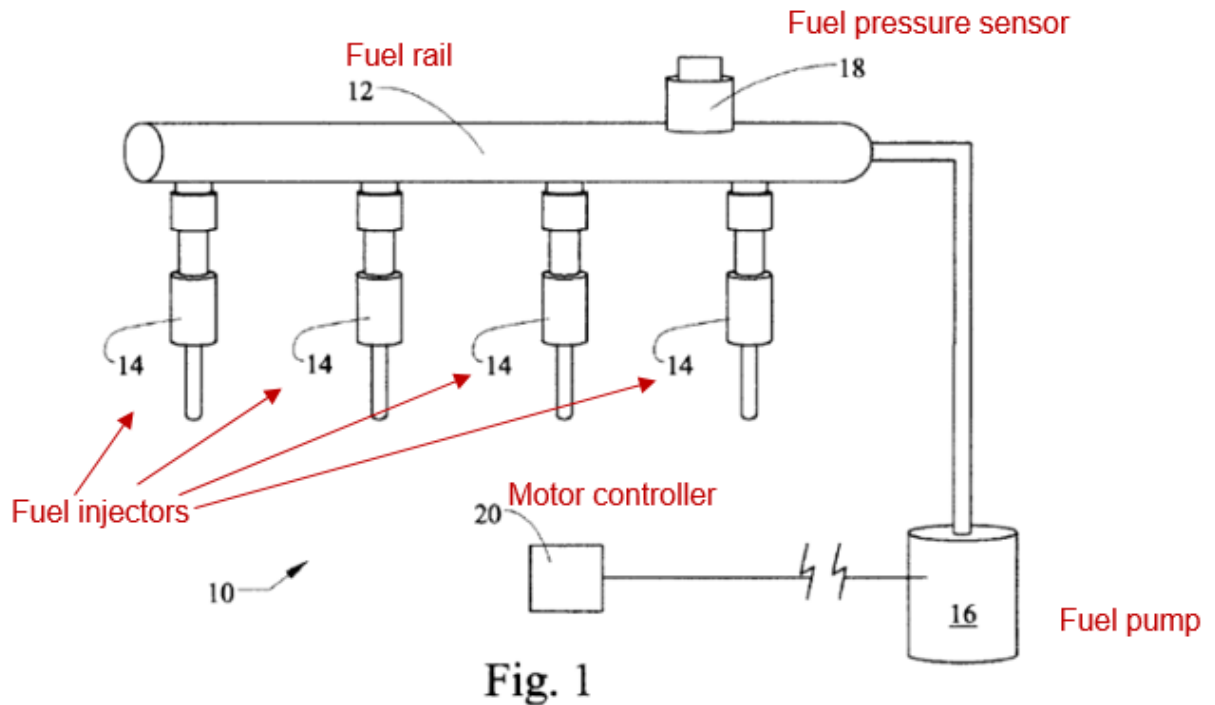


Figure 1 shows “a fuel rail 12 adapted to deliver fuel to fuel injectors 14 of an internal combustion engine, a fuel pump 16 adapted to deliver fuel to the fuel rail 12, a fuel pressure sensor 18, and a fuel pump motor controller 20.” EX1001, 1:44-48, Fig. 1. In Figure 1, the fuel pressure sensor 18 is mounted at the fuel rail 20. *Id.*; EX1003, ¶¶37-38.

Figure 3, which is the “first preferred embodiment of the invention,” shows a method of controlling the fuel delivery system of Figure 1 where the fuel pressure sensor 18 is mounted to the fuel rail 12. EX1001, 2:44-47; EX1003, ¶39.

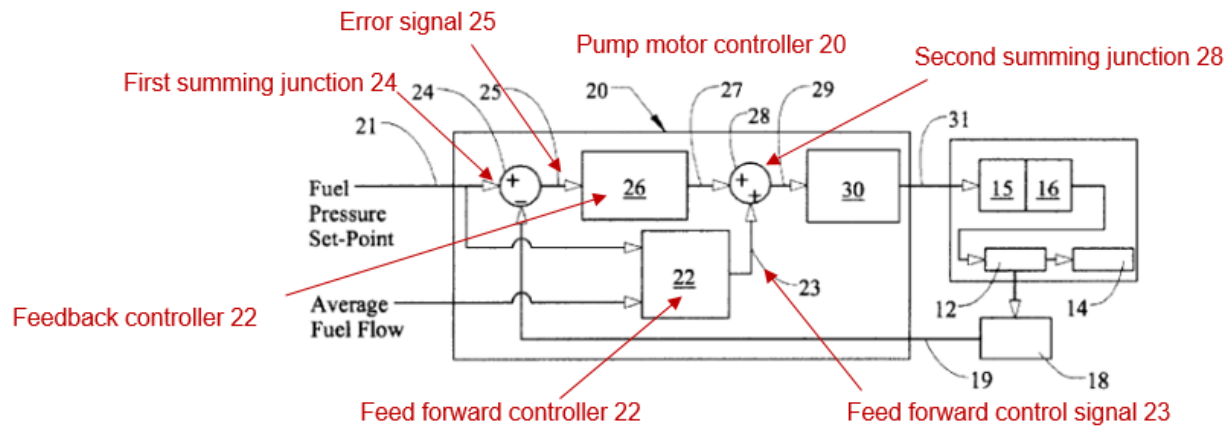


Fig. 3

In Figure 3, the fuel pump motor controller 20 is a processor that is adapted to control the fuel pump 16 by controlling the speed of a motor 15 that drives the fuel pump 16. EX1001, 1:55-58; EX1003, ¶40.

The system includes a feed forward controller 22, and a feedback controller 26. EX1001, 2:13-15. The feed forward controller 22 receives a set-point fuel pressure signal 21 and an average fuel flow demand, and uses a function or algorithm to output a feedforward control signal 23. *Id.*, 2:15-21. The feedback controller 26 receives a fuel rail pressure error signal 25, which is the sum of the set-point fuel pressure signal 21 and a signal 19 from the fuel pressure sensor 18, and generates a feedback control signal 27. *Id.* The feedback control signal 27 and the feed forward control signal are summed at summing junction 28 to create the motor control signal 29. *Id.*, 2:32-37. The motor control signal is input into the fuel pump motor controller driver 30, which outputs a motor drive signal 31. *Id.*,

33-36. The motor drive signal 31 controls the speed of the fuel pump motor 15.

Id.; EX1003, ¶41.

The set-point fuel pressure described above to calculate both the feed forward control signal and error signal is “the pressure at which the fuel delivery system 10 works most efficiently,” *i.e.*, the “optimum pressure.” EX1001, 1:64-67; EX1003, ¶42.

The '574 patent provides several variations to this first embodiment. In Figure 4, the system “further includes an adaptive learning controller 32 which uses an algorithm to monitor the conditions of the fuel delivery system 10 and updates the feed forward controller 22 when the system is operating in a steady state condition.” EX1001, 2:47-53; EX1003, ¶43.

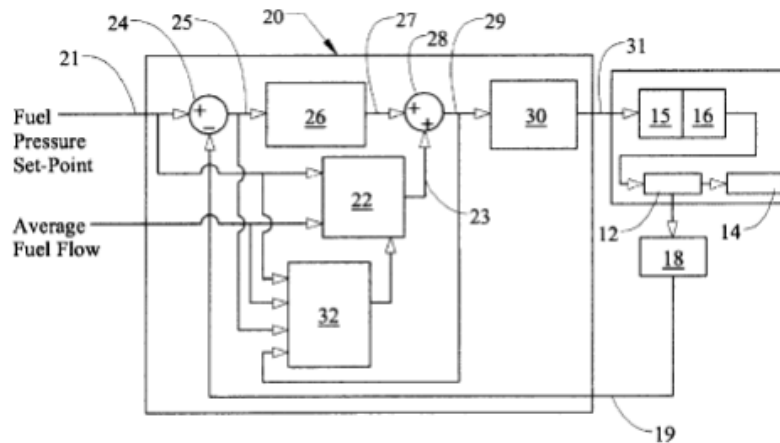
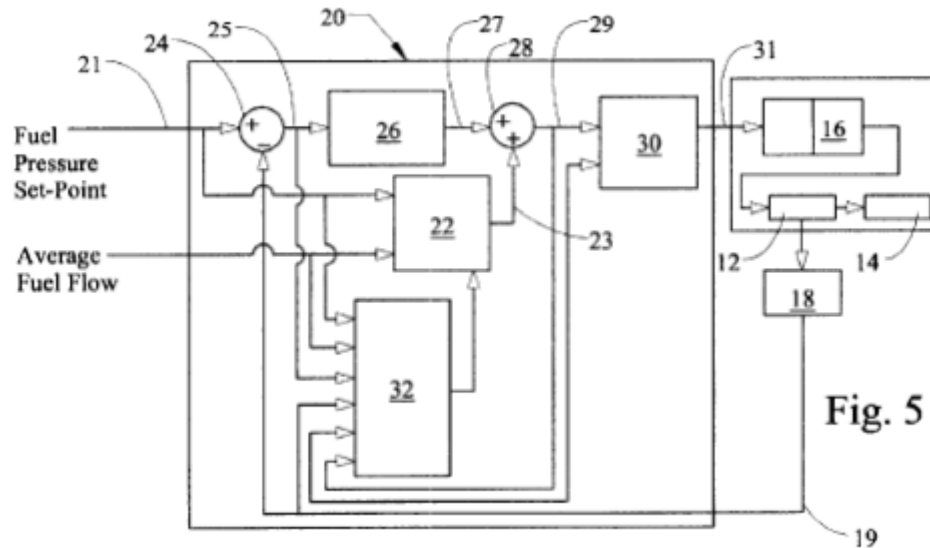


Fig. 4

The variation in Figure 5 additionally provides that “the speed of the fuel pump 16 and the pressure from the pressure sensor 18 can also be received by the adaptive

learning controller 32 to provide additional parameters for more accurate and updating of the feed forward controller 22.” EX1001, 2:66-3:4; EX1003, ¶44.



Last, the '574 patent discloses a second embodiment, which is similar to the first embodiment, except the fuel pressure sensor 34 is mounted at the fuel pump 16 rather than at the fuel rail in the first embodiment. The second embodiment further “also includes a fuel system model 38, a low-pass filter 40, and a device 42 to calculate the average fuel flow.” EX1001, 3:13-18. The average fuel flow rate is calculated by using the injector flow rate, the injector frequency, and the on-time duration. *Id.*, 3:23-44, Figs. 2, 6; *see also* EX1003, ¶45.

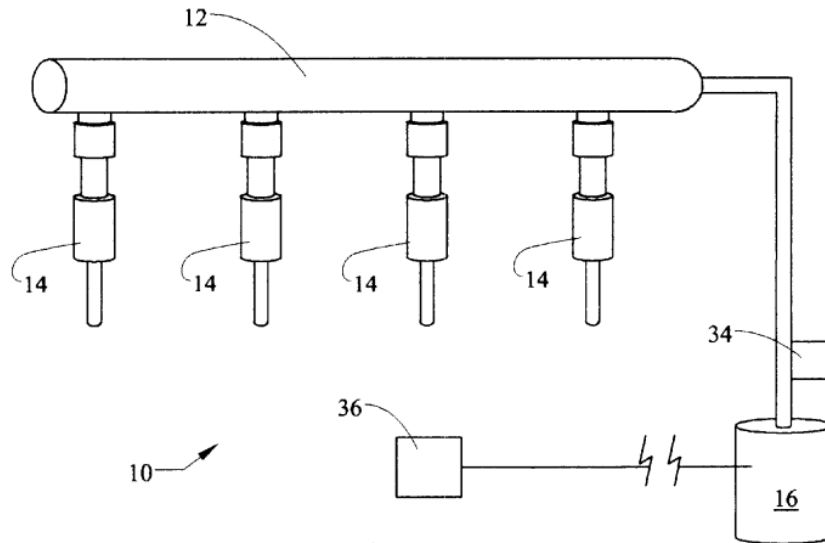


Fig. 2

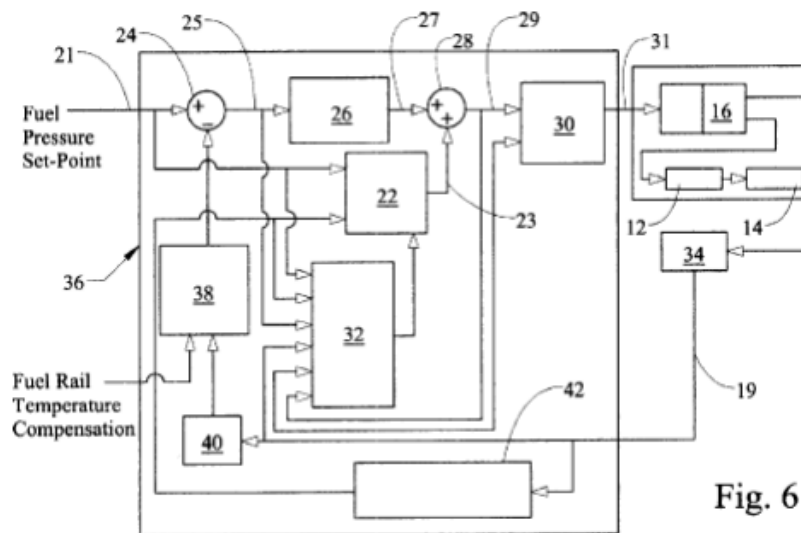


Fig. 6

B. Priority Date

The '574 patent was filed on March 27, 2002, and does not claim the benefit of an earlier-filed application. Petitioners apply a priority date of March 27, 2002, for the purposes of this IPR only.

C. Prosecution History of '574 Patent

During prosecution, the examiner in the first and only office action rejected as-filed claims 1-5 and 8-13. The examiner found, among other things, that U.S. Patent No. 6,349,700 to Buckland discloses “a feed forward fuel control which looks at average fuel flow to determine fuel flow” and that looking to average fuel flow “is common in the art, thus making it obvious to look at an average fuel flow to calculate the feed forward control.” EX1002, 41.¹

However, the examiner further indicated that as-filed claims 6-7 and 14 “would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.” EX1002, 42. In response, the patentee amended the independent claims to incorporate the allowable subject matter of claims 6 and 14. *Id.*, 44-50. Amended claim 1 from prosecution corresponds to claim 1 in the '574 patent, and amended claim 8 from prosecution corresponds to claim 7 in the '574 patent. Further, the patentee added new claim 15 (now independent claim 13), which incorporates the allowable subject matter of original claim 7.

Thus, with the exception of the elements considered “allowable” by the examiner in the first office action the applicant never refuted that all other elements

¹ The reference “Buckland” appears to have been misspelled as “Buchland” in some parts of the prosecution history.

were obvious under Section 103(a) based on the prior art of record during prosecution. And even with respect to the “allowable” claim elements, the references applied in the grounds in the present petition were not before the examiner during prosecution. EX1001; EX1003, ¶¶47-49.

D. Prior IPR Proceedings

There have been two prior IPR proceedings against the '574 patent. First, the Volkswagen Group of America, Inc. (“VW”) filed an IPR proceeding relying on the Japanese Patent Pub. No. 2000-008926 to Heiko, U.S. Patent No. 5,579,738 to Frischmuth, U.S. Patent No. 5,505,180 to Otterman, and U.S. Patent No. 6,223,731 to Yoshiume references. IPR2019-01286. Otterman is the only common reference between the VW IPR and this Petition; however, VW relied on Otterman for claim 4 only, and Petitioners herein rely on Otterman for other claims. The Board denied institution of the VW IPR, finding that VW failed to demonstrate a reasonable likelihood of proving that the combination of Heiko and Frischmuth teach using an estimated average fuel flow as a basis for generating a feed forward control signal as recited in all independent claims. *Id.*, Paper 13 at 7.

Second, Hyundai Motor Co. filed an IPR proceeding relying on the Otterman, Hosoya, and Greiner references, which Petitioners also rely on herein. IPR2018-01064. The Hyundai IPR was settled with no preliminary response filed and before the Board reached an institution decision. *Id.*, Paper 8.

VI. IDENTIFICATION OF CHALLENGES UNDER 37 C.F.R. § 42.104(B)

A. Prior Art

The challenges in this Petition are based on the following references:

Prior Art Reference	Exhibit	Filing Date	Pub. Date	Prior Art Section(s)
U.S. Patent No. 5,505,180 (“Otterman”)	EX1004	3/31/1995	4/9/1996	§102(a), (b), (e)
U.S. Patent No. 5,806,497 (“Hosoya”)	EX1005	3/11/1997	9/15/1998	§102(a), (b), (e)
U.S. Patent No. 4,426,981 (“Greiner”)	EX1006	8/21/1981	1/24/1984	§102(a), (b), (e)
U.S. Patent No. 6,349,700 (“Buckland”)	EX1007	8/11/2000	2/26/2002	§102(a), (e)

B. Challenges

Petitioners request cancellation of claims 1-18 of the ’574 patent based on the following grounds:

Ground	Claims	Basis	Reference(s)
1	1-4, 7-10	§103	Otterman, Hosoya
2	13-16	§103	Otterman, Greiner
3	5-6, 11-12, and 17-18	§103	Otterman, Hosoya, and Greiner
4-6	1-18	§103	Ground 4: the references of Ground 1 in view of Buckland (claims 1-4, 7-10); Ground 5: the references of Ground 2 in view of Buckland (claims 13-16); Ground 6: the references of Ground 3 in view of Buckland (claims 5-6, 11-12, and 17-18)

VII. LEVEL OF ORDINARY SKILL IN THE ART

A POSITA as of the filing date of the '574 patent would have had a bachelors degree in electrical engineering or mechanical engineering (or equivalent) and at least 2-4 years of work experience in automotive electrical or electronics systems design. Additional work or research experience can substitute for less or different education, and vice-versa. Additional work or research experience can substitute for less or different education, and vice-versa. EX1003, ¶¶32-35.

VIII. CLAIM CONSTRUCTION

In an *inter partes* review, claims are “construed using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b).”37 C.F.R. § 42.100 (b). If trial is instituted, all claim terms must be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention, in light of the specification and the prosecution history of the patent. *Id.*; *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312-1313 (Fed. Cir. 2005) (en banc); *see also* 83 Fed. Reg. 51,340 (Oct. 11, 2018).

Petitioners state that no constructions of the Challenged Claims are necessary for the purposes of this Petition. No statement herein should be interpreted to mean that Petitioners believe any term to be definite.

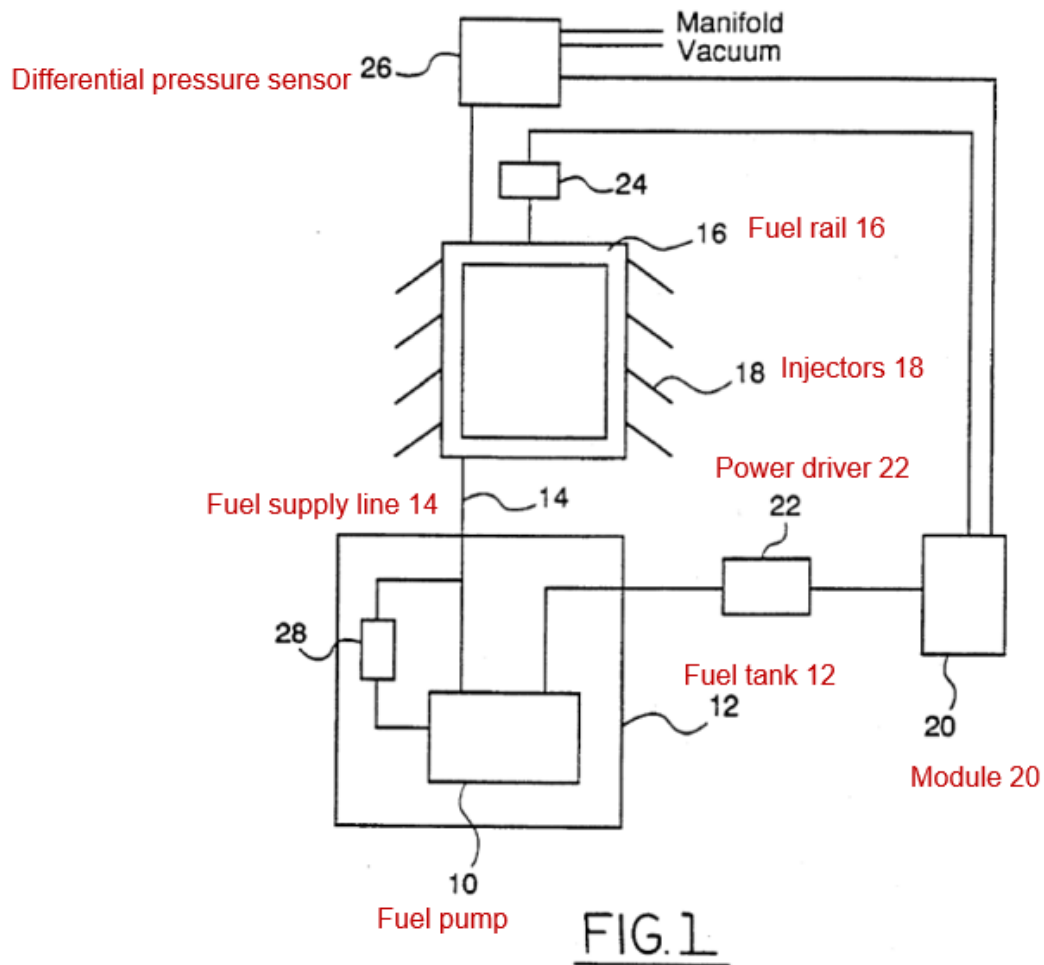
IX. DETAILED EXPLANATION AND SUPPORTING EVIDENCE

A. Overview of the Prior Art

1. Otterman

U.S. Patent No. 5,505,180 (“Otterman”), filed on March 31, 1995, and qualifies as prior art at least under 35 U.S.C. §102(b). Otterman describes a combination feedback and feed forward control system for returnless fuel delivery in an internal combustion engine. EX1004, Abstract, 1:6-11.

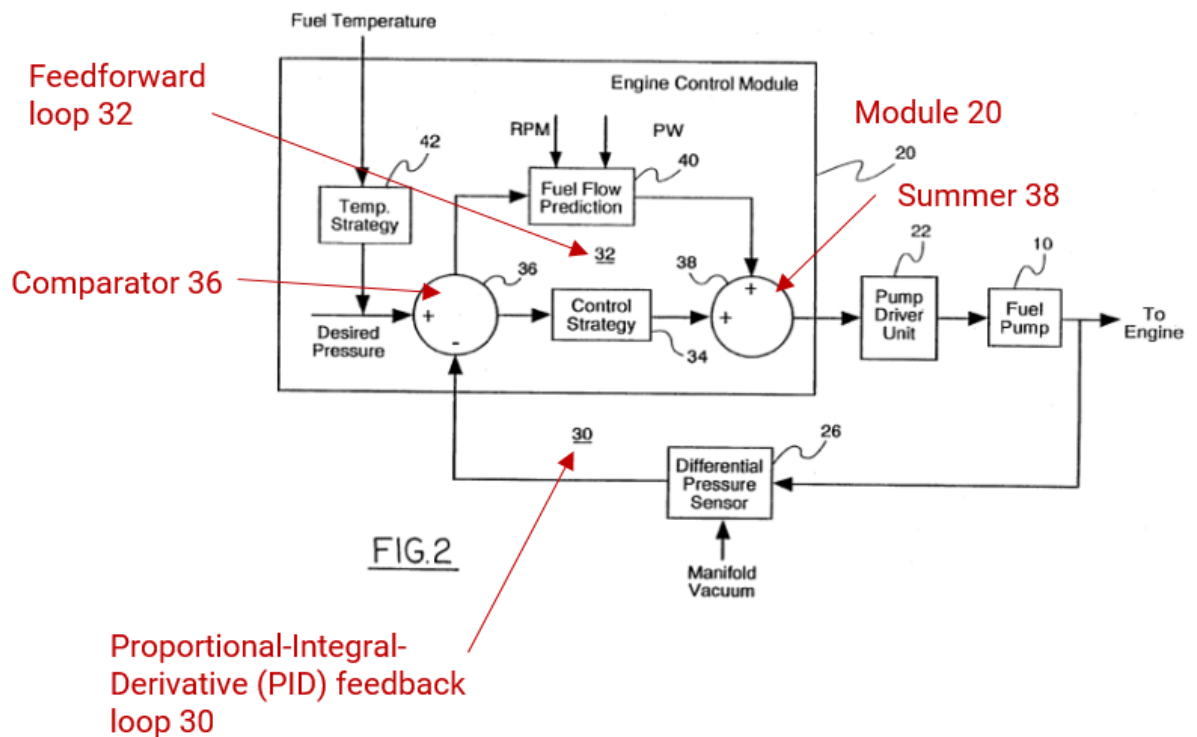
Otterman discloses systems and methods also incorporate “adapting the fuel delivery system operating characteristics to detect and reflect changes in the engine and fuel system over time.” *Id.*, 1:8-10. In Figure 1, Otterman depicts a “returnless fuel system.” *Id.*, 2:29-30.



As shown in Figure 1, the returnless fuel delivery system includes a fuel pump 10, within fuel tank 12. *Id.*, 2:50-52. The fuel tank 12 includes a pressure relief valve 28 which prevents excessive pressure in the fuel rail and assists in smoothing engine running transient pressure fluctuations. *Id.*, 3:1-5. The system further includes supply line 14, fuel rail 16, and injectors 18 along the fuel rail 16. *Id.* 3:1-10. The system further includes a differential pressure sensor 26, which detects the pressure in the fuel rail, and a fuel temperature sensor 24, which detects

the fuel temperature. *Id.*, 2:50-63. An engine control module 20 controls the pulse width of the fuel injector signal. *Id.*, 2:63-67. The engine control module 20 controls the speed of the fuel pump 10, and uses fuel temperature and the pressure signal to determine the fuel pump voltage needed to provide the engine with an optimum fuel pressure and flow rate. *Id.*, 2:50-65.

Figure 2 in Otterman illustrates a control strategy for the returnless fuel system. *Id.*, 2:31-32. Figure 2 includes engine control module 20, as depicted below.



As shown in Figure 2, Otterman discloses that the engine control module 20 “generates a constant frequency pulse width modulated (PWM) fuel pump control signal in accordance with an overall control strategy which includes a

Proportional-Integral-Derivative (PID) feedback loop generally designated 30 which monitors flow error, and a feedforward loop generally designated 32 for determining the fuel pump speed.” *Id.*, 3:12-18. Accordingly, Otterman discloses a system using both feedback and feedforward controls. *Id.*, 3:12-27, 3:38-48. Accordingly, the fuel flow prediction 40, which is part of the feed forward loop 32, “provides a relatively quick response to engine operating conditions which cannot be controlled by PID loop 30,” while the feedback loop, “PID loop 30 provides a fine tuning of the overall control strategy and compensates for pump and engine variability.” *Id.*, 3:48-52.

Otterman further discloses an alternative embodiment in Figure 3, which is reproduced below:

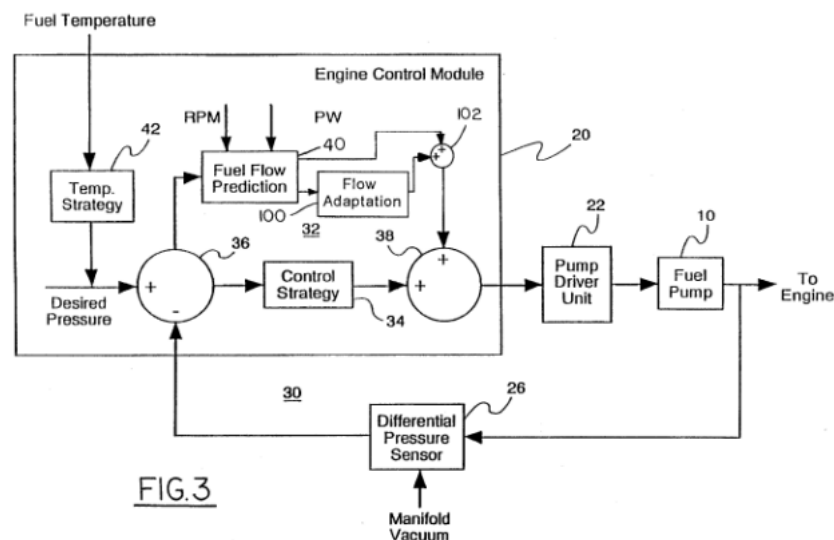


Figure 3 further includes flow adaptation block 100, which provides adjustments to the output of the fuel prediction block 40, based on changes in the fuel system over

time which manifest themselves as constant systematic or offset error. *Id.*, 4:12-22; EX1003, ¶¶51-57.

2. Hosoya

U.S. Patent No. 5,806,497 (“Hosoya”) was filed on March 11, 1997 and qualifies as prior art at least under 35 U.S.C. §102(b). Hosoya is used in this Petition to address the “low-pass filter” limitations. *E.g.*, Limitations 1[e].

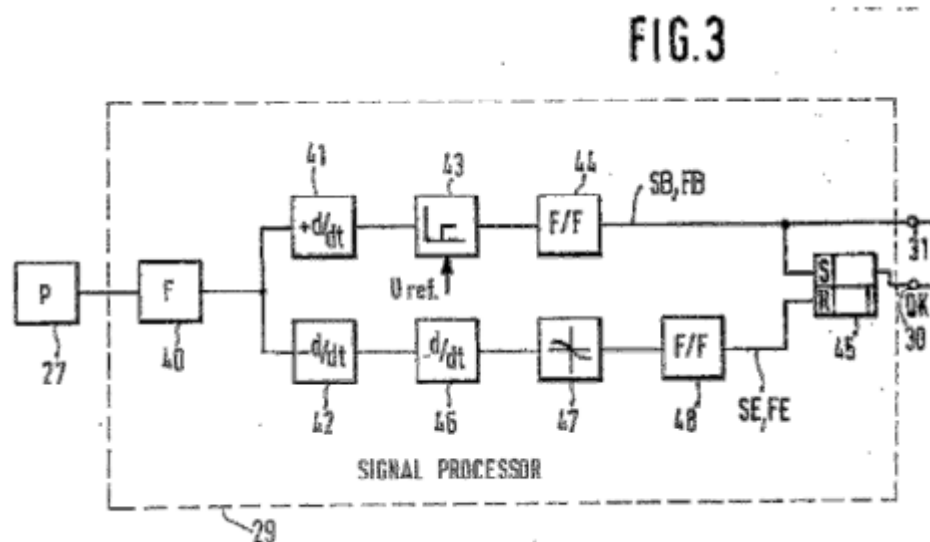
Hosoya describes an apparatus for detecting and controlling fuel injection of an internal combustion engine—specifically addressing the issue of incorrect metering of injected fuel quantity due to fuel pressure drops detected when the fuel is released into the engine (when the injector is opened). EX1005, 1:22-27.

Hosoya recognizes the conventional approach to addressing this issue by smoothing out the fuel pressure signal using a “weighted averaging technique.” *Id.*, 1:28-36. However, as recognized by Hosoya, “the smoothing uses a constant smoothing level or constant cutoff frequency without regard to engine operating state.” *Id.*, 1:37-39. Hosoya further recognizes that the “smoothing” is “unable to properly correct the pulse width in response to an actual fuel pressure,” and thus is not optimal. *Id.*, 1:37-47. Accordingly, Hosoya’s method replaces the weighted average approach by employing “a construction for variably setting the cutoff frequency in a digital or analog low-pass filter.” *Id.*, 6:18-20; EX1003, ¶¶58-59.

3. Greiner

U.S. Patent No. 4,426,981 (“Greiner”) was filed on August 21, 1981 and qualifies as prior art at least under 35 U.S.C. §102(b).

Greiner describes an apparatus for detecting the fuel quantity delivered to the combustion chambers of a diesel engine. EX1006. As shown in Fig. 3, Greiner describes that a “pressure sensor 27 for detecting the fuel pressure emits its output signal to a signal processing circuit 29 . . . which has two outputs 30 and 31 for the injected fuel quantity and the injection onset.” *Id.*, 2:21-26, Fig. 3 (provided below).



Greiner further describes, in reference to the positive inclination differentiation element 41, the onset of the injection pulse can be detected. EX1006, 3:20-34. Greiner further describes, in reference to the negative inclination differentiation element 42, that the end of the injection pulse can be

detected. *Id.*, 3:39-42. Further, Greiner discloses that a fuel pressure sensor can be located in different locations—including the fuel rail or the fuel pump, and provides reasons for design decisions in choosing one location or the other. *Id.*, 2:47-68; EX1003, ¶¶60-62.

4. Buckland

U.S. Patent No. 6,349,700 (“Buckland”) was filed on August 11, 2000, and published on February 26, 2002, and qualifies as prior art at least under 35 U.S.C. §102(a).

Buckland discloses estimating an average fuel flow rate. Buckland discloses a cylinder air/fuel ratio model calculation:

$$r_c = \frac{(1 - F_i)W_{cyl}}{W_f},$$

Buckland discloses that r_c is “the air/fuel ratio in a cylinder, defined as the ratio of total air available in the cylinder for combustion to injected fuel; where total air includes air metered through the throttle body and air recirculated through the exhaust” and “ W_f is *the average fuel flow rate into the cylinder* over an engine event.” EX1007, 8:27-38. Thus, Buckland discloses providing an estimated average fuel flow through the system as claimed.

Buckland thus discloses “a feed forward fuel control which looks at average fuel flow to determine fuel flow,” as the examiner found. The examiner further found that looking to average fuel flow “is common in the art, thus making it obvious to look at an average fuel flow to calculate the feed forward control.” *See supra* §V.C. Buckland is relied on this petition in the alternative for limitations disclosing an average fuel flow EX1003, ¶¶63-65.

B. Ground 1: The Combination of Otterman and Hosoya Render Claims 1-4, 7-10 Obvious

Otterman combined with Hosoya render claims 1-4 and 7-10 obvious. Otterman is relied upon as the primary reference, while Hosoya is relied upon for the “filtering the output of the fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors” limitation. *See* limitation 1[e].

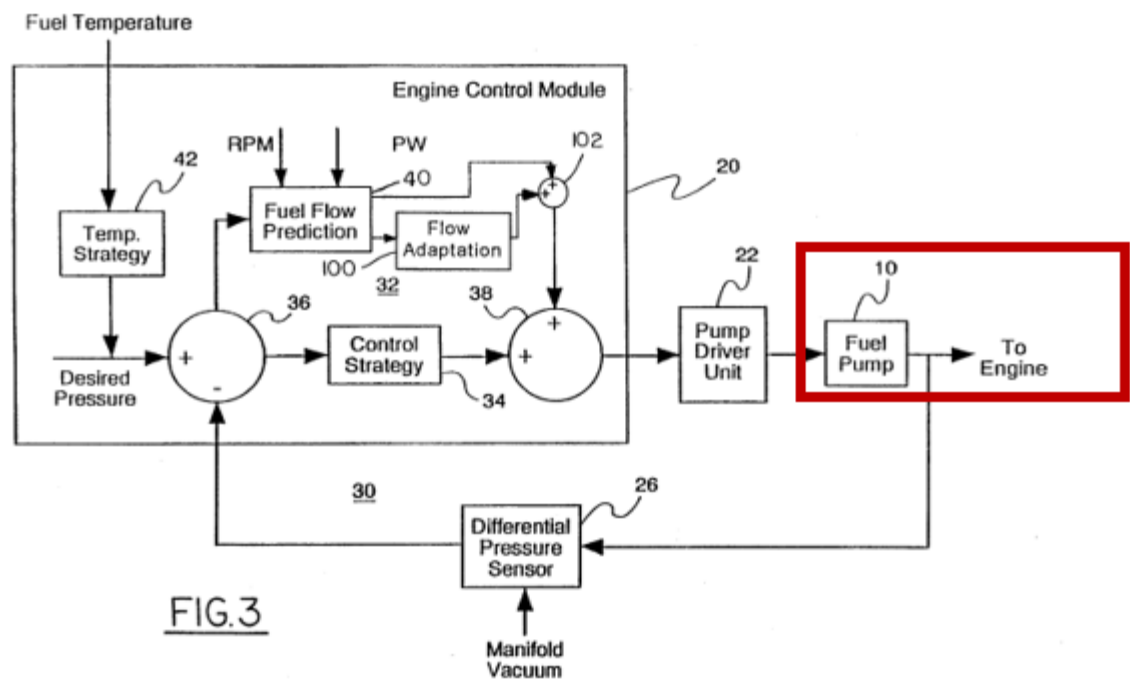
The motivation to combine Otterman and Hosoya is discussed in detail *infra* Section IX.B.9.

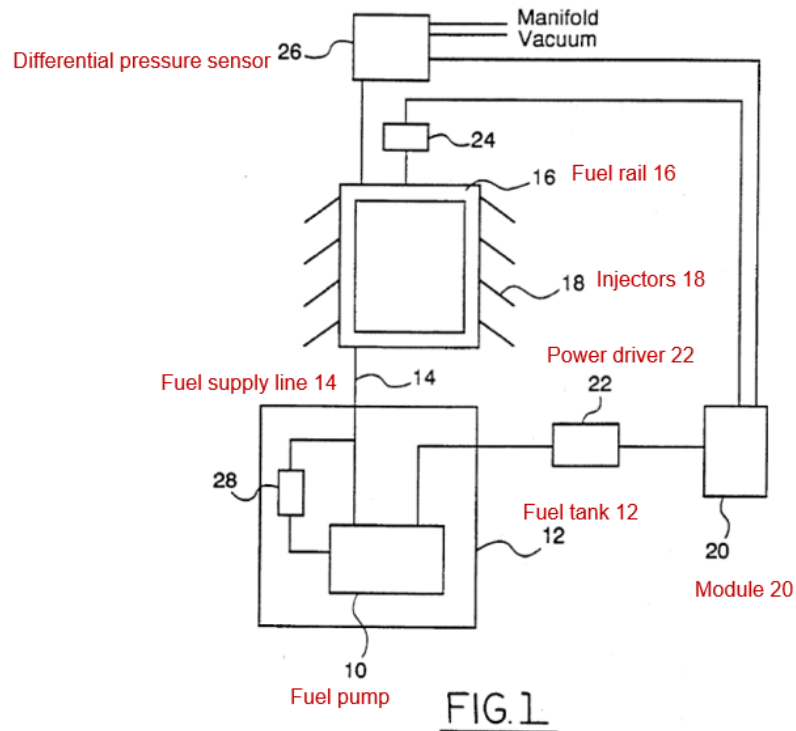
1. Claim 1

- a. Element 1[p]. “A method of controlling the fuel pressure within a fuel delivery system having a fuel pump which delivers fuel to a fuel rail of an internal combustion engine comprising:”**

Otterman discloses this element. EX1003, ¶66. For example, Otterman teaches “a returnless fuel delivery system includ[ing] a fuel pump 10 located within a fuel tank 12 of a vehicle.” EX1004, 2:50-52. Otterman also discloses that

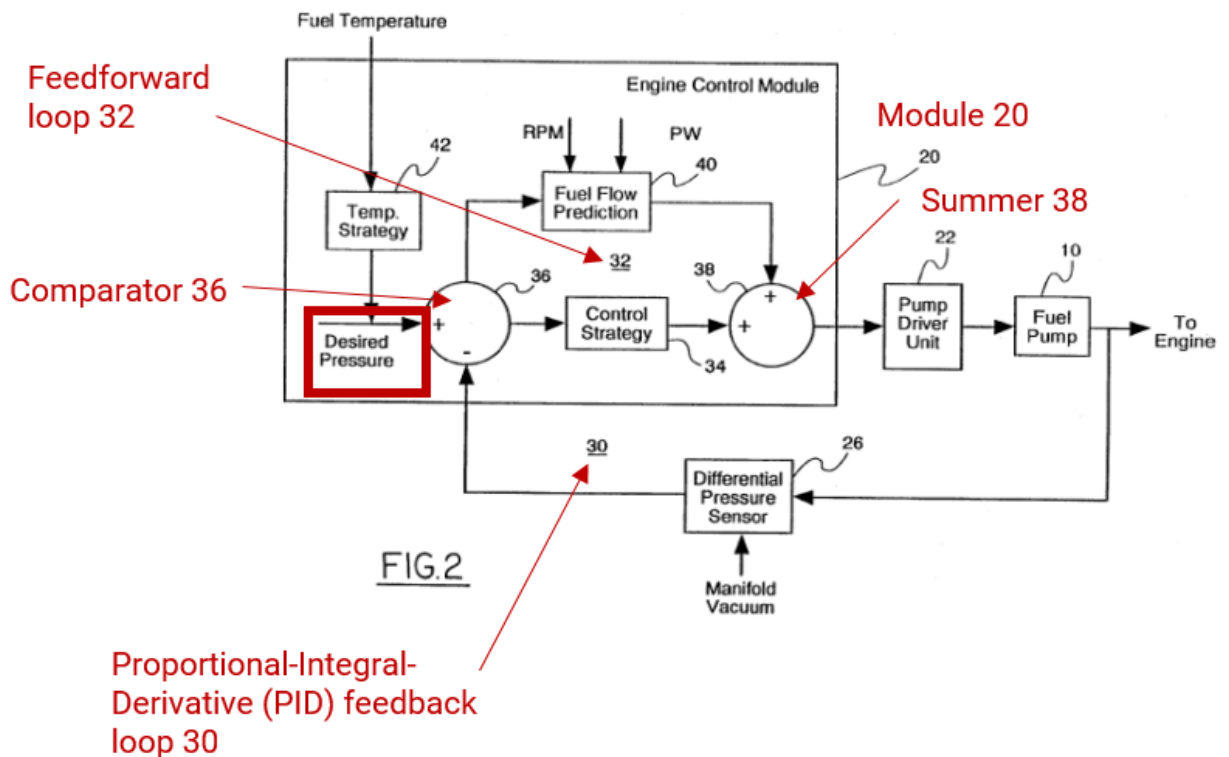
the pump 10 supplies fuel to a fuel rail 16 for “distribution to a plurality of injectors 18.” *Id.*, 2:52-53. Otterman’s system includes an “engine control module 20” for controlling the returnless fuel delivery system, by “supplying control signals which are amplified and frequency multiplied by a power driver 22 and supplied to pump 10.” *Id.*, 55-58. Otterman further discloses that the system controls the fuel pressure within the fuel delivery system. *See, e.g., id.*, cl. 7, 2:63-67, Fig. 3 (showing the control strategy of the returnless fuel system, including fuel pressure control); EX1003, ¶66.





b. Element 1[a]. “providing a set-point fuel pressure;”

Otterman discloses this element. EX1003, ¶¶67-68. As shown in Figure 2, Otterman discloses a “desired pressure” that is received at comparator 36 of the system. EX1004, 3:18-22. The “desired pressure” signal is a set-point or reference fuel pressure signal. *Id.*; EX1003, ¶67. Otterman further explains the desired fuel pressure as a desired “differential” pressure. For example, the flow chart of Figure 4 refers to setting a “target differential fuel pressure” EX1004, 4:57-60; EX1003, ¶67.

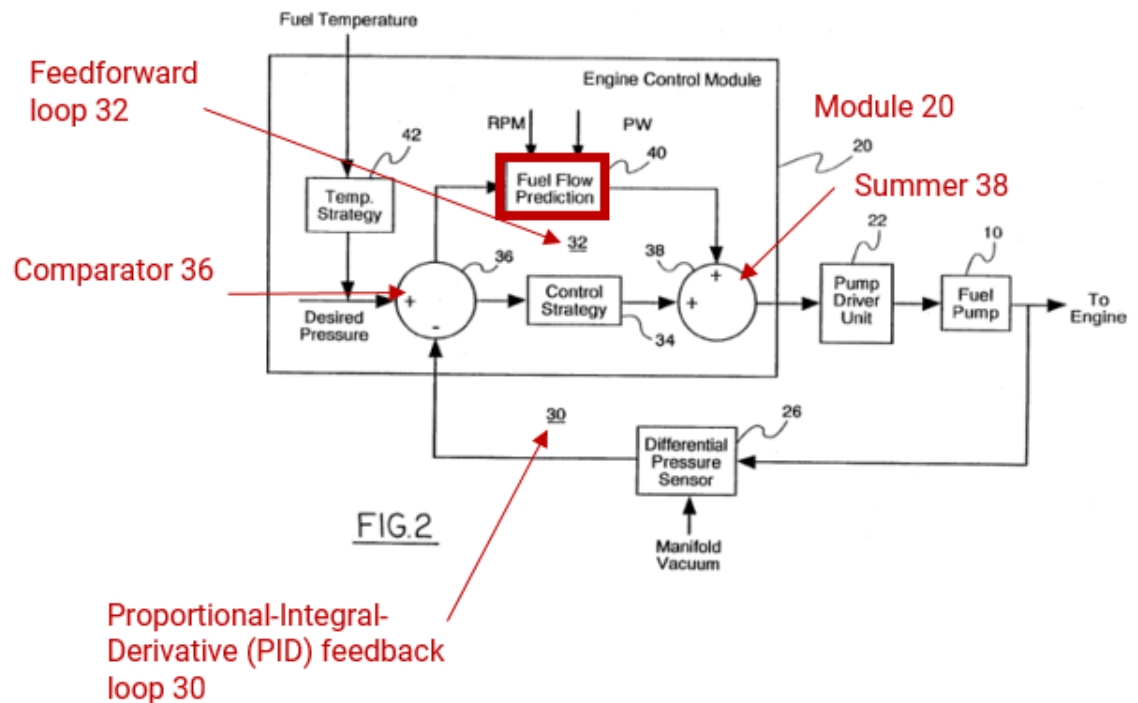


A POSITA would appreciate that the “desired differential pressure” disclosed in Otterman is “the desired pressure of the fuel rail relative to a reference manifold pressure.” EX1003, ¶68. Accordingly, Otterman teaches the claimed “set-point fuel pressure.”

c. Element 1[b]. “providing the estimated average fuel flow through the system;”

Otterman discloses this element. EX1003, ¶¶69-71. Otterman discloses a “fuel flow prediction block 40 to predict mass fuel flow demanded” in the system. EX1004, 3:41-52, Fig. 2 at 40 (as annotated below); EX1003 ¶69. Accordingly, given that Otterman teaches that a predicted or typical fuel flow is provided to the

system, a POSITA would appreciate that Otterman teaches a predicted or “estimated average fuel flow.” EX1003, ¶69.



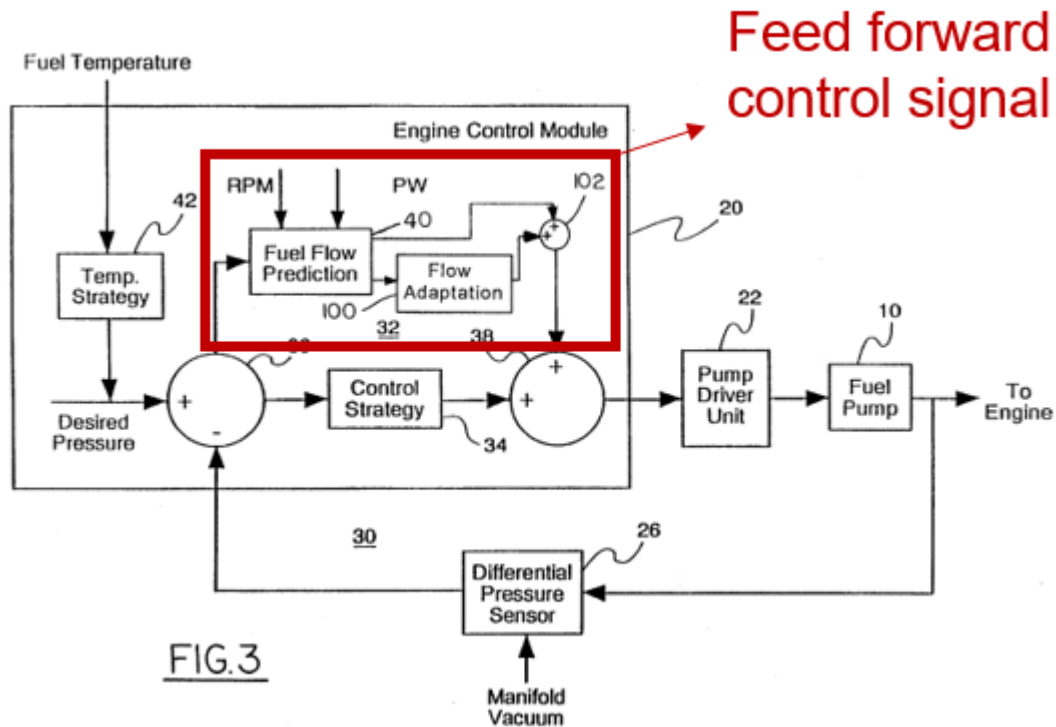
Otterman explains that the fuel flow prediction block compensates for transient instability produced by a sudden change in the manifold vacuum when loop 30 responds to differential pressure. EX1004, 3:37-40. “Fuel flow prediction block 40 compensates for this instability by utilizing engine RPM and injector pulse width (PW) to predict mass fuel flow demanded. The variables are obtained by monitoring one of the fuel injector control lines. These inputs define a particular operating point which is pinpointed in a table to provide a corresponding optimum duty cycle for the PWM signal to pump 10. Fuel flow prediction 40 provides a relatively quick response to engine operating conditions which cannot be

controlled by PID loop 30. PID loop 30 provides a fine tuning of the overall control strategy and compensates for pump and engine variability.” *Id.*, 3:41-52.

Otterman also discloses providing an estimated average fuel flow because Otterman discloses that the system monitors and provides the average fuel flow error. EX1004, 2:2-3, 4:18-22, 3:31-33. A POSITA would appreciate that “to determine the average flow error over time, the PID device would also determine the average fuel flow.” EX1003, ¶71. Otterman explains that while a preferred embodiment utilizes differential pressure to determine flow error, other methods could be used “such as monitoring the fuel stream.” EX1004, 6:25-33 (“What is required is to measure the flow actually supplied by the returnless fuel system against the flow demanded from the returnless fuel system, which is reflected by the feedforward and adaptive terms, and compare the average difference over the time interval against some level of acceptable fluctuation.”). Accordingly, Otterman alternatively provides the “average fuel flow” for this reason.

d. Element 1[c]. “generating a feed forward control signal based upon the set-point fuel pressure and the average fuel flow;”

Otterman discloses this element. EX1003, ¶¶72-75. Figure 3 of Otterman illustrates the feed forward control signal:



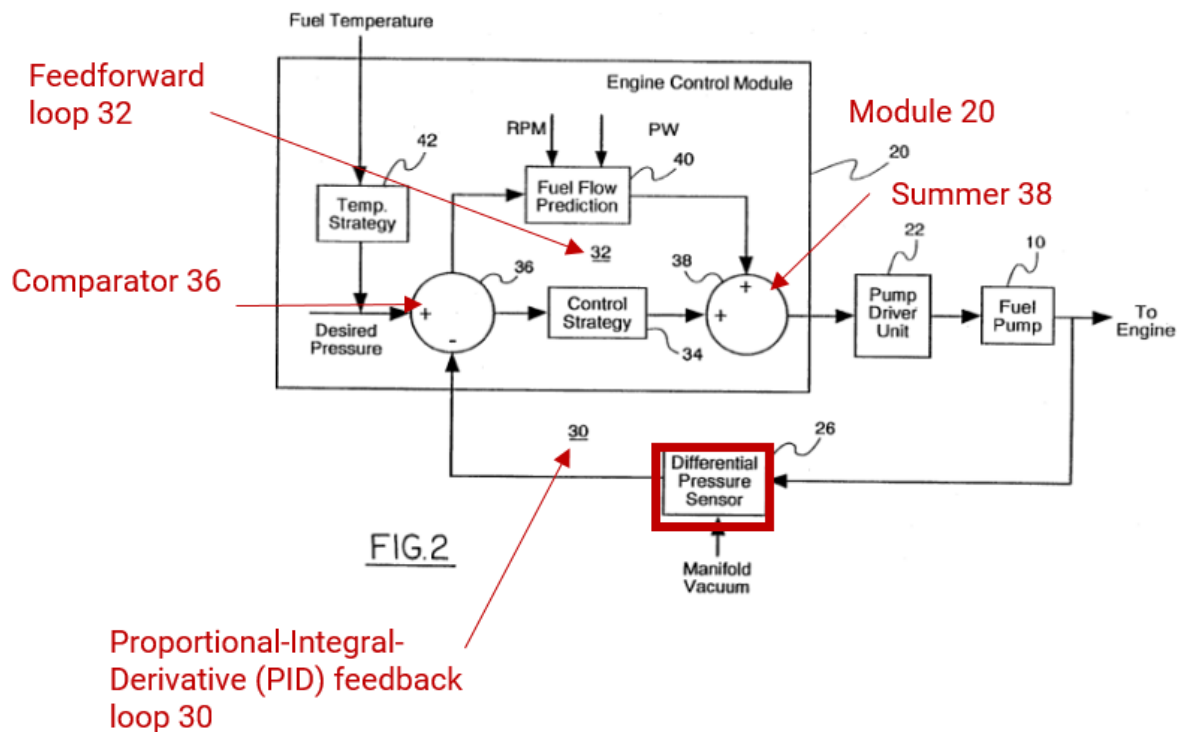
In general, Otterman teaches that the “feed forward” control is designated by reference numeral 32. EX1004, 3:15-17. Otterman further describes that a feedforward term, is generated using a look-up table based upon the set point fuel pressure (i.e., desired pressure input) and average fuel flow (i.e., output of fuel flow prediction). EX1003, ¶73. Specifically, Otterman discloses that the inputs to the fuel flow prediction block 40 “define a particular operating point which is pinpointed in a table to provide a corresponding optimum duty cycle for the PWM signal to pump 10.” EX1004, 3:38-50. As is shown by the annotated Figure 3 above, the signal generated by the fuel flow prediction block is partly based upon desired pressure (average pressure). *Id.*, Fig. 3 at 40. The output of the fuel flow

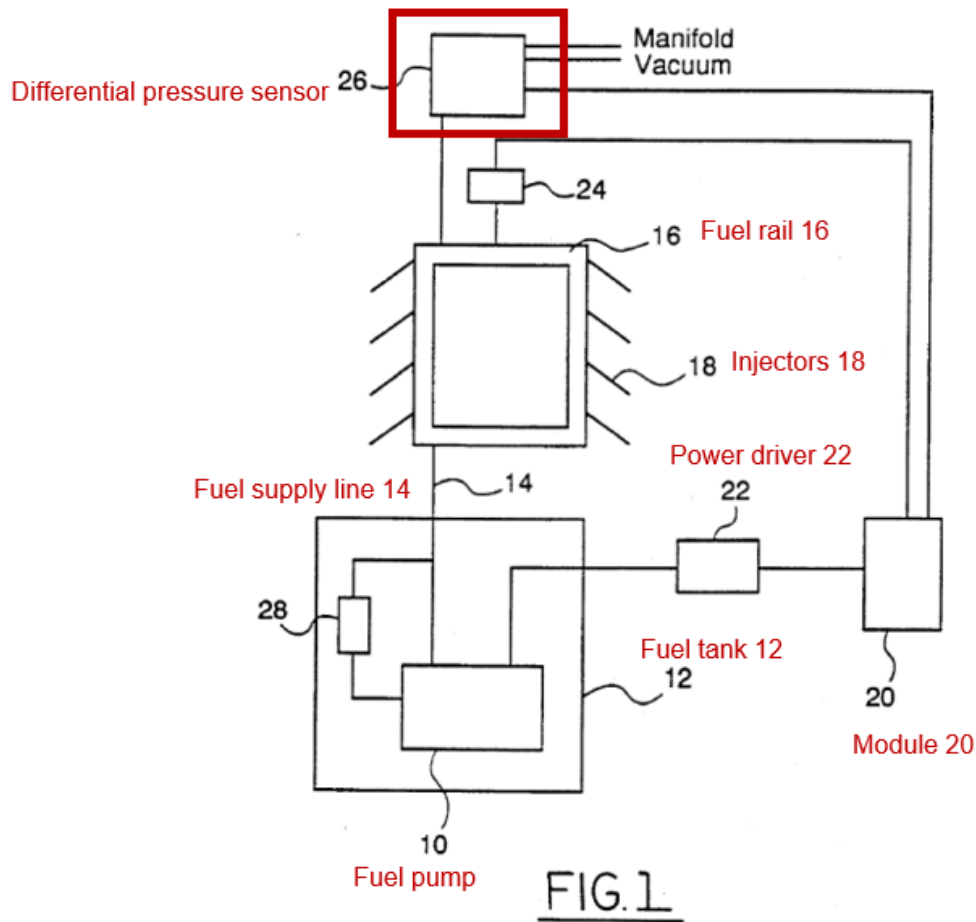
prediction block 40 is an optimum duty cycle for the PWM signal to pump 10 (feedforward fuel pump duty cycle). *Id.*, 3:41-48. The output of the fuel flow prediction block 40 is input into summer 102, which adds an adaptive adjustment to the base feedforward fuel pump duty cycle to provide an “adjusted feedforward value,” which is then continued into summer 38. *Id.*, 4:34-39. Accordingly, Otterman also teaches “generating a feed forward control signal based upon the set-point fuel pressure and the average fuel flow” based on the fuel flow prediction (or typical/average fuel flow value). EX1003, ¶73.

Additionally, considering the “average fuel flow error,” Otterman also teaches that the average fuel flow error value is used by the “flow adaptation block 100,” which adapts the system to certain system changes “by monitoring the average flow error” EX1004, 4:18-22. The adaptive adjustments are generated and added to the duty cycle which was computed by fuel flow prediction block 40 (the feed forward term) to generate an adjusted feed forward term. *Id.*, 4:18-22, 4:34-38. Accordingly, Otterman also teaches “generating a feed forward control signal based upon the set-point fuel pressure and the average fuel flow” based on the average fuel flow error adjustments to the feedforward term. EX1003, ¶74.

e. Element 1[d]. “measuring the fuel rail pressure with a fuel pressure sensor;”

Otterman discloses this element. EX1003, ¶¶76-77. Otterman discloses that the fuel pressure sensor measures the pressure relative to the manifold pressure. EX1004, 2:60-63, Fig. 2 at 26.





A POSITA would appreciate that the “differential pressure signal” provided by the differential pressure sensor 26, as disclosed in Otterman, is “the pressure of the fuel rail relative to a reference manifold pressure.” EX1003, ¶77. Accordingly, Otterman teaches the claimed “measuring the fuel rail pressure with the fuel pressure sensor.” *Id.*

f. Element 1[e]. “filtering the output of the fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors;”

Otterman in view of Hosoya discloses this element. EX1003, ¶¶78-80.

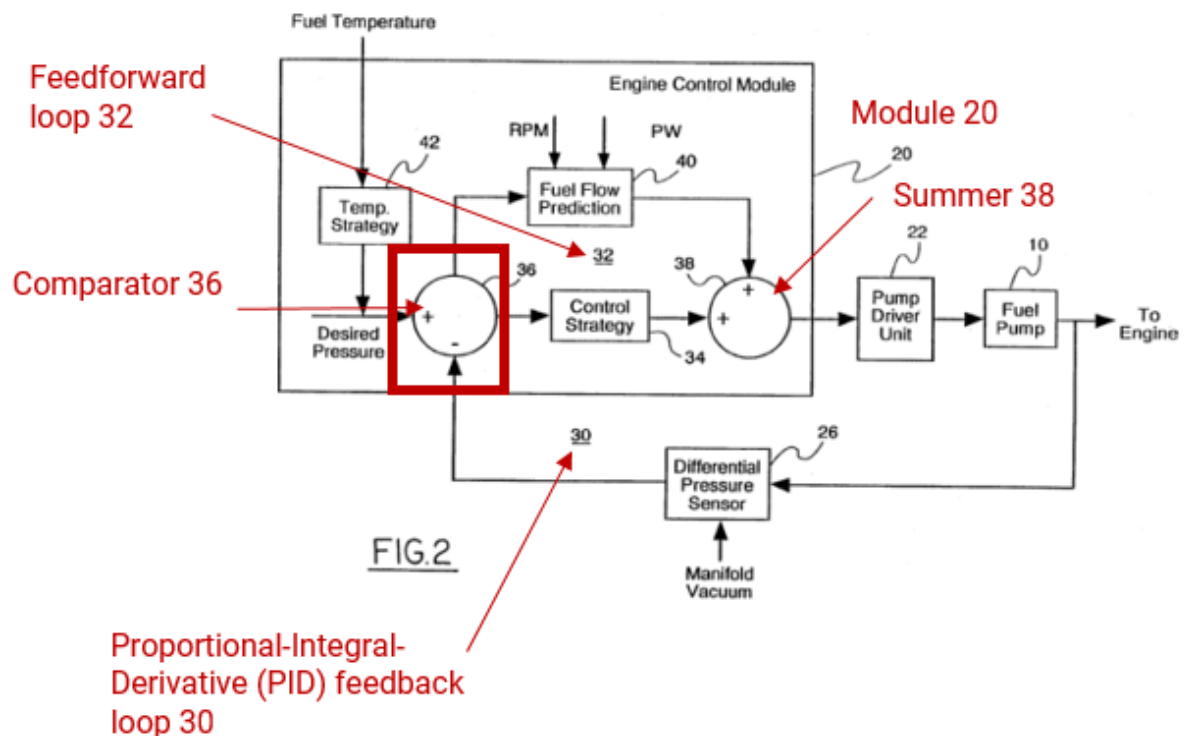
Otterman discloses a PID device with an “integral function whose output represents the average error over time between the desired fuel flow and the system’s actual fuel flow.” EX1004, 3:28- 33. In doing so, Otterman describes smoothing or averaging the difference between the desired fuel flow and the measured fuel flow. EX1003, ¶78. A POSITA would recognize this integration step as a filtering step that would remove the effects of pressure variation as a result of the injector pulses.

Hosoya similarly provides using a variety of approaches, including weighted averaging and using a low pass filter to remove the pulses due to the opening and closing of the fuel injectors. *E.g.*, EX1005, 1:50-55, 2:6-18, 6:18-20. Hosoya provides using a low pass filter to remove the pulses due to the opening and closing of the fuel injectors. *See, e.g., id.*, 1:50-55, 2:6-18, 6:18-20, Fig. 6.

It would have been obvious to combine Hosoya’s low-pass filter with Otterman’s system, as explained in more detail in Section IX.B.9. EX1003, ¶80. A POSITA would have been motivated to combine Hosoya’s low-pass filter with Otterman to avoid using the weighted average approach known in the art and to avoid the suboptimal “smoothing” disclosed in Hosoya. *Id.*

- g. **Element 1[f]. “comparing the fuel rail pressure to the set-point fuel pressure and generating an error signal based upon the difference between the fuel rail pressure and the set-point fuel pressure; and”**

Otterman discloses this element. EX1003, ¶¶81-82. Otterman teaches that the comparator 36 provides an “error output . . . which represents the difference between a desired differential pressure input and the actual differential pressure as input from a differential pressure sensor 26.” EX1004, 3:17-21.

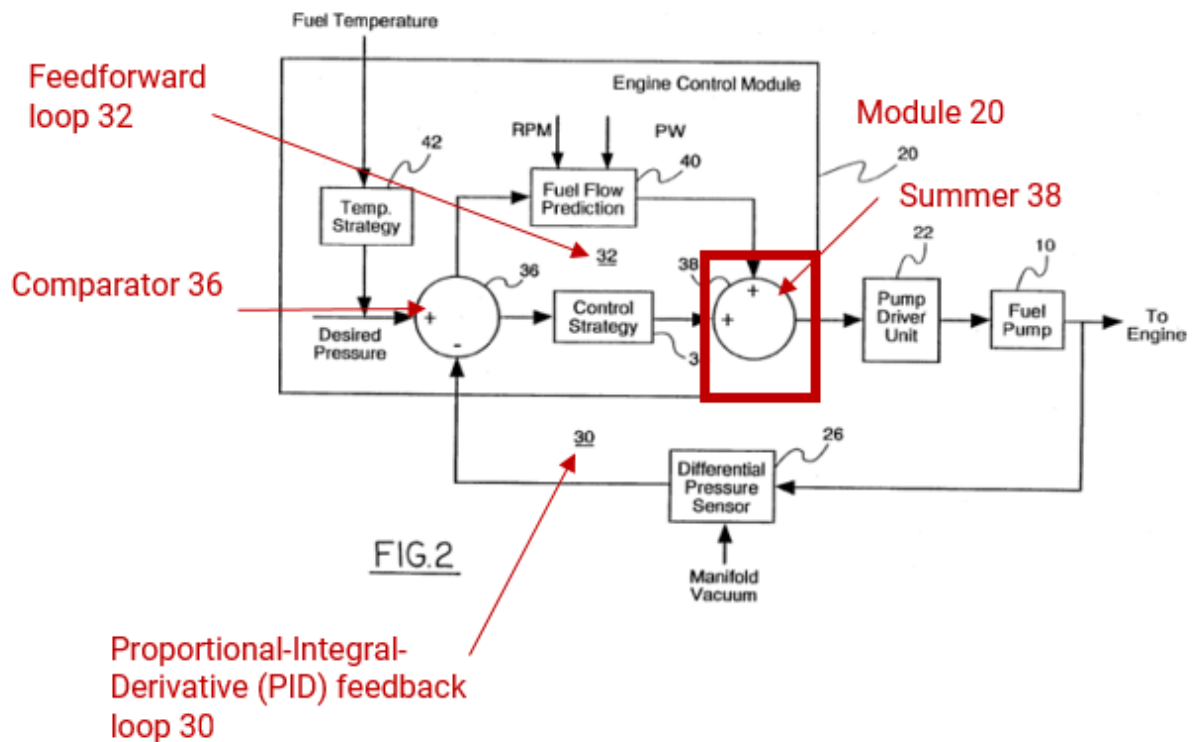


Accordingly, Otterman discloses comparing the desired differential pressure input and the actual differential pressure as input from a differential pressure sensor 26. EX1004, 3:17-21; EX1003, ¶82. The desired differential pressure input is the set point fuel pressure, and the actual differential pressure is the fuel rail pressure itself. A POSITA would appreciate that the “differential pressure” provided by the

differential pressure sensor 26, as disclosed in Otterman, is “the pressure of the fuel rail relative to a reference manifold pressure.” EX1003, ¶82. And a POSITA would also appreciate that the “desired differential pressure” disclosed in Otterman as being provided to the comparator is “the desired pressure of the fuel rail relative to a reference manifold pressure”—or the set point fuel pressure. Accordingly, Otterman teaches this element. *Id.*

h. Element 1[g]. “modifying the feed forward control signal based upon the error signal thereby generating a motor controller signal and sending the motor control signal to the fuel pump motor.”

Otterman discloses this element. EX1003, ¶83. Otterman discloses a summing junction 38, which is a second summing junction, that receives an error signal generated by the feedback loop 30, and more specifically generated by the comparator 36 and processed by the control strategy block 34 in the feedback loop 30. EX1004, 3:12-28. The summing junction 38 also receives a feed forward control signal from the feed forward loop 32, and more specifically from the fuel flow prediction block 40. *Id.* The summing junction 38 modifies the feed forward control signal (the fuel flow prediction signal) by adding the error term. *Id.*, 3:21-25. The signal is then provided to the pump driver block 22 to generate a signal that drives the fuel pump 10. *Id.*, 2:55-58; EX1003, ¶83. A POSITA would know that the fuel pump 10 disclosed in Otterman necessarily has a fuel pump motor. EX1003, ¶83.

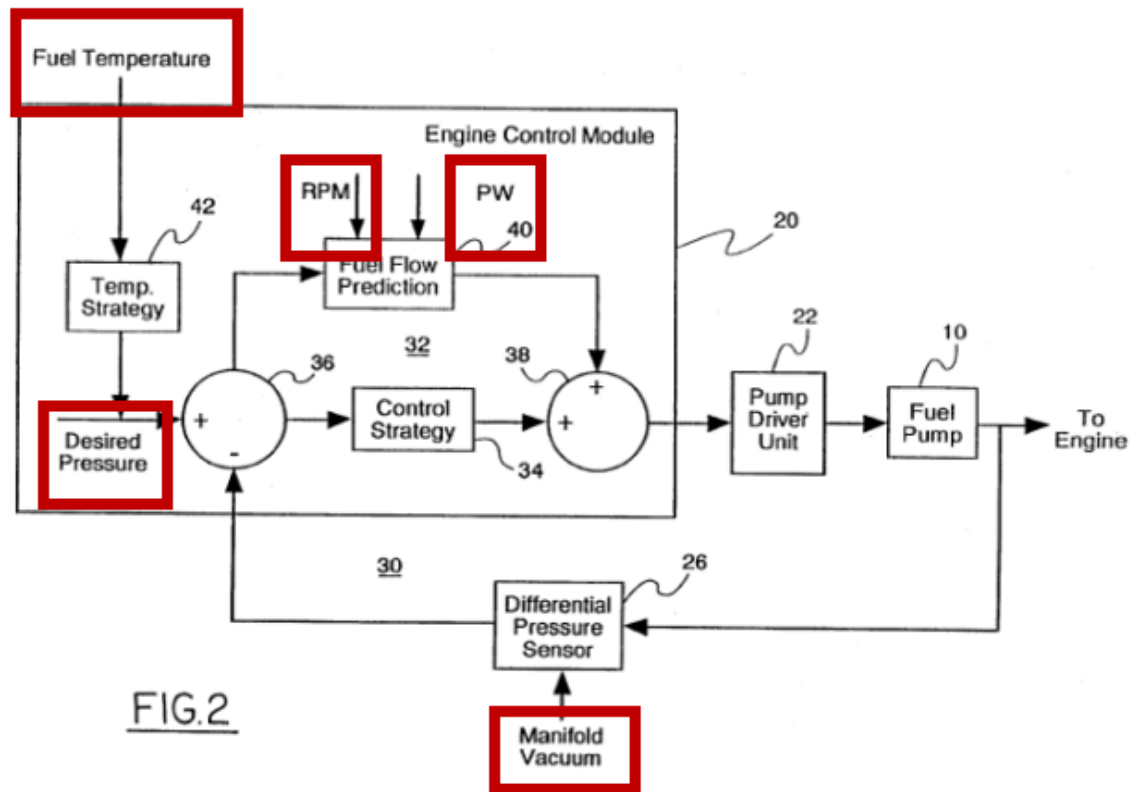


2. **Claim 2: “The method of claim 1 wherein generating a feed forward control signal includes providing a feed forward controller which provides established fuel pump motor control parameters at particular set-point pressure and average fuel flow rate values, wherein the set-point pressure and average fuel flow are input to the feed forward controller and a feed forward control signal having set of corresponding fuel pump motor control parameters is thereby generated.”**

Otterman discloses this element. EX1003, ¶¶84-87. Otterman teaches wherein generating a feed forward control signal includes providing a feed forward controller which generates established fuel pump motor control parameters at particular set-point pressure and average fuel flow rate values, wherein the setpoint pressure and average fuel flow are input to the feed forward controller and a feed

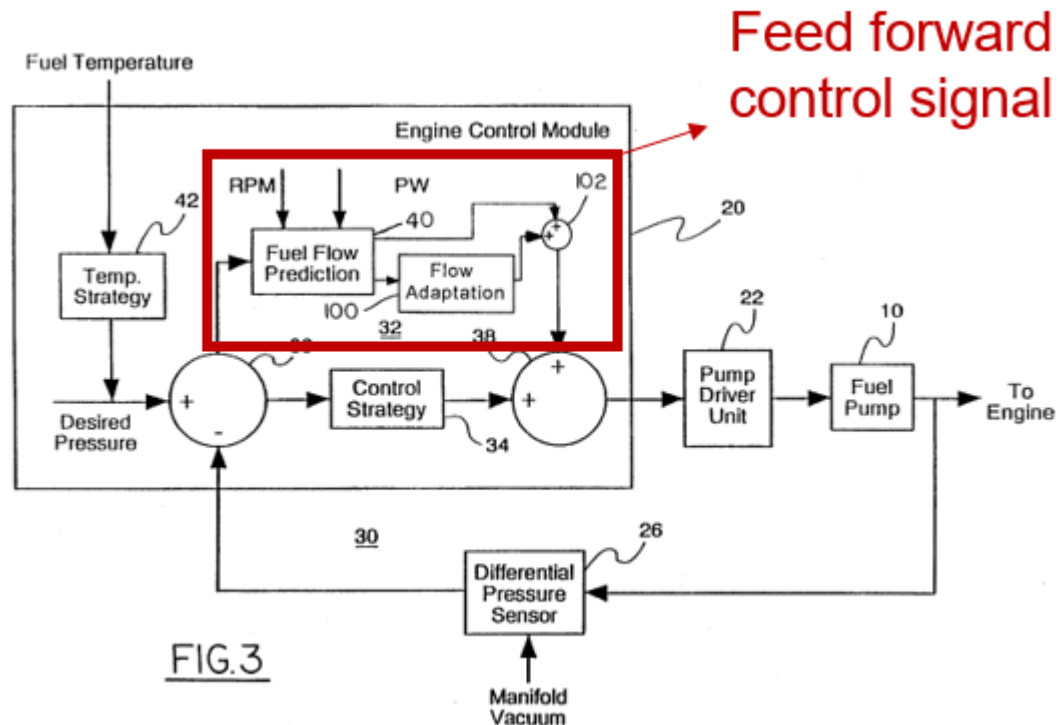
forward control signal having set of corresponding fuel pump motor control parameters is thereby generated. EX1003, ¶84.

As shown in Figure 2, Otterman discloses a feed forward control signal (the output of the fuel flow prediction box 40), and a feed forward controller 20 which provides established fuel pump motor control parameters as part of its pump control signal / feed forward control signal. EX1004, Fig. 2; EX1003, ¶85. Figure 2 (annotated below) also shows that the set point signal (desired pressure) and the average fuel flow (fuel flow prediction) are inputs in the feed forward loop 32.



Further, Otterman teaches that the feed forward controller 32 uses multiple inputs—including desired pressure, fuel temperature, engine RPM, injector pulse width (PW), etc.—to define a particular operating point, “which is pinpointed in a table to provide a corresponding optimum duty cycle for the PWM signal to pump 10.” EX1004, 3:38-50.

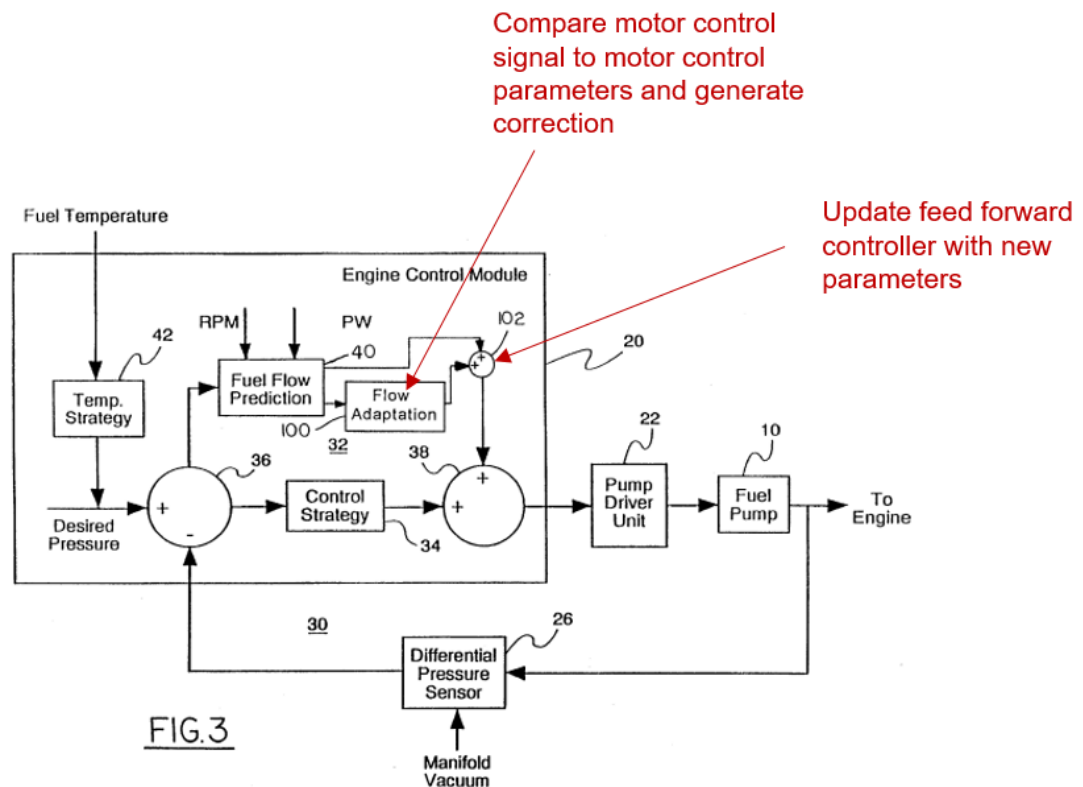
Otterman further discloses an improved embodiment, which uses the average fuel pressure error (from the feedback loop) to adapt the feed forward controller output to account for long term changes in the system. *Id.*, 4:18-22, Fig. 3. As shown below, the feedforward control signal is input into summing junction 38, where it is combined with the output of the control strategy block 34 of the feedback loop 30. *Id.*, 4:65-5:3, Fig. 3. The output of the summing junction 38 is provided to the pump driver unit 22, and then to the fuel pump 10, thereby controlling the fuel pump operation. *Id.*, 4:34-38, 4:65-5:3. Accordingly, Otterman provides an alternative basis for disclosing that the feedforward controller bases the feed forward signal on an average fuel flow (average fuel flow error) and the set point signal (desired pressure).



3. **Claim 3: “The method of claim 1 further including: comparing the motor control signal to the fuel pump motor control parameters within the feed forward controller which correspond to the set-point pressure and the average fuel flow; and updating the feed forward controller with new fuel pump motor control parameters.”**

Otterman discloses this element. EX1003, ¶¶88-89. Otterman teaches an adaptive function in the disclosed control system. EX1004, Fig. 3 at 100, Fig. 4 at 62, 64, 56, 58. Figures 3 and 4 (annotated) are reproduced below for illustration. With reference to Figure 3, Otterman teaches that the “[f]low adaptation block 100 includes an adjusting mechanism which adapts the output of fuel flow prediction block 40 for changes in the fuel system over time which manifest themselves as constant systematic or offset error.” *Id.*, 4:10-15. The flow adaptation block 100

further adapts the system to these changes “by monitoring the average flow error supplied by control strategy block 34 over a time interval and generating cumulative adaptive adjustments to the duty cycle which was computed by fuel flow prediction block 40.” *Id.* To correct any detected errors in the system, the flow adaptation block 100 compares the fuel pump control signal (motor control signal) required to obtain the correct average fuel flow, to the parameters provided by the fuel prediction block 40. *Id.*, 4:10-33. The difference between these values represents the amount that must be added to the fuel pump control parameters in summer 102 to correct for this difference.”



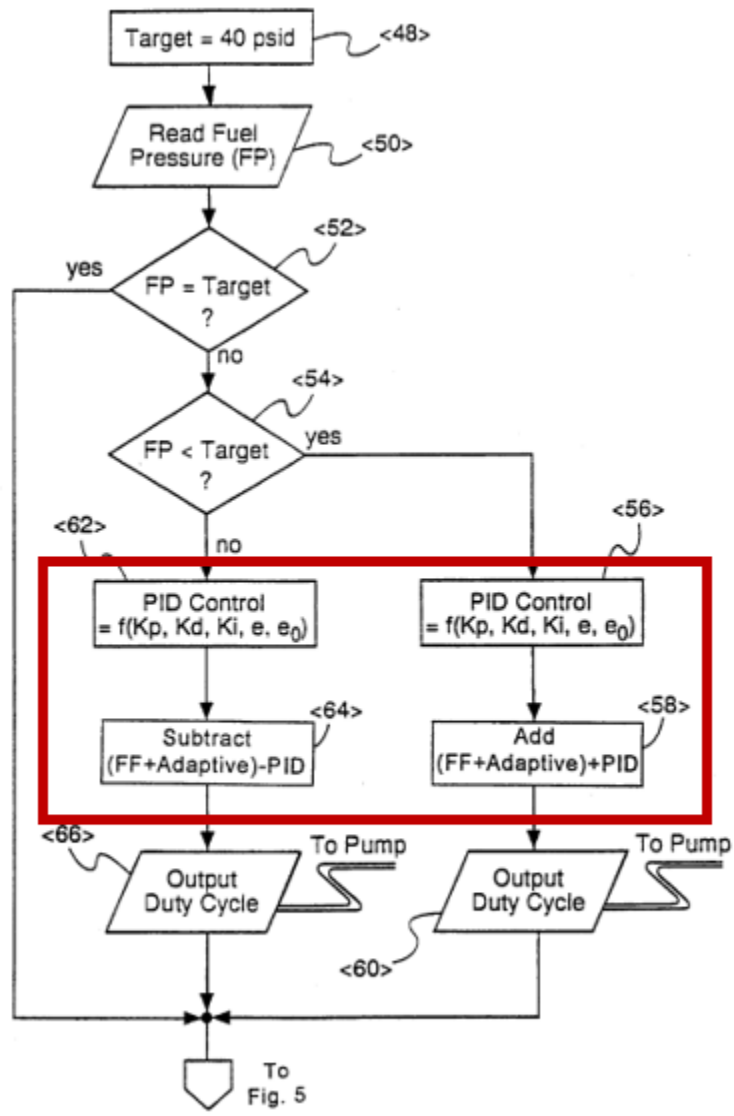
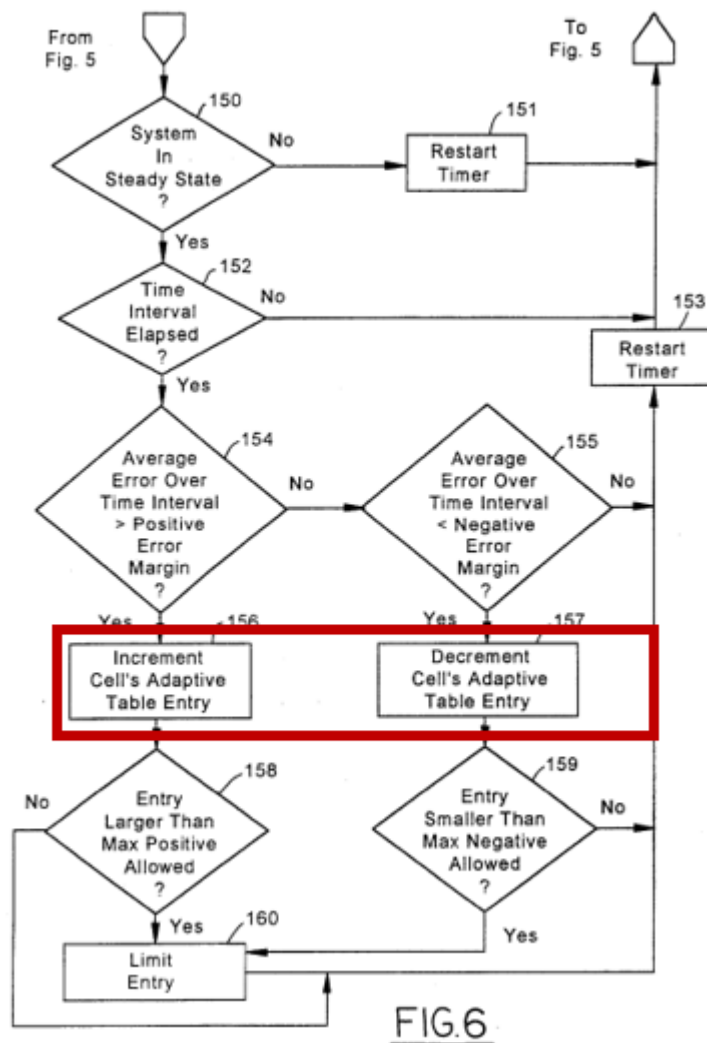


FIG. 4

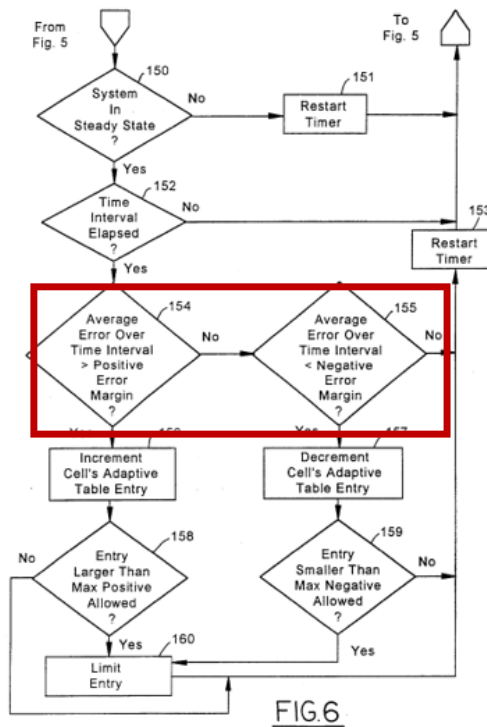
Figure 6 further illustrates this updating of the feed forward controller with the new fuel pump motor control parameters:



4. **Claim 4: “The method of claim 3 further including monitoring the error signal, and updating the feed forward controller after the error signal has stabilized and is below a pre-determined level.”**

Otterman discloses this element. EX1003, ¶90. Otterman teaches monitoring the error signal, and updating the feed forward controller after the error signal has stabilized and is below a pre-determined level. Otterman explains that

the flow adaptation block 100 adapts the system to these changes by “monitoring the average flow error supplied by control strategy block 34 over a time interval and generating cumulative adaptive adjustments to the duty cycle.” EX1004, 4:18-23. Otterman further discloses monitoring the error over time, and making comparisons to a pre-determined threshold, in reference to Figure 6. *Id.*, 6:34-40. Specifically, Otterman explains that, in the Figure 6 embodiment, “the general criteria for making adaptive adjustments is to make them when (PID Integral > Positive Error Limit) or when (PID Integral < Negative Error Limit), with the positive and negative error limits defining a predetermined range of expected error.” *Id.*, 6:14-24.



5. **Claim 7:**

a. **Element 7[p]. “A fuel delivery system comprising:”**

Otterman discloses this element. *See* Element 1[p]; EX1003, ¶91.

b. **Element 7[a]. “a fuel rail adapted to deliver fuel to fuel injectors of an automotive vehicle, a fuel pump adapted to deliver fuel to said fuel rail, a fuel pressure sensor adapted to measure the fuel rail pressure, a low-pass filter adapted to filter the output of said fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors, and”**

Otterman in view of Hosoya discloses this element. EX1003, ¶92.

Otterman teaches a fuel rail for delivering fuel to fuel injectors of an automobile, a fuel pump adapted to deliver the fuel to the fuel rail, and a fuel pump motor controller. *See* Element 1[p]. Otterman further discloses “a fuel pressure sensor adapted to measure the fuel rail pressure.” *See* Element 1[d]. Otterman in view of Hosoya discloses “a low-pass filter adapted to filter the output of said fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors.” *See* Element 1[e]. A POSITA would be motivated to combine Otterman and Hosoya for the reasons in Section IX.B.9.

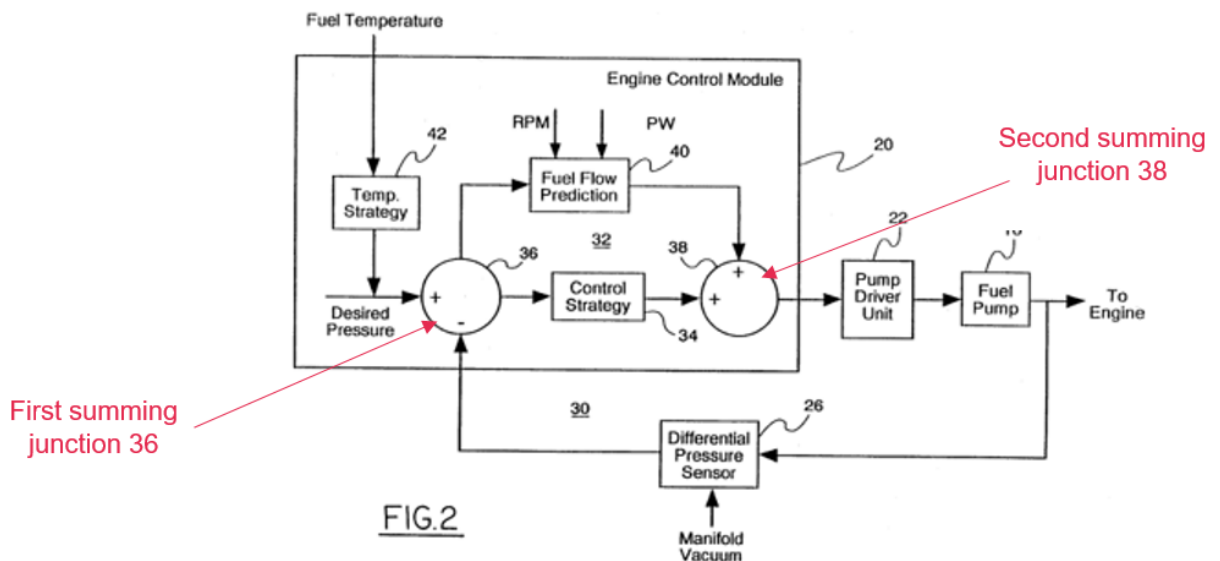
c. **Element 7[b]. “a feed forward controller adapted to provide a feed forward signal having fuel pump motor control parameters based upon a set-point fuel pressure and the average fuel flow through said system;”**

Otterman discloses this element. *See* Elements 1[a]-1[c]; Claim 2; EX1003, ¶93. Otterman teaches that the fuel flow prediction block 40 compensates for

instability in the system by “utilizing engine RPM and injector pulse width (PW) to predict mass fuel flow demanded.” EX1004, 3:38-50. Otterman teaches monitoring the fuel injector control lines to obtain these variables, which are used as inputs defining “a particular operating point which is pinpointed in a table to provide a corresponding optimum duty cycle for the PWM signal to pump 10.” *Id.*, 3:41-52. Accordingly, the feed forward controller provides the feed forward signal (output of feed forward loop 32) which is based on fuel pump motor control parameters, average fuel flow, and a set-point signal.

- d. **Element 7[c]. “a first summing junction adapted to compare the fuel rail pressure to the set-point fuel pressure and to generate an error value based upon the difference between the fuel rail pressure and the set-point fuel pressure;”**

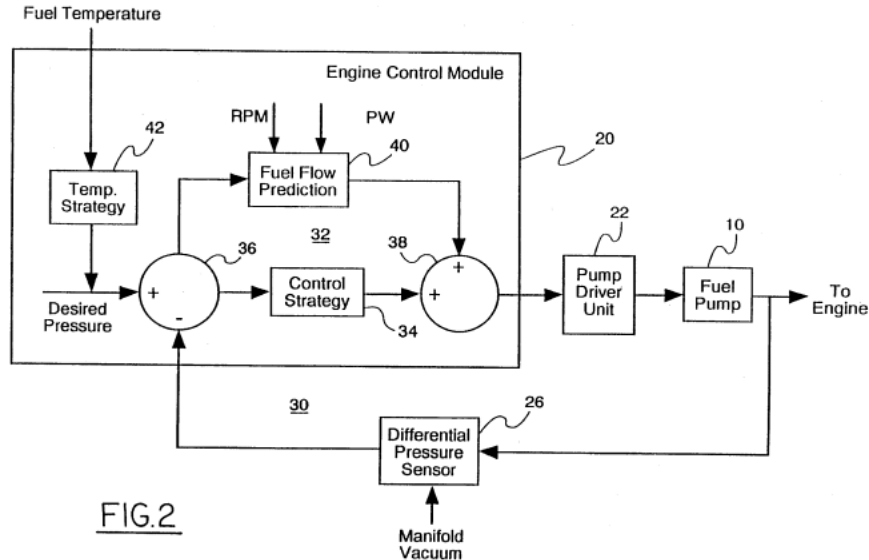
Otterman discloses this element. *See* Element 1[f]; Fig. 2; EX1003, ¶94.



- e. **Element 7[d]. “a feed back controller adapted to receive the error value and to generate a feed back control signal;”**

Otterman discloses this element. See Element 1[f]; Claim 2; EX1003, ¶95.

Otterman teaches a feedback loop that is generally designated with reference numeral 30 in Figure 2. EX1004, 3:15-25. The differential pressure error is processed in control strategy block 34, which receives “the error output of a comparator 36 which represents the difference between a desired differential pressure input and the actual differential pressure as input from a differential pressure sensor 26.” *Id.* Accordingly, the comparator 36 generates a feedback control signal, which is further processed by the control strategy block 34.

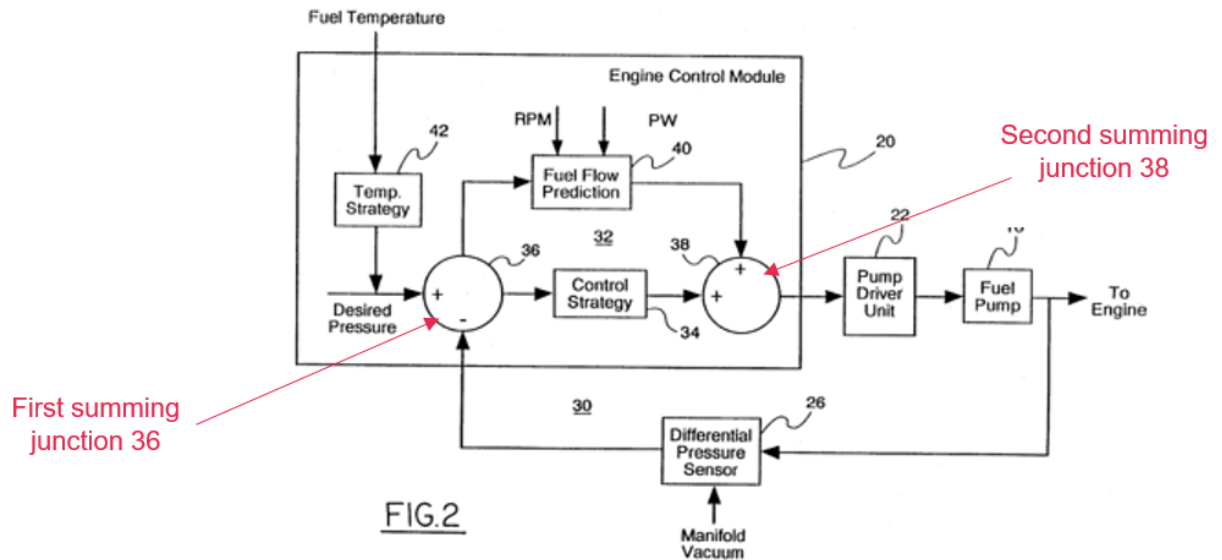


- f. **Element 7[e]. “a second summing junction adapted to receive the feed back control signal from said feed back controller and the feed forward control signal from the feed forward controller and to modify the fuel pump motor control parameters of the feed**

forward control signal based upon the feed back control signal to generate a motor controller signal; and”

Otterman discloses this element. See Element 1[g]; EX1003, ¶¶96-97;

EX1004, 3:21-25, Fig. 2.

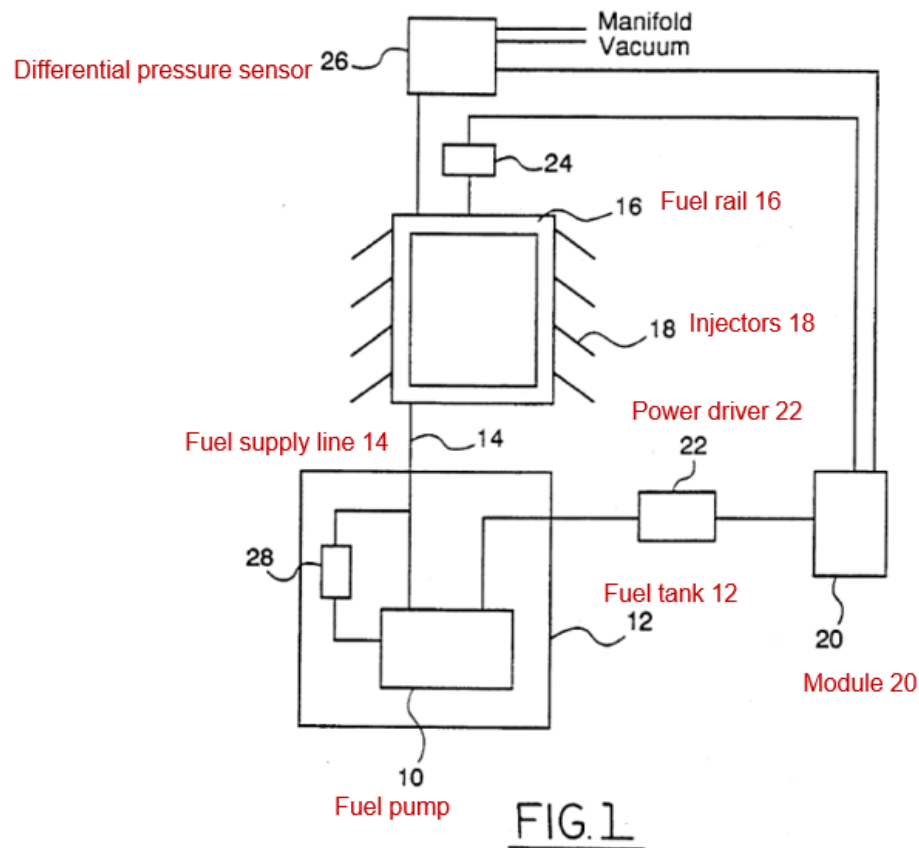


The summing junction 38 that receives an error signal generated by the feedback loop 30, and more specifically generated by the comparator 36 and processed by the control strategy block 34 in the feedback loop 30. EX1004, 3:12-28. The summing junction 38 also receives a feed forward control signal from the feed forward loop 32, and more specifically from the fuel flow prediction block 40. *Id.* The summing junction 38 modifies the fuel pump motor control parameters of the feed forward control signal based upon the feed back control signal generated by the comparator 36 and processed by the control strategy block 34 in the

feedback loop 30 by adding the error term. *Id.*, 3:21-25. The signal is then provided to the pump driver block 22 to generate a motor controller signal that drives the fuel pump 10. *Id.*, 2:55-58.

- g. Element 7[f]. “a fuel pump motor controller driver adapted to receive the motor controller signal and to control the speed of said fuel pump based upon the motor controller signal.”**

Otterman discloses this element. EX1003, ¶98. Otterman discloses that the output of the summing junction 38 (the pulse width modulation signal) is supplied to the power driver 22, which amplifies and frequency multiplies the control signals and supplies the control signals to the pump 10. EX1004, 3:55-58, Fig. 1. A POSITA would know that the fuel pump 10 disclosed in Otterman necessarily has a fuel pump motor. EX1003, ¶98.



6. **Claim 8:** “The fuel delivery system of claim 7 wherein said fuel pressure sensor is mounted at said fuel rail to directly measure the fuel pressure within said fuel rail.”

Otterman discloses this element. EX1003, ¶99. Otterman describes that “sensor 26 responds to intake manifold vacuum and to the pressure in the fuel rail 16 to provide a differential pressure signal to module 20.” EX1004, 2:60-63. Figure 1 further depicts the location of the fuel pressure sensor 26 being mounted directly to fuel rail 16:

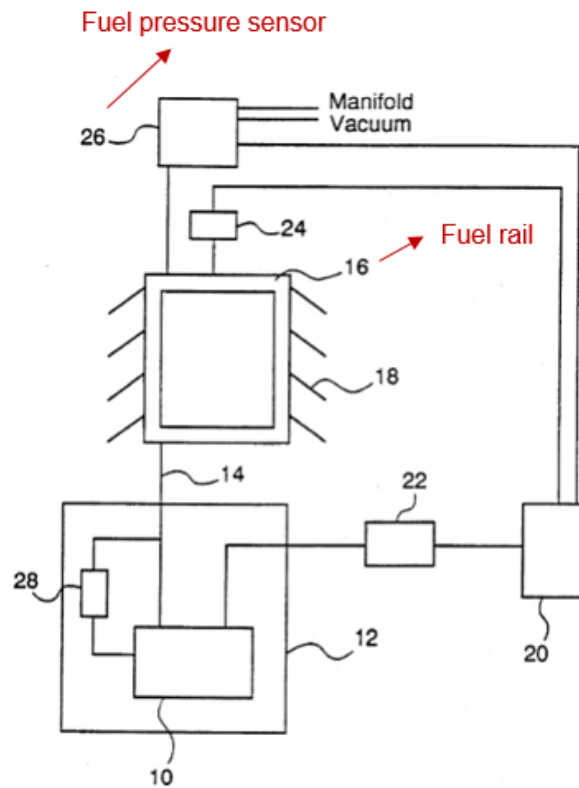


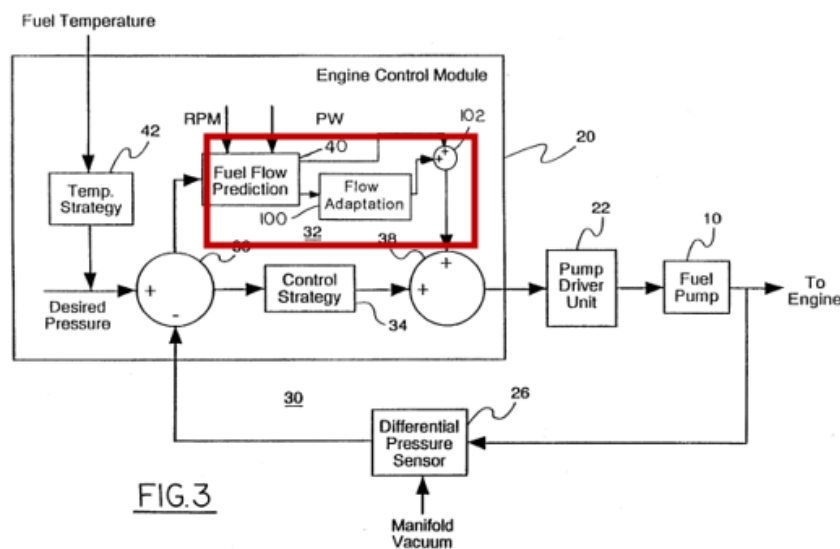
FIG. 1

- 7. Claim 9: “The fuel delivery system of claim 7 wherein said feed back controller is a proportional integration and differential closed loop controller.”**

Otterman discloses this element. EX1003, ¶100. Otterman explains that a “Proportional-Integral-Derivative (PID) feedback loop generally designated 30 ... Loop 30 includes a control strategy block 34 which responds to the error output of a comparator 36 which represents the difference between a desired differential pressure input and the actual differential pressure as input from a differential pressure sensor 26.” EX1006, 3:14-25. Accordingly, Otterman teaches that the differential pressure error is processed in control strategy block 34, which is described as a PID feedback loop.

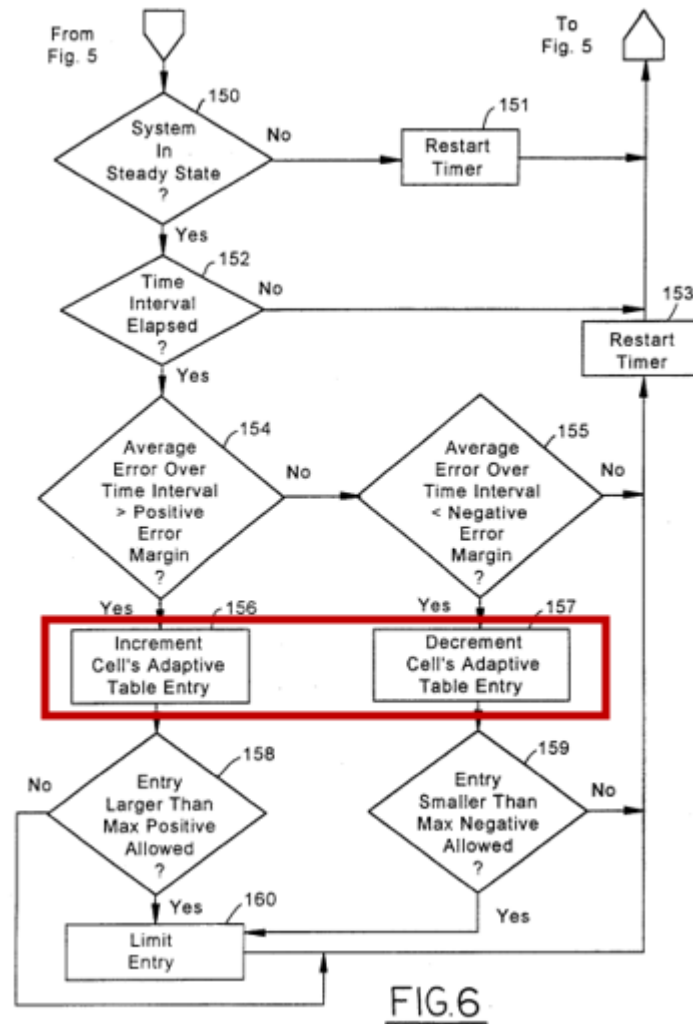
8. **Claim 10: “The fuel delivery system of claim 7 further including an adaptive learning controller having an algorithm which is adapted to monitor the conditions of the fuel delivery system and to update said feed forward controller.”**

Otterman discloses this element. EX1003, ¶¶101-102. Otterman teaches a feed forward controller with an adaptive learning controller 100 (flow adaptation block). EX1004, 4:18-22, Fig. 3.



Otterman explains that “[f]low adaptation block 100 includes an adjusting mechanism which adapts the output of fuel flow prediction block 40 for changes in the fuel system over time which manifest themselves as constant systematic or offset error.” *Id.*, 4:11-15. To do so, block 100 “monitor[s] the average flow error supplied by control strategy block 34 over a time interval and generat[es] cumulative adaptive adjustments to the duty cycle which was computed by fuel flow prediction block 40.” *Id.*, 4:16-22. The adaptive adjustments are added to the

base feedforward fuel pump duty cycle at summer 102, and then continues to summer 38 for combination with the feedback control signal to generate the pump control signal. *Id.*, 4:34-48, 4:65-5:3. The algorithm disclosed by Otterman is provided in Figure 6. *Id.*, 6:34-40.



9. A POSITA Would Have Been Motivated to Combine Hosoya and Otterman.

A POSITA would have a motivation to combine the teachings of Otterman and Hosoya and would have a reasonable expectation of success for several reasons. EX1003, ¶¶103-108.

First, both references are in the same field of endeavor—methods, systems, and apparatuses for controlling fuel injection in engines, focuses on ensuring the correct amount of fuel is administered to the cylinders of the engine, where pressure must be measured and monitored to ensure the correct pressure is present in the fuel control system. *E.g.*, EX1004, 1:5-10 (“The present invention relates to a mechanism *for determining the precise quantity of fuel* required by an internal combustion engine and delivering that quantity from the fuel tank, and more particularly, to adapting the fuel delivery system operating characteristics to detect and reflect changes in the engine and fuel system over time.”); EX1005, 1:7-10 (“The present invention relates to a method of and an apparatus *for controlling fuel injection* of an internal combustion engine, a technique of correcting the width of a fuel injection pulse based on detected values of fuel pressures.”); EX1003, ¶104.

Otterman discloses “[a]n adapting mechanism for controlling the speed of a variable speed fuel pump.” EX1004, Abstract. In the same field, Hosoya addresses ensuring that known quantities are injected into the engine based on

controlling or accounting for fuel pressure. EX1005, 1:23-31 (“Conventionally, in order to prevent such a fluctuation ...due to the drop of fuel pressure, the width of a fuel injection pulse is corrected.”); EX1003, ¶105.

Second, both references cite similar goals of removing systematic errors in the context of fuel delivery. For example, Hosoya discloses “an improved system which learns of the changes, incorporates the changes into the base determination of demand, and adapts the underlying tables or equations accordingly.” EX1005, 1:47-56. And Otterman specifically notes that a goal of the system is to remove systematic errors in the fuel delivery. *E.g.*, EX1004, 2:11-18 (“A primary object of the present invention is to . . . remove[] systematic error.”). Accordingly, given that these references are in the same field of endeavor and addressing similar problems, a POSITA would have had a reason to combine their teachings. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 416-17 (2007); EX1003, ¶106.

Third, Otterman provides the express suggestion to remove systematic errors—such as those caused by the effects of injector pulses. EX1004, 2:11-18 (“A primary object of the present invention is to provide an improved returnless fuel system which tracks fundamental changes in pump operation voltage relative to pump output and removes systematic error.”). Hosoya provides a solution to remove the systematic errors caused by the effects of injector pulses, and so combining Hosoya and Otterman would be nothing more than a combination of

known elements (*e.g.*, Hosoya’s low pass filter for removing injection pulse effects and Otterman’s error and motor control signals) to yield a predictable result. Thus, Hosoya provides an approach to adapt the system to a specific type of systematic error that a POSITA would know to be present in the Otterman system. *KSR*, 550 U.S. at 418; EX1003, ¶107.

As a result, a POSITA would be motivated to use Otterman’s teachings of an error signal and motor control signal and Hosoya’s teachings to remove the “systematic errors” to ensure that the amount and timing of fuel delivered to the engine are accurate. EX1003, ¶108. Indeed, a POSITA would have had a reason to combine the low pass filtering approach described by Hosoya in Otterman because this would improve the accuracy of the differential pressure measurement, and consequently would improve the accuracy of the pump control. *Id.* Combining Hosoya and Otterman in this manner would merely constitute each reference performing its intended function in the same way, and thus would yield a predictable and expected result. *Id.*; *KSR*, 550 U.S. at 416-417.

C. Ground 2: The Combination of Otterman and Greiner Render Claims 13-16 Obvious

Otterman combined with Greiner render claims 13-16 obvious. The motivation to combine Otterman and Greiner is discussed in detail in Section IX.C.5.

1. Claim 13:

- a. Element 13[p]. “A method of controlling the fuel pressure within a fuel delivery system having a fuel pump which delivers fuel to a fuel rail and fuel injectors of an internal combustion engine comprising:”**

Otterman discloses this element. *See* Element 1[p]; EX1003, ¶109.

- b. Element 13[a]. “providing a set-point fuel pressure;”**

Otterman discloses this element. *See* Element 1[a]; EX1003, ¶110.

- c. Element 13[b]. “providing the estimated average fuel flow through the system;”**

Otterman discloses this element. *See* Element 1[b]; EX1003, ¶111.

- d. Element 13[c]. “generating a feed forward control signal based upon the set-point fuel pressure and the average fuel flow;”**

Otterman discloses this element. *See* Element 1[c]; EX1003, ¶112.

- e. Element 13[d]. “measuring the fuel rail pressure with a fuel pressure sensor;”**

Otterman discloses this element. *See* Element 1[d]; EX1003, ¶113.

- f. Element 13[e]. “comparing the fuel rail pressure to the set-point fuel pressure and generating an error signal based upon the difference between the fuel rail pressure and the set-point fuel pressure;”**

Otterman discloses this element. *See* Element 1[f]; EX1003, ¶114.

- g. Element 13[f]. “modifying the feed forward control signal based upon the error signal thereby generating**

a motor controller signal and sending the motor control signal to the fuel pump motor;”

Otterman discloses this element. *See* Element 1[g]; EX1003, ¶115.

h. Element 13[g]. “detecting pulses in the signal from the fuel pressure sensor to establish when the fuel injectors open and close;”

Otterman in view of Greiner discloses this element. EX1003, ¶¶116-117.

Greiner discloses that a branch of the signal processing circuit 29 detects the “injection onset.” EX1006, 3:31-34, Fig. 3 at 41, 43, 44. Greiner explains that the “differentiation element 41 is followed by a threshold value switch 43 and finally by a monostable multivibrator 44.” *Id.*, 3:25-27. The injection onset is detected when a certain threshold has been attained, triggering the monostable multivibrator 44, which “emits a corresponding signal at the output 31 as the identifying mark of the injection onset.” *Id.*, 3:25-38. Greiner similarly discloses detecting the end of the injection pulse, by explaining that the “end of the injection process is ascertained via the second differentiation element 42 for the negative pressure gradient, which is followed by a further differentiation circuit 46.” *Id.*, 3:39-48. Accordingly, Greiner describes a detection circuit that uses fuel pressure measurements and other known characteristics of the injectors to determine when the fuel injectors open and close (*i.e.*, the onset and end of the injection process), thereby determining the duration and quantity of fuel delivered. EX1003, ¶116.

It would have been obvious to combine Greiner and Otterman in this way for the reasons discussed in Section IX.C.5. EX1003, ¶117.

i. Element 13[h]. “measuring the time between when an injector opens and closes to determine how long the injector is open;”

Otterman in view of Greiner discloses this element. EX1003, ¶¶118-119. Greiner discloses that at “the non-inverting output of the flip-flop 45, a signal for the duration of the injection is obtained.” EX1006, 3:50-55. The fuel quantity can then be determined by reference to “a performance graph.” *Id.*

It would have been obvious to combine Greiner and Otterman in this way as further explained in Section IX.C.5. EX1003, ¶119.

j. Element 13[i]. “using the injector flow rate and the injector open time to calculate the average fuel flow.”

Otterman in view of Greiner discloses this element. EX1003, ¶¶120-121. Greiner discloses that it is “efficacious to form the integral via the course of pressure between the onset and end of the injection time, which likewise produces a good measurement signal depending upon the location of the pressure sensor.” EX1006, 3:55-60. A POSITA would appreciate that such integration of a signal is equivalent to averaging the signal. EX1003, ¶120. Accordingly, Greiner also teaches using the injector flow rate and the injector open time to calculate an integral or average fuel flow.

Accordingly, it would have been obvious to combine Greiner and Otterman in this way as further explained in Section IX.C.5. EX1003, ¶121.

2. **Claim 14: “The method of claim 13 wherein generating a feed forward control signal includes providing a feed forward controller which provides established fuel pump motor control parameters at particular set-point pressure and average fuel flow rate values, wherein the set-point pressure and average fuel flow are input to the feed forward controller and a feed forward control signal having set of corresponding fuel pump motor control parameters is thereby generated.”**

Otterman discloses this element. *See* Claim 2; EX1003, ¶122.

3. **Claim 15: “The method of claim 13 further including: comparing the motor control signal to the fuel pump motor control parameters within the feed forward controller which correspond to the set-point pressure and the average fuel flow; and updating the feed forward controller with new fuel pump motor control parameters.”**

Otterman discloses this element. *See* Claim 3; EX1003, ¶123.

4. **Claim 16: “The method of claim 15 further including monitoring the error signal, and updating the feed forward controller after the error signal has stabilized and is below a pre-determined level.”**

Otterman discloses this element. *See* Claim 4; EX1003, ¶124.

5. **A POSITA Would Have Been Motivated to Combine Otterman and Greiner.**

A POSITA would have been motivated to combine Otterman and Greiner for similar reasons to those discussed above in Section IX.B.9. First, Otterman and Greiner are in the same field of endeavor. EX1004, 1:5-10 (“The present invention

relates to a mechanism *for determining the precise quantity of fuel* required by an internal combustion engine and delivering that quantity from the fuel tank, and more particularly, to adapting the fuel delivery system operating characteristics to detect and reflect changes in the engine and fuel system over time.”); EX1006, 1:7-10 (“The invention is based on an apparatus *for detecting the fuel quantity* delivered to the combustion chambers of a Diesel engine.”); EX1003, ¶¶103-108, 125-128.

Second, both references cite similar goals of removing systematic errors in the context of fuel delivery. For example, Greiner discloses several elements that can systematically affect fuel delivery, and proposes various implementations to overcome these effects. EX1006, 3:5-16 (“The invention is based upon the recognition that a very severe variation in pressure occurs with the onset of pressure relief, by opening of the diversion cross section, for instance, at the end of supply; this pressure variation represents a maximum, compared with the other variations in pressure which occur.”); *Id.*, 4:4-11 (“Differences in the injection system, such as divergences from one pump to another, play in the throttle tang caused by sooting up of the nozzles, and changes in the nozzle opening pressure proved to have almost no influence on the result of measurement.”). And Otterman specifically notes that a goal of the system is to remove systematic errors in the fuel delivery. *E.g.*, EX1004, 2:11-18 (“A primary object of the present

invention is to . . . remove[] systematic error.”). Accordingly, given that these references are in the same field of endeavor and addressing similar problems, a POSITA would have had a reason to combine their teachings. *KSR*, 550 U.S. at 416-17; EX1003, ¶126.

Third, Otterman provides express suggestions to remove systematic errors—such as those caused by the effects of injector pulses. EX1004, 2:11-18 (“A primary object of the present invention is to provide an improved returnless fuel system which tracks fundamental changes in pump operation voltage relative to pump output and removes systematic error.”). Greiner provides a solution to detect and address the systematic errors caused by the effects of injector pulses, and so combining Greiner and Otterman would be nothing more than a combination of known elements to yield a predictable result. Thus, Otterman provides an express suggestion to remove systematic errors, and Greiner provides an approach to solve a specific type of systematic error that a person of skill in the art would know to be present in the Otterman system. *KSR*, 550 U.S. at 418; EX1003, ¶127.

As a result, a POSITA seeking to create a system as described by Otterman would be motivated to use Greiner’s teachings to detect and account for the “systematic errors” in the fuel supply system of Otterman to ensure that the amount and timing of fuel delivered to the engine are accurate. Indeed, a POSITA would

have had a reason to combine the pulse detection approach described by Greiner in the system of Otterman because this would improve the accuracy of the differential pressure measurement, and consequently would improve the accuracy of the pump control. Combining Greiner and Otterman in this manner would merely constitute each reference performing its intended function in the same way, and thus would yield a predictable and expected result. *KSR*, 550 U.S. at 416-17; EX1003, ¶128.

D. Ground 3: The Combination of Otterman, Hosoya, and Greiner Render Claims 5-6, 11-12, and 17-18 Obvious

Otterman, Hosoya, and Greiner render claims 5-6, 11-12, and 17-18 obvious. The motivation to combine Otterman, Hosoya, and Greiner is discussed in detail in Section X.

1. Claim 5: “The method of claim 1 wherein measuring the fuel rail pressure includes measuring the fuel pressure at the fuel pump and estimating the fuel rail pressure based upon the fuel pressure as measured at the fuel pump.”

Otterman in view of Hosoya and Greiner discloses this element. EX1003, ¶¶129-130. Otterman and Hosoya disclose claim 1. *See* Ground 1. Greiner discloses that the “question of where the pressure sensor will be located in the fuel line must be decided by weighing various considerations.” EX1006, 2:47-3:4. Accordingly, the sensor may be located at the fuel rail, or the fuel pump, and either scenario is merely a design choice. EX1003, ¶129. Further, as would have been well understood by a POSITA, measuring the pressure at the fuel pump is an

estimate of the pressure at the fuel rail itself. *Id.* And so a POSITA would have been motivated to move the fuel pressure sensor of Otterman to a location at the fuel pump, as taught by Greiner, in order to ensure “the best measurement result for the injected fuel quantity,” as taught by Greiner. *Id.*; EX1006, 2:47-3:4.

Accordingly, it would have been obvious to combine Otterman, Hosoya, and Greiner in this way as further explained in Section IX.D.7. EX1003, ¶130.

2. **Claim 6: “The method of claim 1 further including: detecting pulses in the signal from the fuel pressure sensor to establish when the injectors open and close; measuring the time between when an injector opens and closes to determine how long the injector is open; using the injector flow rate and the injector open time to calculate the average fuel flow.”**

Otterman in view of Hosoya and Greiner discloses this element. EX1003, ¶¶131-132. Otterman and Hosoya disclose claim 1. *See* Claim 1 (Ground 1). Greiner further teaches this element, as explained above in Ground 2. *See* Elements 13[g]-13[i].

Accordingly, it would have been obvious to combine Otterman, Hosoya, and Greiner as further explained in Section IX.D.7. EX1003, ¶132.

3. **Claim 11: “The fuel delivery system of claim 7 wherein said fuel pressure sensor is mounted at said fuel pump to measure the fuel pressure within the fuel delivery system at said fuel pump.”**

Otterman in view of Hosoya and Greiner discloses this element. *See* Claim 5; EX1003, ¶¶133-134. Otterman and Hosoya disclose claim 7. *See* Claim 7 (Ground

1). Greiner further discloses that the “question of where the pressure sensor will be located in the fuel line must be decided by weighing various considerations.” EX1006, 2:47-3:4. Greiner elaborates about those various considerations, and also discloses that the “course of pressure illustrated in FIG. 2a is derived from a pressure sensor disposed on the pump.” *Id.*, 2:47-3:4. Moreover, as discussed, a POSITA would have appreciated that which was disclosed by Greiner—that the placement of the pressure sensor is nothing more than a design choice. EX1003, ¶133. And so a POSITA would have been motivated to move the fuel pressure sensor of Otterman to a location at the fuel pump, as taught by Greiner, in order to ensure “the best measurement result for the injected fuel quantity,” as taught by Greiner. EX1006, 2:47-3:4.

Accordingly, it would have been obvious to combine Otterman, Hosoya, and Greiner in this way as further explained in Section IX.D.7. EX1003, ¶134.

4. Claim 12: “The fuel delivery system of claim 11 further including a fuel system model adapted to estimate the fuel pressure within said fuel rail based upon the fuel pressure as measured at said fuel pump.”

Otterman in view of Hosoya and Greiner discloses this element. EX1003, ¶¶135-136. Otterman, Hosoya, and Greiner disclose claim 11. *See* Claim 11 (Ground 3). Otterman discloses a “fuel system model” because Otterman discloses a “differential pressure sensor 26” that “responds to intake manifold vacuum and to the pressure in fuel rail 16 to provide a differential pressure signal to module 20.”

EX1004, 2:60-63. Greiner discloses that the “question of where the pressure sensor will be located in the fuel line must be decided by weighing various considerations.” EX1006, 2:47-3:4. Accordingly, a POSITA would recognize that the sensor may be located at the fuel rail, or the fuel pump, and either scenario is merely a design choice. EX1003, ¶135.

Accordingly, it would have been obvious to combine Otterman, Hosoya, and Greiner in this way as further explained in Section IX.D.7. EX1003, ¶136.

5. Claim 17: “The method of claim 13 wherein measuring the fuel rail pressure includes measuring the fuel pressure at the fuel pump and estimating the fuel rail pressure based upon the fuel pressure as measured at the fuel pump.”

Otterman and Greiner disclose this element. EX1003, ¶137. Otterman and Greiner disclose claim 13. *See* Claim 13 (Ground 2). As discussed, Greiner discloses this limitation. *See* Claim 5.

6. Claim 18: “The method of claim 13 further including filtering the signal sent from the fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors.”

Otterman in view of Greiner and Hosoya discloses this element. EX1003, ¶138. Otterman and Greiner discloses claim 13. *See* Claim 13 (Ground 2). Hosoya discloses filtering the signal sent from the fuel pressure sensor to filter out pulses due to the opening and closing of the fuel injectors as claimed. *See* Element 1[e] (Ground 1).

7. A POSITA Would Have Been Motivated to Combine Hosoya, Otterman, and Greiner.

A POSITA would have been motivated to combine Otterman, Hosoya, and Greiner and would have a reasonable expectation of success for the same reasons explained in Section IX.B.9 (discussing motivations and expectations of success in combining Hosoya and Otterman) and Section IX.C.5 (discussing motivations and expectations of success in combining Otterman and Greiner). EX1003, ¶¶103-108, 125-128, 139-143.

First, all three references are in the same field of endeavor. *See* Sections IX.B.9, IX.C.5. *E.g.*, EX1004, 1:5-10 (“The present invention relates to a mechanism *for determining the precise quantity of fuel* required by an internal combustion engine and delivering that quantity from the fuel tank, and more particularly, to adapting the fuel delivery system operating characteristics to detect and reflect changes in the engine and fuel system over time.”); EX1005, 1:7-10 (“The present invention relates to a method of and an apparatus *for controlling fuel injection* of an internal combustion engine, a technique of correcting the width of a fuel injection pulse based on detected values of fuel pressures.”); EX1006, 1:7-10 (“The invention is based on an apparatus *for detecting the fuel quantity* delivered to the combustion chambers of a Diesel engine.”); EX1003, ¶140.

Second, all three references cite similar goals of removing systematic errors in the context of fuel delivery. For example, Hosoya discloses “an improved

system which learns of the changes, incorporates the changes into the base determination of demand, and adapts the underlying tables or equations accordingly.” EX1005, 1:47-56. And Otterman specifically notes that a goal of the system is to remove systematic errors in the fuel delivery. *E.g.*, EX1004, 2:11-18 (“A primary object of the present invention is to . . . remove[] systematic error.”). Greiner discloses several elements that can systematically affect fuel delivery, and proposes various implementations to overcome these effects. EX1006, 3:5-16 (“The invention is based upon the recognition that a very severe variation in pressure occurs with the onset of pressure relief, by opening of the diversion cross section, for instance, at the end of supply; this pressure variation represents a maximum, compared with the other variations in pressure which occur.”); *Id.*, 4:4-11 (“Differences in the injection system, such as divergences from one pump to another, play in the throttle tang caused by sooting up of the nozzles, and changes in the nozzle opening pressure proved to have almost no influence on the result of measurement.”). Accordingly, given that these references are in the same field of endeavor and addressing similar problems, a POSITA would have had a reason to combine their teachings. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 416-17 (2007); EX1003, ¶141.

Third, Otterman provides express suggestions to remove systematic errors—such as those caused by the effects of injector pulses. EX1004, 2:11-18 (“A

primary object of the present invention is to provide an improved returnless fuel system which tracks fundamental changes in pump operation voltage relative to pump output and removes systematic error.”). Hosoya and Greiner provide solutions to remove the systematic errors caused by the effects of injector pulses, and so combining Hosoya, Greiner, and Otterman would be nothing more than a combination of known elements (*e.g.*, Hosoya’s low pass filter for removing injection pulse effects and Otterman’s error and motor control signals) to yield a predictable result. Thus, Hosoya and Greiner provide an approach to adapt the system to a specific type of systematic error that a person of skill in the art would know to be present in the Otterman system. *KSR*, 550 U.S. at 418; EX1003, ¶142.

As a result, a POSITA would be motivated to use Otterman’s teachings of an error signal and motor control signal as claimed and Hosoya’s and Greiner’s teachings to remove the “systematic errors” in the fuel supply system of Otterman to ensure that the amount and timing of fuel delivered to the engine are accurate. EX1003, ¶143. Indeed, a POSITA would have had a reason to combine the low pass filtering approach described by Hosoya and Otterman because this would improve the accuracy of the differential pressure measurement, and consequently would improve the accuracy of the pump control. *Id.* Combining Hosoya and Otterman in this manner would merely constitute each reference performing its

intended function in the same way, and thus would yield a predictable and expected result. *Id.*; *KSR*, 550 U.S. at 416-417.

E. Grounds 4-6: Buckland Added To Grounds 1, 2, and 3 For the Estimated Average Fuel Flow Limitation

If it is found that the combination of Hosoya and Otterman (Ground 1); Otterman and Greiner (Ground 2); and Hosoya, Otterman, and Greiner (Ground 3) do not disclose providing an estimated average fuel flow, Buckland discloses this element, and claims 1-18 are obvious in view of those references in further combination with Buckland. EX1003, ¶¶144-150.

Buckland discloses estimating an average fuel flow rate. Buckland discloses a cylinder air/fuel ratio model calculation:

$$r_c = \frac{(1 - F_i)W_{cyl}}{W_f},$$

Buckland discloses that r_c is “the air/fuel ratio in a cylinder, defined as the ratio of total air available in the cylinder for combustion to injected fuel; where total air includes air metered through the throttle body and air recirculated through the exhaust” and “ W_f is *the average fuel flow rate into the cylinder* over an engine event.” EX1007, 8:27-38. Thus, Buckland discloses providing an estimated average fuel flow through the system as claimed. *E.g.*, Limitation 1[b] (Ground 1); EX1003, ¶145.

During prosecution of the '574 patent, the examiner confirmed that Buckland meets the estimated average fuel flow limitation. The examiner found that Buckland discloses “a feed forward fuel control which looks at average fuel flow to determine fuel flow.” EX1002, 41. The examiner further confirmed that it would have been obvious to combine Buckland with prior art fuel delivery control systems, finding that looking to average fuel flow “is common in the art, thus making it obvious to look at an average fuel flow to calculate the feed forward control.”² *Id.*; *see also* EX1003, ¶146. The applicant did not dispute that Buckland met the average fuel flow limitation or that looking to average fuel flow is “common in the art.” Thus, Buckland meets the average fuel flow limitation and it would have been obvious to combine Buckland with the combinations cited herein in Grounds 1-3.

Aside from average fuel flow being “common in the art,” there are additional reasons why it would have been obvious to combine the provided estimated average fuel flow in Buckland with the combinations of Hosoya and

² In the VW IPR, petitioner argued that a combination of Frischmuth and Heiko met the average fuel flow limitation, noting the examiner’s finding that average fuel flow was “common in the art.” The Board rejected this argument, finding that “the Examiner’s finding during prosecution was based on prior art, a reference called ‘Buckland,’ that is not of record in this proceeding.” IPR2019-01286 at 8. Here, Petitioners present Grounds 4-6 based on Buckland (misspelled “Buckland” in the prosecution history) and expert evidence agreeing with the examiner’s finding that looking to average fuel flow was common in the art. EX1003, ¶146.

Otterman (Ground 1); Otterman and Greiner (Ground 2); and Hosoya, Otterman, and Greiner (Ground 3) to generate a feed forward control signal based upon the set-point fuel pressure and the average fuel flow. *E.g.*, Limitation 1[c] (Ground 1). A POSITA would understand that normalized pressure and flow values are used that can coincide with a pre-determined look-up table. Thus, instead of using normalized values, a POSITA would readily understand that average values, such as those used in Buckland, could also be used. Moreover, a POSITA would understand that normalized values can be easily averaged. EX1003, ¶147.

Additionally, a POSITA would have been motivated to combine Buckland with the combinations of Hosoya and Otterman (Ground 1); Otterman and Greiner (Ground 2); and Hosoya, Otterman, and Greiner (Ground 3) and a POSITA would have a reasonable expectation of success in doing so for the same reasons discussed above in Sections IX.B.9, IX.C.5, IX.D.7. EX1003, ¶¶103-108, 125-128, 139-143.

First, Buckland is in the same field of endeavor. Like Hosoya, Greiner, and Otterman, the Buckland reference discloses controlling and measuring fuel delivery. Buckland uses an air/fuel ratio model calculation to do so. EX1007, 8:27-38; *see also* Section IX.D.7 (discussing field of endeavor for Hosoya, Greiner, and Otterman). EX1003, ¶149.

Second, as discussed, the examiner found that looking to average fuel flow was “common in the art,” and thus a POSITA would have been motivated to combine Buckland with other prior art fuel delivery control systems. EX1002, 41; EX1003, ¶150.

X. THIS PETITION IS PROPER UNDER 35 U.S.C. §§ 314(a) AND 325(d)

The Board should decline to exercise its discretion to deny this Petition.

A. Institution Should Not Be Denied Under *Fintiv*

The *Fintiv* factors weigh against discretionary denial. *Apple Inc. v. Fintiv, Inc.*, IPR2020-00019, Paper 11 (PTAB Mar. 20, 2020) (precedential).

Petitioners intend to promptly seek a stay of the related district court actions if the Board institutes this proceeding. This factor weights against discretionary denial, or at worst, is neutral.

A Final Written Decision is expected by around February 2025. In the corresponding district court litigations, a schedule has not yet been set, and thus the courts have not yet set a *Markman* hearing or trial date. Moreover, the Federal Judiciary Report for the period ending March 31, 2023, states that the Northern District of Illinois civil trials have taken a median of 53.5 months from filing to trial, which would place the trials in the corresponding litigations in January 2027.³ EX1008, 47. Thus, this factor weighs against a discretionary denial.

³ The corresponding litigations were filed on July 22 and July 29, 2023.

In *Sand Revolution*, the parties had already exchanged infringement and invalidity contentions, and the court had issued a *Markman* Order. *Sand Revolution II, LLC v. Continental Intermodal Grp. - Trucking LLC*, IPR2019-01393, Paper 24 (June 16, 2020) (informative). Despite these facts, the Board found that the third *Fintiv* factor “weighs only marginally, if at all, in favor of exercising discretion to deny institution.” *Id.* Here, the district court actions are at a drastically earlier phase. The parties do not currently have as schedule to serve contentions. This factor weighs against discretionary denial.

Petitioners stipulate that, if the Board institutes *inter partes* review, Petitioner will not seek resolution in the District Court of any ground of invalidity for the ’574 Patent that utilizes the same combination of prior art reference relied upon in the grounds of the instant petition. Petitioners’ proposal addresses the concern of narrowing the issues, as this stipulation ensures there is no overlap between the ’574 patent invalidity theories before the Board and at issue in the District Court. Accordingly, this factor weighs in favor of institution.

Petitioners and the PO are the parties before the District Court actions. However, members of the Board have noted that *Fintiv* “says nothing about situations in which the petitioner is the same as, or is related to, the district court defendant.” *Cisco Sys., Inc. v. Ramot at Tel Aviv Univ. Ltd.*, IPR2020-00122,

Paper 15, at *10 (PTAB May 15, 2020) (APJ Crumbley, dissenting). This factor is neutral.

This Petition presents compelling unpatentability challenges that warrant institution. *See* USPTO Memorandum, Interim Procedure for Discretionary Denials in AIA Post-Grant Proceedings with Parallel District Court Litigation. This factor weighs against discretionary denial.

B. Institution Should not Be Denied Under § 325(d)

Otterman, Hosoya, and Greiner were not cited during prosecution of the '574 patent. Buckland was considered during prosecution and used as part of a non-final rejection, but the combinations used herein were not considered during prosecution. To the extent that art similar to the grounds presented were considered during prosecution, the examiner made a material error by failing to recognize and reject the challenged claims based on the challenges in this Petition. As a non-limiting example, the examiner erred by failing to recognize that the references relied on in the Grounds could be combined as set out in the grounds of the petition.

Otterman was cited in IPR2019-01286 filed by VW. Otterman is the only common reference between the VW IPR and this Petition; however, VW relied on Otterman for claim 4 only, and Petitioners herein rely on Otterman for other claims. Moreover, the Board denied institution of the VW IPR by finding that VW

failed to demonstrate a reasonable likelihood of proving that the combination of Heiko and Frischmuth teach using an average fuel flow as a basis for generating a feed forward control signal as recited in all independent claims. *Id.*, Paper 13 at 7. Thus, the VW IPR was not denied because of its use of Otterman.

Otterman, Hosoya, and Greiner were cited in IPR2018-01064 filed by Hyundai Motor Co. However, the Hyundai IPR terminated with no preliminary response filed and before the Board reached an institution decision. *Id.*, Paper 8 (noting that the proceeding was at an early stage).

XI. CONCLUSION

Petitioners have shown a reasonable likelihood of prevailing on claims 1-18 and requests institution of *inter partes* review and cancellation of these claims.

Respectfully submitted,

Dated: July 21, 2023

/Ed Sikorski/

CERTIFICATION OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24(c) and (d), Petitioners certify that the word count of Petitioners' Petition for *Inter Partes* Review (exclusive of any table of contents, table of authorities, mandatory notices under § 42.8, certificates of service and word count, and list of exhibits or claim listing) as measured by Microsoft Word is 11,597 words.

By: /Ed Sikorski/

**CERTIFICATE OF SERVICE ON PATENT OWNER
UNDER 37 C.F.R. § 42.105**

Pursuant to 37 C.F.R. §§ 42.6(e) and 42.105(b), the undersigned certifies that, on July 21, 2023, a complete and entire copy of this Petition for *Inter Partes* Review, together with all supporting exhibits, were served on Patent Owner electronically, by agreement, by emailing a copy of the same to the following attorneys for the Patent Owner:

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By: /Ed Sikorski/