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temperature signal. But these features are explicitly disclosed in Takahashi.

EX1003, ¶135; EX1008, 3:13-27, 10:27-66, FIGS. 14, 15.

Takahashi discloses an air charge controller outputting an estimated air charge signal and receiving as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. EX1003, ¶136. Particularly, Takahashi's throttle controller 144 ("air charge controller") receives the demand air charge Q_{map0} ("air charge demand signal") from a target air-mass-flow-rate deciding block 11 and estimates the current air mass flow rate Q_{map} ("estimated air charge signal") using a status-estimating block 142. EX1008, 10:42-60, FIG. 14. Status-estimating block 142 receives a current throttle angle signal θ_{th} from a throttle angle sensor ("throttle position signal"), an intake manifold pressure signal P_m from a pressure sensor ("manifold pressure signal"), an engine speed signal N from the crank angle sensor ("engine speed signal"), and an intake air temperature signal from the intake air temperature sensor ("air charge temperature signal"). *Id.* A POSA would have understood that the throttle angle signal θ_{th} , intake manifold pressure signal P_m , engine speed signal N , intake air temperature signal, and demand air charge Q_{map0} inputted into the combination of Takahashi's throttle controller 144 and status-estimating block 142 are the inputs recited in claim 2. EX1003, ¶136. Based on these inputs, Takahashi's status-estimating block 142 calculates the estimated air

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charge, which the control unit uses to adjust both the throttle-valve position and the fuel-injection quantity. *Id.* Takahashi's air-mass-flow-rate deciding block 11 receives a target torque signal T_o ("desired torque signal"), a target air/fuel ratio signal A/F_o ("desired air/fuel"), and a spark advance signal θ_{adv} ("desired spark angle signal") to determine the target mass flow rate Q_{map0} ("air charge demand signal"). EX1008, 3:28-51; EX1003, ¶136.

A POSA would have sought out these details provided by Takahashi's air charge control unit for modifying Robichaux's analogous air charge controller because combining Takahashi's teachings with Robichaux and Scherer would have yielded predictable benefits and results—for example, precisely controlling the air mass flow rate at the inlet port of the engine cylinder. EX1003, ¶137; EX1008, 2:18-24 ("Since [using] a status estimating model ... ensures a high precision estimation of the airflow status inside the intake manifold, the present invention further provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value."). A POSA would have understood that combining Takahashi's status-estimating block technique with Robichaux's electronic throttle module 158 would have estimated the air mass entering the engine cylinder more accurately, thereby allowing Robichaux's engine controller 20 to converge torque output to the desired torque output more precisely. EX1003, ¶137. Furthermore, a POSA would

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have understood that incorporating Takahashi's target air-mass-flow-rate deciding block 11 into Robichaux's electronic throttle module 158 to output the demand air charge signal would have allowed Robichaux's electronic throttle module 158 to control cylinder air charge more precisely, ultimately allowing engine torque output to achieve the target torque. EX1003, ¶137; EX1008, 1:49-57, 3:24-51. Accordingly, combining Takahashi's known status-estimating block technique and target air-mass-flow-rate deciding block 11 with Robichaux's known electronic throttle module 158 would have merely been applying known techniques in a similar, known device in the same way. *KSR*, 550 U.S. at 416; EX1003, ¶137.

Moreover, a POSA would have had a reasonable expectation of success in combining Robichaux, as modified by Scherer, with Takahashi. EX1003, ¶138. Indeed, a POSA would have recognized that Takahashi's status-estimating block would have been easily applied to Robichaux's electronic throttle module 158 to output the estimate air charge signal based on the detected engine speed, throttle position, manifold pressure, and air charge temperature. *Id.*

A POSA would have also understood how to combine the teachings of Takahashi with Robichaux, as modified by Scherer. *Id.*, ¶139. In view of Takahashi, a POSA would have simply modified the software instructions stored in Robichaux's engine controller 156 such that Robichaux's electronic throttle module 158 receives an air charge demand signal, a throttle position signal, an

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engine speed signal, a manifold pressure signal and an air charge temperature signal to output an estimated air charge signal. *Id.*; EX1019, 102, 223. Considering the similarities in Robichaux's and Takahashi's control systems, any necessary coding modifications to implement Takahashi's teachings into Robichaux's system would have been trivial and well within the skill of a POSA. EX1003, ¶139.

Thus, Robichaux's engine controller 156, Scherer's dynamic torque control system, and Takahashi's technique for generating an estimated air charge signal were known elements that a POSA would have been motivated to combine in known ways to provide the predictable benefits disclosed in the references for providing precise and rapid correction of engine torque demand. *KSR*, 550 U.S. at 419-421; EX1003, ¶140.

Accordingly, it would have been obvious to combine the teachings of Robichaux, Scherer, and Takahashi. EX1003, ¶141.

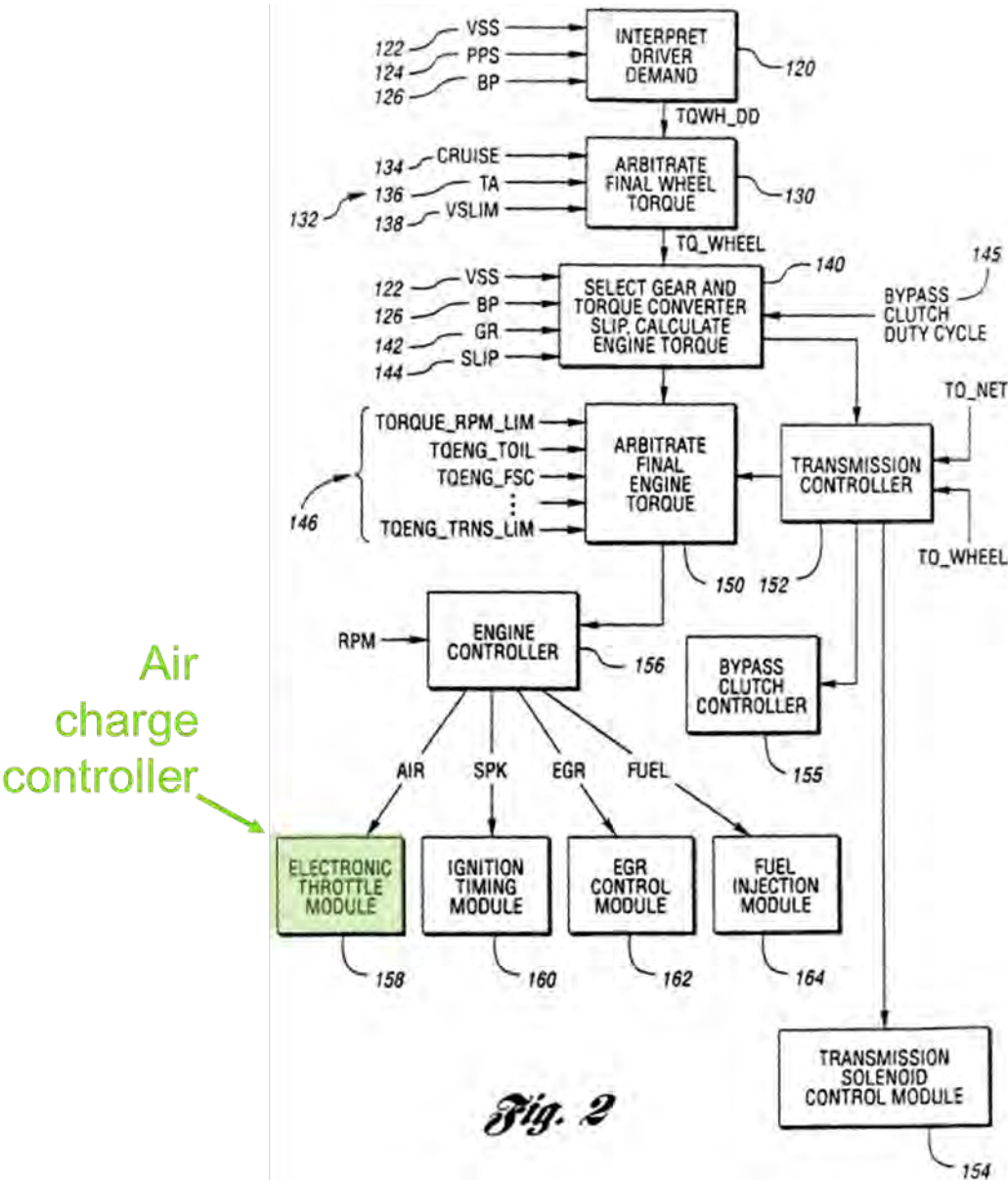
B. Robichaux, Scherer, and Takahashi render obvious claim 2.

Claim 2 depends from claim 1 and recites "wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal." EX1001, 4:23-27, 4:45-49.

Robichaux in combination with Scherer and Takahashi renders obvious this limitation. EX1003, ¶¶142-143. Robichaux's engine controller includes an

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electronic throttle module 158 (“air charge controller”) and generates a signal to adjust “the intake air using throttle valve 70 with an appropriate servomotor or actuator (TVA) 96.” EX1020, ¶¶0020, 0025, FIGS. 1-2; EX1003, ¶143.



EX1020, FIG. 2 (annotated).

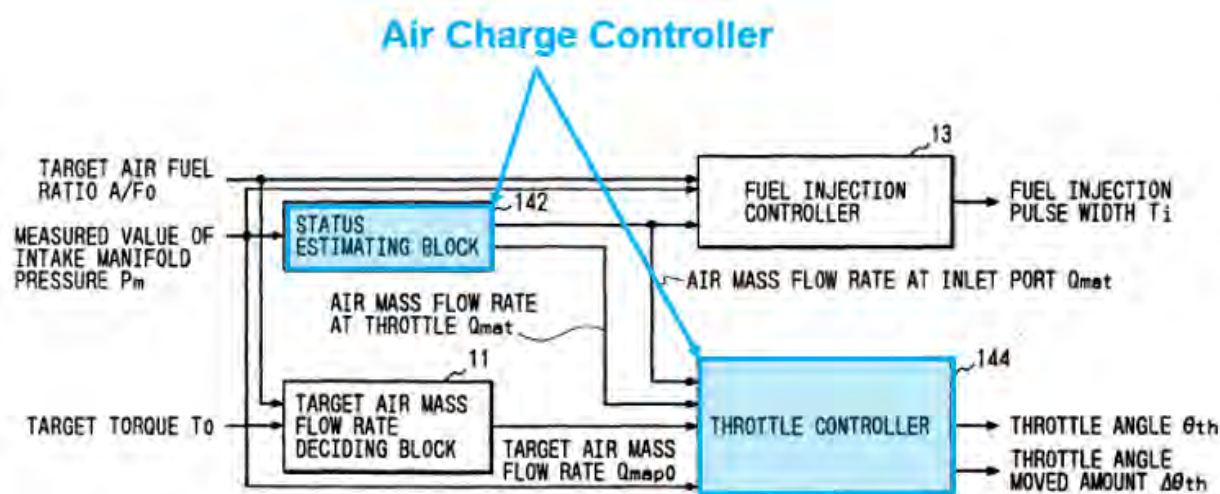
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A POSA would have understood that Robichaux's electronic throttle module is an "air charge controller," as recited in claim 2. EX1003, ¶144. Robichaux's electronic throttle module 158 adjusts the air charge inputted into the engine cylinders by actuating the throttle valve. EX1020, ¶¶0020, 0025, FIGS. 1-2; EX1003, ¶144. Robichaux's electronic throttle module 158 operates in the same manner as the air charge controller 29 disclosed by the '565 patent, which transmits a signal indicating the desired throttle position to the throttle 9. EX1001, 3:19-22; EX1003, ¶144.

Robichaux does not expressly disclose that the electronic throttle module 158 produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. But Takahashi explicitly discloses these features. EX1003, ¶145; EX1008, 3:13-27, 10:27-66, FIGS. 14, 15.

Takahashi's control unit controls torque output based on receiving inputs from a throttle angle sensor, an intake pressure sensor, an intake air temperature sensor, a crank angle sensor, an engine coolant sensor, and an exhaust oxygen sensor. EX1008, 3:10-13, FIG. 13; EX1003, ¶146. The control unit includes a throttle controller 144 that calculates a desired throttle position to set the airflow into the engine cylinder at a desired air charge value, ultimately allowing the

engine to achieve a target torque value. *Id.*, 3:20-27, 6:10-12, 7:50-58, FIG. 14;
EX1003, ¶146.



EX1008, FIG. 14 (annotated).

The throttle controller 144 determines the desired throttle position as a function of a target air mass flow rate Q_{map0} (“air charge demand signal”) and an estimated air mass flow rate at the inlet port Q_{map}^3 (“estimated air charge signal”). EX1008, 10:42-47, FIG. 14; EX1003, ¶147. The throttle controller 144 receives

³ Takahashi has a discrepancy between the reference symbols in the specification and the reference symbols in the figures regarding the “air mass flow rate at the inlet port.” In the specification and FIG. 2, Takahashi refers to the “air mass flow rate at the inlet port” as Q_{map} . EX1008, 10:54-60. However, in FIG. 14, the “air mass flow rate at the inlet port” is represented by Q_{mat} . EX1003, ¶147.

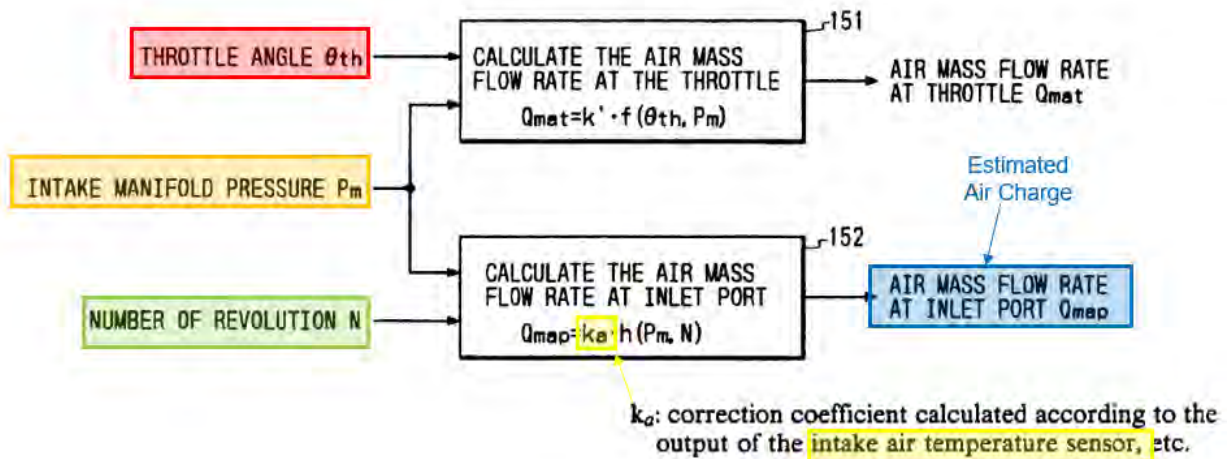
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the demand air charge Q_{map0} from a target air mass flow rate-deciding block 11 and estimates the current air mass flow rate Q_{map} using a status-estimating block 142. EX1008, 10:42-60, FIG. 14; EX1003, ¶147.

As shown below, Takahashi's status-estimating block 142 receives a current throttle angle signal θ_{th} (red, "throttle position signal"), an intake manifold pressure signal P_m (orange, "manifold pressure signal"), and a number of revolutions N (green, "engine speed signal").⁴ EX1008, 10:54-66, FIG. 15; EX1003, ¶148. Status-estimating block 142 estimates the air charge value based on intake pressure P_m , engine speed N , and a correction coefficient k_a determined from current intake temperature sensor (yellow). EX1008, 10:54-66; EX1003, ¶149. The estimated air charge value is used to adjust both the throttle-valve position and the fuel-injection quantity, thereby controlling the engine torque output. EX1008, 3:24-27, 5:53-67, 10:21-27; EX1003, ¶148.

⁴ The measured parameter number of revolutions N as disclosed in Takahashi represents engine speed. EX1008, 3:37 ("N: Engine speed (number of revolutions)"); EX1003, ¶148.

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EX1008, FIG. 15 (annotated).

Takahashi's throttle controller 144 and status-estimating block 142 collectively compose an "air charge controller," as recited in claim 2. EX1003, ¶149. Takahashi's status-estimating block 142 and throttle controller 144 operate in the same manner as the air charge controller 29 disclosed by the '565 patent, which receives an air charge demand signal and signals from throttle position sensor 6, engine speed sensor 3, manifold pressure sensor 110, and temperature meter 5. EX1003, ¶149; EX1001, 3:13-22. Takahashi's throttle controller 144 and status-estimating block 142 also receive as inputs an air charge demand signal (Takahashi's target air mass flow rate Q_{map0}), a throttle position signal (Takahashi's throttle angle signal θ_{th}), an engine speed signal (Takahashi's number of revolutions N), a manifold pressure signal (Takahashi's intake manifold pressure P_m), and an air charge temperature signal (Takahashi's intake air temperature). *Id.* Takahashi's status-estimating block 142 produces an estimated

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air charge signal (Takahashi's air mass flow rate at inlet port Q_{map}), which is ultimately used to adjust both the throttle angle position and fuel quantity. *Id.*

Accordingly, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal, as recited in claim 2. *Id.*

In view of Takahashi, it would have been obvious to a POSA to modify Robichaux's electronic throttle module to receive an air charge demand, a throttle position, an engine speed, a manifold pressure, and an air charge temperature so that Robichaux's electronic throttle module estimates the cylinder air charge more accurately. EX1003, ¶150; EX1008, 1:43-65, 2:18-24, 10:21-27. Indeed, Takahashi expressly discloses that this configuration "provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value." EX1008, 2:18-24; EX1003, ¶150.

Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. *Id.*; *KSR*, 550 U.S. at 416. Accordingly, a POSA would have been motivated to combine Takahashi's and Robichaux's teachings so that the control unit converges the engine output torque to the demand torque more precisely. EX1008, 2:18-24; EX1003, ¶150.

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Likewise, a POSA would have easily implemented Takahashi's teachings by modifying the software instructions stored in Robichaux's electronic throttle module such that the torque control section receives signals indicating air charge demand, throttle position, engine speed, manifold pressure, and air charge temperature to produce an estimated air charge signal. EX1003, ¶151. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux, Scherer, and Takahashi. *Id.*

Thus, Robichaux in combination with Scherer and Takahashi renders obvious claim 2. *Id.*, ¶152.

C. Robichaux, Scherer, and Takahashi render obvious claim 3.

Claim 3 depends from claim 2 and recites "wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel."

Robichaux, Scherer, and Takahashi render obvious this limitation. EX1003, ¶¶153-154. As described above, Takahashi's throttle controller 144 (which composes the recited air charge controller) receives the demand air charge Q_{map0} from a target air mass flow rate-deciding block 11. EX1008, 3:28-29, 10:42-50, FIG. 14. As shown in Figure 14 and Expression 1, Takahashi's air-mass-flow-rate deciding block 11 receives a target torque signal T_o (green, "desired torque signal"), a target air/fuel ratio signal A/F_o (blue, "desired air/fuel"), and a spark

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advance signal θ_{adv} (purple, “desired spark angle signal”) to determine the target mass flow rate Q_{map0} (pink, “air charge demand signal”). EX1008, 3:28-51; EX1003, ¶154.

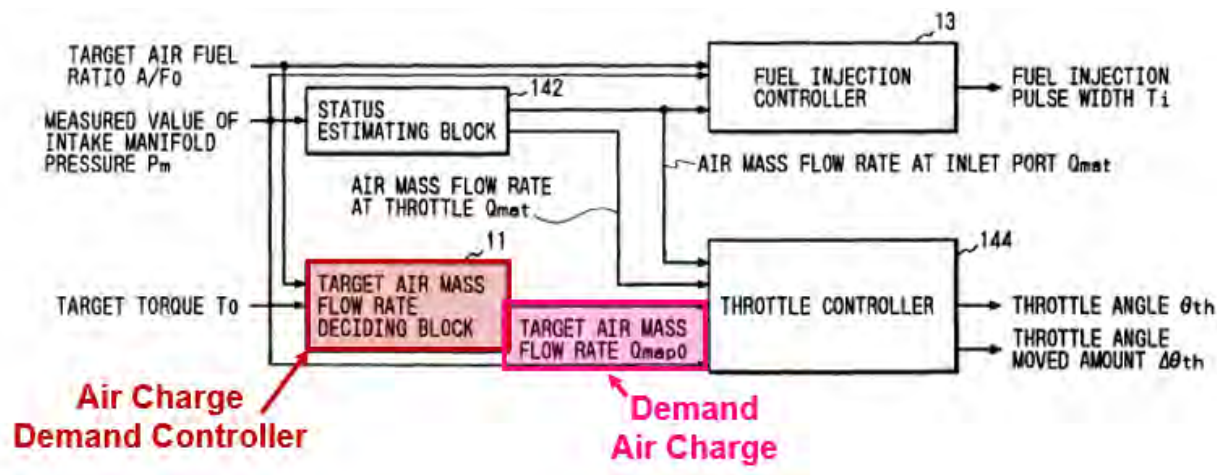
Air Charge Demand

$$Q_{map0} = \frac{N \cdot T_0}{K \cdot F_1(A/F_0) \cdot F_2(N) \cdot F_3(\theta_{adv})} \quad (\text{Expression 1})$$

where,

- T_0 : Target torque
- N : Engine speed (number of revolutions)
- A/F_0 : Target air fuel ratio
- θ_{adv} : Spark advance
- K : Constant
- F_1, F_2, F_3 : Specified function

EX1008, 3:30-42 (annotated).



EX1008, FIG. 14 (annotated).

Takahashi’s target air-mass-flow-rate deciding block 11 is an “air charge demand controller,” as recited in claim 3. EX1003, ¶155. The target air mass flow rate-deciding block 11 determines a demand air charge value for the throttle

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controller 144 based on receiving a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio. *Id.* Indeed, Takahashi's target air-mass-flow-rate deciding block 11 operates in the same manner as the air charge demand controller 27 disclosed by the '565 patent, which also receives a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio and outputs a demand air charge signal to the air charge controller 29. EX1003, ¶155; EX1001, 3:6-12.

A POSA would have been motivated to incorporate Takahashi's target air-mass-flow-rate deciding block 11 into Robichaux's electronic throttle module 158 to output the demand air charge signal. EX1003, ¶¶134-137, 156; EX1008, 1:43-65, 2:17-23, 10:21-27. Takahashi expressly discloses that determining the target air mass flow rate based on the target torque, target air/fuel ratio, and spark advance provides precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. EX1008, 1:49-57, 2:17-23, 3:24-51. This modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. EX1003, ¶¶137, 156. Thus, a POSA would have been motivated to combine the teachings of Takahashi with Robichaux and Scherer so that the control unit converges the engine output torque at the demand torque value with more precision. EX1008, 2:17-23; EX1003, ¶156.

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Likewise, a POSA would have easily implemented Takahashi's teachings by modifying the software instructions stored in Robichaux's electronic throttle module 158 such that the demand air charge value is calculated according to Takahashi's teachings, for example, Expression 1 equation. EX1003, ¶¶139, 157; EX1008, 3:30-41. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux, Scherer, and Takahashi. EX1003, ¶¶139, 157.

Thus, Robichaux, Scherer, and Takahashi render obvious claim 3. *Id.*, ¶158.

IX. Ground 3: The combination of Robichaux, Scherer, and Suzuki renders claim 4 obvious.

A. Rationale for Combining Robichaux, Scherer, and Suzuki

Robichaux, Scherer, and Suzuki are from the same field of endeavor—engine control systems. EX1003, ¶159. Like Robichaux and Scherer, Suzuki is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. *Id.* Like Robichaux and Scherer, Suzuki's "invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions." EX1005, 1:4-6. Moreover, Robichaux and Suzuki disclose similar control architecture that includes, for example, a controller, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, and an airflow meter. EX1005, 4:17-40, FIG. 2; EX1020, ¶¶0015, 0016, FIGS. 1-3. Accordingly, combining their teachings would have simply involved modifying the engine controller (e.g.,

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programming stored instructions in the microcomputer of Robichaux's controller) to perform the steps taught in the references—a basic task for a POSA. EX1003, ¶159.

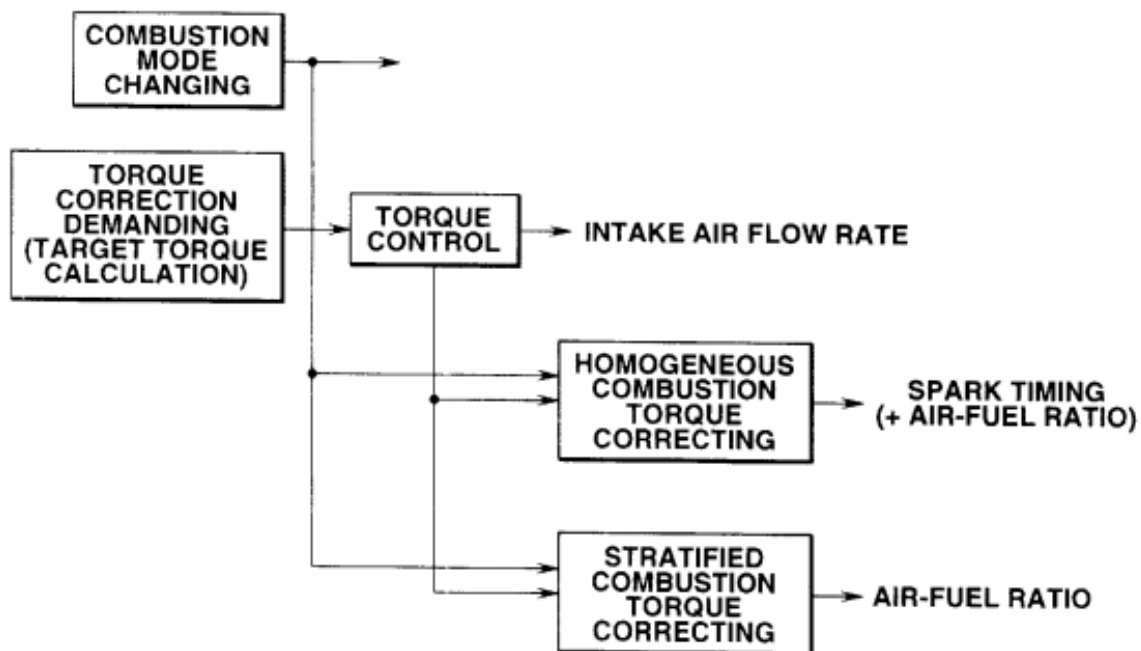
The motivation to combine Robichaux and Scherer discussed in Section VII.B applies here. EX1003, ¶160. For example, a POSA would have been motivated to combine Scherer's transient torque control system with Robichaux's engine controller to control torque output during both transient and steady-state conditions. *See supra* Section VII.B; EX1003, ¶¶90-92, 112-113, 160.

A POSA would have also been motivated to combine Suzuki's teachings with the Robichaux-Scherer combination. EX1003, ¶161. Robichaux's engine controller communicates with engine 14 and transmission 16 to control engine torque. EX1020, ¶¶0012, 0021. Robichaux's engine controller includes various modules that determine specific engine control parameters (e.g., air flow 158, spark 160, EGR 162, and fuel 164). EX1020, ¶¶0025; FIG. 2. Robichaux's control system can incorporate “[v]arious other operational modes and/or engine technologies, such as lean burn, may utilise airflow control, fuel flow control, spark or ignition angle control, and the like as well known in the art.” EX1020, ¶0036.

Suzuki's DISI engine controller corrects torque output by controlling fuel delivery and spark timing. EX1005, 1:39-43; EX1003, ¶162. Suzuki's controller

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includes a combustion mode changing section that switches engine operation between a homogenous mode and a stratified mode. *Id.*, 3:5-10, FIG. 1B.



EX1005, FIG. 1B.

Suzuki's controller also includes a homogenous combustion torque correcting section and a stratified combustion torque correcting section that modify torque output in response to receiving the torque correction demand signal. *Id.*, 2:64-3:22, 15:53-16:6; EX1003, ¶163.

Suzuki's "stratified combustion torque correcting section corrects at least the air-fuel ratio to make torque correction during stratified combustion." EX1005, 3:10-22. To correct the air-fuel ratio, Suzuki's stratified combustion torque correction section adjusts the injection pulse signal ("fuel adjustment signal")

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transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 (“[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function.”). Specifically, Suzuki’s control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*, 6:21-57, 7:35-44. Accordingly, in the stratified combustion mode, Suzuki’s stratified torque correction section controls the fuel adjustment signal. EX1003, ¶164.

Suzuki’s “homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response...during homogenous combustion.” EX1005, 3:10-22. To correct spark timing, Suzuki’s homogeneous combustion torque correction section modifies the timing of a command signal (“spark adjustment signal”) transmitted to spark plug 6 based on the spark timing calculation routine shown in Figure 4. *Id.*, 6:7-9, 7:60-8:4 (“The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting function.”). Specifically, Suzuki’s control unit retards or advances the timing of the spark plug command signal based on a torque correction factor that is derived directly from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*,

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5:59-65, 7:35-59. Accordingly, in the homogeneous combustion mode, Suzuki's homogeneous torque correction section controls the spark adjustment signal. EX1003, ¶165.

A POSA would have been motivated to modify Robichaux's engine controller, including its ignition-timing module 160 and fuel injection module 164, to incorporate Suzuki's dual-combustion-mode control. EX1003, ¶166. This combination would have improved the fuel efficiency of Robichaux's engine. EX1003, ¶166. Operating a dual-combustion-mode engine in stratified combustion mode during idle or part-load operation (low load conditions) to reduce fuel consumption was well-known before the '565 patent. EX1003, ¶166; EX1012, 464, 509. And operating a dual-combustion-mode engine in homogeneous combustion mode during full-load operation to generate maximum torque without degrading exhaust emissions was also well-known before the '565 patent. EX1003, ¶166; EX1012, 464, 509. Accordingly, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual-combustion-mode control to improve fuel efficiency while minimizing the effect on performance and exhaust. EX1003, ¶166.

And there would have been a reasonable expectation of success combining Suzuki's and Robichaux's teachings. EX1003, ¶167. A POSA would have easily implemented Suzuki's dual-combustion-mode control by modifying the software

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instructions stored in Robichaux's engine controller such the engine switches between the stratified combustion mode and the homogeneous combustion mode based on the desired torque. EX1003, ¶167. Accordingly, combining Suzuki's dual-combustion-mode control with Robichaux's engine controller would have simply been applying a known technique to a known device to yield the predictable result of switching between combustion modes based on load for improved fuel efficiency and performance. *KSR*, 550 U.S. at 416; EX1003, ¶167. Therefore, a POSA would have had a reasonable expectation of success in combining Robichaux and Suzuki. EX1003, ¶167.

B. Robichaux, Scherer, and Suzuki render obvious claim 4.

1. [4.A] **"The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode"**

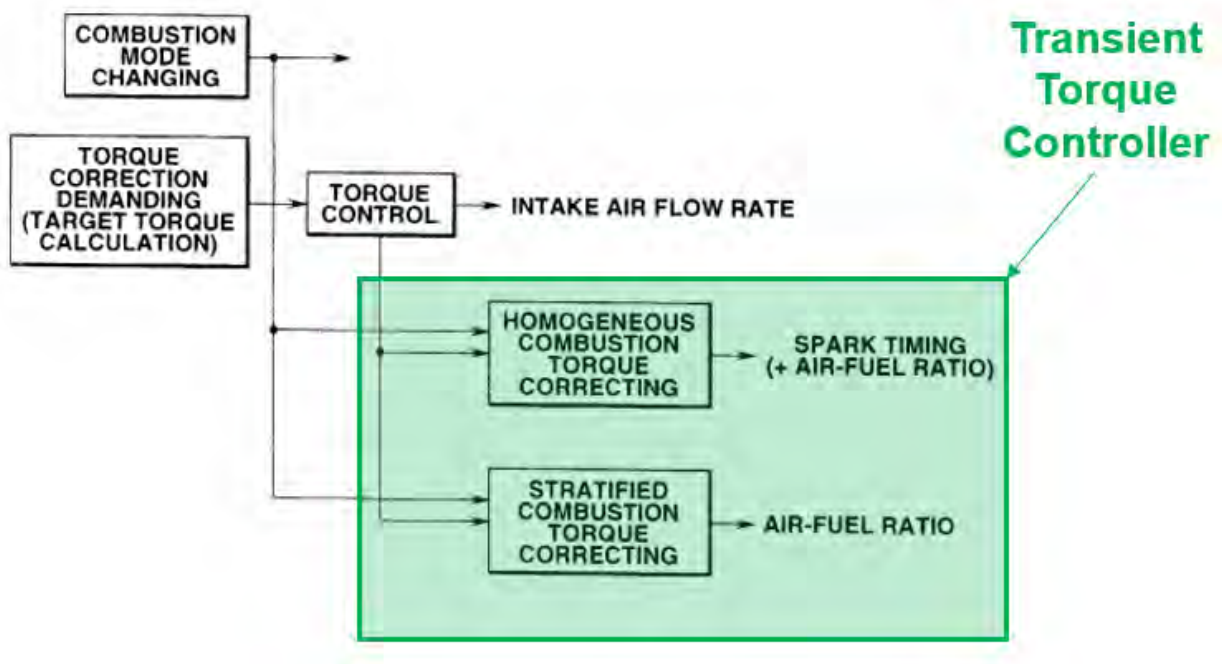
Robichaux, Scherer, and Suzuki render obvious the recited transient torque controller. EX1003, ¶168.

Suzuki's torque correction section includes "a homogenous combustion torque correcting section [that] **corrects at least the spark timing** in order to make a torque correction **with a fast response**...during homogenous combustion" and a "stratified combustion torque correcting section [that] **corrects at least the air-fuel ratio** to make torque correction during stratified combustion." EX1005,

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3:10-22. Moreover, Suzuki's homogeneous and stratified torque correction sections are configured to adjust torque output during transient engine operations:

"[Suzuki's engine control apparatus] widens the range (**dynamic range**) over which torque can be controlled...." *Id.*, 1:44-63, 3:10-22; EX1003, ¶169.



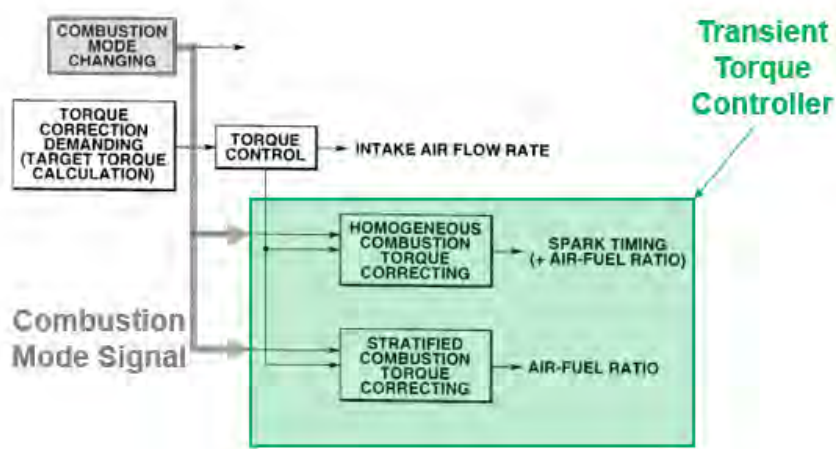
EX1005, FIG. 1B (annotated).

A POSA would have understood that Suzuki's homogeneous and stratified torque correction sections collectively compose a "transient torque controller," as recited in claim 4. EX1003, ¶170. These correction sections are a controller, because they generate spark timing adjustment and fuel adjustment signals used to control torque output. EX1005, 3:4-21; EX1003, ¶170. Indeed, Suzuki's torque correction sections operate in the same manner as the transient torque controller 21

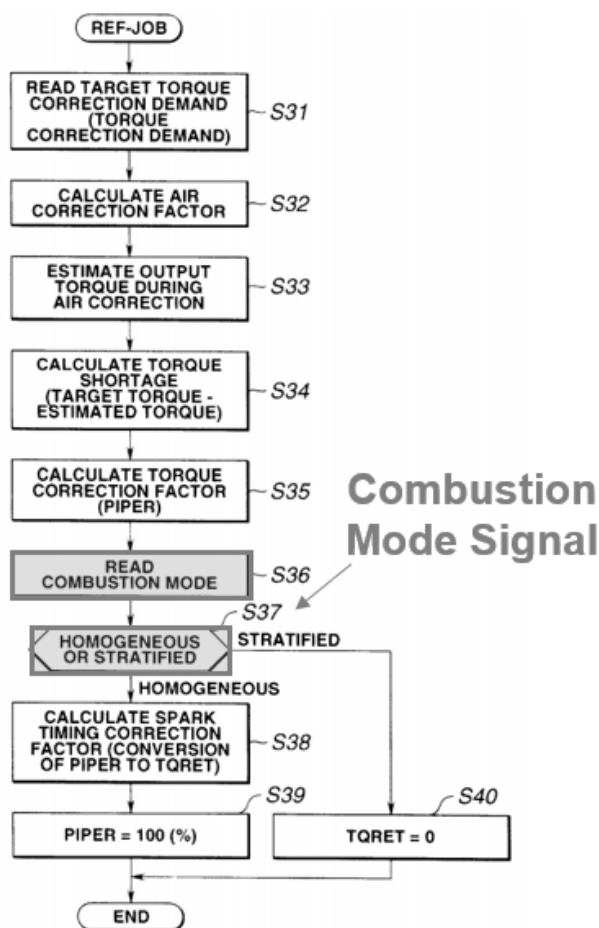
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disclosed by the '565 patent, which generates a fuel adjustment signal when the engine 100 is set in the stratified mode and a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:35-51; EX1003, ¶170.

Suzuki's homogeneous and stratified torque correction sections ("transient torque controller") receive a signal from the combustion mode changing section to determine whether the engine is operating in the homogeneous or stratified mode. EX1005, 7:45-8:4, FIGS. 1B, 6; EX1003, ¶171.



EX1005, FIG. 1B (annotated).



EX1005, FIG. 6 (annotated).

A POSA would have been motivated to combine Suzuki’s teachings with the Robichaux-Scherer combination. EX1003, ¶172. To start, Robichaux expressly acknowledges that its control system can incorporate “[v]arious other **operational modes and/or engine technologies, such as lean burn**, may utilise airflow control, fuel flow control, spark or ignition angle control, and the like as well known in the art.” EX1020, ¶0036. And Suzuki discloses a DISI engine controller

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that uses other such operational modes and engine technologies known in the art.

EX1005, 3:5-22; EX1003, ¶172.

Specifically, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual-combustion-mode control to improve fuel efficiency and performance. EX1003, ¶¶161, 173. As explained in Section IX.A, operating a dual-combustion-mode engine in stratified combustion mode during low load conditions, and operating in homogeneous combustion mode during high load conditions were well-known before the '565 patent. EX1003, ¶¶164-166, 173. Accordingly, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual-combustion-mode control to improve fuel efficiency and performance, without degrading exhaust emissions. EX1003, ¶¶166, 173.

Moreover, there would have been a reasonable expectation of success combining Robichaux's and Suzuki's teachings. EX1003, ¶¶167, 174. A POSA would have easily implemented Suzuki's dual-combustion-mode control by modifying the software instructions stored in Robichaux's engine controller such the engine switches between the stratified combustion mode and the homogeneous combustion mode based on the desired torque. *Id.* Combining Suzuki's dual-combustion-mode control with Robichaux's engine controller would have simply been applying a known technique to a known device to yield the predictable result

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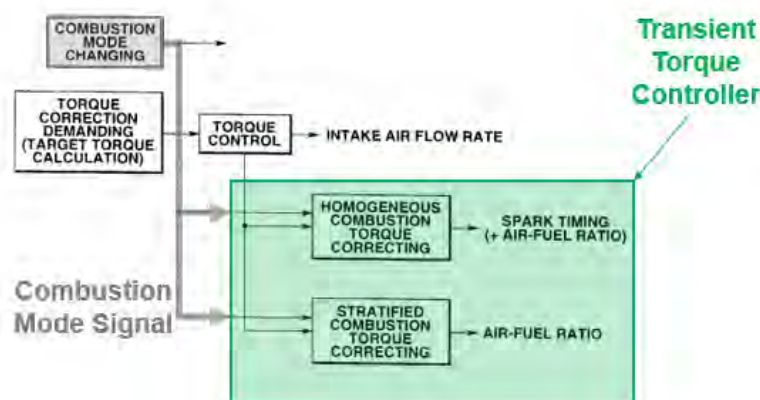
of switching between combustion modes based on load for improved fuel efficiency. *Id.* Therefore, a POSA would have had a reasonable expectation of success in combining Robichaux, Scherer, and Suzuki. *Id.*

Thus, Robichaux, Scherer, and Suzuki render obvious [4.A]. EX1003, ¶175.

2. [4.B] “wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode”

Robichaux, Scherer, and Suzuki render obvious the recited transient torque controller. EX1003, ¶177. Although Robichaux does not explicitly disclose that the engine controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, Suzuki discloses this feature. EX1003, ¶176.

Again, Suzuki’s stratified torque correction section composes, in part, the “transient torque controller” recited in claim 4. *See supra* Section IX.B.1.



EX1005, FIG. 1B (annotated).

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Suzuki's "stratified combustion torque correcting section **corrects at least the air-fuel ratio** to make torque correction **during stratified combustion.**"

EX1005, 3:10-22. To correct the air-fuel ratio, Suzuki's stratified combustion torque correction section adjusts the injection pulse signal ("fuel adjustment signal") transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 ("[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function."). Specifically, Suzuki's control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived ultimately from the torque shortage signal ("the difference signal") generated in step S34 (Figure 6). EX1005, 6:21-57, 7:35-44, FIG. 6. Thus, in the stratified combustion mode, Suzuki's stratified torque correction section controls the fuel adjustment signal. Indeed, Suzuki's stratified torque correction operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a transient fuel adjustment signal when the engine 100 is operating in the stratified mode. EX1001, 3:34-50; EX1003, ¶¶164, 178. Thus, Suzuki discloses [4.B]. EX1003, ¶179.

As explained above for [4.A], a POSA would have been motivated to combine the teachings of Robichaux, Scherer, and Suzuki for at least the same

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reasons and would have had a reasonable expectation of success in doing so.

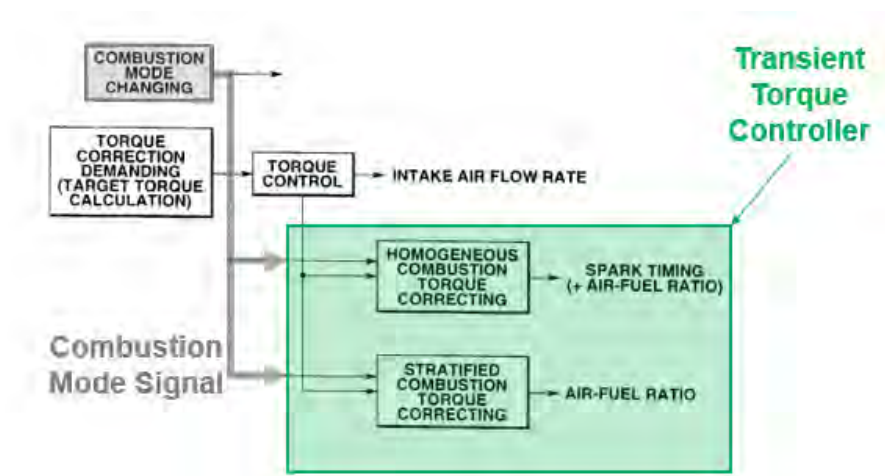
EX1003, ¶¶179.

Thus, Robichaux, Scherer, and Suzuki render obvious [4.B]. EX1003, ¶180.

1. [4.C] “wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode”

Robichaux, Scherer, and Suzuki render obvious the recited transient torque controller. EX1003, ¶181. Although Robichaux does not explicitly disclose the engine controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode, Suzuki discloses this feature. EX1003, ¶181.

Again, Suzuki’s homogeneous torque correction section composes, in part, the “transient torque controller” recited in claim 4. *See supra* Section IX.B.1.



EX1005, FIG. 1B (annotated).

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Suzuki's "homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response...during homogenous combustion." EX1005, 3:10-22. To correct spark (ignition) timing, Suzuki's homogeneous combustion torque correction section modifies the timing of a command signal ("spark adjustment signal") transmitted to spark plug 6 based on the spark timing calculation routine shown in Figure 4. *Id.*, 6:7-9, 7:60-8:4 ("The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting function."). Specifically, Suzuki's control unit retards or advances the timing of the ignition command signal based on a torque correction factor that is derived directly from the torque shortage signal ("the difference signal") generated in step S34 of Figure 6. *Id.*, 5:59-65, 7:35-59. Thus, in the homogeneous combustion mode, Suzuki's homogeneous torque correction section controls the spark adjustment signal. Indeed, Suzuki's homogeneous torque correction section operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50; EX1003, ¶¶165, 182. Thus, Suzuki discloses [4.C].

As explained above for [4.A], a POSA would have been motivated to combine the teachings of Robichaux, Scherer, and Suzuki for at least the same

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reasons and would have had a reasonable expectation of success in doing so.

EX1003, ¶¶161, 166, 183.

Thus, Robichaux, Scherer, and Suzuki render obvious [4.C]. EX1003, ¶184.

X. Ground 4: The combination of Robichaux, Scherer, Suzuki, and Takahashi renders obvious claims 5 and 6.

A. Rationale for Combining Robichaux, Scherer, Suzuki, and Takahashi

Robichaux, Scherer, Suzuki, and Takahashi are from the same field of endeavor—engine control systems. EX1003, ¶185. Like Robichaux, Scherer, and Suzuki, Takahashi is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. EX1003, ¶185. Like Robichaux, Scherer, and Suzuki, Takahashi’s “invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values.” EX1008, 1:5-9. Takahashi’s electronic control module (ECM) 11 has a control unit, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, an engine water temperature sensor, and an airflow meter. EX1008, 3:8-16, FIGS. 1, 13. These components are similar to the Robichaux, Scherer, and Suzuki control components. EX1003, ¶185.

Combining Takahashi’s teachings with Robichaux, Scherer, and Suzuki would have simply involved modifying the engine controller (e.g., programming

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stored instructions in Robichaux's engine controller) to perform the steps taught in Takahashi—a basic task for a POSA. EX1003, ¶186. A POSA would have been motivated to combine the teachings of Robichaux, Scherer, Suzuki, and Takahashi for at least the reasons below and would have had a reasonable expectation of success in doing so. *Id.*

The motivations to combine Robichaux and Scherer discussed in Section VII.B apply here. EX1003, ¶187. For example, a POSA would have been motivated to combine Scherer's transient torque controller with Robichaux's engine controller 156 to control torque output during both transient and steady-state conditions. *See supra* Section VII.B; EX1003, ¶187. The motivations to combine Suzuki with Robichaux and Scherer, discussed in Section IX.A, also apply here. EX1003, ¶188. For example, a POSA would have been motivated to incorporate Suzuki's dual-combustion-mode control into Robichaux's engine controller to improve fuel efficiency and performance. *See supra* Section IX.A; EX1003, ¶188. And the motivations to combine Takahashi's teachings with Robichaux's and Scherer's teachings discussed in Section VIII.A apply here. EX1003, ¶189. For example, a POSA would have been motivated to combine Takahashi's teachings with Robichaux's engine controller to converge torque output to the desired torque output more precisely. *See supra* Section VIII.A; EX1003, ¶189.

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B. Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 5.

Claim 5 depends from claim 4 and recites “wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.”

As explained in Section IX, Robichaux, Scherer, and Suzuki render obvious claim 4. And Takahashi in combination with Robichaux, Scherer, and Suzuki renders obvious claim 5. EX1003, ¶¶190-191.

Further, as explained in Section VIII regarding claim 2, which recites the same features, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. EX1003, ¶192.

And a POSA would have been motivated to modify Robichaux’s electronic throttle module to receive, as signal inputs, an air charge demand, a throttle position, an engine speed, a manifold pressure, and an air charge temperature so that Robichaux’s engine controller, including the electronic throttle module, estimates the cylinder air charge more accurately. EX1003, ¶¶134, 137-140, 193; EX1008, 1:43-65, 2:18-24, 10:21-27. This modification would have simply been

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applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. EX1003, ¶¶137, 193; *KSR*, 550 U.S. at 416. Thus, a POSA would have been motivated to combine the teachings of Takahashi with Robichaux, Scherer, and Suzuki so that Robichaux's controller converges the engine output torque to the demand torque more precisely. EX1008, 2:18-24; EX1003, ¶¶134, 137, 193.

Likewise, a POSA would have easily implemented Takahashi's teaching by modifying the software instructions stored in Robichaux's electronic throttle module such that the torque control section receives signals indicating air charge demand, throttle position, engine speed, manifold pressure, and air charge temperature to produce an estimated air charge signal. EX1003, ¶¶138-139, 194. Accordingly, a POSA would have had a reasonable expectation of success in combining Takahashi with Robichaux, Scherer, and Suzuki. *Id.*

Thus, Robichaux in combination with Scherer, Suzuki, and Takahashi renders obvious claim 5. EX1003, ¶195.

C. Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 6.

Claim 6 depends from 5 and recites "wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel [ratio]."

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As explained in Section X.B, Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 5. Robichaux, Scherer, Suzuki, and Takahashi also render obvious claim 6. EX1003, ¶197.

As explained in Section VIII.C regarding claim 3, which recites the same features, Takahashi's air charge demand controller produces an air charge demand signal and receives as inputs the desired torque signal, a desired spark angle signal, and a desired air/fuel ratio, as recited in claim 6. EX1003, ¶198.

A POSA would have been motivated to incorporate Takahashi's air charge demand controller into Robichaux's engine controller to generate a demand air charge signal based on the target torque, target air/fuel ratio, and spark advance to provide precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. EX1003, ¶¶137, 199; EX1008, 1:49-57, 2:17-23, 3:24-51 ("Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention...provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque."). This modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. EX1003, ¶¶137, 199. Thus, a POSA would have been motivated to combine the teachings of Takahashi with Robichaux, Scherer, and Suzuki so that

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the control unit converges the engine output torque at the demand torque value with more precision. EX1008, 2:17-23; EX1003, ¶¶134, 137, 199.

Likewise, a POSA would have easily implemented Takahashi's teachings by modifying the software instructions stored in Robichaux's engine controller such that the demand air charge value is calculated according to Takahashi's teachings. EX1003, ¶¶139, 200; EX1008, 3:30-41. Accordingly, a POSA would have had a reasonable expectation of success in combining Takahashi with Robichaux, Scherer, and Suzuki. EX1003, ¶¶138, 200.

Thus, Robichaux in combination with Scherer, Suzuki, and Takahashi renders obvious claim 6. EX1003, ¶201.

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XI. Conclusion

For the reasons above, *inter partes* review and cancelation of claims 1-7 of U.S. Patent No. 6,581,565 is requested.

Respectfully submitted,

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*Petition for Inter Partes Review of
U.S. Patent No. 6,581,565*

**CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATION,
TYPEFACE REQUIREMENTS, AND TYPE STYLE REQUIREMENTS**

1. This Petition complies with the type-volume limitation of 14,000 words, comprising 13,976 words, excluding the parts exempted by 37 C.F.R. § 42.24(a).

2. This Petition complies with the general format requirements of 37 C.F.R. § 42.6(a) and has been prepared using Microsoft® Word 2010 in 14 point Times New Roman.

Respectfully submitted,

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***Petition for Inter Partes Review of
U.S. Patent No. 6,581,565***

CERTIFICATION OF SERVICE (37 C.F.R. §§ 42.6(e), 42.105(a))

The undersigned hereby certifies that on January 31, 2020, true and correct copies of the foregoing **PETITION FOR INTER PARTES REVIEW OF U.S. PATENT NO. 6,581,565**, Petitioner's Power of Attorney, and all associated exhibits were served in their entirety on the following parties via FedEx Express® or Express Mail:

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US006581565B2

(12) **United States Patent**
Heslop et al.

(10) **Patent No.:** **US 6,581,565 B2**
(45) **Date of Patent:** **Jun. 24, 2003**

(54) **ENGINE TORQUE CONTROLLER**

(75) Inventors: **Garon Nigel Heslop**, Billericay (GB);
Jon Dixon, Maldon (GB); **Richard Stephen Blachford**, Cambridge (GB)

(73) Assignee: **Visteon Global Technologies, Inc.**,
Dearborn, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/191,641**

(22) Filed: **Jul. 9, 2002**

(65) **Prior Publication Data**
US 2003/0015169 A1 Jan. 23, 2003

(30) **Foreign Application Priority Data**
Jul. 23, 2001 (EP) 01306301

(51) **Int. Cl.**⁷ **F02D 41/14; F02B 17/00**

(52) **U.S. Cl.** **123/295; 123/406.23; 123/406.47; 123/478**

(58) **Field of Search** **123/295, 350, 123/352, 399, 406.23, 406.47, 406.55, 478, 480, 488**

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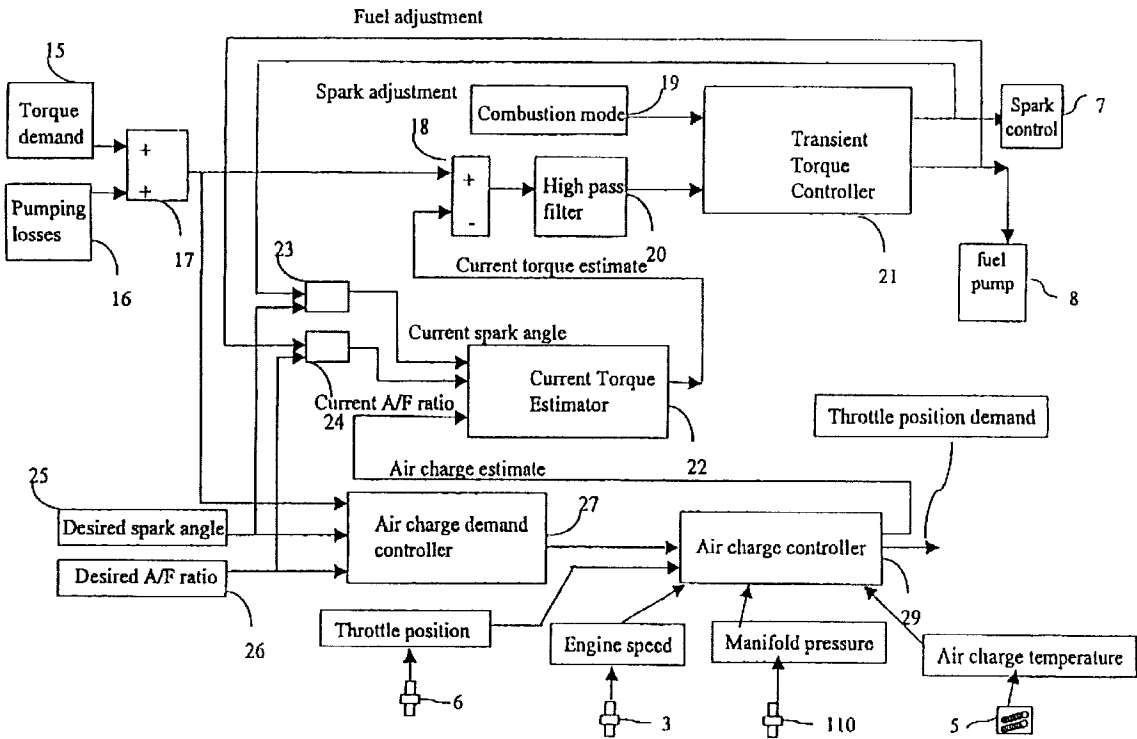
* cited by examiner

Primary Examiner—Tony M. Argenbright
(74) Attorney, Agent, or Firm—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

7 Claims, 3 Drawing Sheets



VW EX1001
U.S. Patent No. 6,581,565

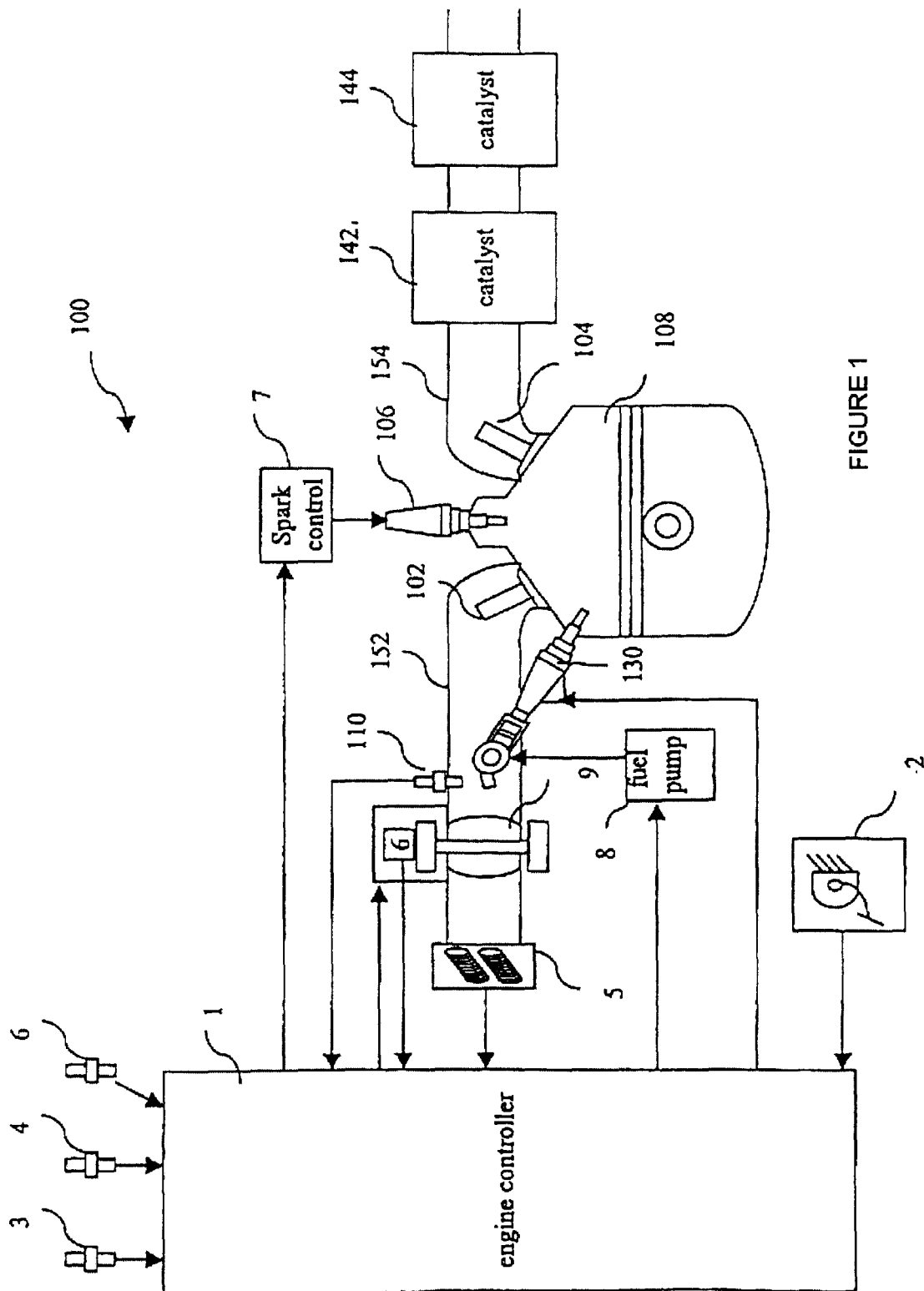


FIGURE 1

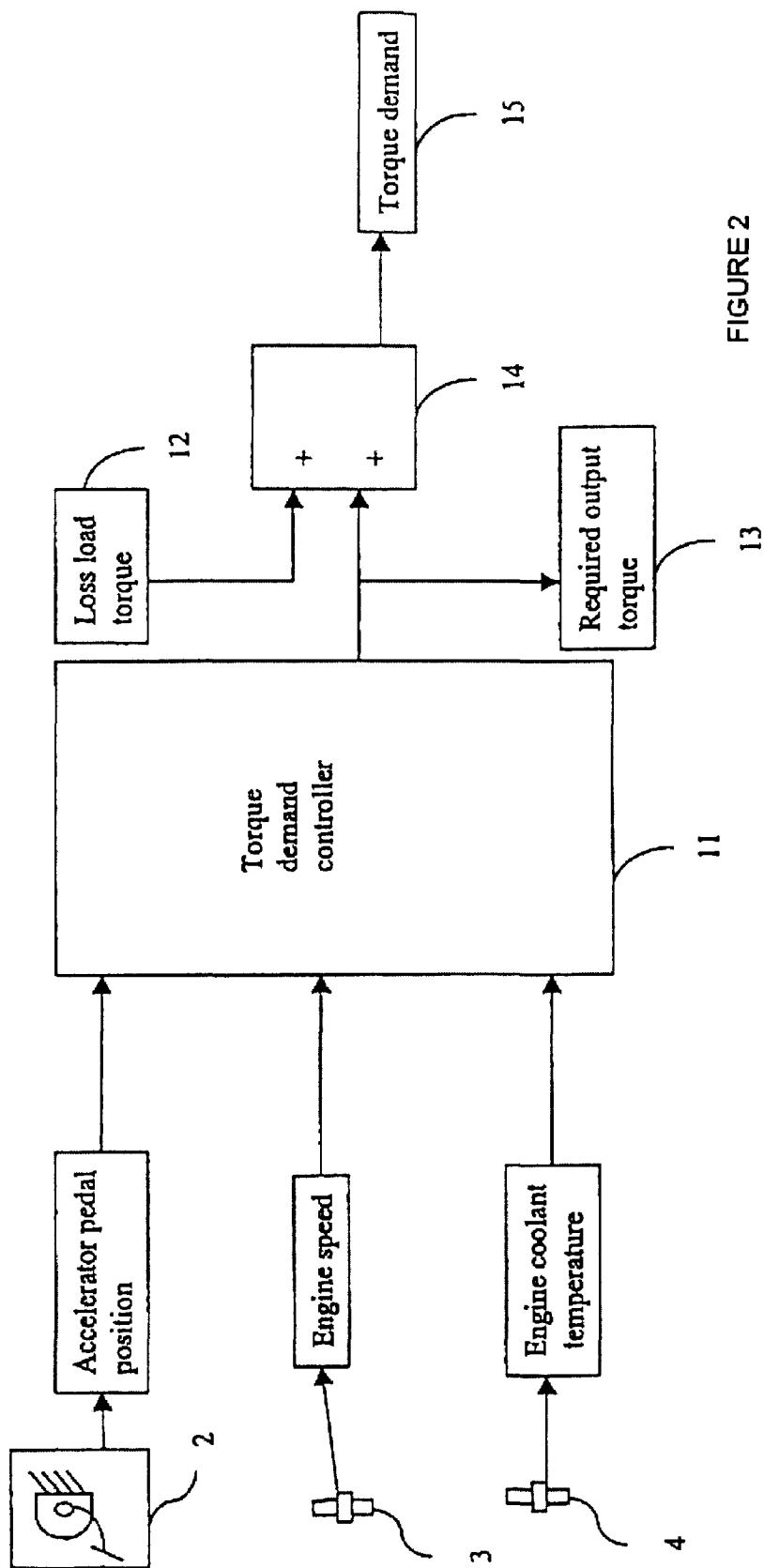


FIGURE 2

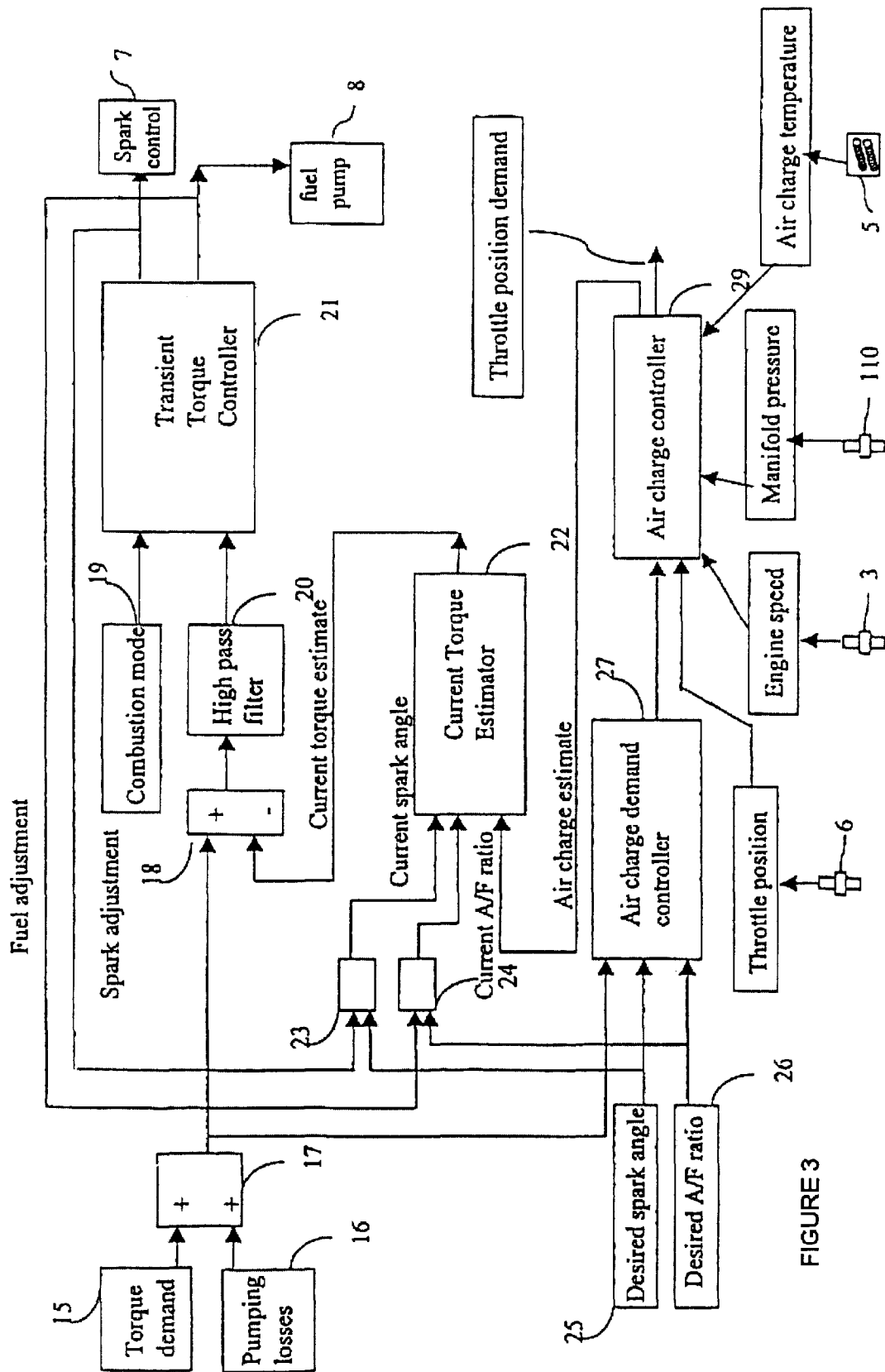


FIGURE 3

1

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark

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controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;

FIG. 2 is a block diagram of a torque demand controller, in accordance with the present invention; and

FIG. 3 is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

FIG. 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

FIG. 2 illustrates an embodiment of a torque demand controller 11 that is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque signal 12, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal 13 by an adder 14 to generate a torque demand signal 15.

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Referring now to FIG. 3, an adder 17 receives as inputs the torque demand signal 15 and a pumping losses signal 16, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder 17 outputs a

An air charge demand controller 27 receives as inputs the desired torque signal, a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1 and depend upon signals such as engine speed, engine load and engine temperature.

The air charge demand controller 27 generates an air charge demand signal that is received by an air charge controller 29. The air charge controller 29 also receives as inputs a signal indicating throttle position that is received from the throttle position indicator 6 (FIG. 1), the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller 29 generates a signal indicating desired throttle position that is sent to throttle 9 (FIG. 1) and a signal representing an estimate of the air charge.

The estimated air charge may be different from the air charge demanded by the air charge demand controller 27 due to delays in the engine 100, such as the time taken for the throttle 9 to move, the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in a stratified mode or in a homogeneous mode. If the engine 100 is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogeneous mode then a spark adjustment signal is generated and sent to the spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogeneous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

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What is claimed is:

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim 1, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

3. The device in claim 2, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

4. The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim 4, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim 5, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

7. A method for controlling a torque output of an engine, the method comprising:

estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to output a difference signal;

filtering out a plurality of low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

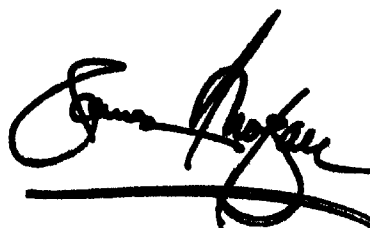
Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003

A handwritten signature in black ink, appearing to read "James E. Rogan", with a long horizontal flourish extending from the bottom of the signature.

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,

Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003

A handwritten signature in black ink, appearing to read "James E. Rogan", with a long horizontal flourish extending from the bottom of the signature.

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

31045 U.S. PTO
10/191641
07/09/02

WDI

JUN 24 2003

PATENT NUMBER and

6581565



6581565

U.S. UTILITY Patent Application

AP NU	APPL NUM 10191641	FILING DATE 07/09/2002	CLASS 123	SUBCLASS 295	GAU 3747	EXAMINER ARGENBRIGHT
**APPLICANTS: Heslop Garon; Dixon Jon; Blachford Richard;						
**CONTINUING DATA VERIFIED: <i>True</i> <i>none</i>						
** FOREIGN APPLICATIONS VERIFIED: <i>True</i> EUROPEAN PATENT OFFICE (EPO) 01306301.1 07/23/2001						
☐ PUB ☐ DO NOT PUBLISH ☐ RESCIND ☐						
Foreign priority claimed ☒ yes ☐ no			ATTORNEY DOCKET NO			
35 USC 119 conditions met ☒ yes ☐ no			10541-1524			
Verified and Acknowledged Examiners's Initials <i>True</i>						
TITLE: Engine torque controller						

U.S. DEPT. OF COMM./PAT. & TM.-PTO-436L (Rev. 12-94)

5-23-03 Formal Drawings (3 sets) set 1 7-9-02

NOTICE OF ALLOWANCE MAILED		CLAIMS ALLOWED	
3/21/03		Total Claims 7	Print Claim for O.G. 1
ISSUE FEE		DRAWING	
Amount Due \$1600.00	Date Paid 5-12-03	Sheets Drwg. 3	Figs. Drwg. 3
		Print Fig. 3	
☐ TERMINAL DISCLAIMER		Application Examiner <i>W. J. P.</i>	
		PREPARED FOR ISSUE	
WARNING: The information disclosed herein may be restricted. Unauthorized disclosure may be prohibited by the United States Code Title 35, Sections 122, 181 and 368, Possession outside the U.S. Patent & Trademark Office is restricted to authorized employees and contractors only.			
FILED WITH: ☐ DISK (CRF) ☐ CD-ROM (Attached in pocket on right inside flap)			

0001

VW EX1002
U.S. Patent No. 6,581,565

1019-6-0-1
10191641

11046 U.S. PTO
10/191641
07/09/02

INITIALS _____

CONTENTS

		Date Received (Incl. C. of M.) or Date Mailed	Date Received (Incl. C. of M.) or Date Mailed
1.	Application _____ papers.		31.
2.	Priority _____	7/9/02	32.
3.	IDS _____	7/9/02	33.
4.	Exr's Wmdt. 1A	3/21/03	34.
5.	RCZ for code	09/02/03	35.
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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

07/16/2002 WASFAW1 00000025 061500 10191641
01 FC:101 740.00 CH

PTO-1556
(5/87)

*U.S. Government Printing Office: 2001 — 481-697/59173

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07/09/02
3-759 U.S. MAIL

Express Mail® mailing label number EV 107432431 US
Date of Deposit July 9, 2002

07-10-02 17191641.020902

#2/Priority
8/16/02

Case No. 10541-1524

PATENT APPLICATION TRANSMITTAL LETTER

To the Commissioner for Patents:

Transmitted herewith for filing is the patent application of: Garon Nigel Heslop; Jon Dixon; and Richard Stephen Blachford for: ENGINE TORQUE CONTROLLER. Enclosed are:

- ☒ 3 sheet(s) of drawings, 12 pages of application (including title page), and the following Appendices : ____.
- ☒ Declaration.
- ☒ Power of Attorney.
- ☐ Verified statement to establish small entity status under 37 CFR §§ 1.9 and 1.27.
- ☒ Assignment transmittal letter and Assignment of the invention to : Visteon Global Technologies, Inc..
- ☒ Certified Copy of European Priority Document; Information Disclosure Statement, Form PTO 1449 with references; Two Return Postcards.

1046 U.S. PTO
10/19/01
07/09/02

Claims as Filed	Col. 1	Col. 2
For	No. Filed	No. Extra
Basic Fee		
Total Claims	7-20	
Indep. Claims	2-3	
Multiple Dependent Claims Present		

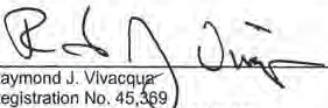
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Total	\$

Other Than Small Entity	
Rate	Fee
	\$ 740
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- ☒ Please charge my Deposit Account No. 06-1500 in the amount of \$: 740.00. A duplicate copy of this sheet is enclosed.
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July 9, 2002
Date


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17191641.070902

"Express Mail" mailing label number EV 107432431

Date of Deposit: July 9, 2002

Attorney Docket No.: 10541-1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTORS: GARON NIGEL HESLOP
 JON DIXON
 RICHARD STEPHEN BLACHFORD

TITLE: **ENGINE TORQUE CONTROLLER**

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Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

[0001] This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

[0002] An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

[0003] Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

[0004] When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may

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be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

[0005] In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

[0006] A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

[0007] In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in

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the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

[0008] Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

[0009] According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

[0010] These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

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- [0011] FIGURE 1 is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;
- [0012] FIGURE 2 is a block diagram of a torque demand controller, in accordance with the present invention; and
- [0013] FIGURE 3 is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

[0014] Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

[0015] A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

[0016] Figure 2 illustrates an embodiment of a torque demand controller 11 that is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal

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received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque signal 12, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal 13 by an adder 14 to generate a torque demand signal 15.

[0017] Referring now to Figure 3, an adder 17 receives as inputs the torque demand signal 15 and a pumping losses signal 16, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder 17 outputs a desired torque signal.

[0018] An air charge demand controller 27 receives as inputs the desired torque signal, a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1 and depend upon signals such as engine speed, engine load and engine temperature.

[0019] The air charge demand controller 27 generates an air charge demand signal that is received by an air charge controller 29. The air charge controller 29 also receives as inputs a signal indicating throttle position that is received from the throttle position indicator 6 (Figure 1), the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller 29 generates a signal indicating desired throttle position that is sent to throttle 9 (Figure 1) and a signal representing an estimate of the air charge.

[0020] The estimated air charge may be different from the air charge demanded by the air charge demand controller 27 due to delays in the engine 100,

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such as the time taken for the throttle 9 to move, the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

[0021] The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

[0022] The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

[0023] A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in a stratified mode or in a homogenous mode. If the engine 100 is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

[0024] The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any

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fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

[0025] As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

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CLAIMS

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim 1, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

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3. The device in claim 2, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel_{ratio} ratio.

4. The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim 4, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim 5, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

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7. A method for controlling a torque output of an engine, the method comprising:
- estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;
 - comparing the estimated current torque signal with a desired torque signal to output a difference signal;
 - filtering out a plurality of low frequency components from the difference signal; and
 - controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

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Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ABSTRACT

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

Attorney Docket No.: 10541-1524
Visteon Case No.: V200-0895

DECLARATION AND POWER OF ATTORNEY ORIGINAL APPLICATION

As a below named inventor, I hereby declare:
My residence, post office address and citizenship are as stated below next to my name;
I believe I am the original, first and sole inventor or an original, first and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled:

ENGINE TORQUE CONTROLLER

the specification of which (check one)
X is attached hereto.
_____ was filed on _____ as United States Application Serial No. _____ and was amended on _____ (if applicable).

I acknowledge my duty to disclose to the United States Patent and Trademark Office all information that I know to be material to the patentability of this application as defined in Title 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s):			Priority Not Claimed
01306301.1 (Number)	Europe (Country)	23 July 2001 (Filing Date)	☐
_____ (Number)	_____ (Country)	_____ (Filing Date)	☐
_____ (Number)	_____ (Country)	_____ (Filing Date)	☐

I hereby claim the benefit under 35 U.S. C. Section 119(e) of any United States provisional application(s) listed below:

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I hereby claim the benefit under 35 U.S.C. Section 120 of any United States applications(e); or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorneys, agents, and each shareholder, attorney of counsel, associate, and employee of Brinks Hofer Gilson & Lione, who is a registered Patent Attorney or registered Patent Agent, and who is associated with the customer number printed below, my attorney with full power of substitution and revocation to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith and to act on my behalf before the competent International Authorities in connection with any and all international applications filed by me.

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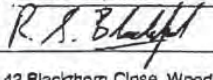
PATENT TRADEMARK OFFICE

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Citizenship	<i>BRITISH</i>
Post Office Address	Same As Residence Address

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Second inventor's signature		Date	July 9, 2002
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Post Office Address	Same As Residence Address		

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Third inventor's signature		Date	9 th July 2002
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Citizenship	British		
Post Office Address	Same As Residence Address		

Full name of fourth inventor, if any			
Fourth inventor's signature		Date	
Residence			
Citizenship			
Post Office Address			

Full name of fifth inventor, if any			
Fifth inventor's signature		Date	
Residence			
Citizenship			
Post Office Address			

Full name of sixth inventor, if any			
Sixth inventor's signature		Date	
Residence			
Citizenship			
Post Office Address			

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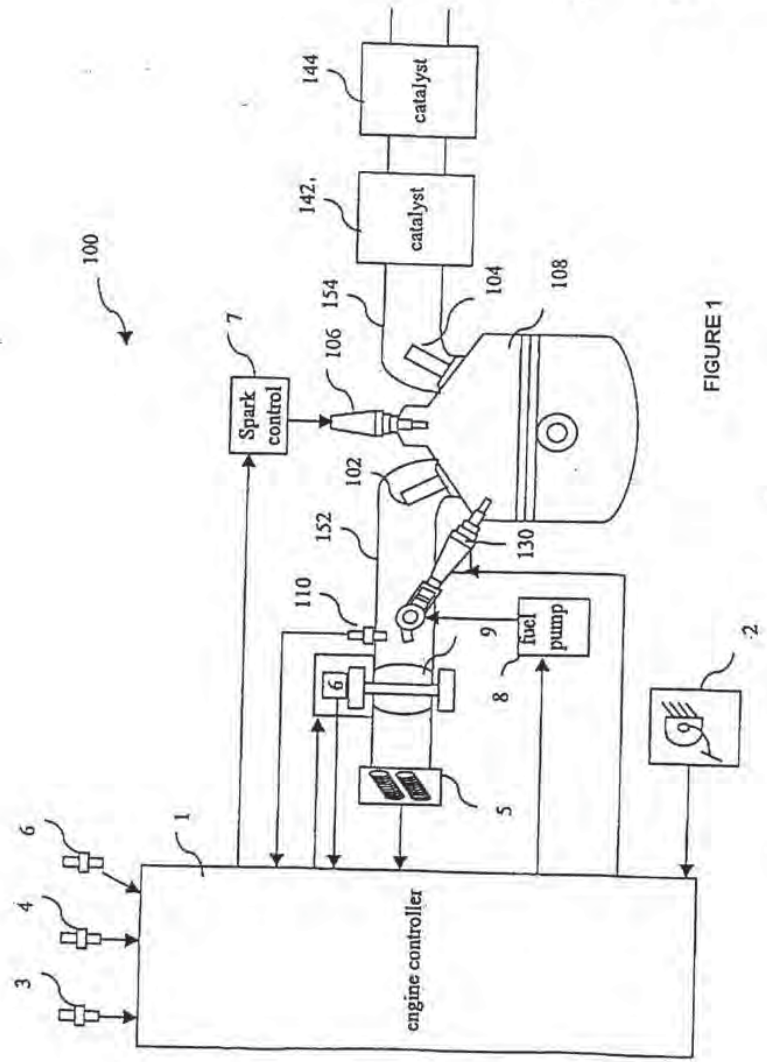


FIGURE 1

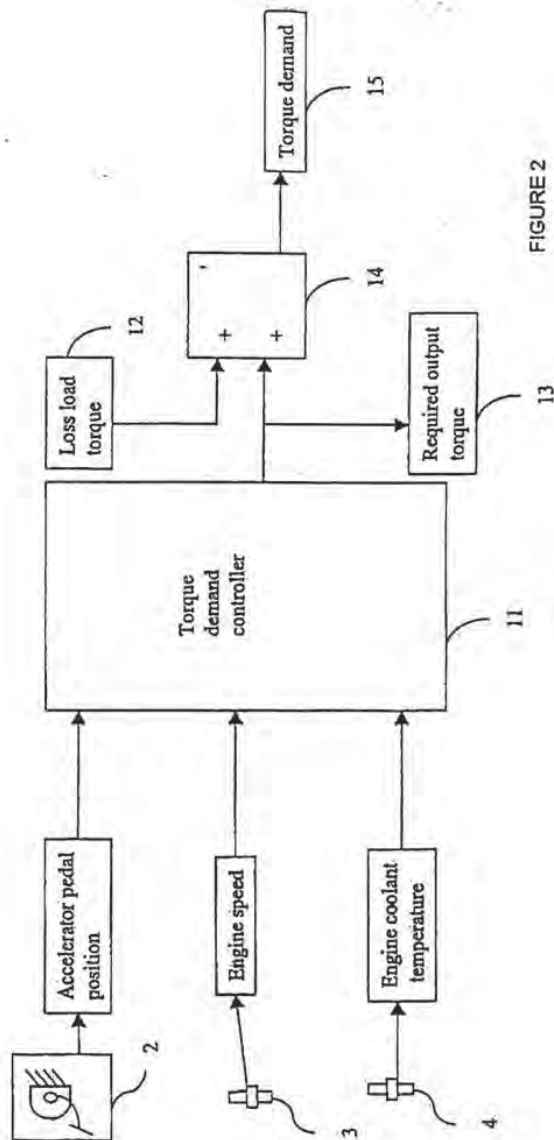


FIGURE 2

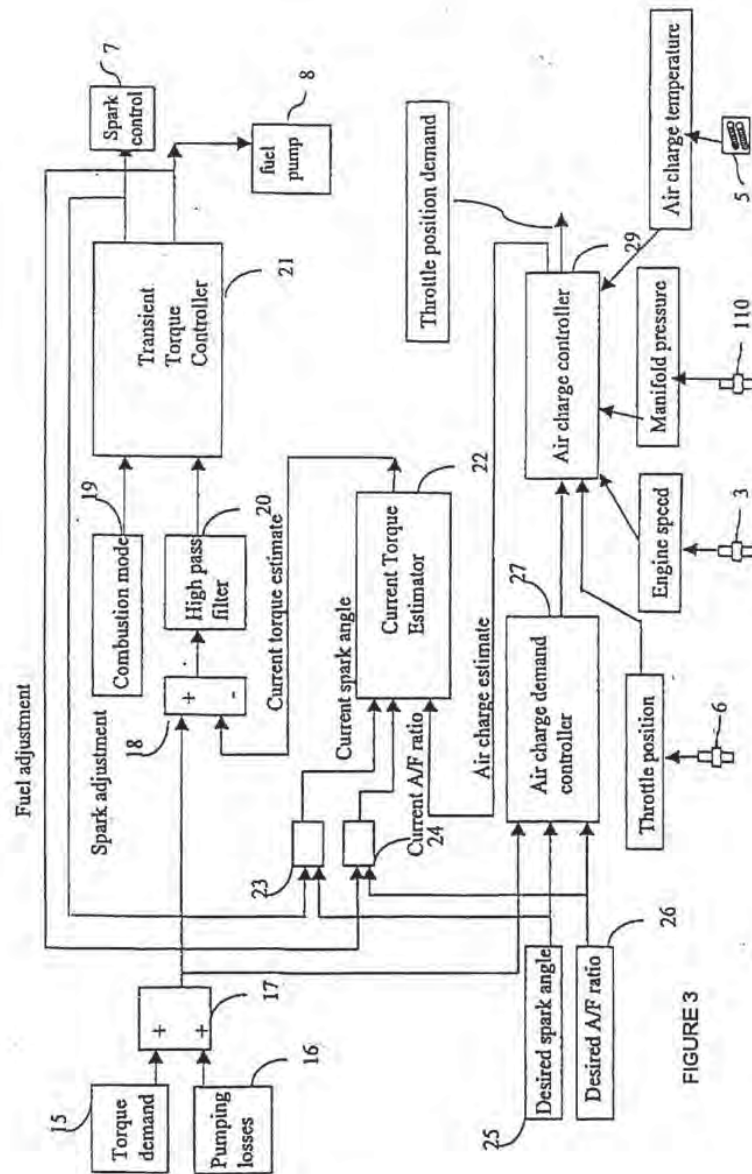
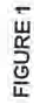


FIGURE 3

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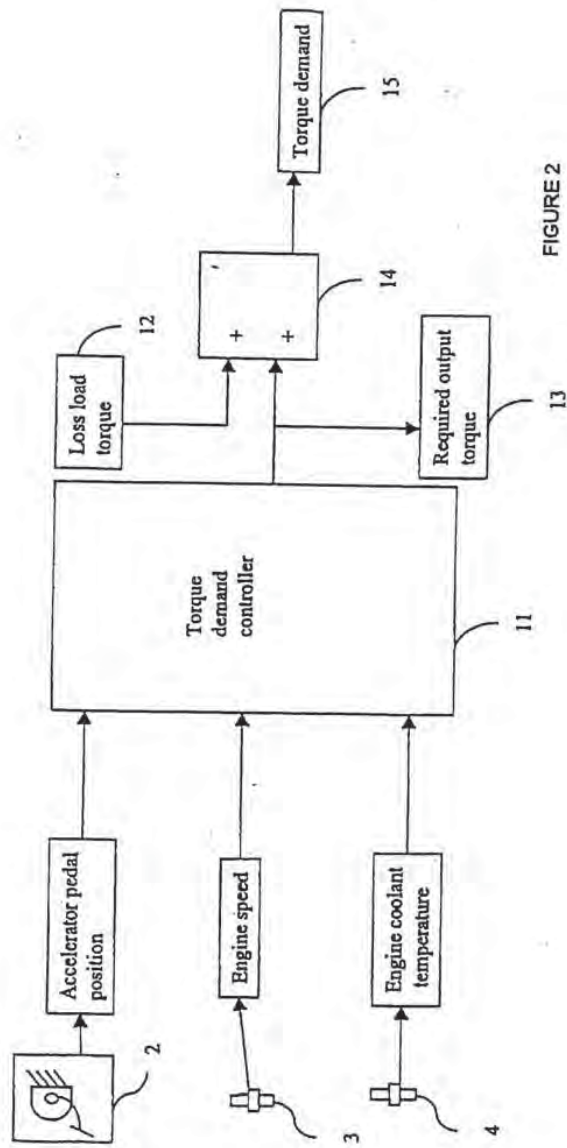


FIGURE 2

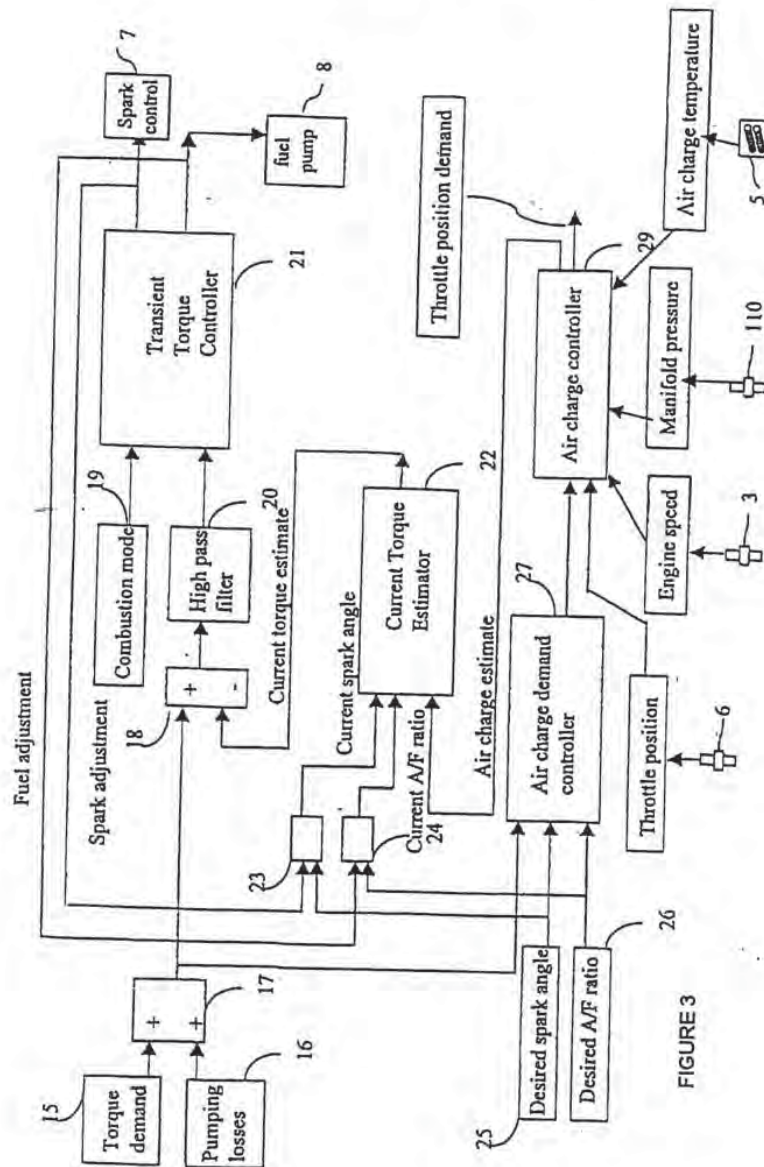


FIGURE 3

#2



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européen spécifiée à la
page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

01306301.1

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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R C van Dijk

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**Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation**

Anmeldung Nr.: 01306301.1
Application no.:
Demande n°:

Anmeldetag: 23/07/01
Date of filing:
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Visteon Global Technologies, Inc.
Dearborn, Michigan 48126-2490
UNITED STATES OF AMERICA

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Engine torque controller

In Anspruch genommene Priorität(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

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Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
F02D41/30, F02D41/14

Am Anmeldetag benannte Vertragsstaaten:
Contracting states designated at date of filing:
Etats contractants désignés lors du dépôt: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR

Bemerkungen:
Remarks:
Remarques:

ENGINE TORQUE CONTROLLER

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

An engine torque controller comprises a torque demand controller, and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and the like. This determined torque is then used by the torque producer to produce the desired torque by control of sparking angle and air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers with different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which there is exactly the amount of air to combust the amount of fuel present, i.e. when combusted leaves no excess oxygen of unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in stratified mode occurs at lower speeds and lower load conditions.

When the engine is in the homogeneous mode, a homogeneous mixture of air and fuel is introduced into the combustion

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chamber. Homogeneous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air/fuel ratio).

- 5 In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel ratio in order to control the torque produced. Conversely, when the engine is
- 10 operating in homogenous mode the air/fuel ratio is controlled tightly, in order to maintain correct operation of a catalytic converter to reduces noxious emissions, and the torque producer modifies the timing of the spark ignition in order to control the torque produced.
- 15 A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and an estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal, and fuel
- 20 economy will suffer and performance of the catalytic converters will deteriorate. In the homogenous mode if the timing of the spark ignition is altered due to such a steady state torque error, then fuel economy will suffer once again, and the engine is more likely to stall when a
- 25 load is imposed.

This invention serves to alleviate the aforementioned problems.

According to the present invention there is provided a

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torque controller for an engine, the torque controller comprising a torque demand controller and a torque producer, in which the torque producer comprises

an estimator arranged to receive a current spark angle
5 signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;

a comparator arranged to receive the estimated torque signal and the desired torque signal, and arranged to
10 output a difference signal; and

a high pass filter arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and

a transient torque controller arranged to receive the
15 filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller
20 is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment
25 signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably the controller also has an air charge controller
30 arranged to receive an air charge demand signal, a throttle

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position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably there is also an air charge demand controller
5 arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to a second aspect of the invention there is
10 provided a method of controlling torque for an engine comprising the steps of

estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge
15 signal;

comparing the estimated current torque signal with a desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

20 controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

An embodiment of the invention will now be described, by
25 way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram illustrating part of an engine and an engine controller;

Figure 2 is a schematic block diagram of a torque demand

controller; and

Figure 3 is a schematic block diagram of a torque producer.

Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1.

5 The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

10 A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel
15 pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a
20 Nox trap/catalyst 144.

Figure 2 illustrates schematically a torque demand controller 11 which is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position
25 signal received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque

signal 12, which represents losses due to losses in the engine and power train system, is added to the required output torque signal 13, at an adder 14 to generate a torque demand signal 15.

- 5 Referring now to Figure 3, the torque demand signal 15 is added to a pumping losses signal 16, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases) at an adder 17 to generate a desired
10 torque signal.

- An air charge demand controller 27 is arranged to receive the desired torque signal, together with a desired spark angle signal 25 and a desired air fuel ratio signal 26. The
15 desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1, and depend upon signals such as engine speed, engine load and engine temperature.

- The air charge demand controller 27 generates an air charge demand signal, which is received by an air charge
20 controller 29, together with a signal indicating throttle position which is received from the throttle position indicator 6 (figure 1). The air charge controller 29 generates a signal indicating desired throttle position, which is sent to the throttle 9 (figure 1).

- 25 The air charge controller 29 also receives signals from the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller uses these received signals to generate a

signal representing an estimate of the air charge. This estimated air charge may be different to the air charge demanded by the air charge demand controller 27 due to delays in the engine 100, such as the time taken for the
5 throttle 9 to move, or the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

The current torque estimator 22 uses the air charge
10 estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the
15 desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine
20 100.

A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in stratified mode or in homogenous mode. If the engine 100 is operating in stratified mode then a fuel
25 adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the

spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle
5 and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller 21. When the
10 engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

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CLAIMS

1. A torque controller for an engine, the torque controller comprising a torque demand controller (1) and a torque producer, in which the torque producer comprises
 - 5 an estimator (22) arranged to receive a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;
 - a comparator (18) arranged to receive the estimated
 - 10 torque signal and a desired torque signal, and arranged to output a difference signal; and
 - a high pass filter (20) arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and
 - 15 a transient torque controller (21) arranged to receive the filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.
2. A torque controller according to claim 1, in which
 - 20 the engine is a direct injection spark ignition engine;
 - the transient torque controller (21) is arranged to receive a combustion mode signal (19) indicating whether the engine is operating in a stratified mode or a
 - 25 homogeneous mode;
 - the transient torque controller (21) is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode ; and
 - 30 the transient torque controller is arranged to control

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the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5 3. A torque controller according to claim 1 or claim 2, further comprising an air charge controller (29) arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output
10 the estimated air charge signal.

4. A torque controller according to claim 4 further comprising an air charge demand controller (20) arranged to receive the desired torque signal, a desired spark angle
15 signal and a desired air/fuel ratio signal and to output the air charge demand signal.

5. A method of controlling torque for an engine comprising the steps of

20 estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a
25 desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

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ABSTRACT
Engine Torque Controller

This invention relates to an engine torque controller for
5 spark ignition internal combustion engines and more
specifically for direct injection engines. The invention
provides a torque controller and a method of controlling
torque for an engine, in which torque is controlled in
dependence upon a filtered difference signal where the
10 filtered difference signal is the difference between a
desired torque signal and a signal representing an estimate
of the current torque.

Figure 3

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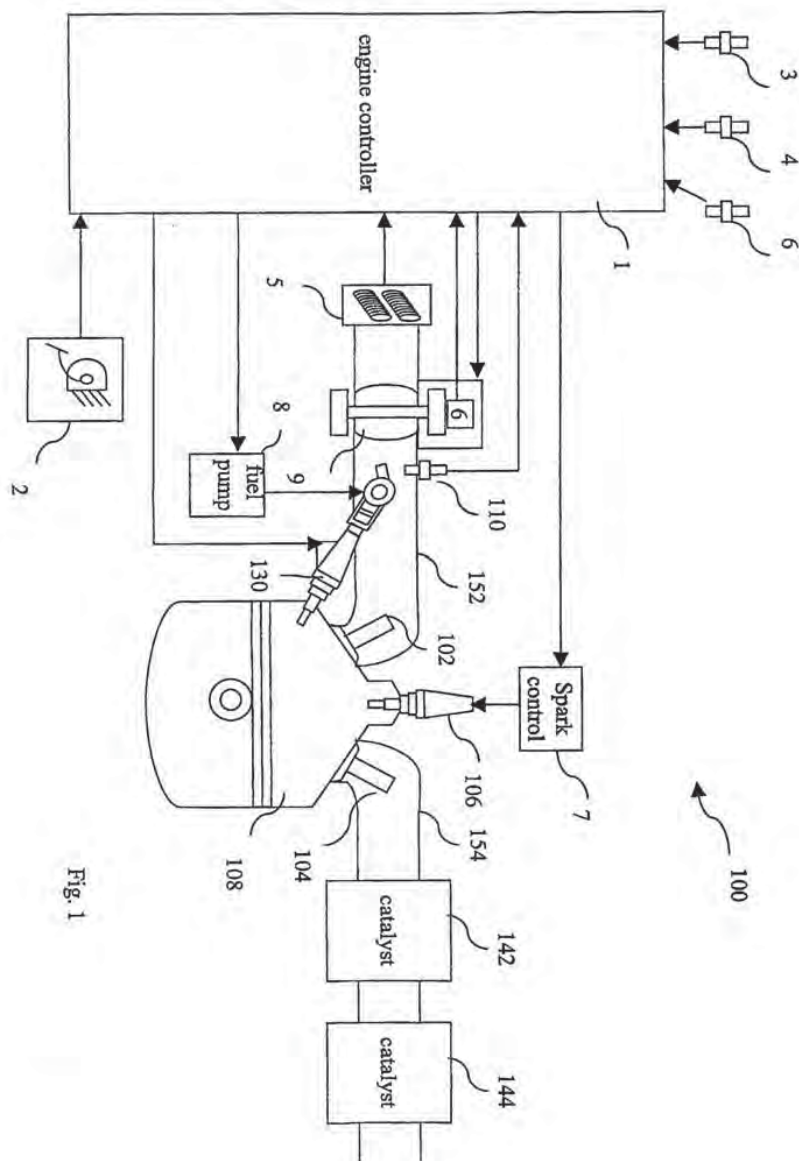


Fig. 1

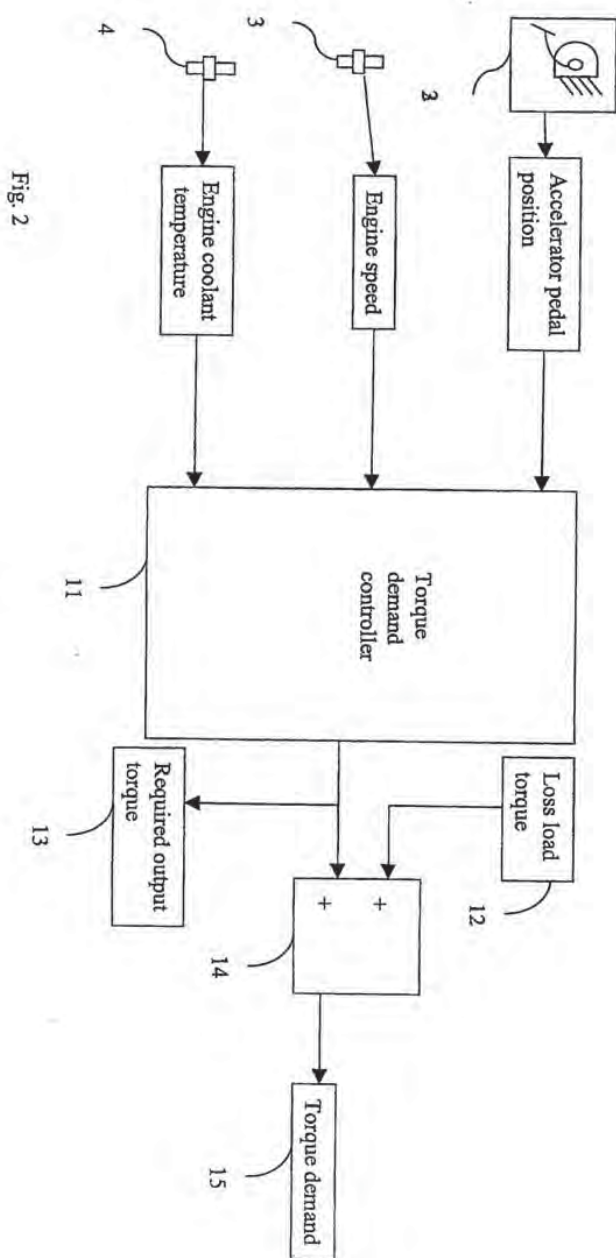


Fig. 2

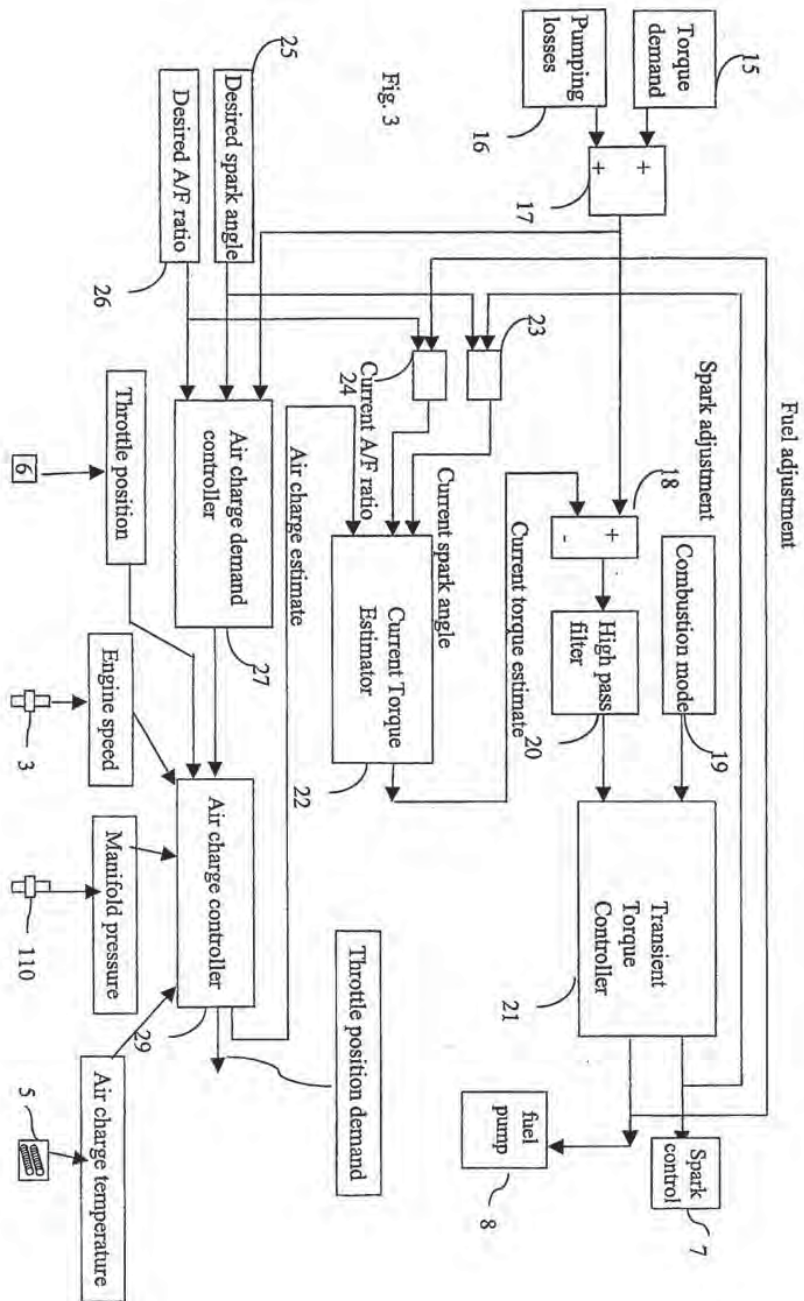


Fig. 3

#3/IDS
PATENT
8/16/02
KW
Attorney Docket No.: 10541-1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Group Art Unit: Unknown
Examiner: Unknown
Inventors: Heslop et al.
Serial No: Unknown
Filed: Concurrent Herewith
For: ENGINE TORQUE CONTROLLER

INFORMATION
DISCLOSURE
STATEMENT



Commissioner for Patents
Washington, DC 20231

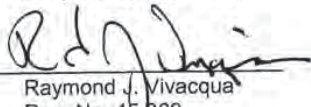
Sir:

Under the duties of disclosure, candor, and good faith of 37 CFR §1.56, the Applicant hereby submits the references listed on the attached PTO-1449 form for consideration by the Examiner. In the opinion of the Applicant, the pending claims are patentably distinct from the listed references. Furthermore, the filing of this information disclosure statement shall not be construed to be an admission that the information cited in the statement is material to patentability (37 C.F.R. §1.97(h)).

Under 37 CFR §1.97(b)(1), no fee should be required. If a fee is required, however, please charge any such fee pursuant to 37 CFR §1.16 or §1.17 to deposit account no. 06-1500.

Respectfully submitted,

Date: July 9, 2002

By: 

Raymond J. Vivacqua
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10/191641 ALCON BRIGHT



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 6301

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 237 563 B1 (TREINIES STEFAN ET AL) 29 May 2001 (2001-05-29) * column 1, line 66 - column 2, line 47 * * figures 2,3 *	1,5	F02D41/30 F02D41/14
A	DE 42 32 974 A (BOSCH GMBH ROBERT) 7 April 1994 (1994-04-07) * column 2, line 34 - line 50 *	1,5	
A	US 5 954 026 A (STOSS PETER ET AL) 21 September 1999 (1999-09-21) * column 2, line 41 - line 56 * * figure 1 *	1,5	
A	US 6 047 681 A (HEMBERGER HANS-HUBERT ET AL) 11 April 2000 (2000-04-11) * figures 1,2 *	1,5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F02D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 14 January 2002	Examiner De Vita, D
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons & : member of the same patent family, corresponding document			

1
EPO FORM 1503 03.02 (P4/C01)

FORM PTO-1449	SERIAL NO.	CASE NO. 10541-1524
LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT	FILING DATE	GROUP ART UNIT 3747
(use several sheets if necessary)		APPLICANT(S): Heslop et al.

REFERENCE DESIGNATION		U.S. PATENT DOCUMENTS				
EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS/ SUBCLASS	FILING DATE
	A1	6,237,563	05/29/2001	Frechlich et al. <i>on 892</i>		
<i>DM2</i>	A2	6,047,681	04/11/2000	Scherer et al.	123 / 406.46	
<i>DM2</i>	A3	5,954,026	09/21/1999	Stoss et al.	123 / 406.24	
	A4					
	A5					
	A6					
	A7					
	A8					
	A9					
	A10					
	A11					
	A12					
	A13					

FOREIGN PATENT DOCUMENTS						
EXAMINER INITIAL		DOCUMENT NUMBER	DATE	COUNTRY	CLASS/ SUBCLASS	TRANSLATION YES NO
<i>DM2</i>	A14	DE 42 32 974 A1	07/04/1994	Germany		
	A15		04/07			X
	A16					
	A17					
	A18					

EXAMINER INITIAL	OTHER ART (Including Author, Title, Date, Pertinent Pages, etc.)	
	A19	
	A20	
	A21	
	A22	
	A23	
	A24	

EXAMINER <i>Argente</i>	DATE CONSIDERED <i>3-19-03</i>
-------------------------	--------------------------------

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Notice of Allowability		Application No.	Applicant(s)
		10/191,641	HESLOP ET AL
		Examiner	Art Unit
		T. M. Argenbright	3747

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☐ This communication is responsive to ____.

2. ☒ The allowed claim(s) is/are 1-7.

3. ☒ The drawings filed on 09 July 2002 are accepted by the Examiner.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a) ☒ All b) ☐ Some* c) ☐ None of the:

1. ☒ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. ____.

3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: ____.

5. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).

(a) ☐ The translation of the foreign language provisional application has been received.

6. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application. **THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

7. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

8. ☐ CORRECTED DRAWINGS must be submitted.

(a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached

1) ☐ hereto or 2) ☐ to Paper No. ____.

(b) ☐ including changes required by the proposed drawing correction filed ____, which has been approved by the Examiner.

(c) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No. ____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the top margin (not the back) of each sheet. The drawings should be filed as a separate paper with a transmittal letter addressed to the Official Draftsperson.

9. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1 ☒ Notice of References Cited (PTO-892)

3 ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

5 ☒ Information Disclosure Statements (PTO-1449), Paper No. 3

7 ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material

2 ☐ Notice of Informal Patent Application (PTO-152)

4 ☐ Interview Summary (PTO-413), Paper No. ____

6 ☒ Examiner's Amendment/Comment

8 ☐ Examiner's Statement of Reasons for Allowance

9 ☐ Other

Application/Control Number: 10/191,641
Art Unit: 3747

Page 2

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In claims 3 and 6, last line, --ratio-- has been inserted after "air/fuel".

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to T. M. Argenbright whose telephone number is 703-308-1955. The examiner can normally be reached 6:30am-3:00pm M-Th and 6:30am-2:00pm alt. Fridays.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Henry C. Yuen can be reached on 703-308-1946. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9302 for regular communications and 703-872-9303 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0861.

0046

Application/Control Number: 10/191,641
Art Unit: 3747

Page 3

T. M. Argenbright
T. M. Argenbright
Primary Examiner
Art Unit 3747

March 19, 2003

0047

Notice of References Cited	Application/Control No. 10/191,641	Applicant(s)/Patent Under Reexamination HESLOP ET AL.	
	Examiner T. M. Argenbright	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS					
*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6237563	05-2001	FROEHLICH ET AL	123/350
*	B	US-6227163	05-2001	ENOKI ET AL	123/295
*	C	US-6219611	04-2001	RUSSELL	123/399x
*	D	US-5638788	06-1997	SANVIDO ET AL	123/339.2
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS						
*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS		
*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.



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NOTICE OF ALLOWANCE AND FEE(S) DUE

7590 03/21/2003
Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	CLASS-SUBCLASS
3747	123-295000

DATE MAILED: 03/21/2003

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1300	\$300	\$1600	06/23/2003

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN **THREE MONTHS** FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. **THIS STATUTORY PERIOD CANNOT BE EXTENDED.** SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

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If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.

☐ Applicant claims SMALL ENTITY status.
See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** Box ISSUE FEE
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)
7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1300	\$300	\$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47, Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1	_____
2	_____
3	_____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☐ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed:

- ☐ Issue Fee
☐ Publication Fee
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):

- ☐ A check in the amount of the fee(s) is enclosed.
☐ Payment by credit card. Form FTO-2038 is attached.
☐ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above:

(Authorized Signature)

(Date)

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent, or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004. OMB 0651-0033

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815
7590 03/21/2003 Steven L. Oberholtzer BRINKS HOFER GILSON & LIONE P.O. Box 10395 Chicago, IL 60610			EXAMINER ARGENBRIGHT, TONY MICHAEL	
			ART UNIT 3747	PAPER NUMBER
DATE MAILED: 03/21/2003				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The patent term adjustment to date is 0 days. If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the term adjustment will be 0 days.

If a continued prosecution application (CPA) was filed in the above-identified application, the filing date that determines patent term adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system. (<http://pair.uspto.gov>)

Any questions regarding the patent term extension or adjustment determination should be directed to the Office of Patent Legal Administration at (703)305-1383.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815
7590 03/21/2003				
Steven L. Oberholtzer BRINKS HOFER GILSON & LIONE P.O. Box 10395 Chicago, IL 60610 UNITED STATES				
EXAMINER ARGENBRIGHT, TONY MICHAEL				
ART UNIT PAPER NUMBER				
3747				
DATE MAILED: 03/21/2003				

Notice of Fee Increase on January 1, 2003

If a reply to a "Notice of Allowance and Fee(s) Due" is filed in the Office on or after January 1, 2003, then the amount due will be higher than that set forth in the "Notice of Allowance and Fee(s) Due" since there will be an increase in fees effective on January 1, 2003. See Revision of Patent and Trademark Fees for Fiscal Year 2003, Final Rule, 67 Fed. Reg. 70847, 70849 (November 27, 2002).

The current fee schedule is accessible from: <http://www.uspto.gov/main/howtofees.htm>.

If the issue fee paid is the amount shown on the "Notice of Allowance and Fee(s) Due," but not the correct amount in view of the fee increase, a "Notice to Pay Balance of Issue Fee" will be mailed to applicant. In order to avoid processing delays associated with mailing of a "Notice to Pay Balance of Issue Fee," if the response to the Notice of Allowance and Fee(s) due form is to be filed on or after January 1, 2003 (or mailed with a certificate of mailing on or after January 1, 2003), the issue fee paid should be the fee that is required at the time the fee is paid. If the issue fee was previously paid, and the response to the "Notice of Allowance and Fee(s) Due" includes a request to apply a previously-paid issue fee to the issue fee now due, then the difference between the issue fee amount at the time the response is filed and the previously paid issue fee should be paid. See Manual of Patent Examining Procedure, Section 1308.01 (Eighth Edition, August 2001).

Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

I hereby certify that this correspondence is being deposited with the United States Postal Service, with sufficient postage, as first class mail in an envelope addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on

8/28/03

(Date of Deposit)

Raymond J. Vivacqua - Reg. No. 45,369

Name of applicant, assignee, or
Registered Representative

Signature

8/28/03

Date of Signature



P. CAC
Certificate
SEP 08 2003
of Correction
M
#5

Our File No. 10541/1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Garon N. Heslop et al.

Patent No.: 6,581,565 B2

Issue Date: June 24, 2003

Serial No.: 10/191,641

Filing Date: July 9, 2002

For: ENGINE TORQUE CONTROLLER

)
)
)
)
) Examiner: Tony M. Argenbright
)
) Group Art Unit: 3747
)
)
)
)
)
)

REQUEST FOR CERTIFICATE OF CORRECTION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attn: Certificate of Corrections Branch

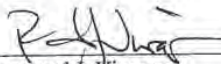
Sir:

Please issue a Certificate of Correction for the above-identified patent to correct the errors listed on the accompanying PTO Form 1050. This request is being made pursuant to 35 U.S.C. § 254, since the errors comprise minor or typographical errors by the Patent and Trademark Office.

SEP 09 2003

The Commissioner is hereby authorized to charge any fees required to Deposit Account No. 06-1500 (Visteon Global Technologies, Inc.). A duplicate copy of this sheet is enclosed.

Respectfully submitted,


Raymond J. Vivacqua
Registration No. 45,369
Attorney for Applicants

BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610
(312) 321-4200

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

~~In the Claims~~

~~In claim 3~~, line ^{Col. 4} 30, after "air/fuel" insert --ratio--
before "." (period).

~~In claim 6~~, line ^{Col. 4} 53, after "air/fuel" insert --ratio--
before "." (period).

MAILING ADDRESS OF SENDER:

Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

FORM PTO 1050 (Rev. 2-93)

PATENT NO. 6,581,565 B2

No. of add'l copies
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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In claim 3, line 4, after "air/fuel" insert --ratio-- before "." (period).

In claim 6, line 4, after "air/fuel" insert --ratio-- before "." (period).

MAILING ADDRESS OF SENDER:
Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

PATENT NO. 6,581,565 B2

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FORM PTO 1050 (Rev. 2-93)

0056

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this
Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office



PART B - FEE(S) TRANSMITTAL

Completed and send this form, together with applicable fee(s), to: **Mail Box ISSUE FEE**
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. Further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark up with any certificate or use Block 1)

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

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Raymond J. Vivacqua (Depositor's name)
[Signature] (Signature)
5/9/03 (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4813

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	\$1300	\$300	\$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47, Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

Brinks Hofer Gilson & Lione

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY AND STATE OR COUNTRY)

Visteon Global Technologies, Inc.

Dearborn, Michigan

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☒ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed:

☒ Issue Fee

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☐ Advance Order - # of Copies

4b. Payment of Fee(s):

☐ A check in the amount of the fee(s) is enclosed.

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Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) [Signature] (Date) 5/9/03

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant, a registered attorney or agent, or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

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05/13/2003 BSAYRS12 00000106 061500 10191641

01 FC:1501 1300.00 CH
02 FC:1504 300.00 CH

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PTOL-85 (REV. 04-02) Approved for use through 01/31/2004, OMB 0651-0033

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1 EPAS ID: PAT4575384
Stylesheet Version v1.2

SUBMISSION TYPE:	NEW ASSIGNMENT	
NATURE OF CONVEYANCE:	ASSIGNMENT	
CONVEYING PARTY DATA		
Name		Execution Date
MOBILE AUTOMOTIVE TECHNOLOGIES, LLC		08/28/2017
RECEIVING PARTY DATA		
Name:	MICHIGAN MOTOR TECHNOLOGIES LLC	
Street Address:	2360 ORCHARD LAKE ROAD SUITE 100	
City:	SYLVAN LAKE	
State/Country:	MICHIGAN	
Postal Code:	48320	
PROPERTY NUMBERS Total: 42		
Property Type	Number	
Patent Number:	6345604	
Patent Number:	6347680	
Patent Number:	6379281	
Patent Number:	6443128	
Patent Number:	6510839	
Patent Number:	6557540	
Patent Number:	6561166	
Patent Number:	6571157	
Patent Number:	6581565	
Patent Number:	6581574	
Patent Number:	6588260	
Patent Number:	6598581	
Patent Number:	6607302	
Patent Number:	6609497	
Patent Number:	6612287	
Patent Number:	6619106	
Patent Number:	6644115	
Patent Number:	6736122	
Patent Number:	6741441	
Patent Number:	6752741	

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
Patent Number:	6976477
Patent Number:	6988031
Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010
Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.
Phone: 3024499010
Email: mmccclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 2
source=michmotorassn#page1.tif

source=michmotorassn#page2.tif

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

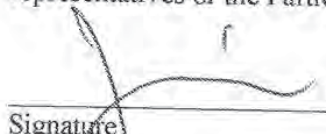
WHEREAS, Michigan Motor Technologies LLC ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

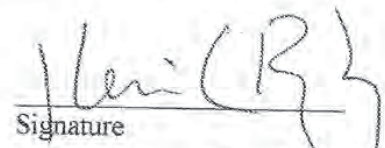
WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature 
Name John Meli
Mobile Automotive Technologies LLC
Date: 8/25/17

Signature 
Name KEVIN C BRADY
Michigan Motor Technologies LLC
Date: 8/28/17

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
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US6856209
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US7168637
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US7198207
US7293554
US7487761
US7712451
US7982358
DE103 44 494.7-34
GB2385013
GB2422688
JP4235485
DE103 22 529.3

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1 EPAS ID: PAT4575232
Stylesheet Version v1.2

SUBMISSION TYPE:	NEW ASSIGNMENT	
NATURE OF CONVEYANCE:	ASSIGNMENT	
CONVEYING PARTY DATA		
Name		Execution Date
GODO KAISHA IP BRIDGE		09/02/2016
RECEIVING PARTY DATA		
Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC	
Street Address:	951 GOVERNMENT STREET, SUITE B	
City:	MOBILE	
State/Country:	ALABAMA	
Postal Code:	36604	
PROPERTY NUMBERS Total: 42		
Property Type	Number	
Patent Number:	6345604	
Patent Number:	6347680	
Patent Number:	6379281	
Patent Number:	6443128	
Patent Number:	6510839	
Patent Number:	6557540	
Patent Number:	6561166	
Patent Number:	6571157	
Patent Number:	6581565	
Patent Number:	6581574	
Patent Number:	6588260	
Patent Number:	6598581	
Patent Number:	6607302	
Patent Number:	6609497	
Patent Number:	6612287	
Patent Number:	6619106	
Patent Number:	6644115	
Patent Number:	6736122	
Patent Number:	6741441	
Patent Number:	6752741	

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
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Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
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Patent Number:	6976477
Patent Number:	6988031
Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010
Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.
Phone: 3024499010
Email: mmccclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
source=MobileAutoSignedPAA#page1.tif

source=MobileAutoSignedPAA#page2.tif
source=MobileAutoSignedPAA#page3.tif

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Godo Kaisha IP Bridge 1 ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

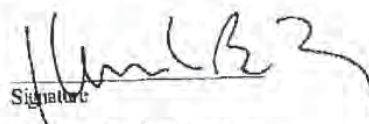
WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.


Signature
Hideyuki Ogata
Name

Date: Sept. 2, 2016


Signature
KEVIN C. BRADY
Name

Date: AUG 27, 2016

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
US6763804
US6766788
US6817592
US6847882
US6856209
US6874362
US6976477
US6988031
US7089894
US7116081
US7124963
US7137577
US7143501
US7168637
US7191755
US7198207

US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575296

SUBMISSION TYPE:	NEW ASSIGNMENT	
NATURE OF CONVEYANCE:	ASSIGNMENT	
CONVEYING PARTY DATA		
Name		Execution Date
GODO KAISHA IP BRIDGE		11/02/2016
RECEIVING PARTY DATA		
Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC	
Street Address:	951 GOVERNMENT STREET, SUITE B	
City:	MOBILE	
State/Country:	ALABAMA	
Postal Code:	36604	
PROPERTY NUMBERS Total: 42		
Property Type	Number	
Patent Number:	6345604	
Patent Number:	6347680	
Patent Number:	6379281	
Patent Number:	6443128	
Patent Number:	6510839	
Patent Number:	6557540	
Patent Number:	6561166	
Patent Number:	6571157	
Patent Number:	6581565	
Patent Number:	6581574	
Patent Number:	6588260	
Patent Number:	6598581	
Patent Number:	6607302	
Patent Number:	6609497	
Patent Number:	6612287	
Patent Number:	6619106	
Patent Number:	6644115	
Patent Number:	6736122	
Patent Number:	6741441	
Patent Number:	6752741	

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
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Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

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Fax Number: (302)449-9010
Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.
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Email: mmccclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
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PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1 EPAS ID: PAT4630877
Stylesheet Version v1.2

SUBMISSION TYPE:	RESUBMISSION
NATURE OF CONVEYANCE:	ASSIGNMENT
RESUBMIT DOCUMENT ID:	504528590
CONVEYING PARTY DATA	
Name	Execution Date
GODO KAISHA IP BRIDGE	11/02/2016
RECEIVING PARTY DATA	
Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604
PROPERTY NUMBERS Total: 42	
Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
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Phone:

3024499010

Email:

mmccclain@devlinlawfirm.com

Correspondent Name:

TIMOTHY DEVLIN

Address Line 1:

1306 N. BROOM STREET

Address Line 2:

1ST FLOOR

Address Line 4:

WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/Timothy Devlin/
DATE SIGNED:	10/06/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).
Total Attachments: 6	

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source=MobileAutoSignedPAA#page2.tif
source=MobileAutoSignedPAA#page3.tif

AMENDMENT NO. 1 TO THE PATENT ASSIGNMENT AGREEMENT

This Amendment No. 1 (the "Amendment"), dated as of the latest execution date below, is entered into by Mobile Automotive Technologies, LLC, an Alabama limited liability company and Godo Kaisha IP Bridge 1, with its principal offices at c/o Sakura Sogo Jimusho, 1-11 Kanda Jimbocho, Chiyoda-ku, Tokyo 102-0083, Japan, and amends the Patent Assignment Agreement entered into by the parties, executed on September 2, 2016 (the "PTA"). Capitalized terms not defined herein are defined in the PTA.

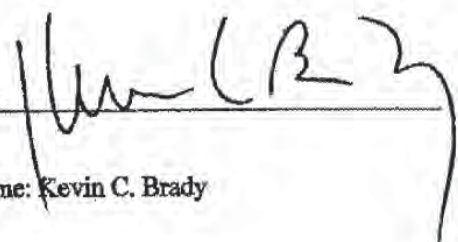
The parties agree to retroactively amend the PTA as follows:

1. Exhibit A to the PTA is hereby retroactively amended and restated in its entirety in the form of Exhibit A attached hereto.
2. The parties intend and agree that this Amendment shall be effective as of the Effective Date of the PTA with the same force and effect as if executed on that date. Except as expressly amended by this Amendment, all other terms, conditions and provisions of the PTA shall apply.

IN WITNESS WHEREOF, the parties have executed this Amendment through their duly authorized representatives.

Mobile Automotive Technologies, LLC

Godo Kaisha IP Bridge 1

By: 

By: 

Name: Kevin C. Brady

Name: Hideyuki Ogata

Title: Managing Member

Title: Executive Manager

Date: 10-21-2016

Date: 11-2-2016

EXHIBIT A

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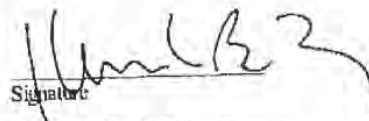
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NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

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Name

Date: Sept. 2, 2016


Signature
KEVIN C. BRADY
Name

Date: AUG 27, 2016

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US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PATENT APPLICATION FEE DETERMINATION RECORD Effective October 1, 2001					Application or Docket Number 10541-1524			
CLAIMS AS FILED - PART I								
			(Column 1)	(Column 2)				
TOTAL CLAIMS			7					
FOR			NUMBER FILED	NUMBER EXTRA				
TOTAL CHARGEABLE CLAIMS			7 minus 20=	*				
INDEPENDENT CLAIMS			2 minus 3 =	*				
MULTIPLE DEPENDENT CLAIM PRESENT			☐					
* If the difference in column 1 is less than zero, enter "0" in column 2								
CLAIMS AS AMENDED - PART II								
			(Column 1)	(Column 2)	(Column 3)			
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA			
	Total	*	Minus	**	=			
	Independent	*	Minus	***	=			
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					☐		
			(Column 1)	(Column 2)	(Column 3)			
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA			
	Total	*	Minus	**	=			
	Independent	*	Minus	***	=			
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					☐		
			(Column 1)	(Column 2)	(Column 3)			
AMENDMENT C	CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA			
	Total	*	Minus	**	=			
	Independent	*	Minus	***	=			
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					☐		
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20." ***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3." The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.								
FORM PTO-875 (Rev. 8/01)					U.S. Government Printing Office: 2001 — 484-484/59268		Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE	

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL		OR	TOTAL	740

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

SEARCH			
Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	Tmt

INTERFERENCE SEARCHED			
Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	Tmt

SEARCH NOTES		
(List databases searched. Attach search strategy inside.)		
	Date	Exmr.

ISSUE SLIP STAPLE AREA (for additional cross-references)

ORIGINAL		ISSUING CLASSIFICATION	
CLASS	SUBCLASS	CLASS	CROSS REFERENCE(S) SUBCLASS (ONE SUBCLASS PER BLOCK)
123	295	123	406.23 406.47 478
INTERNATIONAL CLASSIFICATION			
F02D	4114		
F02B	17100		
	1		
	1		
	1		

^ Continued on Issue Slip Inside File Jacket

INDEX OF CLAIMS

✓ Rejected - (Through numeral) ... Canceled N Non-elected A Appeal
= Allowed + ... Restricted I Interference O Objected

Claim	Date	Claim	Date	Claim	Date
Final		Final		Final	
Original		Original		Original	
1		51		101	
2		52		102	
3		53		103	
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47		97		147	
48		98		148	
49		99		149	
50		100		150	

If more than 150 claims or 9 actions staple additional sheet here

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VOLKSWAGEN GROUP OF AMERICA, INC.
Petitioner

v.

MICHIGAN MOTOR TECHNOLOGIES LLC
Patent Owner

Case IPR2020-00445
Patent 6,581,565

**DECLARATION OF C. ARTHUR MACCARLEY, PH.D., P.E. IN SUPPORT
OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO.
6,581,565**

Mail Stop PATENT BOARD
Patent Trial and Appeal Board
U.S. Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

VW EX1003
U.S. Patent No. 6,581,565

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3.	[1.B] “a torque producer which receives the torque demand signal”	52
4.	[1.C] “the torque producer includes: an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal”	55
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6.	[1.E] “a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent”	58
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I. INTRODUCTION

I, C. Arthur MacCarley, Ph.D., P.E., declare as follows:

1. I have been retained on behalf of Volkswagen Group of America, Inc. (“VWGoA”) for the above-captioned *inter partes* review proceeding to provide my expert opinions and expert knowledge. I understand that this proceeding involves U.S. Patent No. 6,581,565 (“the ’565 patent”), titled “Engine Torque Controller,” and that the ’565 patent is currently assigned to Michigan Motor Technologies LLC (“MMT”). I understand that the Petition submitted by VWGoA challenges claims 1-7 of the ’565 patent.

2. The ’565 patent describes a device and a method for controlling the engine torque output. I am familiar with the technology described in the ’565 patent as of its earliest possible priority date, July 23, 2001.

3. I have been asked to provide my independent technical review, analysis, insights, and opinions regarding the ’565 patent and the references that form the basis for the grounds of unpatentability set forth in the Petition for *inter partes* review of the ’565 patent filed by VWGoA.

4. In preparing this Declaration, I have reviewed and am familiar with all the documents cited herein. I have reviewed and am familiar with the ’565 patent and its file history. I confirm that to the best of my knowledge the accompanying exhibits are true and accurate copies of what they purport to be, and that an expert in

the field would reasonably rely on them to formulate opinions such as those set forth in this Declaration.

5. I am being compensated at my customary rate of \$300 per hour for my work on this case. My compensation is not dependent upon my opinions, my testimony, or the outcome of this case.

II. SUMMARY OF GROUNDS

6. I understand that the Petition for *inter partes* review of the '565 patent filed by VWGoA asserts the following grounds of unpatentability:

Ground	References	Basis	Claims Challenged
1	Robichaux, Scherer	§103	1, 7
2	Robichaux, Scherer, Takahashi	§103	2, 3
3	Robichaux, Scherer, Suzuki	§103	4
4	Robichaux, Scherer, Suzuki, Takahashi	§103	5, 6

III. SUMMARY OF OPINIONS

7. In my opinion, the challenged claims of the '565 patent would have been obvious in view of the combinations of references that VWGoA asserts, as well as the state of the art in automotive engine control on or before the year 2001, known to a person of ordinary skill in the art.

8. Independent claim 1 of the '565 patent recites a device for controlling a torque output of an engine. EX1001, '565 patent, 4:2-3. The claimed device includes a torque demand controller for generating a torque demand signal and a torque producer which receives the torque demand signal. *Id.*, 4:5-8. The claimed torque producer includes an estimator that receives as inputs a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal and outputs an estimated torque signal. *Id.*, 4:9-12. The claimed torque producer includes a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal. *Id.*, 4:13-15. The claimed torque producer includes a high-pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent. *Id.*, 4:16-18. The claimed torque producer includes a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal. *Id.*, 4:19-22.

9. As discussed in this Declaration, all these recited elements—for example, a torque demand controller and a torque producer having an estimator, a comparator, a high-pass filter, and a transient torque controller—were basic, well-known components found in generic engine control systems as of July 23, 2001, the earliest possible priority date of the '565 patent. And, as discussed in this Declaration, the claimed solution for compensating between estimated and demand

torques during transient engine operations was well-known and had been solved by the prior art in exactly the same way as recited in claims 1-7 of the '565 patent.

Moreover, as further discussed in this Declaration, well before the '565 patent's July 23, 2001 earliest possible priority date, a person of ordinary skill in the art would have had a good reason to combine the asserted prior art references, and in so doing, they would have had a reasonable expectation of success.

10. Therefore, it is my opinion that the challenged claims would have been obvious in view of the disclosures in the asserted prior art references, as described in detail below.

IV. QUALIFICATIONS

11. My experience and education are detailed in my curriculum vitae ("CV"), a copy of which is provided as EX1004. My CV also lists peer-reviewed publications on which I am the primary or a named author and identifies parties on behalf of whom I have previously provided expert testimony.

12. My research and development work since the late 1970s has focused on advanced control systems in automotive or transportation applications, including developing microprocessor-based engine control systems for regulating air intake, fuel injection, and ignition. As an academic for 31 years, my teaching specialization is control systems and electronics applicable to automotive and similar applications, as well as internal combustion engines and fuels. I have conducted research and

managed many projects that are highly relevant to the subject matter of the '565 patent, as detailed below.

13. I obtained my Bachelor of Science in Engineering (Energy and Kinetics specialization) and my Master of Science (Electrical Engineering) from the University of California, Los Angeles in 1976 and 1978, respectively. I then earned a Ph.D. in Electrical Engineering with a specialty in Computer-based Control Systems in 1987 from Purdue University, West Lafayette, Indiana.

14. Before pursuing my Ph.D., I was employed by the Digital Communications Laboratory of the Hughes Aircraft Corp between 1977 and 1979. Between 1979 and 1983, I was employed by the University of Denver Research Institute and by the American Bosch Division of United Technologies. My work at that time included the design and optimization of electronic diesel and spark ignition engine fuel injection controls. This included responsibility for the development and validation of electronic engine control algorithms. I also designed, constructed, and tested electronic fuel injection and ignition control systems for hydrogen, methanol, and natural gas fueled engines under contract to the U.S. Department of Energy.

15. While earning my Ph.D. at Purdue University, I was the recipient of the David Ross Fellowship for Doctoral Study, and I focused my research on microprocessor-based control systems and indirect sensing methods for automotive fuel injection applications.

16. I am currently a Professor of Electrical and Computer Engineering at the California Polytechnic State University, San Luis Obispo (Cal Poly). I have been on the faculty since 1988, tenured since 1994. I have served as the Chair of the Electrical Engineering Department, the Director of the Computer Engineering Program, and as the interim Head of the BioResource and Agricultural Engineering Department. I am currently the Director of the Transportation Electronics Laboratory and have been since 1995. I have also served as a Guest Professor of Electrical Engineering at Olin College in Needham, Massachusetts in 2011, and I have taught Electrical and Mechanical Engineering in the International Summer School program at Munich University of Applied Science in Munich, Germany every year from 2014 to the present.

17. My university teaching and research specialties include digital control systems, microprocessor-embedded systems, automotive and transportation electronics, internal combustion engines, advanced sensors, and alternative engine fuels, all with applications in the field of automotive engineering

18. I am a Senior Member of the Society of Automotive Engineers (SAE), the Institute of Electrical and Electronic Engineers (IEEE), and Sigma Xi (Scientific Research Honor Society). I have been a Registered Professional Engineer in good standing in the state of Colorado continuously since 1981.

19. Based upon on my education, my professional experience from 1978 through the present, and my scholarly publications, I am an expert in the relevant field of the '565 patent at issue here, and I have been an expert in this field since before the '565 patent was filed with the United States Patent and Trademark Office ("USPTO"). I am intimately familiar with how a person of ordinary skill in the art ("POSA") would have understood and used the terminology found in the '565 patent at the time of its filing.

V. MATERIALS CONSIDERED

20. In formulating my opinions, I have relied upon my training, knowledge, and experience that are relevant to the '565 patent. Furthermore, I have specifically considered the following documents, in addition to any other documents cited in this Declaration:

Exhibit No.	Description
1001	U.S. Patent No. 6,581,565 B2 to Heslop <i>et al.</i> ("'565 Patent")
1002	Prosecution File History of U.S. Patent No. 6,581,565 B2 ("'565 history")
1004	Curriculum Vitae of C. Arthur MacCarley, Ph.D., P.E.
1005	U.S. Patent No. 6,006,717 A to Suzuki <i>et al.</i> , titled "Direct-Injection Spark-Ignition Type Engine Control Apparatus," issued December 28, 1999 ("Suzuki")
1006	U.S. Patent No. 5,241,855 A to Cullen <i>et al.</i> , titled "Method and Apparatus for Inferring Engine Torque," issued September 7, 1993 ("Cullen")
1007	U.S. Patent No. 6,07,681 A to Scherer <i>et al.</i> , titled "Process and Apparatus for Adjusting the Torque of an Internal-Combustion Engine," issued April 11, 2000 ("Scherer")

Exhibit No.	Description
1008	U.S. Patent No. 5,282,449 A to Takahashi <i>et al.</i> , titled “Method and System for Engine Control,” issued February 1, 1994 (“Takahashi”)
1009	“Bosch Fuel Injection Systems,” F. Aird, Berkeley Publishing Group, 2001, ISBN 1-55788-365-3 (“Aird”)
1010	U.S. Patent No. 6,209,519 B1 to Melchior <i>et al.</i> , titled “Method and Arrangement for Controlling the Quiet Running of an Internal Combustion Engine,” issued April 3, 2001 (“Melchior”)
1012	“Bosch Automotive Handbook,” Robert Bosch GmbH, 2000, ISBN 0-7680-0669-4 (“Bosch”)
1014	John B. Heywood, Internal Combustion Engine Fundamentals, 1st Ed. McGraw-Hill, Inc., 1988. (“Heywood”)
1015	Ronald K. Jurgen, “Automotive Electronics Handbook,” McGraw-Hill, Inc., ISBN0-07-033189-8, c.1994 (selected portions) (“Jurgen”)
1019	Understanding Automotive Electronics, Fifth Edition (1998), William B. Ribbens, Ph.D. (“Ribbens”)
1020	European Patent Application Pub. No. EP 1 076 165 A2 to Robichaux <i>et al.</i> , titled “System and Method for Controlling Engine Torque,” published February 14, 2001 (“Robichaux”)
1029	Amended Complaint for Patent Infringement, Michigan Motor Technologies LLC v. Volkswagen AG, Case No. 2:19-cv-10485 (E.D. Mich.), filed April 30, 2019

VI. LEGAL STANDARDS

21. I have also relied upon various legal principles (as explained to me by Volkswagen’s counsel) in formulating my opinions. My understanding of these principles is summarized below.

22. I have been told the following legal principles apply to analysis of patentability. I also have been told that, in an *inter partes* review proceeding, a patent claim may be deemed unpatentable if it is shown by a preponderance of the

evidence that the claim is anticipated by one prior art reference under 35 U.S.C. § 102, or rendered obvious by one or more prior art references under 35 U.S.C. § 103.

23. I understand that documents and materials such as printed publications or patents that qualify as prior art can be used to render a patent claim as anticipated or as obvious.

24. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation or obviousness of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

A. My Understanding of Claim Construction

25. I understand that during an *inter partes* review proceeding, claims are to be construed in light of the specification as would be read by a person of ordinary skill in the relevant art at the time of the purported priority date. I understand that claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the relevant art in the context of the entire disclosure. A claim term, however, will not receive its ordinary meaning if the patentee acted as his own lexicographer and clearly set forth a definition of the claim term in the specification. In this case, the claim term will receive the definition set forth in the patent.

B. A Person of Ordinary Skill in the Art

26. I understand that a person of ordinary skill in the relevant art (herein “POSA”) is presumed to be aware of all pertinent art, thinks along conventional wisdom in the art, and is a person of ordinary creativity—not an automaton.

27. I have been asked to consider the level of ordinary skill in the field that someone would have had at the time the alleged invention was made. In deciding the level of ordinary skill, I considered the following:

- the levels of education and experience of persons working in the field;
- the types of problems encountered in the field; and
- the sophistication of the technology.

28. I understand that the relevant time for considering whether a claim would have been obvious to a POSA is at the time of the alleged invention, which I have been told to assume for this case is July 23, 2001.

29. Regardless if I use “I” or “POSA” during my technical analysis below, all of my statements and opinions are to be understood to be based on how a POSA would have understood or read a document at the time of the alleged invention.

C. My Understanding of Obviousness

30. I understand that a patent claim is unpatentable if the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the alleged invention. I understand that this means that even if all of the elements of the

claim cannot be found in a single prior art reference that would anticipate the claim, the claim can still be unpatentable.

31. It is my understanding that, to obtain a patent, a claimed invention must have been, as of its earliest possible priority date, non-obvious in view of the prior art in the field. I understand that a patent claim is obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time the alleged invention was made.

32. When considering the issues of obviousness, I have been told that I am to do the following:

- Determine the scope and content of the prior art;
- Ascertain the differences between the prior art and the claims at issue;
- Resolve the level of ordinary skill in the pertinent art;
- and
- Consider evidence of secondary indicia of non-obviousness (if available).

33. With respect to determining the proper scope of prior art to examine, I understand that in order for a prior art reference to be properly used in an obviousness ground under 35 U.S.C. § 103, the prior art reference must be

analogous art to the claimed invention. I have been told that a reference is analogous art to the claimed invention only if: (1) the reference is from the same field of endeavor as the claimed invention; or (2) the reference is reasonably pertinent to the particular problem solved by the inventor.

34. I understand that factors relevant to determining the proper field of endeavor include the inventor's explanations of the subject matter (including the patent specification), as well as the claimed invention's structure and function. And I further understand that to be reasonably pertinent to the particular problem solved by the inventor, a prior art reference must logically commend itself to the inventor's attention in considering his or her problem.

35. I have been told that an analogous reference may be modified or combined with other analogous references or with the POSA's own knowledge if the person would have found the modification or combination obvious. I have also been told that a POSA is presumed to know all relevant, analogous prior art, and the obviousness analysis may take into account the inferences and creative steps that a POSA would employ.

36. In determining whether a prior art reference would have been combined with another prior art reference or other information known to a POSA, I have been told that the following principles may be considered:

- A combination of familiar elements according to known methods is likely to be obvious if it yields predictable results;
- The simple substitution of one known element for another is likely to be obvious if it yields predictable results;
- The use of a known technique to improve similar devices, products, or methods in the same way is likely to be obvious if it yields predictable results;
- The application of a known technique to a prior art reference that is ready for improvement is likely obvious if it yields predictable results;
- Any need or problem known in the field and addressed by the reference can provide a reason for combining the elements in the manner claimed;
- A skilled artisan often will be able to fit the teachings of multiple references together like a puzzle; and
- The proper analysis of obviousness requires a determination of whether a POSA would have a “reasonable expectation of success”—not “absolute

predictability” of success—in achieving the claimed invention by combining prior art references.

37. I understand that whether a prior art reference renders a claim unpatentable as obvious is determined from the perspective of a POSA. I have also been told that, while there is no requirement for the prior art to contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole or individually, as filtered through the knowledge of one skilled in the art. In addition, I have been told the inferences and creative steps a person of ordinary skill in the art would employ are also relevant to the determination of obviousness.

38. I also understand that when a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field or in another. I have also been told that if a POSA can implement a predictable variation and would see the benefit of doing so, that variation is likely to be obvious. I have been told that in many fields, there may be little discussion of obvious combinations, and in these fields market demand—not scientific literature—may drive design trends. I have been told that, when there is a design need or market pressure and there are a finite number of predictable solutions, a POSA has good reason to pursue those known options.

39. I have been told there is no rigid rule prescribing that a reference or combination of references must contain a “teaching, suggestion, or motivation” to combine references. But I also have been told that the “teaching, suggestion, or motivation” test can be a useful guide in establishing a rationale for combining elements of the prior art. I have been told that this test poses the question as to whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention and that it seeks to counter impermissible hindsight analysis.

VII. LEVEL OF ORDINARY SKILL IN THE ART

40. In my opinion, a person of ordinary skill in the art (“POSA”) in the context of the ’565 patent as of July 23, 2001 (the earliest possible priority date of the ’565 patent) would possess a Bachelor of Science degree in electrical, mechanical, automotive, or a similar field of engineering; be knowledgeable of the principles and operation of internal combustion engines of that time period; and have the equivalent of two years’ experience or hands-on education in the design or implementation of automotive or vehicular control systems or components. Experience could take the place of some formal training, as domain knowledge may be learned on the job. This description is approximate, and a higher level of education or skill might make up for less experience and vice versa.

41. I am well qualified to determine the level of ordinary skill in the art.

First, I am very familiar with the technology of the '565 patent as of the July 23, 2001 timeframe. My academic and teaching background in both Electrical and Mechanical Engineering also provides significant insight into the expectations of a person of a given academic level or graduate certification. As mentioned above, by 2001, I had acquired extensive experience relating to engine control systems in vehicles, including developing microprocessor-based engine control systems for regulating air intake, fuel injection, and ignition. Specifically, by 2001, I had over 20 years of experience working with advanced control technologies for internal combustion engines, technologies including, for example: electronic engine control of fuel and air delivery, electronic equipment for regulating air intake, and fuel injection and ignition systems. *See supra* Section IV.

VIII. OVERVIEW OF THE '565 PATENT

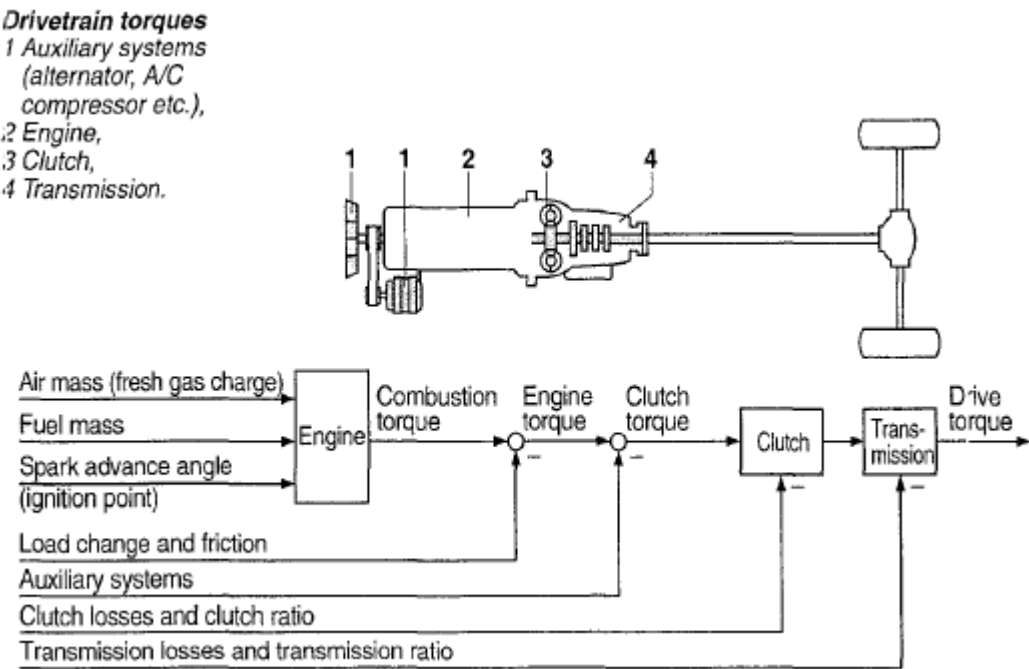
A. Technology Overview

1. Torque Feedback Control

42. Long before the '565 patent, using torque feedback control via an engine controller was common practice. EX1012, 498; EX1011, 139; EX1019, 224.

43. As shown below, the engine controller typically regulates engine torque output by adjusting three primary parameters: (1) the available air mass in the cylinder's combustion chamber, (2) the available fuel mass in the cylinder's combustion chamber, and (3) the ignition's spark angle (timing). EX1011, 1:25-31

(“The conversion of a torque desired value for ... an internal combustion engine ... is achieved by influencing the ignition angle, by interrupting or resuming the metering of fuel to individual cylinders and/or by influencing the air supplied to the engine.”); EX1012, 452, 498 (“[T]he variables for determining the engine torque: the charging of the cylinders with air, the mass of the injected fuel and the ignition angle.”); EX1019, 147 (“Engine control in the vast majority of engines means regulating fuel and air intake as well as spark timing to achieve desired performance in the form of torque or power output.”).



EX1012, 452.

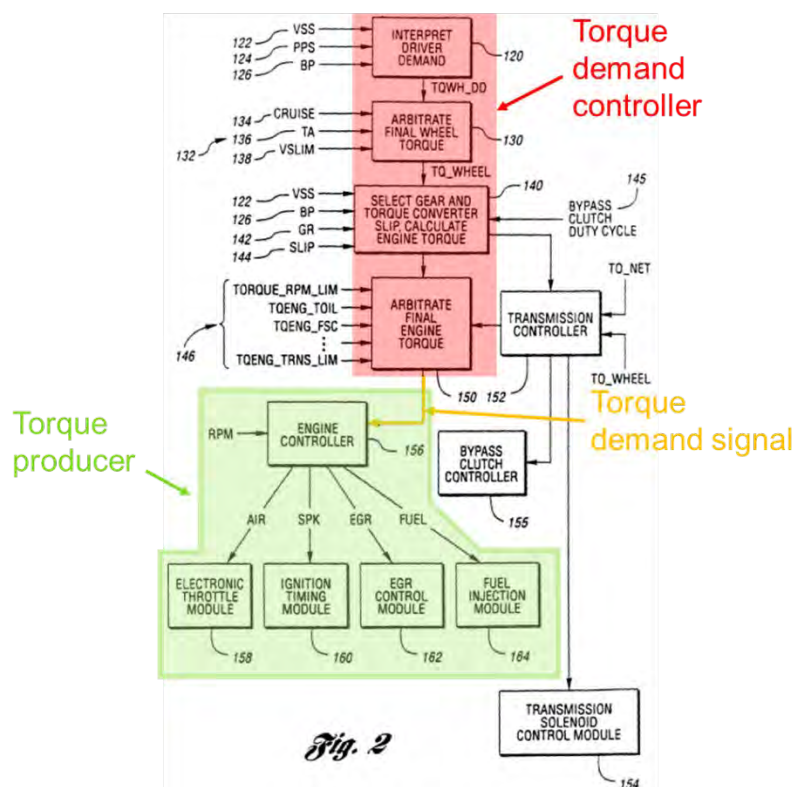
44. The engine controller typically includes a sub-module (i.e., air charge controller) directed to actuating the throttle valve to adjust the cylinder’s air mass (also known as air charge) at any RPM. EX1012, 452, 500-501; EX1019, 154. The

engine controller typically includes a sub-module (i.e., fuel pump controller) directed to regulating the timing and duration of the fuel injector to adjust the cylinder's fuel mass. EX1012, 452, 463-464 (“[B]oth the fuel mass appropriate to each cylinder and the correct start of injection are calculated by the control unit (ECU).”); EX1019, 154. The engine controller also typically includes a sub-module (i.e., ignition controller) directed to regulating the cylinder's spark plug to adjust the ignition spark timing. EX1012, 452, 493; EX1015, 12.10; EX1019, 154, 239-243.

45. The engine controller's objective for controlling torque output is to make available the torque requested by the driver, while also accommodating the variable torque demands on the engine. EX1012, 453, 498. As the '565 patent recognizes, an engine controller typically includes a demand torque controller and a torque producer. EX1001, 1:11-15; EX1005, 3:10-22; EX1012, 507. The demand torque controller generates a demand torque signal based on operational changes, such as a depressed accelerator pedal. EX1001, 1:11-15; EX1005, 4:48-58, EX1012, 507. The torque producer receives the torque demand signal and, in response, adjusts the engine's torque output by modifying, for example, the air supply, the fuel supply, or the spark timing so that the output torque converges to the demand torque. EX1001, 1:11-15; EX1005, 3:5-22; EX1012, 452, 498, 507.

46. Robichaux discloses a prior-art engine controller including a torque demand controller and a torque producer. EX1020, ¶¶0023, 0025, FIG. 2. Similar to

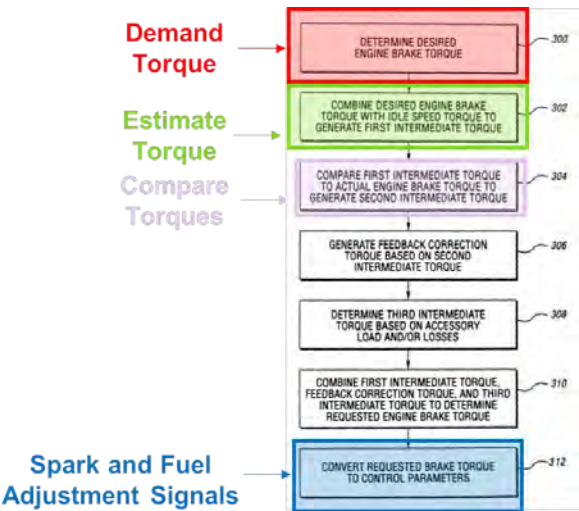
other typical engine controllers, Robichaux's torque producer adjusts the cylinder's available air mass (i.e., air charge) through control of the throttle valve, the cylinder's available fuel mass through control of the fuel injector, and the spark timing through control of the spark plug. *Id.*, ¶¶0025, 0048.



EX1020, FIG. 2 (annotated).

47. Using feedback control based on various sensor inputs to align the produced torque with the demand torque was common before the '565 patent. EX1005, 1:7-16, EX1012, 498, 503, 507, 508; EX1020, ¶¶0001, 0006, 0008, FIGS. 1-2. This alignment typically includes estimating a torque output and modifying engine parameters, such as spark timing and the air/fuel ratio, so that the measured or estimated torque output converges with the demanded torque value. EX1005, 1:7-

17; EX1012, 503, 504, 507, 508; EX1020, ¶¶0034, 0036. As shown below in Figure 4, Robichaux also discloses a prior-art technique for controlling torque output based on compensating for the difference between the demand torque and the estimated actual output torque. EX1020, FIG. 4.



EX1020, FIG. 4 (annotated).

2. Engine Parameter Estimation Techniques

48. As explained above, comparing the actual engine output torque to a demanded torque during feedback control was well-known. Estimating various engine parameters (e.g., current output torque and cylinder air charge) was also common for executing feedback torque control before the '565 patent. EX1005, 4:48-58; EX1020, ¶¶0008, 0025.

49. Given that the direct real-time measurement of engine torque was challenging and expensive, output torque was commonly estimated by a real-time computer model of the engine and vehicle, producing an indirect measure that is

accurate enough for the torque feedback control process. The engine controller typically estimated the output torque based on numerous operational parameters to account for various engine operations that influence the actual torque output.

EX1005, 4:48-58; EX1006, 2:26-42; EX1011, 2:58-3:2.

50. As shown below, Robichaux discloses an example of a prior art technique for calculating an estimated actual torque output. EX1020, ¶¶0008, 0025, FIGS. 1-2. Specifically, Robichaux discloses using “current engine operating parameters including ignition angle, air/fuel ratio, number of cylinders, ... engine speed, airflow,” as inputs for estimating the engine torque output. *Id.*, ¶0033. Robichaux’s system and method for engine torque control “more accurately compensate[s] for current operating conditions such as additional frictional losses ... and for variable accessory losses which correct for variations between desired and actual torque using a torque feedback signal.” *Id.*, ¶0008.

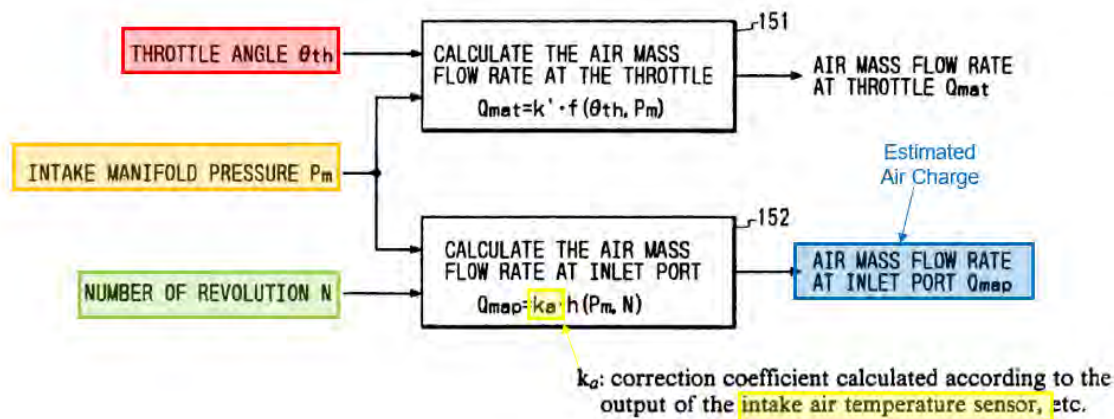
51. One of the common inputs for determining torque output is air charge—the mass of air that is drawn into the engine cylinder. EX1006, 5:32-52; EX1008, Takahashi, 3:42-55; EX1012, 452, 501-502 (“[A]ir charge ... serves to calculate the torque currently being delivered by the engine.”); EX1015, 12.6; EX1019, 176. Because there is no feasible way to measure the air mass in the engine cylinder directly, engine controllers typically estimate the current air charge. EX1012, 503 (“The relative charge cannot be measured directly but it can be

determined from the available measurement signals.”); EX1014, 294-296; EX1015, 12.6; EX1019, 176-177 (“There is no practically feasible way of measuring the mass of air in the cylinder directly.”)

52. There are two primary techniques for estimating air charge: (1) speed-density model and (2) air flow measurement model. EX1006, 4:5-10; EX1012, 501-502; EX1014, 294-97; EX1015, 12.6; EX1019, 177. In applying the speed-density model, the engine controller determines the cylinder air charge based on the intake manifold pressure, the engine speed, and the intake manifold temperature (i.e., air charge temperature). EX1012, 501-502; EX1014, 296 (“In the speed-density system, the primary inputs to the ECU are the outputs from the manifold pressure sensor, the engine speed sensor ..., and the temperature sensors installed in the intake manifold to monitor air temperature... .”); EX1015, 12.6 (“In the speed density method, the air charge is calculated by the engine electronic control unit based on the measurement of air inlet temperature, intake manifold pressure, and engine RPM.”); EX1019, 177-179. In applying the air flow measurement model, the engine controller measures the air mass flow rate in the intake manifold using an air-mass sensor. EX1006, 4:5-10; EX1014, 297; EX1015, 12.6; EX1019, 230. The engine controller then calculates the air charge based on the measured mass flow rate and the measured engine speed. EX1006, 4:5-8; EX1014, 297; EX1015, 12.6; EX1019,

230 (“The quantity of air drawn into the cylinder, A , is computed from the mass air flow rate and the RPM.”).

53. Takahashi discloses a prior-art engine air charge controller that calculates an estimated air charge according to the speed-density model. As shown below, Takashi’s status estimating block 152 calculates the air charge on intake pressure P_m , engine speed N , and a correction coefficient k_a determined from a current intake temperature sensor. EX1008, 10:54-66. Takahashi’s control unit adjusts both the throttle valve position and the fuel injection quantity based on the estimated air charge, which ultimately controls the torque output of the engine. *Id.*, 3:24-27, 5:53-66, 10:21-27.



EX1008, FIG. 15 (annotated).

3. Low and High-Frequency Components of Demanded Torque

54. It was well-known that the demanded torque includes a low-frequency (or steady-state) component and a high-frequency component. The so-called low-

frequency component represents changes in torque demand during quasi-static conditions (e.g., idle or cruising—operating speed conditions), and the high-frequency component represents changes in torque demand during transient-state conditions (e.g., a rapidly depressed accelerator pedal, the momentary torque drop occurring during a gear shift, or the abrupt increase or decrease of an accessory load such as an air conditioner). EX1005, 4:48-55; EX1007, 1:25-33; EX1012, 478, 505.

55. It was also well-known that control compensation for an abrupt (high-frequency) change in demanded torque could not be adequately addressed by throttle adjustment because of electromechanical delays in throttle valve actuation and air flow dynamics in the intake manifold. EX1005, 1:13-17 (“In order to achieve the target torque, the torque control ... requires a faster response than intake air flow rate control can provide....”); EX1007, 1:22-25 (“The dynamics of engine torque regulation by controlling only the airflow rate are significantly restricted by the finite speed of the throttle valve control element....”). However, it was also well-known that the engine ignition timing and/or fuel quantity could be changed much more quickly, in fact, by the time of the next engine intake stroke. Accordingly, control systems commonly addressed dynamic torque demands by isolating the transient component from the demanded torque signal. EX1007, 2:38-3:10. For example, Scherer discloses a prior art transient torque control system that includes a high-pass filter. *Id.*, 4:20-52. Scherer’s high-pass filter isolates the transient torque

component from the desired torque signal and outputs a transient torque adjustment to a transient torque controller, thereby expediting the engine's response time for correcting torque output. *Id.*, 4:20-52, 5:9-15.

56. Correcting transient components of the demand torque signal were commonly addressed by adjusting either the ignition or fuel injection timing. EX1005, 1:13-17; EX1007, 2:67-3:5 (“**highly dynamic** engine torque adjustment (by regulating the ignition point or the injection start)”¹); EX1012, 503 (“For setting the internal torque, the ME-Motronic's torque converter has a slow path ... for the throttle valve (ETC), and a **high-speed path** ... for variation of the ignition angle and/or injection blank-out of individual cylinders.”).

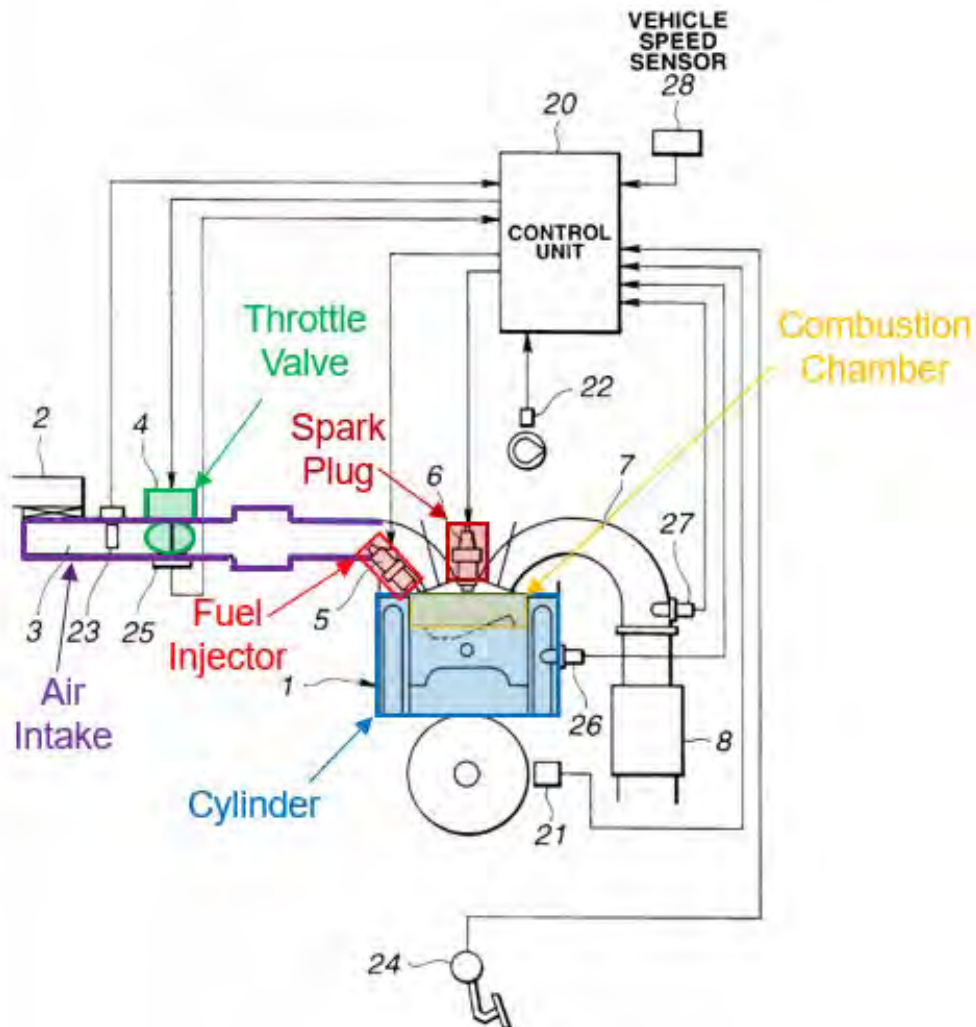
4. DISI Engines Having Two Combustion Modes

57. DISI engines, also known as direct cylinder injection (DCI) or gasoline direct injection (GDI or DGI) engines, were well-known for decades before the '565 patent. EX1009, 19-21, 26, 30-32. For example, automobile manufacturers, such as Robert Bosch GmbH and Mercedes Benz, began experimenting with timed, high-pressure, direct gasoline injection in the mid-1930s. EX1009, 19-21, 26. By the 1950s, Mercedes Benz started implementing “the direct (into the combustion chamber) injection scheme used in diesels” for its gasoline-powered Formula One engine and 300SL model. *Id.*, 21-22. By the 1990s, DISI engines were implemented

¹ Emphasis added throughout unless otherwise indicated.

in large-scale passenger car production. EX1005, 1:18-28; EX1009, 30-32. Thus, the auto industry had been using DISI engines well before the '565 patent.

58. For example, referencing Suzuki's Figure 2, a DISI engine 1 typically includes an air intake 3 for directing air toward the engine cylinders and an adjustable throttle valve 4 for controlling the air volume drawn through the intake 3. EX1005, 3:23-31. The DISI engine 1 further includes an electrically-actuated fuel injector 5 associated with each engine cylinder for injecting fuel directly into the cylinder's combustion chamber and a spark plug 6 disposed in the cylinder's combustion chamber for igniting the cylinder's air-fuel mixture. *Id.*, 3:23-51. By forming the air-fuel mixture within the cylinder's combustion chamber, DISI engines can form the fuel-air charge in the cylinder in two ways: a homogeneous charge in which a stoichiometric well-mixed charge populates the entire combustion chamber and a stratified charge, in which a stoichiometric mixture is formed near the spark plug to assure proper ignition but the overall mixture in the combustion chamber is lean (more air than available fuel). Direct cylinder injection provides other benefits for engine efficiency and emissions, including the elimination of precipitating or condensing injected fuel on the walls of the intake manifold—a common problem for engines using manifolds, port fuel injectors, or carburetors. EX1012, 464; EX1009, 33.



EX1005, FIG. 2 (annotated).

59. Operating DISI engines in either a stratified mode or a homogenous mode was well-known before the '565 patent. EX1005, 1:18-28; EX1012, 464, 509; EX1014, 37-38 (“Since the 1920s, attempts have been made to develop a hybrid internal combustion engine that combines the best features of the spark-ignition engine and the diesel.”). In the homogenous mode, fuel is injected during the intake stroke to allow maximum time for air and fuel to combine evenly throughout the entire combustion chamber. EX1005, 1:18-28; EX1012, 464. In the stratified mode,

fuel is injected during the compression stroke to provide the heterogeneous charge, as discussed above. EX1005, 1:18-28; EX1012, 464; EX1014, 38. Direct cylinder fuel injection makes possible the formation of the heterogeneous or stratified fuel-air mixture in the cylinder simply by altering the injection timing and fuel delivery, functions easily performed by an electronic engine control system.

60. For dual-mode (capable of homogeneous charge and stratified charge control modes) DISI engines, it was well-known for the engine controllers to control torque output rapidly by (1) adjusting the amount and timing of injected fuel when the DISI engine is in a stratified mode and (2) adjusting the spark timing when the DISI engine is in a homogenous mode. EX1005, 3:10-22; EX1010, 6:5-8 (“For a direct-injection engine, the outputted torque can be additionally changed in stratified operation by varying the injection time point.”), 7:8-15, 8:34-37. Modifications to the spark angle have little influence on the torque output of a DISI engine operating under the stratified mode, so torque output is typically adjusted by modifying the quantity of injected fuel. EX1005, 3:10-22; EX1014, 37-38. Conversely, when the engine is set in the homogeneous mode, torque output is modified by adjusting the spark ignition timing. EX1005, 3:10-22.

61. In sum, the ’565 patent’s claim elements—generating a torque demand, estimating a torque output, comparing the estimated and demand torque outputs to output a difference signal, using a high-pass filter to the remove the low-frequency

component of the torque difference signal, and outputting fuel and spark adjustments based on the filtered torque difference signal—were well-known, basic techniques executed by generic electronic controllers for DISI engines at the time of the '565 patent.

B. Alleged Problem in the Prior Art

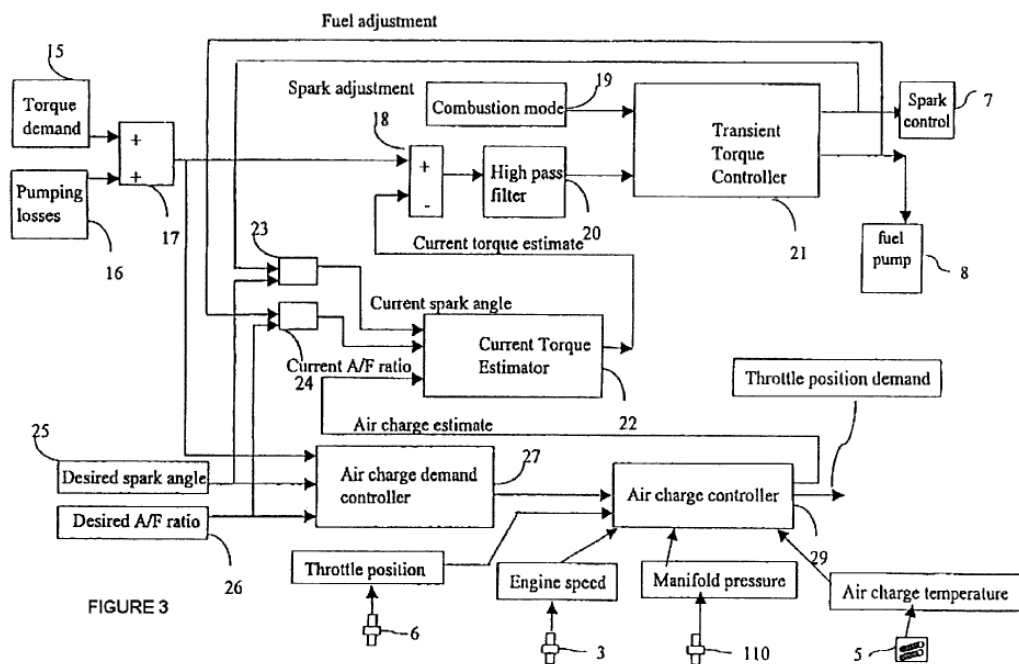
62. The '565 patent is directed to compensating for differences between the torque estimated by the torque producer and the torque demanded by the demand controller. EX1001, 1:57-59, 3:23-29. But as explained above, compensating for differences between estimated torque and demand torque, as well as solutions for this problem, were well-known before the '565 patent. And as discussed below, the '565 patent adds nothing to the realm of previously known solutions.

C. Alleged Invention of the '565 Patent

63. The '565 patent admits that a DISI engine controller's torque producer that modifies torque output in terms of fuel adjustment in stratified mode and spark timing in homogeneous mode were known. EX1001, 1:36-43. But according to the '565 patent, these known DISI engine controllers allegedly could not provide fuel and spark adjustment signals that accounted for the differences between the estimated output torque and the demand torque. *Id.*, 1:33-35.

64. To allegedly solve the known problem, the '565 patent provides “a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered

difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.” *Id.*, Abstract. As shown below, the ’565 patent’s control system included (1) a current torque estimate 22 for estimating a current torque signal; (2) a comparator 18 for comparing the estimated current torque signal with a desired torque signal; (3) a high-pass filter 20 for filtering out the low-frequency component of the torque desired torque signal; and (4) a transient torque controller 21 for adjusting spark timing and the amount of injected fuel. *Id.*, 3:29-50, FIG. 3.



EX1001, FIG. 3.

65. But well before the ’565 patent’s earliest possible priority date, this problem (compensating for differences between estimated torque and demand torque) had been solved in the same way. For example, Robichaux estimates the

current torque, compares the estimated torque to a desired torque signal, and adjusts spark timing and the injected fuel amount. Robichaux also uses the current spark angle, current air/fuel ratio, and estimated air charge to estimate the actual torque output. And Scherer's transient torque control system has a high-pass filter to filter out low-frequency components of the demanded torque signal, allowing for a quicker response time during transient operating conditions. EX1008, 4:20-55.

66. Thus, the claim elements that purport to capture the '565 patent's alleged inventive concept recite nothing more than what was already taught in the prior art and would have been well-known to a POSA.

D. Prosecution History Summary

67. The application that issued as the '565 patent underwent limited prosecution at the U.S. Patent and Trademark Office. The Examiner issued a Notice of Allowance without a single Office Action. *See generally* EX1002. Moreover, the Examiner did not provide any reasons for allowing the claims. *See id.*, 0045-0052.

68. Robichaux, Suzuki, and Takahashi, references upon which this Petition relies, were not before the Examiner during prosecution. *Id.* And Scherer was never expressly considered or applied by the Examiner.

E. Claim Construction

69. It is my understanding that the challenged claims of the '565 patent are to be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the alleged invention in light of the specification and the

prosecution history pertaining to the patent. Therefore, for the purposes of this Declaration, all claim terms are given their plain and ordinary meaning.

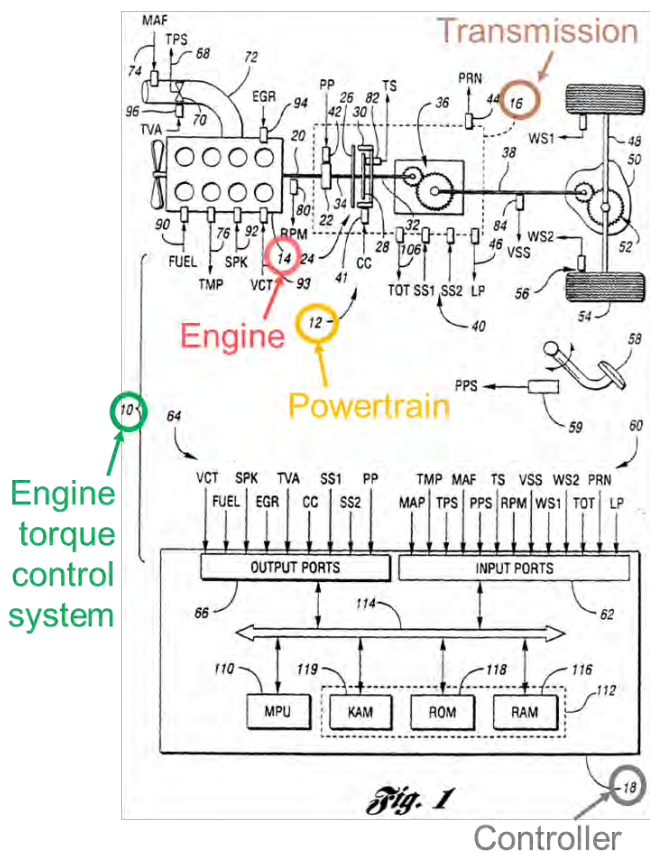
IX. SUMMARY OF THE APPLIED REFERENCES

70. Each applied reference discloses an engine control system and, thus, is from the same field of endeavor as the '565 patent.

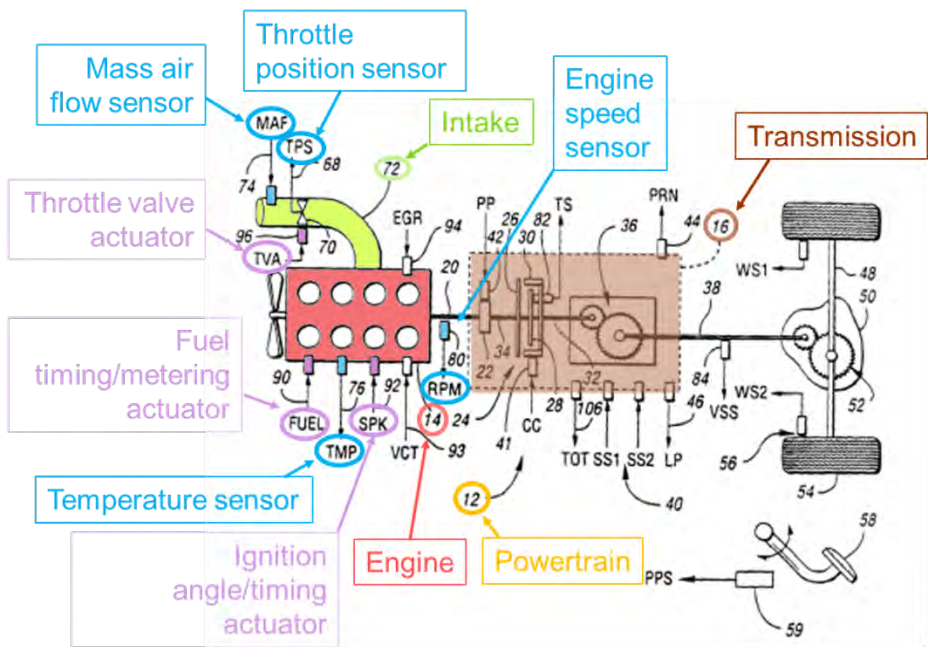
A. Robichaux

71. Robichaux, like the '565 patent, is directed to an engine controller for controlling torque output by adjusting various engine control parameters, including air flow, spark timing, and fuel delivery. EX1020, ¶0025.

72. Robichaux's system 10 "includes a vehicular powertrain 12 having an internal combustion engine 14" and "a controller 18 in communication with engine 14 ... for providing various information and control functions." *Id.*, ¶0012.



EX1020, FIG. 1 (annotated).



EX1020, FIG. 1 (excerpt, annotated).

73. Robichaux's system 10 includes various sensors 60 connected to controller 18, including a throttle valve position sensor (68/TPS), a mass airflow sensor (74/MAF), an engine temperature sensor (76/TMP), and an engine speed sensor (80/RPM), among others. EX1020, ¶¶0016-0017. Robichaux's torque control system 10 includes various actuators 64 to effect movement of the various powertrain devices, including actuators for adjusting fuel supply (90/FUEL), ignition timing (92/SPK), and air supply (96/TVA), among others. ¶0020.

74. Communicating with the sensors 62 and actuators 64, Robichaux's controller 18 provides integrated control of engine 14, including torque output. *Id.*, ¶0021. Controller 18 includes a microprocessor 110 that executes an engine torque control method stored as instructions in the controller's computer readable media 112. *Id.* Robichaux's control architecture for controlling engine torque includes various sensors, actuators, and controllers. *Id.*, ¶0022, FIG. 2.

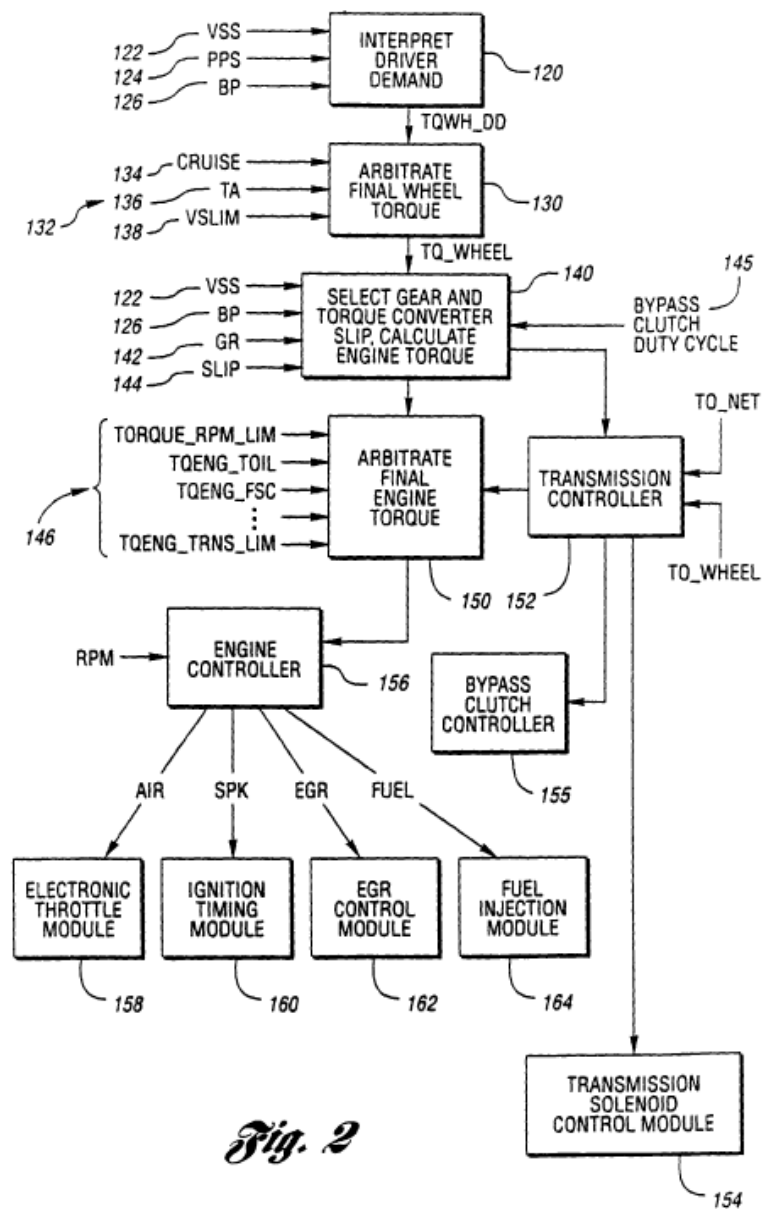


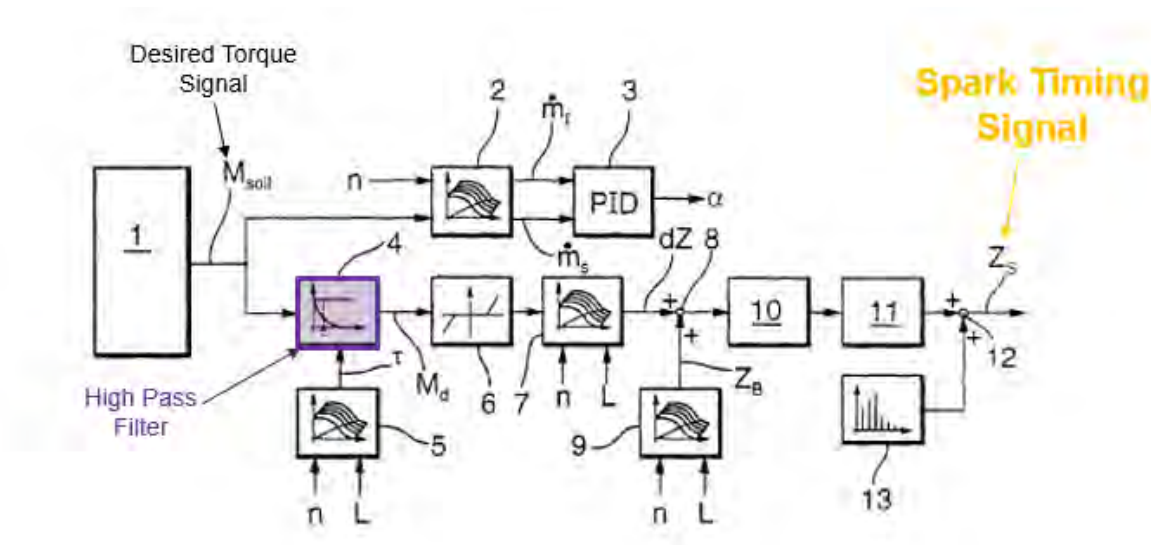
Fig. 2

EX1020, FIG. 2.

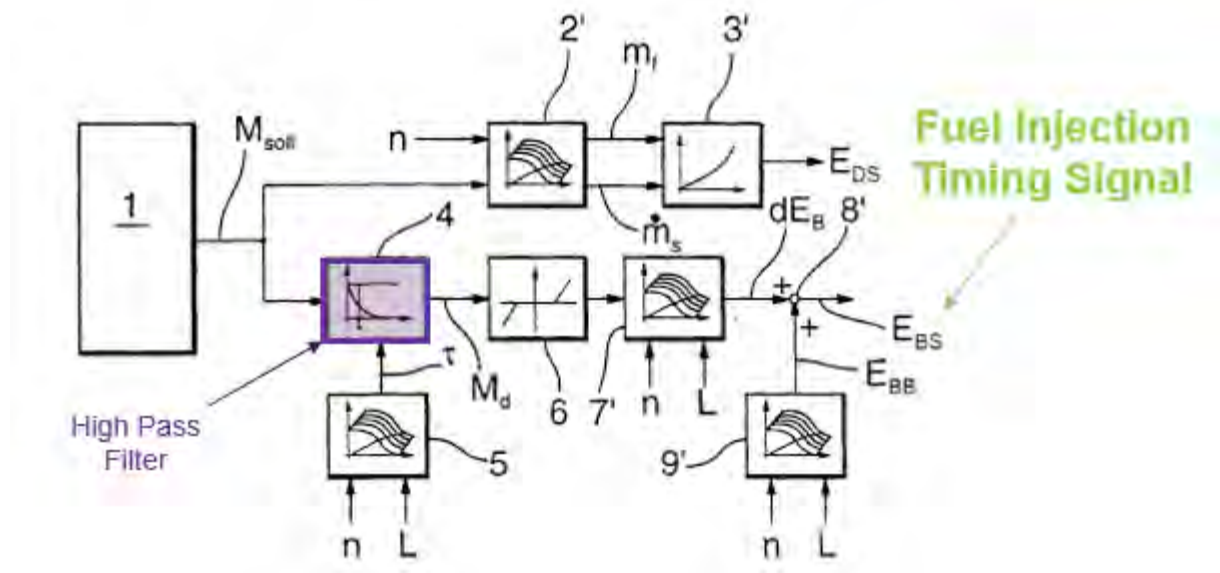
B. Scherer

75. Like Robichaux and the '565 patent, Scherer is directed to an engine controller. EX1007, 1:7-11. Scherer's controller adjusts torque output through airflow, spark timing, and fuel delivery adjustments. *Id.*, 2:47-3:10. The controller includes a transient torque signal-processing branch, which includes a high-pass

filter 4 that receives a desired engine torque signal and outputs a dynamic torque component to a torque controller that adjusts torque output through correcting spark timing for homogeneous fuel-charged configurations or fuel delivery for heterogeneous fuel-charged configurations. *Id.*, 2:51-59, 4:20-45, 5:35-55, 8:26, FIGS. 1, 2. The transient torque signal-processing branch, including the high-pass filter, allows the engine controller to more quickly correct transient torque demand. *Id.*, 2:38-42, 5:10-21.



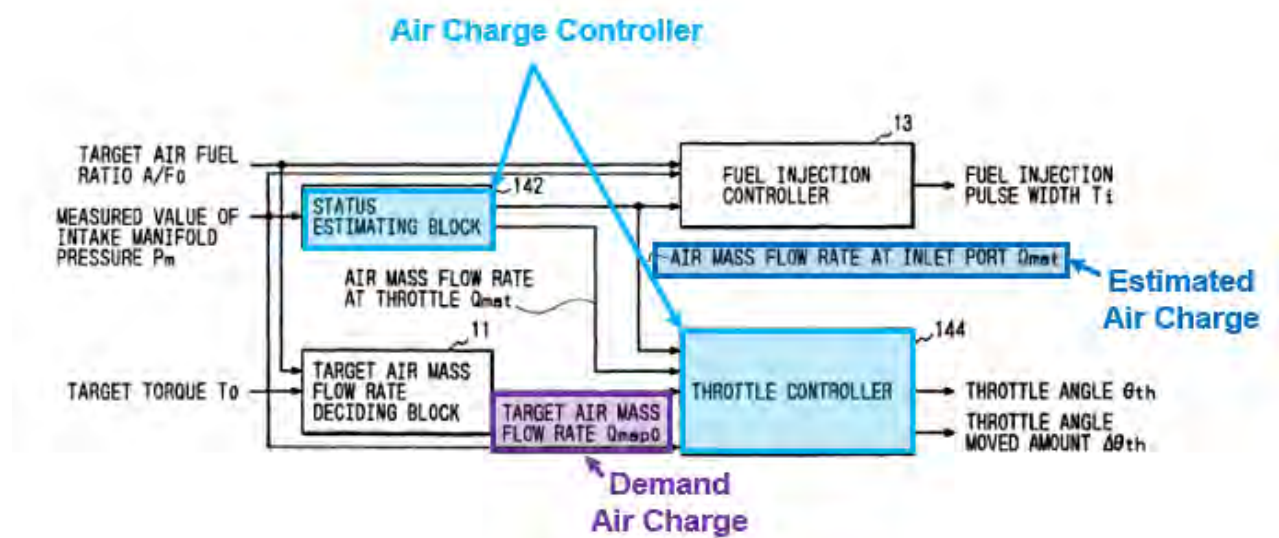
EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

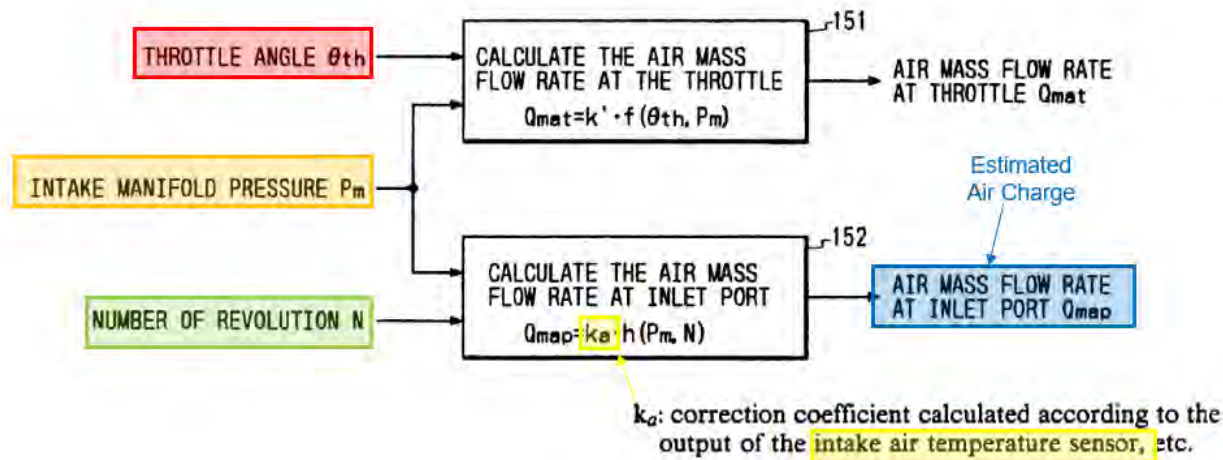
C. Takahashi

76. Takahashi, like Robichaux, Scherer, and the '565 patent, is directed to an engine controller. Takahashi's controller controls torque output by fuel and throttle adjustments. EX1008, 1:5-9, 3:4-16. Takahashi's control unit includes a target air mass flow rate module 11, a status estimating module 142, a fuel injection controller 13, and a throttle controller 144. *Id.*, 3:16-24, 10:32-50, FIG. 14. The throttle controller 144 calculates the desired throttle position to set the airflow into the engine cylinder at the desired air charge value and achieve a target torque value. *Id.*, 3:20-27, 6:10-13, 7:50-58.



EX1008, FIG. 14.

77. The throttle controller 144 determines the desired throttle position based on a target air mass flow rate (i.e., demand air charge) and an estimated air mass flow rate (i.e., estimated air charge) at the inlet port. EX1008, 10:42-50, FIG. 14. The throttle controller 144 receives the target air mass flow rate from a target air mass flow rate deciding block 11 and estimates the current air mass flow rate using a status estimating block 142. *Id.*, 10:42-60, FIG. 14. The status estimating block 142 estimates the current air mass flow rate based on throttle position, engine speed, intake manifold pressure, and intake air temperature as inputs. *Id.*, 10:43-67, FIG. 15. The target air mass flow rate module 11 receives a target air/fuel ratio signal, a target torque signal, an engine speed signal, and a spark advance signal and outputs a target air mass flow rate signal. *Id.*, 3:20-41.

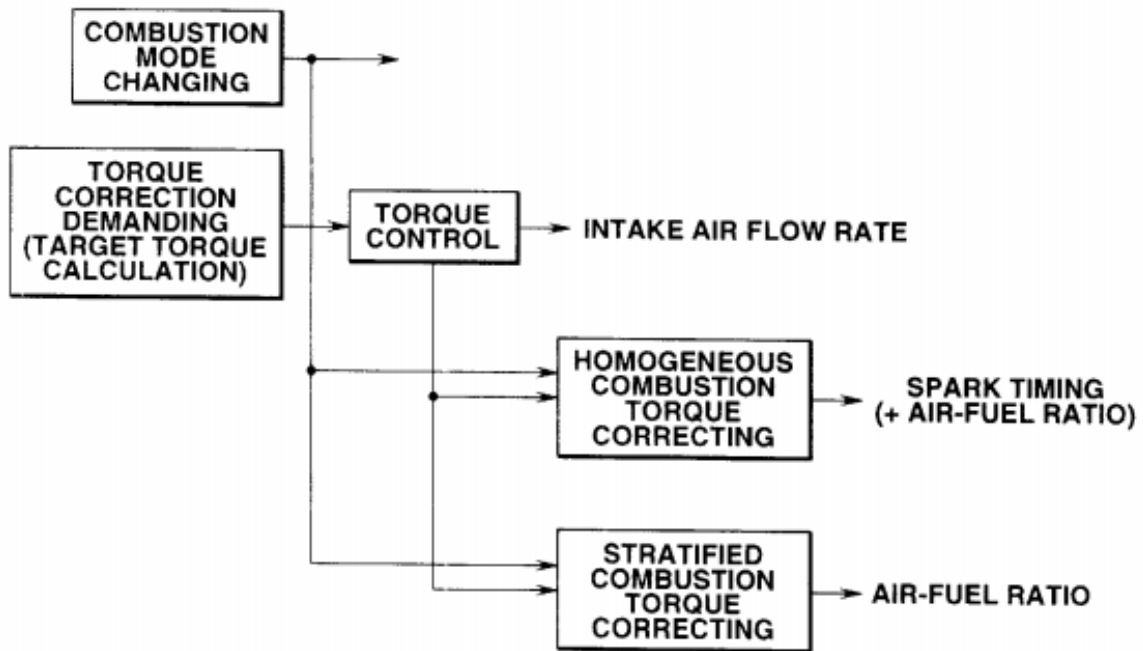


EX1008, FIG. 15 (annotated).

D. Suzuki

78. Suzuki, like Robichaux, Scherer, Takahashi, and the '565 patent, is directed to an engine controller for adjusting torque output by fuel injection and spark timing adjustments. EX1005, 1:39-43.

79. Suzuki's controller includes a combustion mode changing section that switches engine operation between a homogenous mode and a stratified mode. *Id.*, 2:54-61, FIG. 1B.



EX1005, FIG. 1B.

The controller also includes a torque correction demanding section that generates a torque correction demand signal based on a change in engine operating conditions. EX1005, 2:61-63. The controller includes a torque control section that controls the amount of air permitted to enter into the engine based on the received torque correction demand signal. *Id.*, 3:12-15. The controller includes a homogenous combustion torque correcting section and a stratified combustion torque correcting section that modifies the torque output based on the received torque correction demand signal. *Id.* 2:64-3:22, 15:53-16:6.

80. When in the homogenous combustion mode, the torque correction section adjusts the spark timing based on the calculated torque shortage (S38 and S39). *Id.*, 5:59-6:6, 7:51-54, 8:1-4, 15:53-16:2. When in the stratified combustion

mode, the torque correction section adjusts the fuel delivery based on the calculated torque shortage (step S40, as well as steps 22-25 in Figure 5). *Id.*, 6:20-57, 7:60-64, 8:1-4, 15:53-16: 2. To adjust fuel delivery, the torque correction section transmits an injection pulse signal to the fuel injector, thereby modifying the air/fuel ratio. *Id.*, 6:35-7:2.

X. GROUND 1: THE COMBINATION OF ROBICHAUX AND SCHERER RENDERS OBVIOUS CLAIMS 1 AND 7.

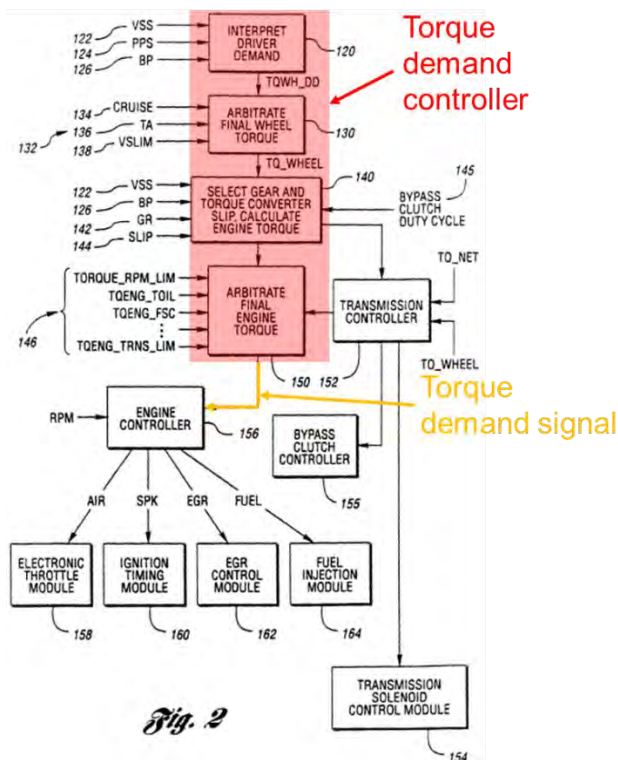
A. The rationale for combining Robichaux with Scherer

81. In my opinion, a POSA would have been motivated to combine the teachings of Robichaux with Scherer and would have had a reasonable expectation of success in doing so for at least the reasons discussed below.

82. To start, Robichaux and Scherer are from the same field of endeavor—engine control systems. Robichaux and Scherer are directed to engine controllers that determine an input target torque value for adjusting engine operational parameters (e.g., fuel quantity, spark timing, or air intake). Robichaux’s “invention is directed to a system and method for controlling engine torque using feedback and feed forward control.” EX1020, ¶0001. Scherer’s “invention relates to a process and apparatus for adjusting the torque of an internal-combustion engine by regulating the ignition point and the air flow rate in an Otto engine.” EX1007, 1:7-11.

83. Robichaux’s controller 18 includes blocks 120, 130, 140, 150 (“a torque demand controller”) that generate a desired engine brake torque signal (“a

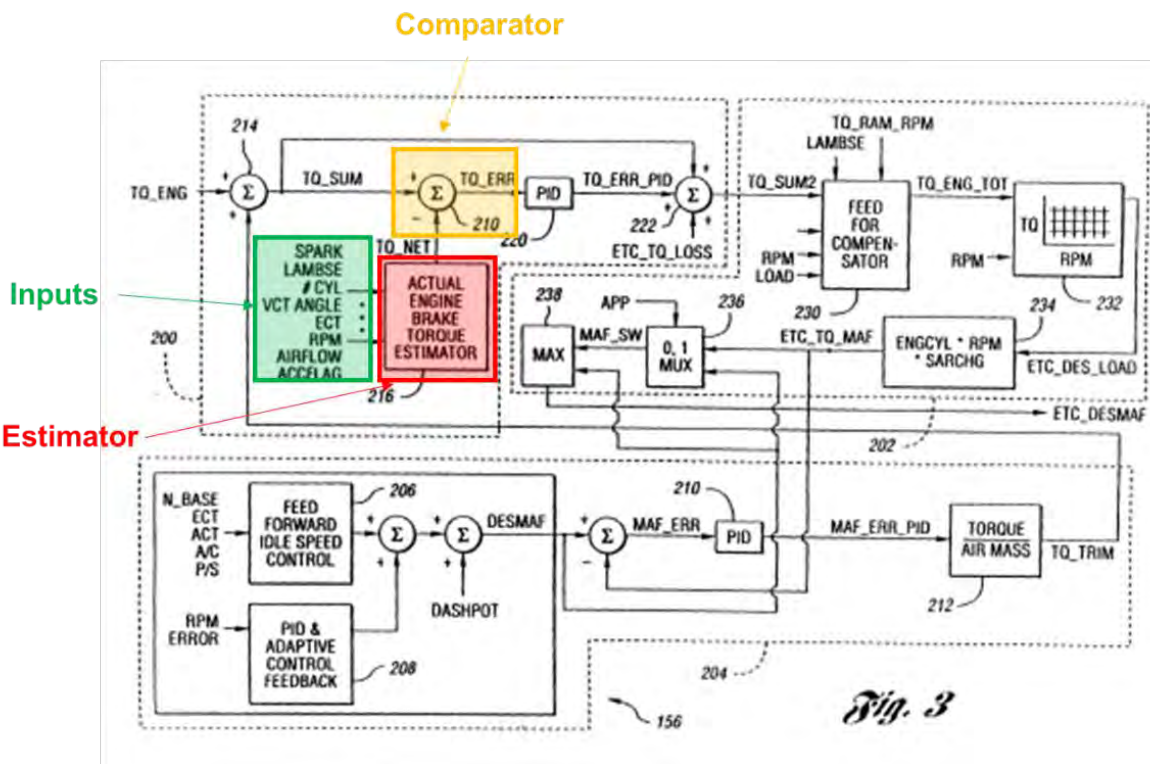
demand torque signal”) and an engine controller (“torque producer”) that receives the demand torque signal. EX1020, ¶0023, FIG. 2.



EX1020, FIG. 2 (annotated).

84. As shown in Figure 3, block 216 (“estimator”) (1) receives an ignition angle signal SPARK (“current spark angle signal”), an air/fuel ratio signal LAMBSE (“current air/fuel ratio signal”), and an air flow signal AIRFLOW (“estimated air charge”) and (2) outputs an estimated actual engine brake torque TQ_NET. Robichaux’s controller includes a block 218 (“comparator”) that compares the estimated actual engine brake torque with a first intermediate torque to generate a torque error signal TQ_ERROR (“a difference signal”). Ultimately, section 202 of engine controller 156 converts the torque error signal to an

appropriate control parameter (e.g., an airflow, fuel, and spark angle). EX2020, ¶¶0027, 0048.



EX1020, FIG. 3 (annotated).

85. Robichaux’s proportional-integral-derivative (PID) controller 220 processes the torque error signal during steady-state conditions. A PID controller typically controls output using three terms: (1) a proportional control action that provides output proportional to control error, (2) an integrator action that reduces steady-state error to zero, and (3) a derivative control action that provides momentary adjustments proportional to the rate of change of the control error. EX1020, ¶0032.

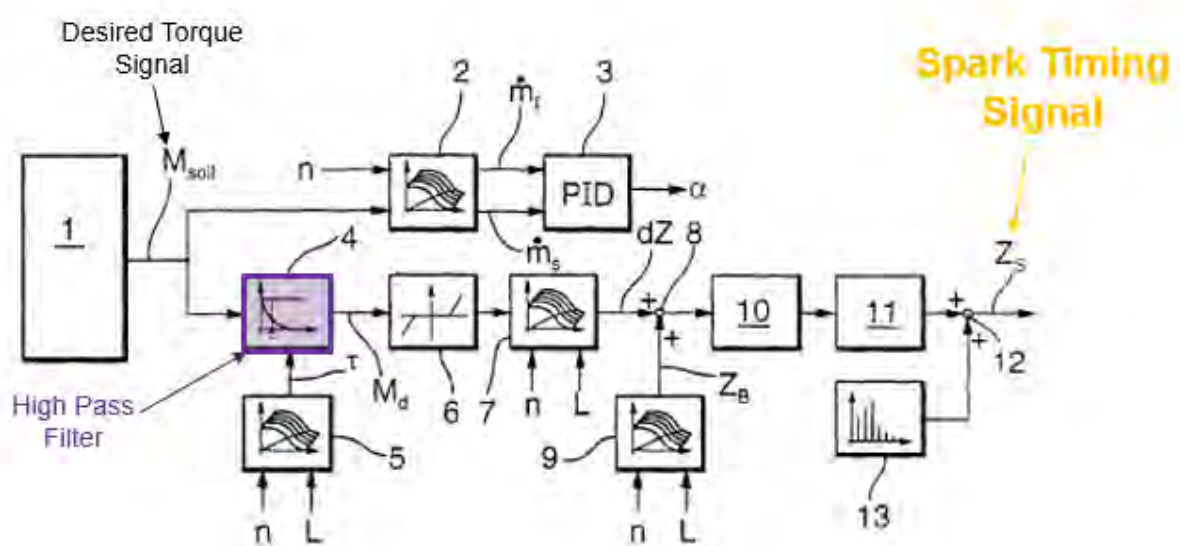
86. The derivative control action usually generates large output adjustments in response to abrupt changes in demand, similar to the functionality of a high-pass filter. And while the derivative and proportional terms combined allow the PID controller to respond to abrupt torque transients, the PID controller's integrator is subject to the well-known problem of "integrator wind-up." That is, the integrator accumulates a growing output term for the duration of the engine transient to a new state, leading to an unacceptable level of control overshoot that goes beyond the new steady-state target and slowly recovers. Recognizing this problem, Robichaux discloses that the PID controller "is not active during certain transient torque limiting control modes" and "sets the proportional and derivative terms to zero while [resetting or] holding the integral term constant during these control modes." *Id.* Accordingly, Robichaux's controller 220 identifies and isolates the transient torque condition in response to abrupt changes in load or demand torque (e.g., gear shift, air conditioning engages, traction assist action), and Robichaux suggests that the steady state PID controller 220 be disabled, reset, or frozen during such transients. *Id.*

87. Although Robichaux does not explicitly disclose a controller for transient torque demands, Robichaux does indicate that the PID controller 220 should be deactivated in response to significant torque error signals. Recognizing this requirement, Robichaux invites combinations with any reference disclosing

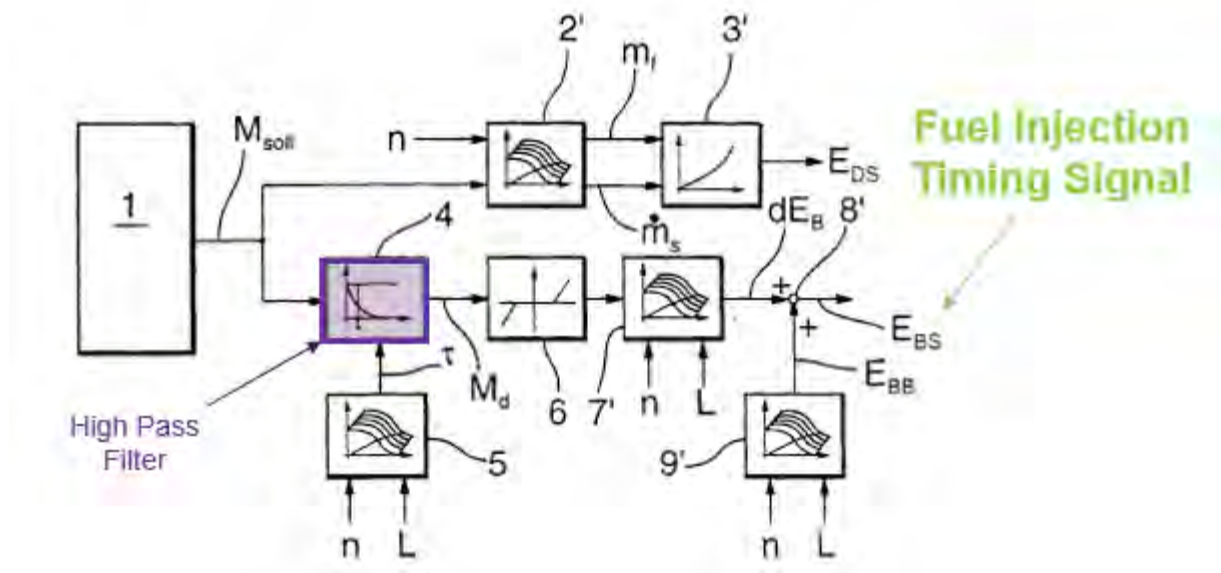
transient control functionality to process the torque demand signal during transient conditions.

88. Scherer's system controls torque during such transient conditions. Scherer's controller includes a transient control branch having a high-pass filter 4 that determines a dynamic desired torque component (M_d) by isolating the high-frequency (dynamic) component of the desired torque signal M_{des} . EX1007, 4:31-38, 5:35-40. Removing the desired torque signal's low frequency component allows Scherer's controller to "react very rapidly to sudden changes of the engine torque," arising during transient engine operations. *Id.*, 4:20-28, 4:40-45, 5:10-15.

89. The desired torque signal's filtered dynamic component is used for both spark ignition timing adjustments (Figure 1) and for fuel injection adjustments (Figure 2). *Id.*, 2:51-54; 4:20-52, 5:16-55, FIGS. 1, 2.



EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

90. To address demand torque changes in Robichaux’s system, a POSA would have been motivated to use Scherer’s transient control branch. Scherer’s transient control branch, including high-pass filter 4, would have been easily implemented with Robichaux’s controller to provide both steady-state and transient torque corrections. Combining Scherer’s transient control branch with Robichaux’s controller would have merely been applying a known technique (Scherer’s transient control) in a similar, known device (Robichaux’s controller) in the same way. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 416 (2007) (“[I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious.”).

91. Furthermore, a POSA would have had a reasonable expectation of success in combining Robichaux and Scherer. Robichaux’s and Scherer’s controllers

receive similar measured engine parameters (e.g., engine speed, airflow rate, and air/fuel ratio) and determine a target torque value based on these parameters.

EX1020, ¶¶0016- 0018, 0025; EX1007, 4:61-5:2. And combining these teachings would have simply involved modifying the controller's software to perform the steps taught in the references—a basic task for a POSA. EX1019, 102, 223.

Specifically, a POSA would have recognized that Scherer's transient control branch, including high-pass filter 4, would have been easily implemented in Robichaux's controller 18 by modifying the software instructions stored in the computer readable media 112 of Robichaux's controller 18 so that the torque error signal transmitted to a transient control branch. EX1007, 3:6-10, 4:31-38; EX1019, 138.

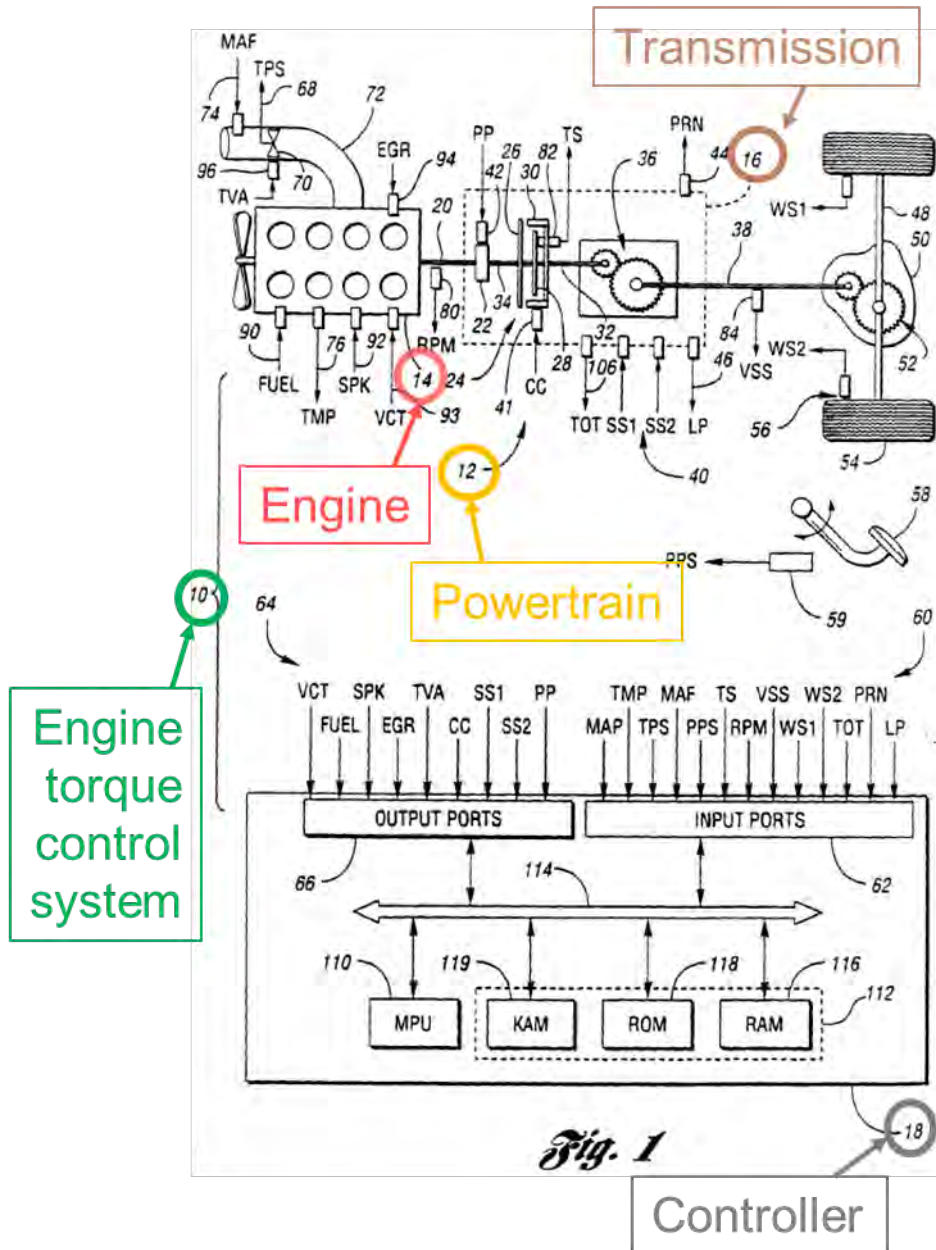
92. Scherer's transient control branch also includes various modules, for example, units 6, 7, 9, 10, 11 and 13 (Figure 1) and units 6, 7, and 9 (Figure 2) that produce a spark timing signal Z_s for adjusting torque output in homogeneous fuel-charged configurations or a fuel injection timing signal for adjusting torque output in heterogeneous fuel-charged configurations. EX1007, 2:51-55, 4:20-45, 5:35-59. A POSA would have been motivated to incorporate Scherer's transient torque control (including the ignition-point-adjustment branch (Figure 1) or injection-start-adjusting branch (Figure 2)) into Robichaux's controller to enable torque control during transient conditions. A POSA would have easily implemented Scherer's control modules 6, 7, 9, 10, 11 and 13 by modifying the software instructions stored

in Robichaux's engine controller to perform the same function as disclosed in Scherer and generate a spark ignition timing signal and fuel delivery timing signal to control torque.

B. Robichaux and Scherer render obvious claim 1.

1. [1.P] "A device for controlling a torque output of an engine, the device comprising:"

93. Robichaux discloses a device for controlling an engine's torque output. Particularly, Robichaux discloses "a system and method for controlling engine torque using feedback and feed forward control." EX1020, ¶0001. Robichaux's engine torque control system 10 has a powertrain 12 including an engine 14. *Id.*, ¶0012, FIG. 1. Robichaux's control system 10 also includes "a controller 18 in communication with engine 14 ... for providing various information and control functions." *Id.*, ¶0012. Controller 18 "provides integrated control of engine 14." *Id.* Controller 18's microprocessor "implement[s] the method for controlling engine torque." *Id.* Accordingly, control system 10 controls the engine's torque output.



EX1020, FIG. 1 (annotated).

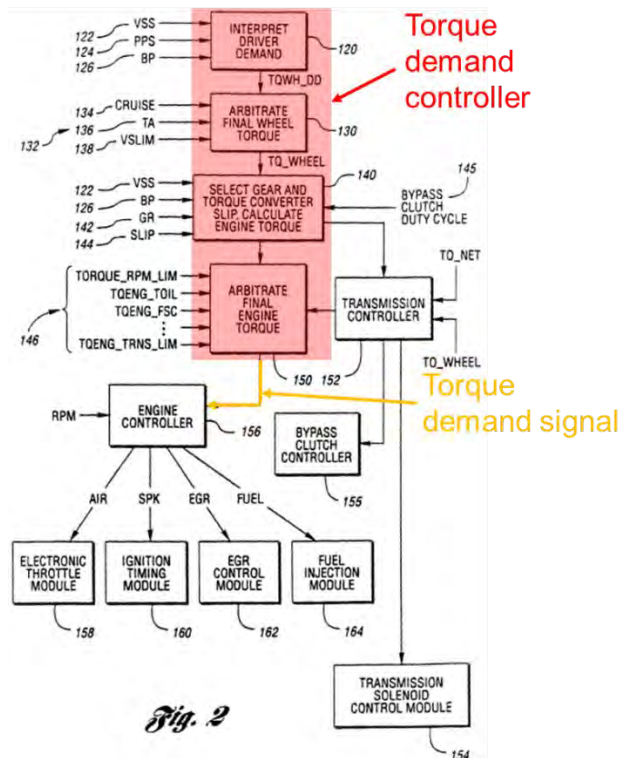
94. Thus, Robichaux discloses [1.P].

2. [1.A] “a torque demand controller for generating a torque demand signal”

95. Robichaux discloses the recited torque demand controller. Robichaux’s controller architecture determines the desired engine torque. EX1020, ¶0010 (“an output torque based powertrain control strategy including **determination of a desired engine torque** according to the present invention”), ¶¶0023-0025, FIG. 2. This controller architecture includes an “interpret drive demand block 120,” an “arbitrate final wheel torque” block 130, a “select gear and torque converter slip, calculate engine torque” block 140, and an “arbitrate final engine torque” block 150 that collectively produce “a desired engine brake torque” signal that is communicated to the engine controller. *Id.*, ¶¶0023- 0025 (“final engine torque determined by block 150 is communicated as **a desired engine brake torque** to engine controller 156”), FIG. 2. Based on the speed of the vehicle 122 (VSS), accelerator pedal position 124 (PPS), and barometric pressure 126 (BP), block 120 determines a driver’s demand TQWH_DD. *Id.*, ¶0023, FIG. 2. Block 130 arbitrates the driver’s demand TQWH_DD with other torque demands 132 to provide a final wheel torque signal TQ_WHEEL. *Id.* Based on the current operating conditions, including for example, vehicle speed 122 (VSS), barometric pressure 126 (BP), current gear ratio 142 (GR), among others, block 140 calculates a requested engine torque, which is an input to block 150. *Id.*, ¶¶0023- 0024, FIG. 2. Block 150 then arbitrates the received designed engine torque signal with other engine torque

limiting functions 146 to determine the final “desired engine brake torque”

transmitted to the engine controller 156. *Id.*, ¶¶0024- 0025, FIG. 2.



EX1020, FIG. 2 (annotated).

96. Robichaux’s blocks 120, 130, 140, and 150, either individually or in combination with each other, constitute a “torque demand controller,” as recited in claim 1. Each block generates a signal corresponding to the desired torque, including the torque demand signal transmitted from block 150 to the engine controller. And Robichaux’s blocks 120, 130, 140, and 150 operate in the same manner as the ’565 patent’s torque demand controller 11, which calculates a required output torque signal based on operating parameters. EX1001, 2:57-67.

97. Thus, Robichaux discloses [1.A].

3. [1.B] **“a torque producer which receives the torque demand signal”**

98. Robichaux discloses the claimed torque producer. Robichaux discloses that “[t]he final engine torque determined by block 150 is communicated as a desired engine brake torque to engine controller 156.” EX1020, ¶0025. The engine controller executes instructions to control the engine torque. *Id.*, ¶¶0021 (“Computer readable media 112 include [*sic*] stored data representing **instructions executable by microprocessor 110 to implement the method for controlling engine torque** according to the present invention.”).

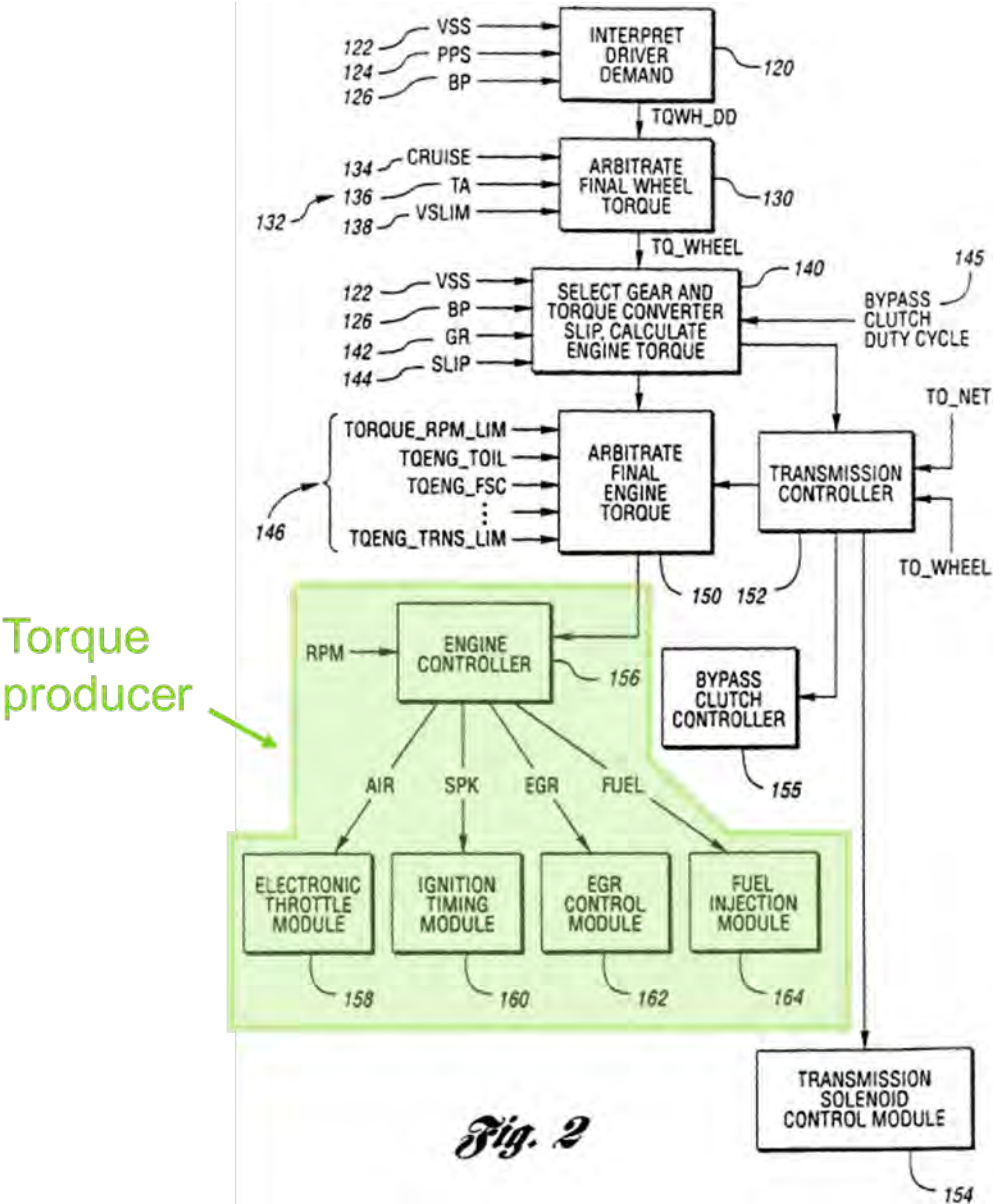
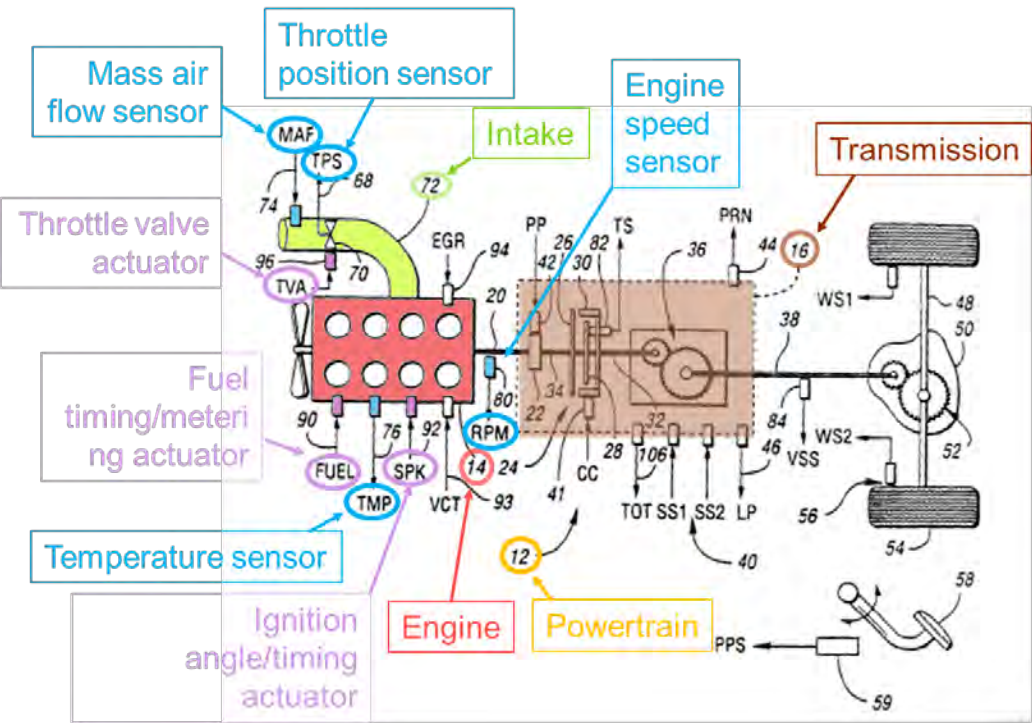


Fig. 2

EX1020, FIG. 2 (annotated).

99. Robichaux’s engine controller modifies the produced torque by adjusting various “control parameters such as air flow [(158)], spark [(160)], EGR [(162)], and fuel [(164)].” EX1020, ¶0025, FIG. 2. Based on these determined parameters, various actuators adjust the produced engine torque. *Id.*, ¶¶0020, 0025], FIGS. 1-2. These actuators include “actuators for timing and metering fuel (FUEL)

90, controlling ignition angle or timing (SPK) 92, . . . and adjusting the intake air using throttle valve 70 with an appropriate servomotor or actuator (TVA) 96.” *Id.*, ¶¶0020.



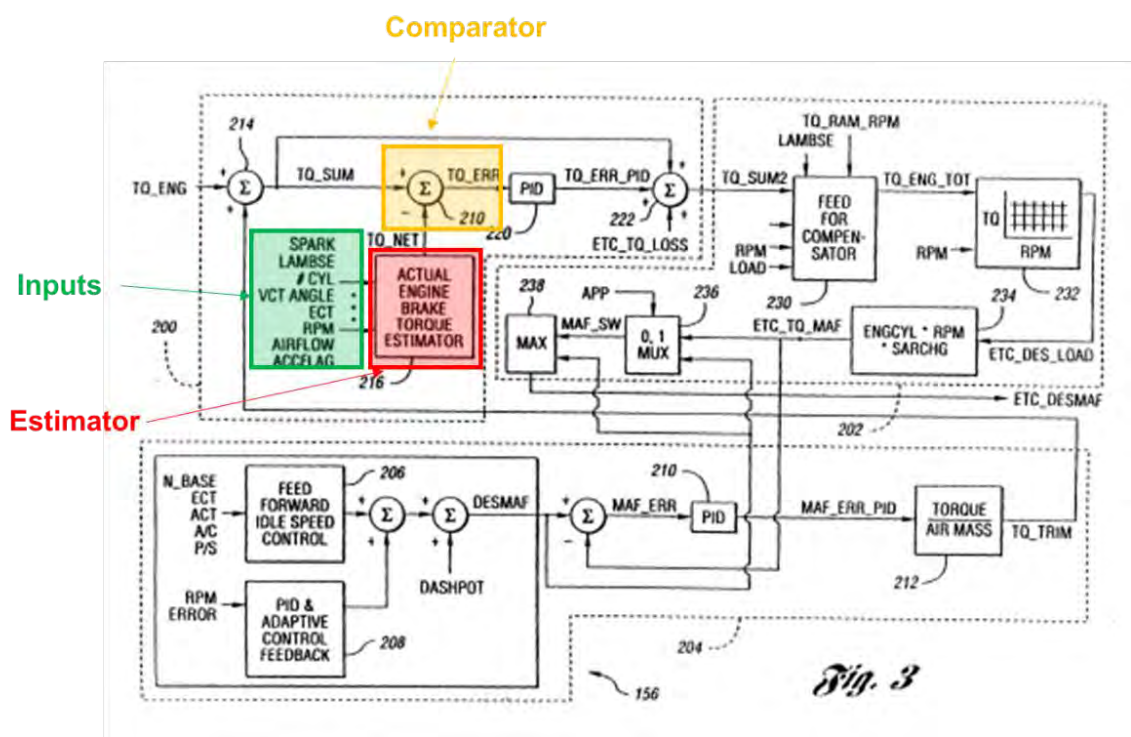
EX1020, FIG. 2 (annotated excerpt).

100. A POSA would have understood that Robichaux’s engine controller, as well as the various actuators, constitute a “torque producer,” as recited in claim 1. The engine controller and the actuators adjust various control parameters (e.g., airflow, spark ignition angle or timing, and air/fuel ratio) to produce torque. Accordingly, Robichaux discloses a torque producer.

101. Thus, Robichaux discloses [1.B].

4. [1.C] “the torque producer includes: an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal”

102. Robichaux discloses, or at least renders obvious, the recited torque estimator. Robichaux’s engine controller (part of the torque producer) includes an “actual engine brake torque estimator” block 216 that “provides an estimate of the actual engine brake torque based on current engine operating parameters including ignition angle[(“current spark angle signal”)], air/fuel ratio [(“current air/fuel ratio signal”)], number of cylinders, variable CAM timing angle, engine coolant temperature, engine speed, **airflow**, and operation state of accessories such as the air conditioning compressor.” EX1020, ¶0033, FIG. 3.



EX1020, FIG. 3 (annotated).

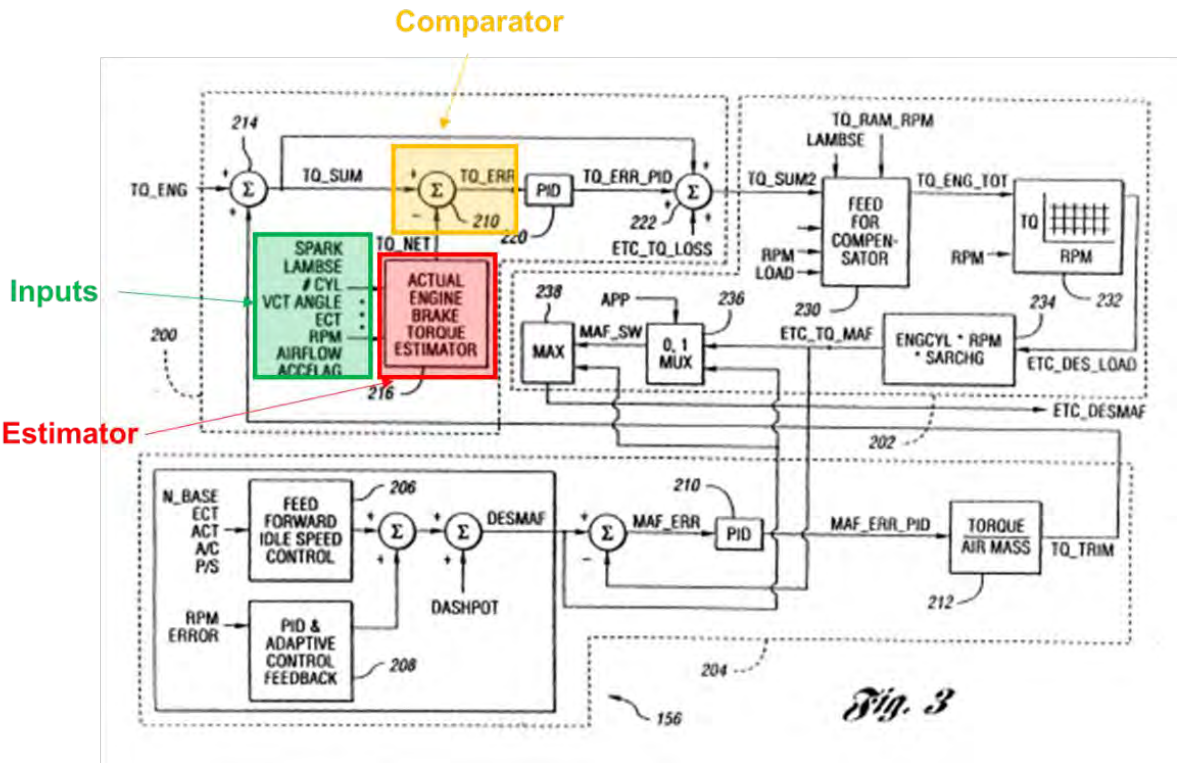
103. A POSA would have understood that “airflow” in paragraph 0033 and Figure 3 of Robichaux was the recited “air charge.” Air charge was also known as “mass **flow rate of incoming air.**” EX1015, 12.6 (“the mass flow rate of incoming air, known as the air charge”); EX1012, 452 (“air mass (fresh gas charge)”). Moreover, it was well-known that the generated torque is a function of air charge. EX1012, 452 (“The combustion torque is generated in the power cycle and determined by the following variables ... the air mass that is available for combustion once the intake valves have closed....”). Accordingly, Robichaux discloses, or at least renders obvious, an estimator that receives an estimated air charge, a current spark angle and a current air/fuel ratio.

104. Thus, Robichaux discloses or renders obvious [1.B].

5. [1.D] “a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal”

105. Robichaux discloses the recited comparator. Robichaux’s summing junction 214 adjusts the desired engine brake torque TQ_ENG from block 150 (in Figure 2) by adding an idle speed torque TQ_TRIM to generate a first intermediate torque TQ_SUM. EX1020, ¶0029, FIG. 3. Block 218 receives the TQ_SUM torque signal, compares this signal to the actual engine brake torque TQ_NET signal (“estimated torque signal”) estimated by block 216, and produces a torque error TQ_ERROR. EX1020, ¶0030, FIG. 3. The generated torque error TQ_ERROR is a

“difference signal,” representing the difference between the estimated actual engine brake torque TQ_NET and the desired engine brake torque TQ_ENG.



EX1020, FIG. 3 (annotated).

106. Accordingly, Robichaux’s engine controller 156 includes a “comparator” that receives an estimated torque signal and a desired torque signal and outputs a difference signal. And Robichaux’s engine controller operates in the same manner as the ’565 patent’s comparator, which generates an error signal representing a shortage between the estimated torque and the desired torque.

EX1001, 3:34-38.

107. Thus, Robichaux discloses [1.D].

6. [1.E] “a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent”

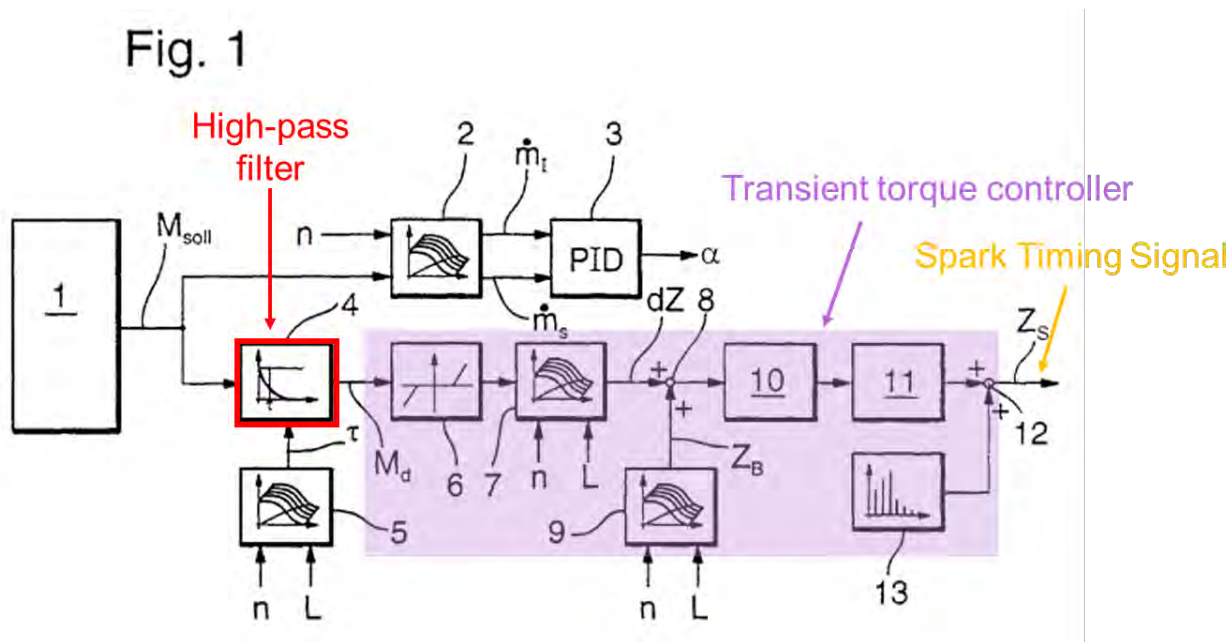
108. Robichaux and Scherer render obvious the recited high-pass filter.

109. Robichaux’s engine controller 156 includes a proportional-integral-derivative (PID) controller 220 that receives the generated torque error TQ_ERROR (“difference signal”) and generates a feedback correction torque TQ_ERR_PID.

EX1020, ¶¶0030-0031, 0046, FIG. 3. The steady-state PID control is suspended during abrupt transients in the torque error signal, but Robichaux does not expressly disclose a specific course of action during such transients. *Id.*, ¶0032. Recognizing this requirement to suspend the PID controller 220, Robichaux invited combinations with references disclosing transient torque control to process the torque demand signal during transient conditions.

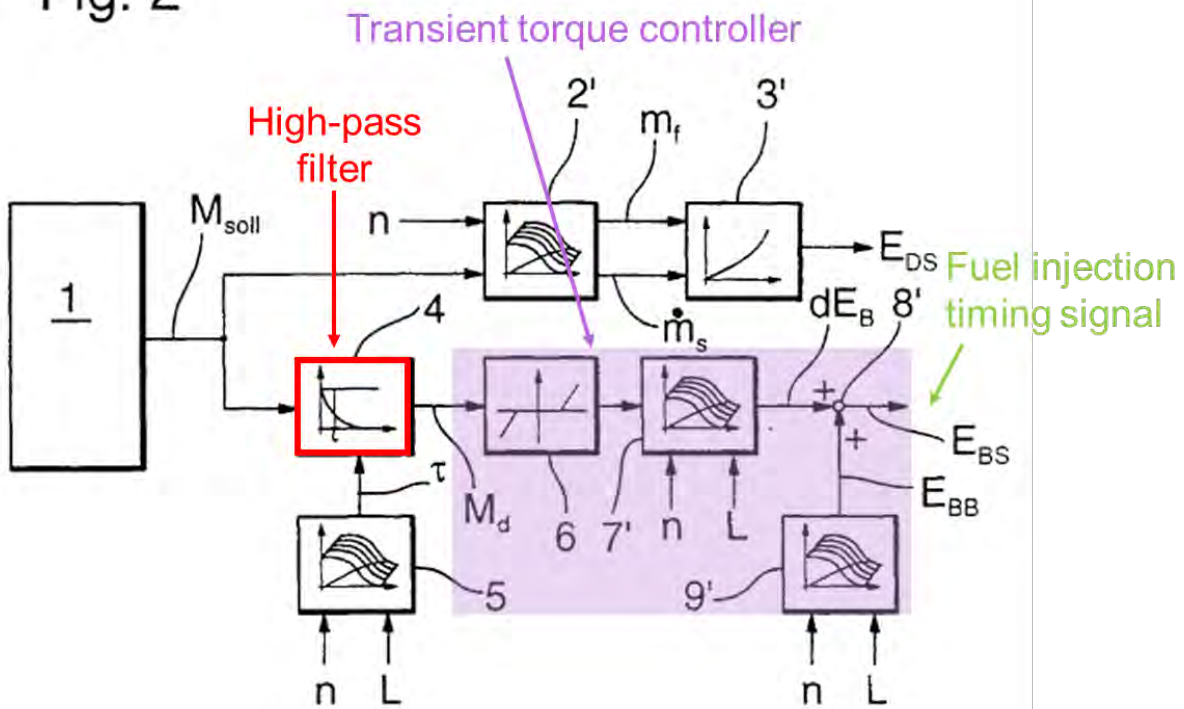
110. Scherer’s control system controls torque during such transient conditions. Particularly, Scherer’s control system adjusts engine torque output through spark timing and fuel delivery adjustments during transient conditions. EX1007, 4:20-24, 5:35-55. Scherer’s transient control system can “react very rapidly to sudden changes of the engine torque.” *Id.*, 4:23-25. Scherer’s control system includes a transient control branch having a high-pass filter 4 that isolates the dynamic desired torque component (M_d) of the desired torque signal M_{des} . *Id.*, 4:31-36, 5:35-40, FIGS. 1, 2. Scherer’s transient control branch functions the same

as the '565 patent's high-pass filter, removing the torque signal's low frequency component to isolate and pass the transient component for correcting dynamic torque changes.



EX1007, FIG. 1 (annotated).

Fig. 2



EX1007, FIG. 2 (annotated).

111. Scherer also discloses adjusting both spark and fuel injection timing based on the isolated dynamic torque component outputted from the high-pass filter 4. EX1007, 2:51-59, 4:20-5:9, 5:16-55, FIGS. 1, 2. Specifically, Scherer's control system adjusts torque output by adjusting the spark timing for homogeneous fuel-charged configurations (Figure 1) or by adjusting fuel delivery for heterogeneous fuel-charged configurations (Figure 2). *Id.*, 2:51-59, 4:20-45, 5:35-55, 8:26, FIGS 1, 2.

112. A POSA would have been motivated to incorporate Scherer's transient torque control system, including high-pass filter 4, into Robichaux's engine

controller to control torque during transient conditions. Combining Scherer's control system, including high-pass filter 4, with Robichaux's controller would provide a control system that precisely controls torque in *both* steady-state and transient conditions. Indeed, Scherer expressly discloses using the high-pass filter "permits a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes." *Id.*, 4:40-45, 5:9-15.

113. Moreover, there would have been a reasonable expectation of success in making such a combination. To implement the Robichaux-Scherer combination, during transient conditions, the Robichaux's torque signal TQ_ERR would be transmitted to Scherer's transient control branch instead of Robichaux's PID controller 220, and Scherer's high-pass filter 4 would then output a filtered difference signal in which low frequency components are absent. A POSA would have easily implemented this configuration by modifying the software instructions stored in Robichaux's engine controller such that the torque error signal TQ_ERROR is inputted into a high-pass filter as taught by Scherer. A POSA would have also understood that the high-pass filter would have been easily implemented into Robichaux's engine controller through a minor software change. Accordingly, combining Scherer's transient torque controller, including the high-pass filter 4, with Robichaux's controller that adjusts ignition timing in homogeneous mode and injected fuel quantity in stratified mode would have simply been applying a known

technique to a known device to yield the predictable result of more quickly correcting dynamic torque changes. Therefore, a POSA would have had a reasonable expectation of success in combining Robichaux and Scherer.

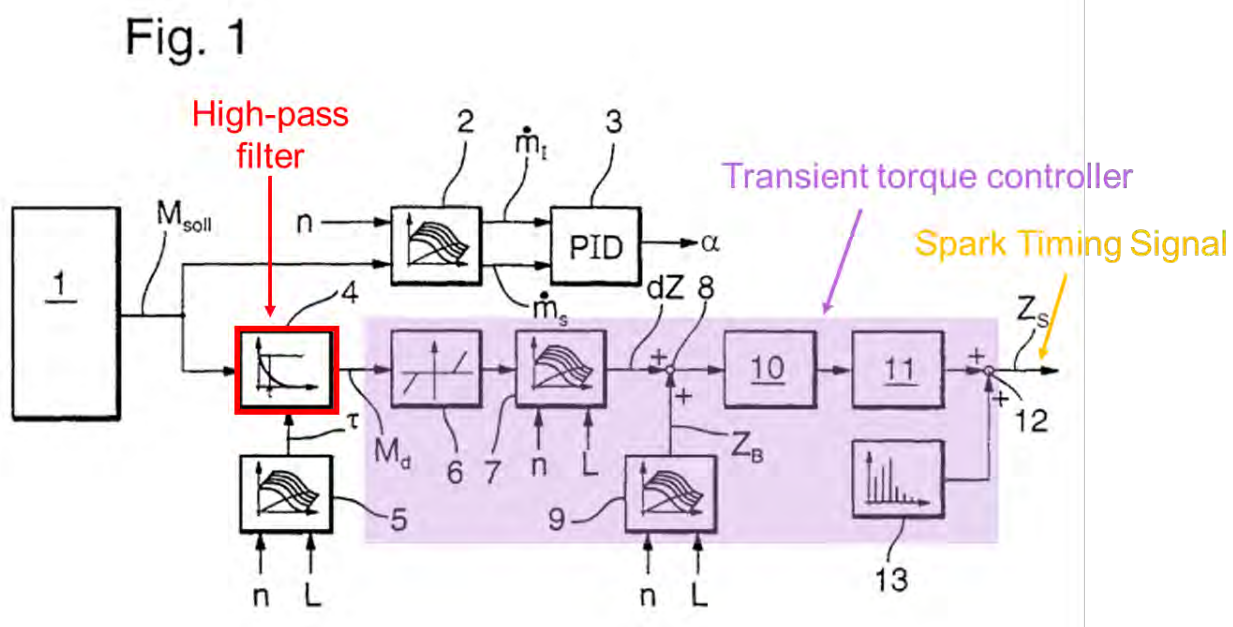
114. Thus, Robichaux and Scherer render obvious [1.E].

7. **[1.F] “a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal”**

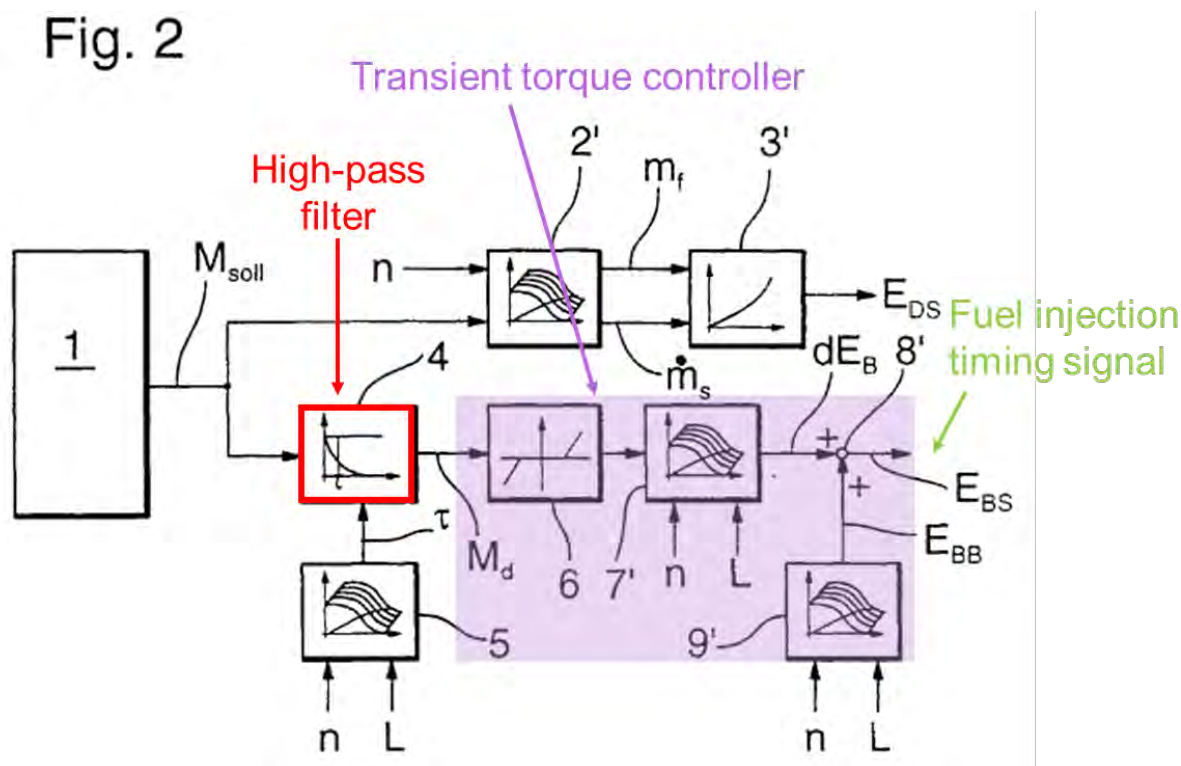
115. Robichaux and Scherer render obvious the recited transient torque controller.

116. Again, Robichaux invites combination with references disclosing transient control functionality to process the torque demand signal's transient component. EX1020, ¶0032. And Scherer discloses such a transient torque controller to correct for transient torque demands that would have been combined with Robichaux's controller. *See supra* Section X.B.6.

117. In addition to a high-pass filter 4, Scherer's transient control system also includes various units, for example, units 6, 7, 9, 10, 11 and 13 in Figure 1 and units 6, 7, and 9 in Figure 2, that produce a spark timing signal Z_s for adjusting torque output for homogeneous fuel-charged configurations or a fuel injection timing signal for adjusting torque output for heterogeneous fuel-charged configurations. EX1007, 2:51-59, 4:20-45, 5:35-55, 8:26, FIGS 1, 2.



EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

118. Scherer's transient control system units collectively compose "a transient torque controller," as recited in claim 1.² These control units adjust torque

² Notably, a POSA would have understood that different software or instruction modules of a control unit constitute different controllers, as the term "controller" is used in the '565 patent. Neither the claims nor the '565 patent specification specify that the recited controllers, "torque demand controller" and "transient torque controller," are separate physical structures. Indeed, in a district court complaint, the Patent Owner alleges that the software embedded within an engine control module constitutes a "controller," as recited in the '565 patent. EX1029, 34 ("[T]he transient torque controller (software within the ECM) receives as an input the filtered difference signal (described above) and outputs a fuel adjustment signal (to the ECM) and spark adjustment signal (used for engine control intervention)."). EX1029, 34. As such, a POSA would have understood that different transient control system units of Scherer constitute a controller, as that term is used in the '565 patent. And even assuming that the '565 patent required separate physical controllers, implementing Scherer's transient control system units ("transient torque controller") as one physical controller and Robichaux's torque correction demanding section ("torque demand controller") as a separate physical controller would have been an obvious design choice to a POSA. Indeed, a POSA

based on the isolated dynamic component of the desired torque signal during transient conditions and, thus, constitute a transient torque controller. *Id.*, 2:51-59, 4:20-5:9, 5:16-55, FIGS. 1, 2.

119. As explained above regarding [1.E], a POSA would have been motivated to incorporate Scherer's transient torque controller into Robichaux's engine controller to enable torque control during transient conditions. Robichaux suggested using a transient torque controller, and Scherer discloses one such transient torque controller. Incorporating Scherer's transient torque controller into

would have understood that electronic engine control systems often consist of multiple physically separate controllers for controlling a particular engine parameter, such as fuel injection, spark timing, or air flow. *See* EX1019, 155, 187. Moreover, a POSA would have understood that these separate physical controllers can be integrated as a single controller merely by changing a controller's software code. *See* EX1019, 250 (“[A] fully integrated electronic engine control system can include these subsystems and provide additional functions. (Usually the flexibility of the digital control system allows such expansion quite easily because the computer program can be changed to accomplish the expanded functions.).”) (Emphasis added). Thus, Robichaux and Scherer render obvious, a “transient torque controller,” as recited in claim 1

Robichaux's engine controller would allow Robichaux's engine controller to adjust torque output to a desired value more quickly during transient operation conditions. *Id.*, 5:9-15("permit[ing] a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes.") Accordingly, a POSA would have been motivated to incorporate Scherer's transient controller into Robichaux's engine controller to "adjust[] the engine torque to a desired value with the least possible expenditures in both steady-state and transient engine operation with a comparatively short reaction time." *Id.*, 2:38-42. Combining Scherer's transient torque controller with Robichaux's steady-state torque controller would result in a control system that precisely controlled torque in both steady-state conditions and transient conditions.

120. Moreover, a POSA would have had a reasonable expectation of success in combining Scherer's and Robichaux's teachings. A POSA could have easily implemented Scherer's control units 6, 7, 9, 10, 11 and 13 by modifying the software instructions stored in Robichaux's engine controller to perform the same function as disclosed in Scherer and ultimately generate a spark ignition timing signal and fuel delivery timing signal to control torque.

121. Thus, Robichaux and Scherer render obvious [1.F].

C. Robichaux and Scherer render obvious claim 7.

1. [7.P] “A method for controlling a torque output of an engine, the method comprising:”

122. Claim 7 recites a method analogous to the apparatus of claim 1.

Element [7.P] is similar to [1.P], which is disclosed by Robichaux. *See supra* Sections X.B.1. Particularly, Robichaux discloses “a system and method for controlling engine torque using feedback and feed forward control.” EX1020, ¶0001. Accordingly, Robichaux discloses [7.P] for at least the same reasons as [1.P].

2. [7.A] “estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal”

123. Element [7.A] is similar to [1.C], which is disclosed, or at least rendered obvious, by Robichaux. *See supra* section X.B.4. For example, Robichaux’s engine controller includes an “actual engine brake torque estimator” block 216 that “provides an estimate of the actual engine brake torque based on current engine operating parameters including **ignition angle** [(“**current spark angle signal**”)], **air/fuel ratio** [(“**current air/fuel ratio signal**”)], number of cylinders, variable CAM timing angle, engine coolant temperature, engine speed, **airflow**, and operation state of accessories such as the air conditioning compressor.” EX1020, ¶¶0033, 0044, FIG. 3. And a POSA would have understood that the term “airflow” in ¶0033 and Figure 3 of Robichaux was referencing “air charge.” Accordingly, Robichaux discloses, or at least renders obvious, an estimator that

receives as an input an estimated air charge signal, as well as a current spark angle signal and a current air/fuel ratio signal.

124. Accordingly, Robichaux discloses, or renders obvious, [7.A] for at least the same reasons as element [1.C].

3. [7.B] “comparing the estimated current torque signal with a desired torque signal to output a difference signal”

125. Element [7.B] is similar to the claim element [1.D], which is disclosed by Robichaux. *See supra* section X.B.5. For example, Robichaux discloses a block 218 that receives the an intermediate torque value, compares this value to the actual engine brake torque TQ_NET (“estimated torque signal), and produces a torque error signal TQ_ERROR (“a difference signal”). EX1020, ¶0030, FIG. 3.

Accordingly, Robichaux discloses element [7.B] for at least the same reasons as element [1.D].

4. [7.C] “filtering out a plurality of low frequency components from the difference signal”

126. Element [7.C] is similar to elements [1.E], which is rendered obvious by Robichaux and Scherer. *See supra* section X.B.6. Again, Robichaux recognizes the need for an alternative to its PID controller 220 during transient torque demands. EX1020, ¶¶0023, 0032, 0046. And Scherer discloses such a transient torque controller with a high-pass filter that filters out the low frequency component of the torque demand signal, passing only the torque demand signal’s high-frequency

component. *See supra* Sections X.B.6. A POSA would have been motivated to incorporate Scherer's transient torque control system, including high-pass filter 4, into Robichaux's engine controller, for example, to control torque during transient conditions, as well as during steady-state conditions.

127. Accordingly, Robichaux and Scherer render obvious [7.C] for at least the same reasons as element [1.E].

5. [7.D] “controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal”

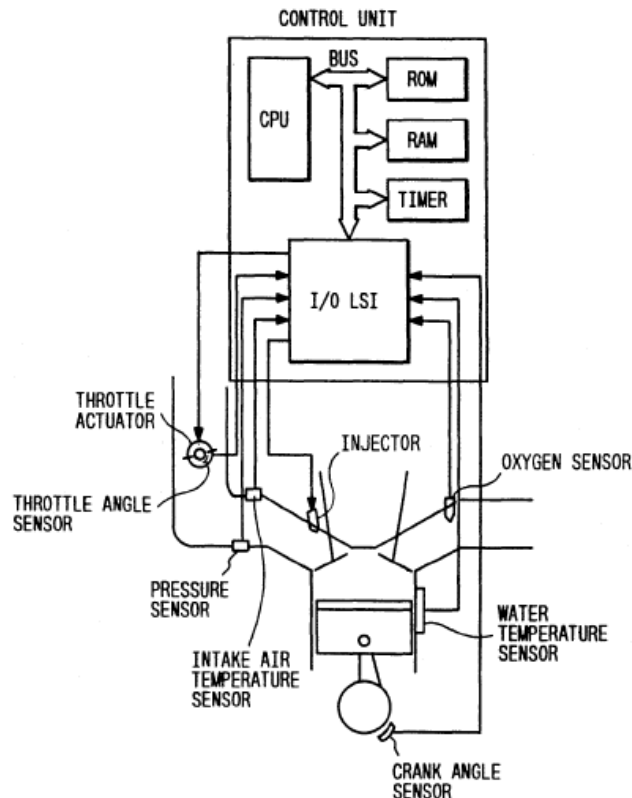
128. Element [7.D] is similar to element [1.F], which is disclosed by Robichaux. *See supra* section X.B.7. Again, Robichaux, as modified by Scherer, provides a filtered difference signal that isolates the transient component. *See supra* Sections X.B.6, X.B.7. And Scherer further discloses a transient torque controller that produces a spark timing signal Z_s for homogeneous fuel-charged configurations or a fuel injection timing signal for heterogeneous fuel-charged configurations. *See supra* Section X.B.7. A POSA would have been motivated to incorporate Scherer's transient torque controller into Robichaux's engine controller to control torque during both transient and steady-state conditions.

129. Accordingly, Robichaux discloses [7.D] for at least the same reasons as element [1.F].

XI. GROUND 2: THE COMBINATION OF ROBICHAUX, SCHERER, AND TAKAHASHI RENDERS OBVIOUS CLAIMS 2 AND 3.

A. Rationale for combining Robichaux, Scherer and Takahashi

130. As an initial matter, Robichaux, Scherer, and Takahashi are from the same field of endeavor—engine control systems. Like Robichaux and Scherer, Takahashi is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. Takahashi’s “invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values.” EX1008, 1:6-9. Takahashi’s electronic control module (ECM) 11 has a control unit, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, an engine water temperature sensor, and an airflow meter. EX1005, 4:17-40, FIG. 2; EX1008, 3:8-16, FIGS. 1, 13.



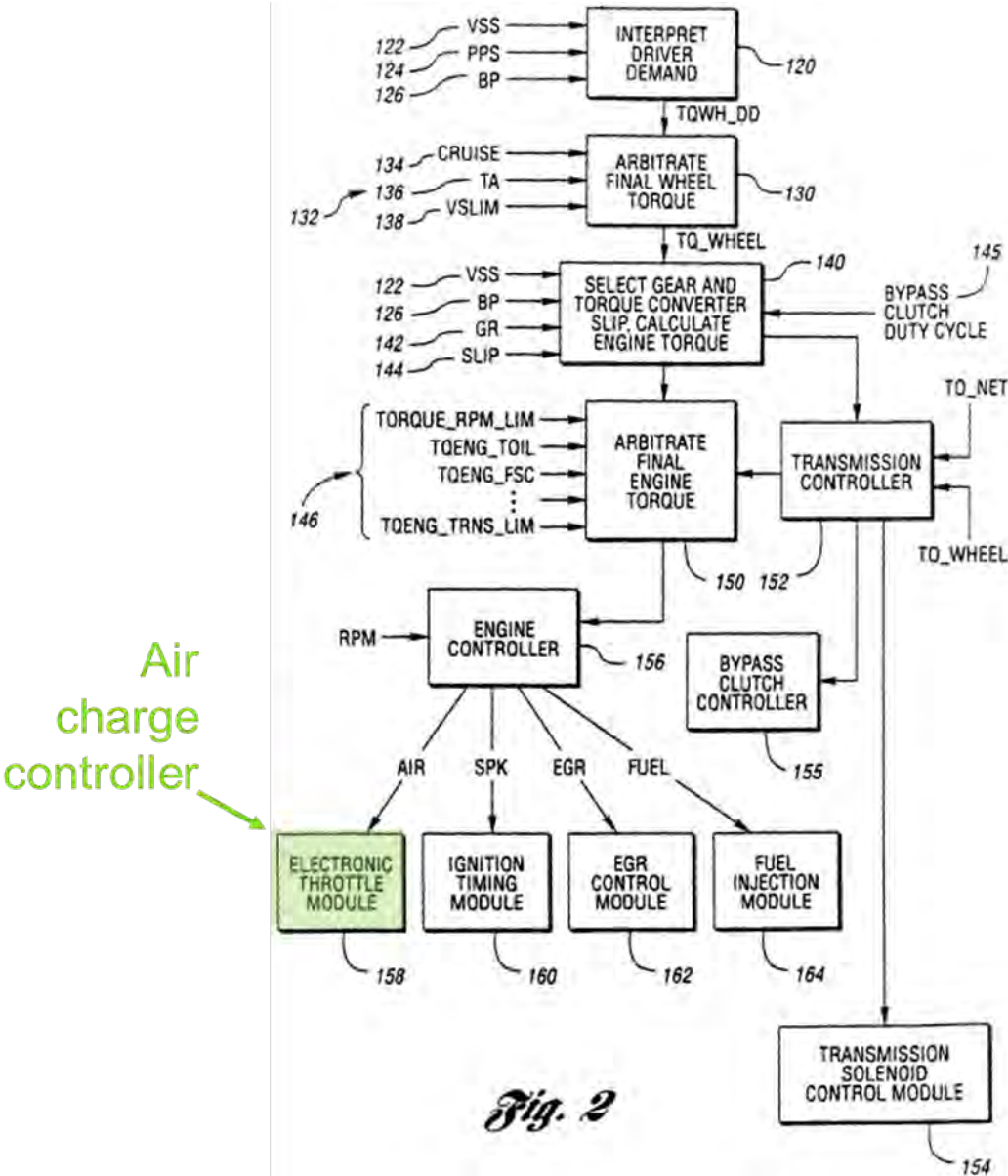
EX1008, FIG. 13.

131. These components are similar to Robichaux and Scherer components.

132. Combining the teachings of Takahashi, Robichaux, and Scherer would have simply involved modifying the engine controller (e.g., reprogramming stored instructions in Robichaux's engine controller 156) to perform the steps taught in the references—a basic task for a POSA. A POSA would have been motivated to combine the teachings of Robichaux, Scherer, and Takahashi for at least the reasons discussed below and would have had a reasonable expectation of success in doing so.

133. The motivation to combine Robichaux and Scherer is discussed above in Section X.B. That motivation still applies here for claims 2 and 3. For example, a POSA would have been motivated to combine Scherer's transient torque control system with Robichaux's engine controller 156 to control torque output during transient conditions. *See supra* Section X.B.

134. A POSA would have also been motivated to combine the teachings of Takahashi with the Robichaux-Scherer combination. Robichaux's engine controller 156 includes an electronic throttle module in Figure 2 ("air charge controller") for controlling the throttle valve to adjust the cylinder air charge. EX1020, ¶¶0020, 0025; FIG. 2.



EX1020, FIG. 2 (annotated).

135. Although Robichaux discloses an air charge controller, Robichaux does not expressly disclose that that the air charge controller produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge

temperature signal. But these features are explicitly disclosed in Takahashi.

EX1008, 3:13-27, 10:27-66, FIGS. 14, 15.

136. Takahashi discloses an air charge controller outputting an estimated air charge signal and receiving as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. Takahashi's throttle controller 144 ("air charge controller") receives the demand air charge Q_{map0} ("air charge demand signal") from a target air mass flow rate deciding block 11 and estimates the current air mass flow rate Q_{map} ("estimated air charge signal") using a status-estimating block 142. EX1008, 10:43-60, FIG. 14. The status-estimating block 142 receives a current throttle angle signal θ_{th} from a throttle angle sensor ("throttle position signal"), an intake manifold pressure signal P_m from a pressure sensor ("manifold pressure signal"), an engine speed signal N from the crank angle sensor ("engine speed signal"), and an intake air temperature signal from the intake air temperature sensor ("air charge temperature signal"). *Id.* A POSA would have understood that the throttle angle signal θ_{th} , intake manifold pressure signal P_m , engine speed signal N , intake air temperature signal, and demand air charge Q_{map0} inputted into the combination of Takahashi's throttle controller 144 and status-estimating block 142 are the inputs recited in claims 2 and 5. And based on these inputs, the status-estimating block 142 of Takahashi calculates the estimated air charge, which is used by the control unit to

adjust both the throttle valve position and the fuel injection quantity. Takahashi's air mass flow rate deciding block 11 receives a target torque signal T_o ("desired torque signal"), a target air/fuel ratio signal A/F_o ("desired air/fuel"), and a spark advance signal θ_{adv} ("desired spark angle signal") to determine the target mass flow rate Q_{map0} ("air charge demand signal"). EX1008, 3:28-51.

137. A POSA would have sought out these details provided by Takahashi's air charge control unit for modifying Robichaux's analogous air charge controller because combining Takahashi's teachings with Robichaux and Scherer would have yielded predictable benefits and results—for example, precisely controlling the air mass flow rate at the inlet port of the engine cylinder. EX1008, 2:18-24 ("Since [using] a status estimating model ... ensures a high precision estimation of the airflow status inside the intake manifold, the present invention further provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value."). A POSA would have understood that combining Takahashi's status-estimating block technique with Robichaux's electronic throttle module 158 would have estimated the air mass entering the engine cylinder more accurately, thereby allowing Robichaux's engine controller 20 to converge torque output to the desired torque output more precisely. *Id.* Furthermore, a POSA would have understood that incorporating Takahashi's target air mass flow rate deciding block 11 into

Robichaux's electronic throttle module 158 to output the demand air charge signal would have allowed Robichaux's electronic throttle module 158 to control cylinder air charge more precisely, ultimately allowing engine torque output to achieve the target torque. *Id.*, 1:49-57, 3:24-51. Accordingly, combining Takahashi's known status-estimating block technique and target air-mass-flow-rate deciding block 11 with Robichaux's known electronic throttle module 158 would have merely been applying known techniques in a similar, known device in the same way. *KSR*, 550 U.S. at 416.

138. Moreover, a POSA would have had a reasonable expectation of success in combining Robichaux, as modified by Scherer, with Takahashi. Indeed, a POSA would have recognized that Takahashi's status-estimating block would have been easily applied to Robichaux's electronic throttle module 158 to output the estimate air charge signal based on the detected engine speed, throttle position, manifold pressure, and air charge temperature.

139. A POSA would have also understood how to combine the teachings of Takahashi with Robichaux, as modified by Scherer. *Id.* A POSA would have simply modified the software instructions stored in Robichaux's engine controller 156 such that Robichaux's electronic throttle module 158 receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and generates an estimated air charge

signal, as disclosed in Takahashi. EX1019, 102, 223. Considering the similarities in Robichaux's and Takahashi's control systems, any necessary coding modifications to implement Takahashi's teachings into Robichaux's system would have been trivial and well within the skill level of a POSA.

140. In sum, Robichaux's engine controller 156, Scherer's dynamic torque control system, and Takahashi's technique for generating an estimated air charge signal were known elements that a POSA would have been motivated to combine in a known way to provide the predictable benefits disclosed in the references for providing precise and rapid correction of engine torque demand. *KSR*, 550 U.S. at 419-421.

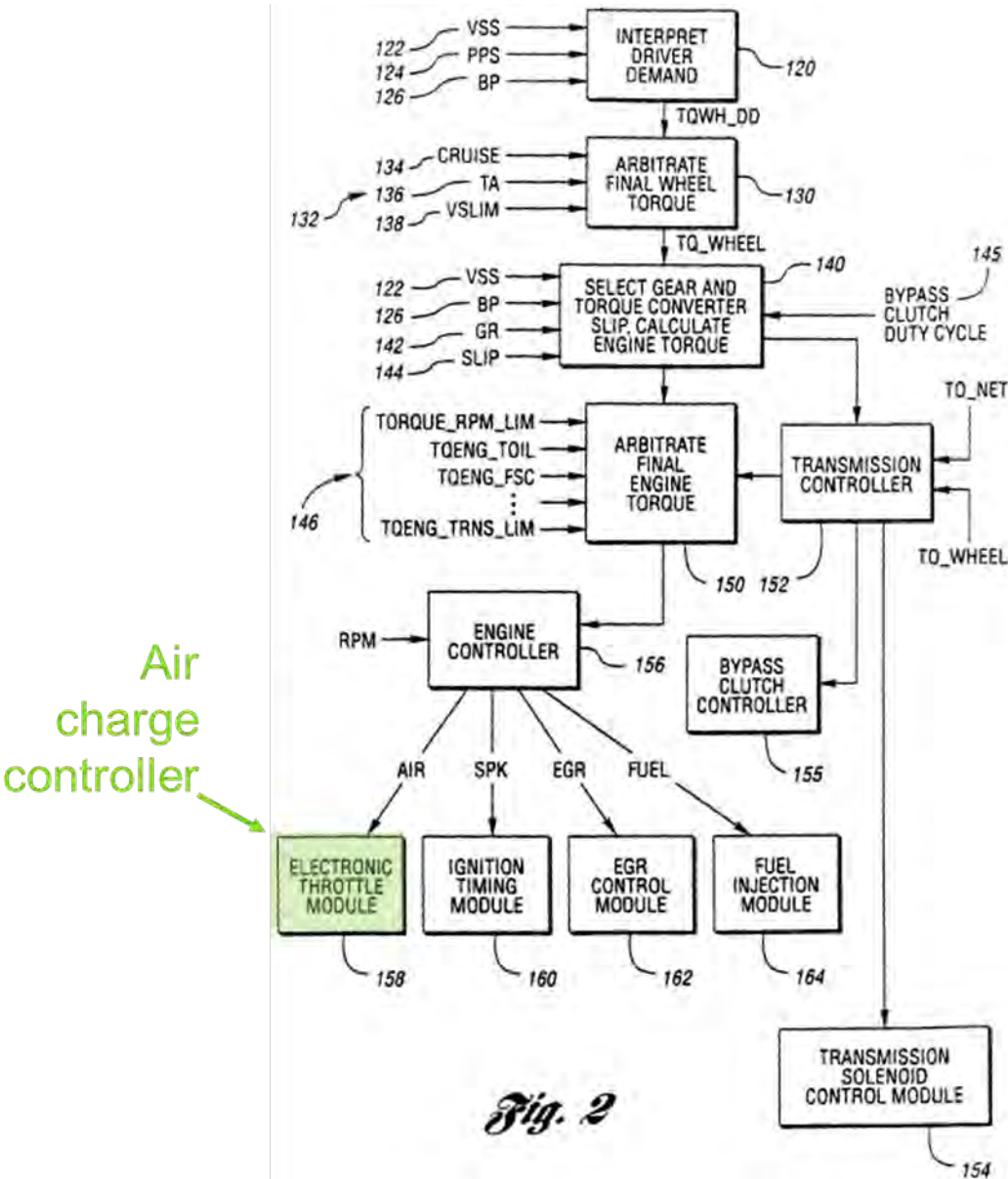
141. Accordingly, it would have been obvious to combine the teachings of Robichaux, Scherer, and Takahashi.

B. Robichaux, Scherer, and Takahashi render obvious claim 2.

142. Claims 2 depends from claims 1 and recites "wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal." EX1001, 4:23-27, 4:45-48.

143. Robichaux in combination with Scherer and Takahashi renders obvious this limitation. Robichaux's engine controller includes an electronic throttle module 158 ("air charge controller") and generates a signal to adjust "the intake air using

throttle valve 70 with an appropriate servomotor or actuator (TVA) 96.” EX1020, ¶¶ 0020, 0025, FIGS. 1, 2.



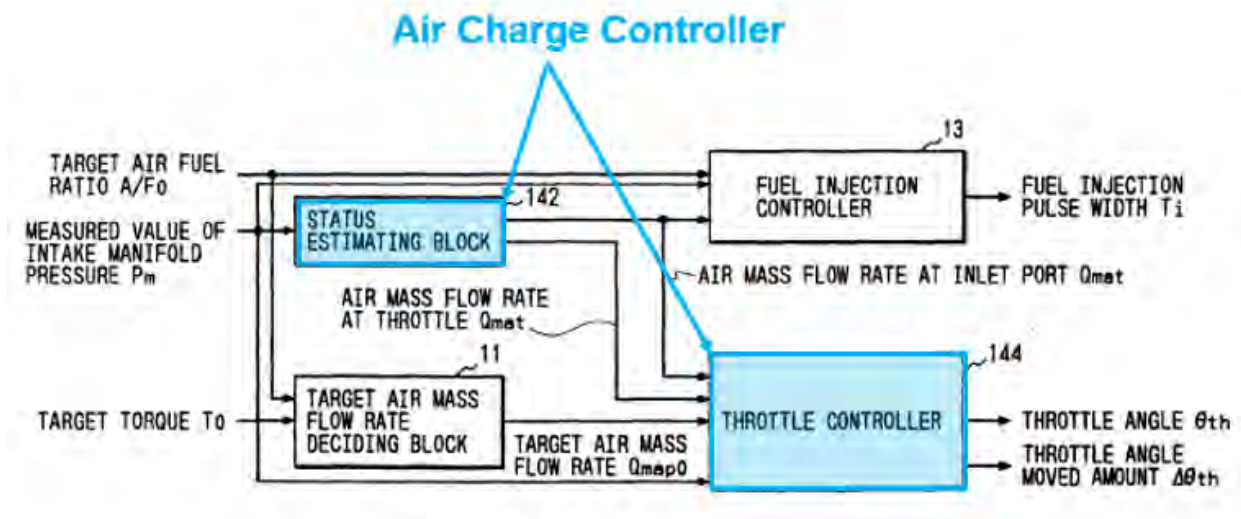
EX1020, FIG. 2 (annotated).

144. A POSA would have understood that Robichaux’s electronic throttle module is an “air charge controller,” as recited in claim 2. Robichaux’s electronic throttle module 158 adjusts the air charge inputted into the engine cylinders via

actuating the throttle valve. EX1020, ¶¶ 0020, 0025, FIGS. 1, 2. Robichaux's electronic throttle module 158 operates in the same manner as the air charge controller 29 disclosed by the '565 patent, which transmits a signal indicating the desired throttle position to the throttle 9. EX1001, 3:19-22.

145. Robichaux does not expressly disclose that the electronic throttle module 158 produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. But Takahashi explicitly discloses these features. EX1008, 3:13-27, 10:27-67, FIGS. 14, 15.

146. Takahashi's control unit controls torque output based on receiving inputs from a throttle angle sensor, an intake pressure sensor, an intake air temperature sensor, a crank angle sensor, an engine coolant sensor, and an exhaust oxygen sensor. *Id.*, 3:10-13, FIG. 13. The control unit includes a throttle controller 144 that calculates a desired throttle position for the throttle valve to set the airflow into the engine cylinder at a desired air charge value, ultimately allowing the engine to achieve a target torque value. *Id.*, 3:20-27, 6:10-12, 7:50-58, FIG. 14.



EX1008, FIG. 14 (annotated).

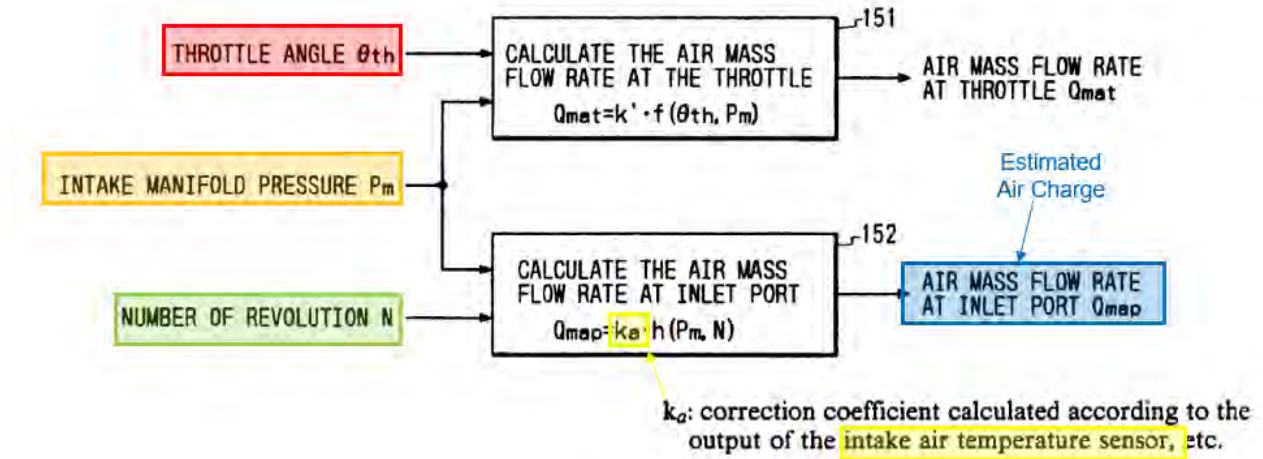
147. The throttle controller 144 determines the desired throttle position as a function of a target air mass flow rate Q_{map0} (“air charge demand signal”) and an estimated air mass flow rate at the inlet port Q_{map}^3 (“estimated air charge signal”). EX1008, 10:42-47, FIG. 14. The throttle controller 144 receives the demand air charge Q_{map0} from a target air mass flow rate-deciding block 11 and estimates the

³ Takahashi has a discrepancy between the reference symbols used in the specification and the reference symbols shown in the figures regarding the “air mass flow rate at the inlet port.” In the specification and Figure 2, Takahashi refers to the “air mass flow rate at the inlet port” using the reference symbol Q_{map} . EX1008, 10:54-60. However, in Figure 14 of Takahashi, the “air mass flow rate at the inlet port” is represented by the reference symbol Q_{mat} .

current air mass flow rate Q_{map} using a status-estimating block 142. EX1008, 10:42-60, FIG. 14.

148. As shown below, Takashi's status-estimating block 142 receives a current throttle angle signal θ_{th} (red, "throttle position signal"), an intake manifold pressure signal P_m (orange, "manifold pressure signal"), and a number of revolutions N (green, "engine speed signal").⁴ EX1008, 10:54-66. The status-estimating block 142 estimates the air charge value based on intake pressure P_m , engine speed N , and a correction coefficient k_a determined from current intake temperature sensor (yellow). EX1008, 10:54-66. The estimated air charge value is used to adjust both the throttle valve position and the fuel injection quantity, thereby controlling the engine torque output. EX1008, 3:24-27, 5:53-67, 10:21-27.

⁴ The measured parameter number of revolutions N as disclosed in Takahashi represents engine speed. EX1008, 3:36 ("N: Engine speed (number of revolutions)").



EX1008, FIG. 15 (annotated).

149. Takahashi's throttle controller 144 and status-estimating block 142 collectively compose an "air charge controller," as recited in claim 2. Takahashi's status-estimating block 142 and throttle controller 144 operate in the same manner as the air charge controller 29 disclosed by the '565 patent, which receives an air charge demand signal and signals from throttle position sensor 6, engine speed sensor 3, manifold pressure sensor 110, and temperature meter 5. EX1001, 3:13-22. And Takahashi's throttle controller 144 and status-estimating block 142 receive as inputs an air charge demand signal (Takahashi's target air mass flow rate Q_{map0}), a throttle position signal (Takahashi's throttle angle signal θ_{th}), an engine speed signal (Takahashi's number of revolutions N), a manifold pressure signal (i.e., Takahashi's intake manifold pressure P_m), and an air charge temperature signal (Takahashi's intake air temperature). Takahashi's status-estimating block 142 produces an estimated air charge signal (Takahashi's air mass flow rate at inlet port

Q_{map}), which is ultimately used to adjust both the throttle angle position and fuel quantity. Accordingly, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal, as recited in claim 2.

150. In view of Takahashi, it would have been obvious for a POSA to modify Robichaux's electronic throttle module to receive as signal inputs an air charge demand, a throttle position, an engine speed, a manifold pressure, and an air charge temperature so that Robichaux's electronic throttle module estimates the cylinder air charge more accurately. EX1008, 1:43-65, 2:18-24, 10:21-27. Indeed, Takahashi expressly discloses that this configuration "provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value." *Id.*, 2:18-24. Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. *KSR*, 550 U.S. at 416. Accordingly, a POSA would have been motivated to combine Takahashi's and Robichaux's teachings so that the control unit converges the engine output torque to the demand torque more precisely. EX1008, 2:18-24.

151. Likewise, a POSA would have easily implemented Takahashi's teachings by modifying the software instructions stored in Robichaux's electronic throttle module such that the torque control section receives signals indicating air charge demand, throttle position, engine speed, manifold pressure, and air charge temperature to produce an estimated air charge signal. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux and Takahashi.

152. Thus, Robichaux in combination with Cullen and Takahashi renders obvious claim 2.

C. Robichaux, Scherer, and Takahashi render obvious claim 3.

153. Claim 3 depends from claim 2 and recites "wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel."

154. Robichaux and Takahashi render obvious this limitation. As described above, Takahashi's throttle controller 144 (which composes the recited air charge controller) receives the demand air charge Q_{map0} from a target air mass flow rate-deciding block 11. EX1008, 3:28-29, 10:42-50, FIG. 14. As shown below in Figure 14 and Expression 1 recited in column 3 of the specification, Takahashi further discloses that the air mass flow rate deciding block 11 receives a target torque signal T_o (green, "desired torque signal"), a target air/fuel ratio signal A/F_o (blue, "desired

air/fuel”), and a spark advance signal θ_{adv} (purple, “desired spark angle signal”) to determine the target mass flow rate Q_{map0} (pink, “air charge demand signal”).

EX1008, 3:28-51.

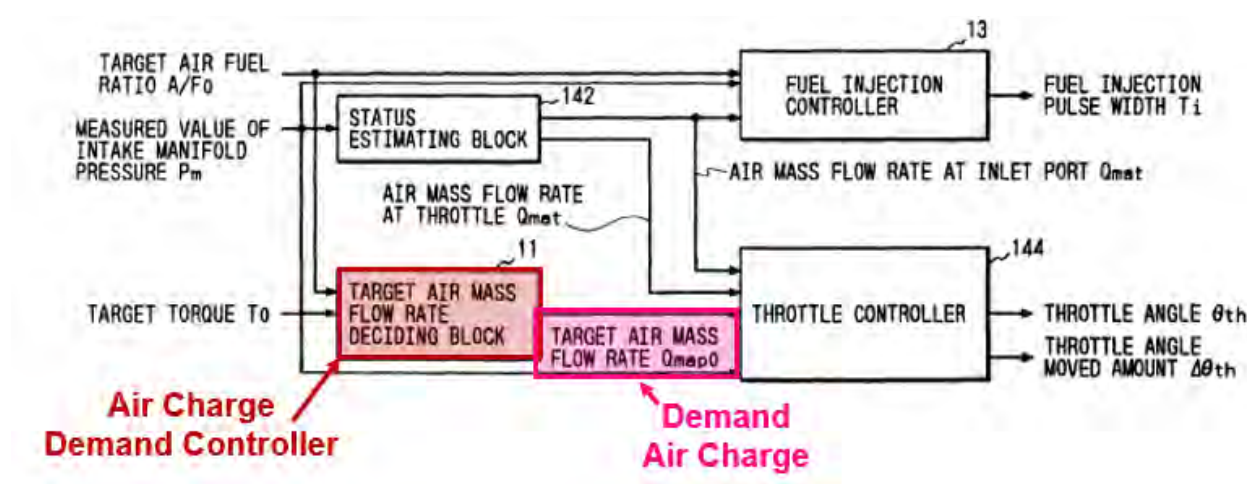
Air Charge Demand

$$Q_{map0} = \frac{N \cdot T_0}{K \cdot F_1(A/F_0) \cdot F_2(N) \cdot F_3(\theta_{adv})} \quad (\text{Expression 1})$$

where,

- T_0 : Target torque
- N : Engine speed (number of revolutions)
- A/F_0 : Target air fuel ratio
- θ_{adv} : Spark advance
- K : Constant
- F_1, F_2, F_3 : Specified function

EX1008, 3:30-41 (annotated).



EX1008, FIG. 14 (annotated).

155. Takahashi’s target air mass flow rate deciding block 11 is an “air charge demand controller,” as recited in claim 3. The target air mass flow rate-

deciding block 11 determines a demand air charge value for the throttle controller 144 based on receiving a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio. Indeed, Takahashi's target air mass flow rate deciding block 11 operates in the same manner as the air charge demand controller 27 disclosed by the '565 patent, which receives a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio and outputs a demand air charge signal to the air charge controller 29. EX1001, 3:6-15.

156. A POSA would have been motivated to incorporate Takahashi's target air mass flow rate deciding block 11 into Robichaux's electronic throttle module 158 to output the demand air charge signal. EX1008, 1:43-65, 2:17-23, 10:21-27. Takahashi expressly discloses that determining the target air mass flow rate based on the target torque, target air/fuel ratio, and spark advance provides precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. *Id.*, 1:49-57, 2:17-24, 3:24-51 ("Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention ... provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque."). Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. In sum, a POSA would have been motivated to combine the

teachings of Takahashi with Robichaux so that the control unit converges the engine output torque to the demand torque value with more precision. *Id.*, 2:17-24.

157. Likewise, a POSA would have easily implemented Takahashi's teachings by modifying the software instructions stored in Suzuki's electronic throttle module 158 such that the demand air charge value is calculated according to Takahashi's teachings, for example, Expression 1 equation. *Id.*, 3:30-41. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux and Takahashi.

158. Thus, Robichaux, Scherer, and Takahashi render obvious claim 3.

XII. GROUND 3: THE COMBINATION OF ROBICHAUX, SCHERER, AND SUZUKI RENDERS CLAIM 4 OBVIOUS.

A. Rationale for combining Robichaux, Scherer, and Suzuki

159. As an initial matter, Robichaux, Scherer, and Suzuki are from the same field of endeavor—engine control systems. Like Robichaux and Scherer, Suzuki is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. Like Robichaux and Scherer, Suzuki's "invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions." EX1005, 1:4-6. Moreover, Robichaux and Suzuki both disclose similar control architecture that includes, for example, a controller, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, and an airflow meter. EX1005,

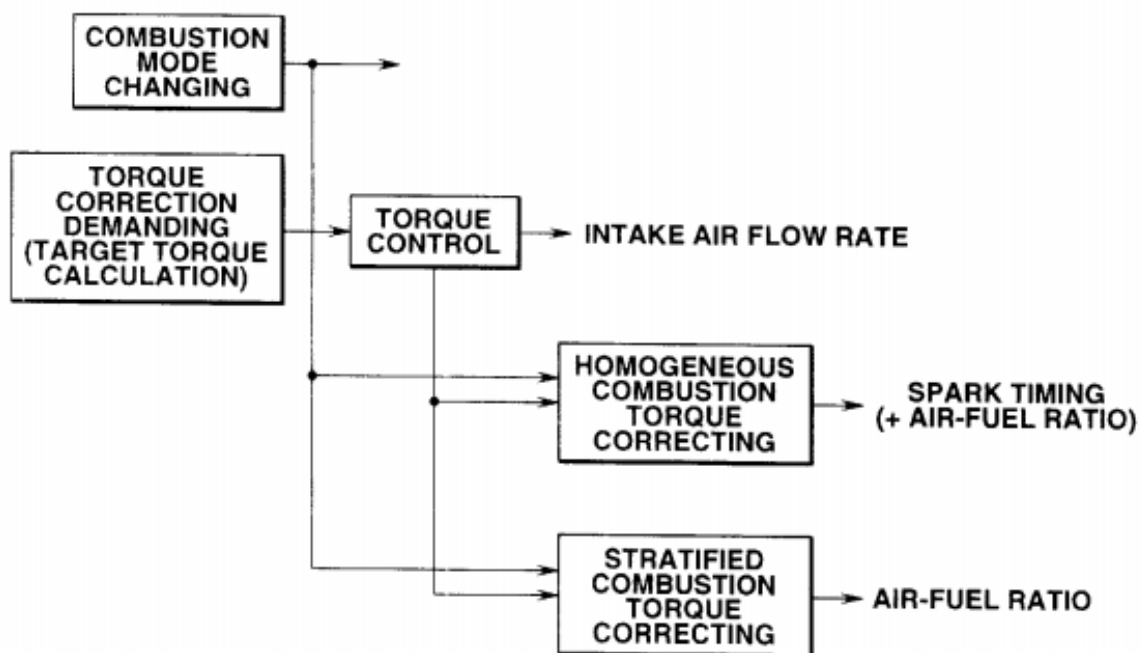
4:18-40, FIG. 2; EX1020, ¶¶0015, 0016, FIGS. 1-3. Accordingly, combining their teachings would have simply involved modifying the engine controller (e.g., reprogramming stored instructions in the microcomputer of Robichaux's controller) to perform the steps taught in the references—a basic task for a POSA.

160. The motivation to combine of Robichaux and Scherer is discussed above in Section X.B. That motivation still applies here for claim 4. For example, a POSA would have been motivated to combine Scherer's transient torque control system with Robichaux's engine controller to control torque output during transient conditions, as well as during steady-state conditions. *See supra* Section X.B.

161. A POSA would have also been motivated to combine Suzuki's teachings with the Robichaux-Scherer combination. Robichaux's engine controller communicates with engine 14 and transmission 16 to control engine torque. EX1020, ¶¶0012, 0021. Robichaux's engine controller includes various modules that determine specific engine control parameters (e.g., air flow 158, spark 160, EGR 162, and fuel 164). *Id.*, ¶¶0025, FIG. 2. Robichaux's control system can incorporate “[v]arious other operational modes and/or engine technologies, such as lean burn, may utilize airflow control, fuel flow control, spark or ignition angle control, and the like as well-known in the art.”

162. Suzuki's DISI engine controller corrects torque output by controlling fuel delivery and spark timing. EX1005, 1:39-43. As shown below in Figure 1B,

reproduced below, Suzuki's controller includes a combustion mode changing section that switches engine operation between a homogenous mode and a stratified mode. *Id.*, 3:5-10.



EX1005, FIG. 1B.

163. Suzuki's controller also includes a homogenous combustion torque correcting section and a stratified combustion torque correcting section that modify torque output in response to receiving the torque correction demand signal. *Id.*, 2:64-3:22, 15:53-16:6.

164. Suzuki's "stratified combustion torque correcting section corrects at least the air-fuel ratio to make torque correction during stratified combustion." EX1005, 3:10-22. To correct the air-fuel ratio, Suzuki's stratified combustion torque correction section adjusts the injection pulse signal ("fuel adjustment signal")

transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 (“[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function.”). Specifically, Suzuki’s control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived ultimately from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*, 6:21-57, 7:35-44. Accordingly, in the stratified combustion mode, Suzuki’s stratified torque correction section controls the fuel adjustment signal.

165. Suzuki’s “homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response ... during homogenous combustion.” EX1005, 3:10-22. To correct spark timing, Suzuki’s homogeneous combustion torque correction section modifies the timing of a command signal (“spark adjustment signal”) transmitted to spark plug 6 based on the spark timing calculation routine shown in Figure 4. *Id.*, 6:7-9, 7:60-8:4 (“The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting function.”). Specifically, Suzuki’s control unit retards or advances the timing of the spark plug command signal based on a torque correction factor that is derived directly from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*, 5:59-65, 7:35-59.

Accordingly, in the homogeneous combustion mode, Suzuki's homogeneous torque correction section controls the spark adjustment signal.

166. A POSA would have been motivated to modify Robichaux's engine controller, including its ignition-timing module 160 and fuel injection module 164, to incorporate Suzuki's dual combustion mode control. This combination would have improved the fuel efficiency of Robichaux's engine. Operating a dual-combustion-mode engine in stratified combustion mode during idle or part-load operation (low load conditions) to reduce fuel consumption was well-known before the '565 patent. EX1012, 464, 509. And operating a dual-combustion-mode engine in homogeneous combustion mode during full-load operation to generate maximum torque without degrading exhaust emissions was also well-known before the '565 patent. *Id.* Accordingly, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual combustion mode control to improve fuel efficiency while minimizing the effect on performance and exhaust.

167. And there would have been a reasonable expectation of success combining Suzuki's and Robichaux's teachings. A POSA would have easily implemented Suzuki's dual combustion mode control by modifying the software instructions stored in Robichaux's engine controller such the engine switches between the stratified combustion mode and the homogeneous combustion mode

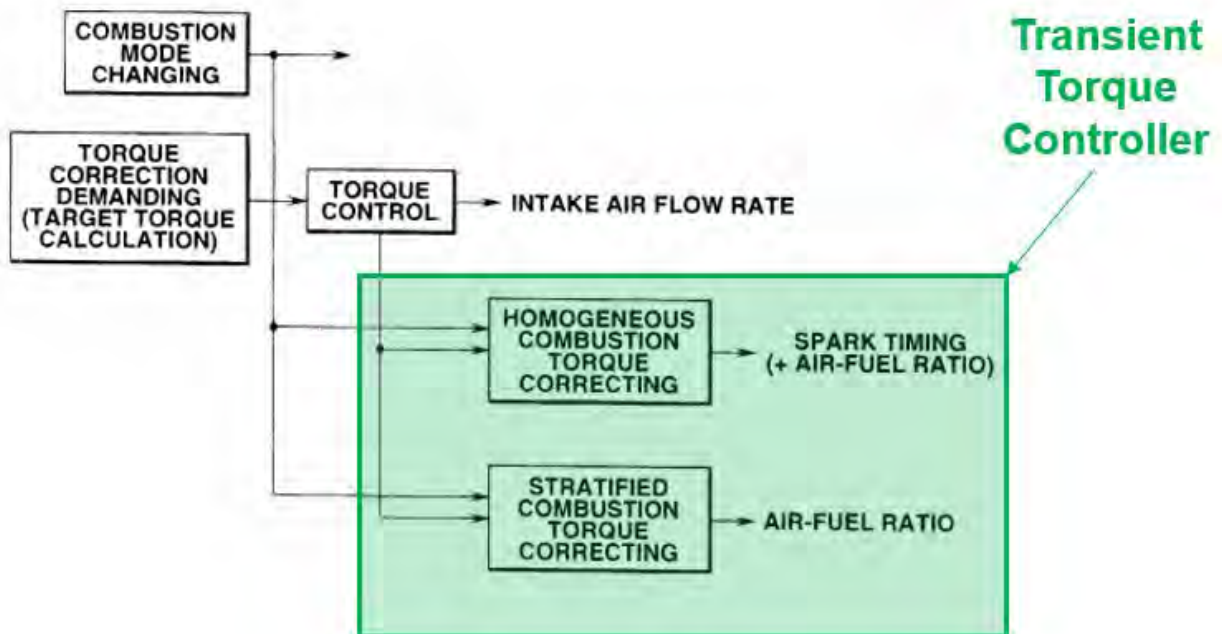
based on the desired torque. Accordingly, combining Suzuki's dual combustion mode control with Robichaux's engine controller would have simply been applying a known technique to a known device to yield the predictable result of switching between combustion modes based on load for improved fuel efficiency and performance. Therefore, a POSA would have had a reasonable expectation of success in combining Robichaux and Suzuki.

B. Robichaux, Scherer, and Suzuki render obvious claim 4.

1. [4.A] **"The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode"**

168. Robichaux and Suzuki render obvious the transient torque controller as claimed.

169. Suzuki's torque correction section includes "a homogenous combustion torque correcting section [that] **corrects at least the spark timing** in order to make a torque correction **with a fast response** ... during homogenous combustion" and a "stratified combustion torque correcting section [that] **corrects at least the air-fuel ratio** to make torque correction during stratified combustion." EX1005, 3:10-22. Moreover, Suzuki's homogeneous and stratified torque correction sections are configured to adjust torque output during transient engine operations: "[Suzuki's engine control apparatus] widens the range (**dynamic range**) over which torque can be controlled" *Id.*, 1:44-63, 3:10-22.

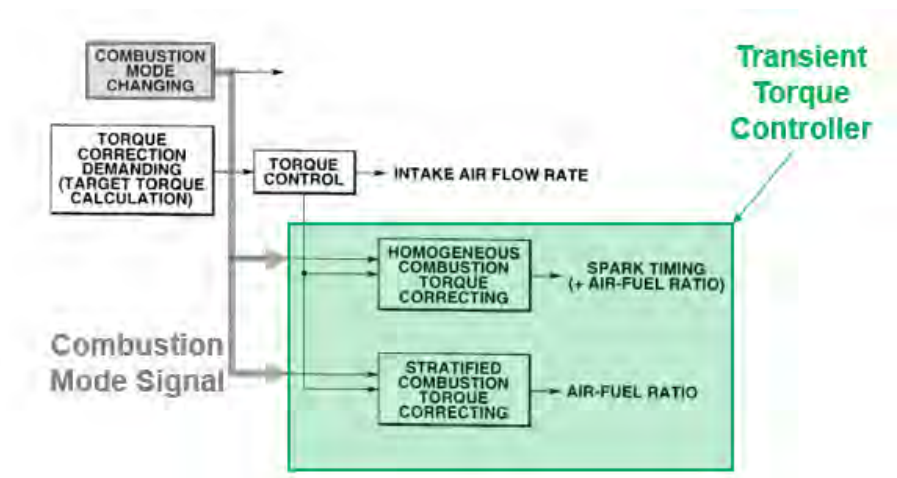


EX1005, FIG. 1B (annotated).

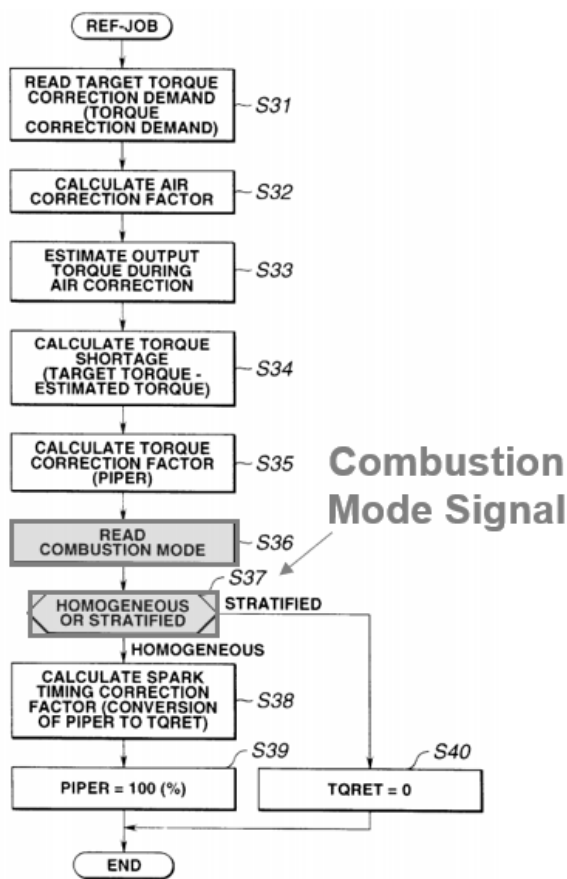
170. A POSA would have understood that Suzuki’s homogeneous and stratified torque correction sections collectively compose a “transient torque controller,” as recited in claim 4. These correction sections are a controller, because they generate spark timing adjustment and fuel adjustment signals used to control torque output. EX1005, 3:5-22. Indeed, Suzuki’s torque correction sections operate in the same manner as the transient torque controller 21 disclosed by the ’565 patent, which generates a fuel adjustment signal when the engine 100 is set in the stratified mode and a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50.

171. Suzuki’s homogeneous and stratified torque correction sections (“transient torque controller”) receive a signal from the combustion mode changing

section to determine whether the engine is operating in the homogeneous or stratified mode. EX1005, 7:45-8:4; FIGS. 1.B, 6.



EX1005, FIG. 1B (annotated).



EX1005, FIG. 6 (annotated).

172. A POSA would have been motivated to combine the Suzuki's teachings with the Robichaux-Scherer combination. To start, Robichaux expressly acknowledges that its control system can incorporate "[v]arious other **operational modes and/or engine technologies, such as lean burn**, may utilize airflow control, fuel flow control, spark or ignition angle control, and the like as well-known in the art." And Suzuki discloses a DISI engine controller that uses other such operational modes and engine technologies known in the art.

173. Specifically, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual combustion mode control to improve the fuel efficiency and performance. As explained in Section VIII.A.4, operating a dual-combustion-mode engine in stratified combustion mode during low load conditions, and operating in homogeneous combustion mode during high load conditions were well-known before the '565 patent. Accordingly, a POSA would have been motivated to modify Robichaux's engine controller to incorporate Suzuki's dual-combustion-mode control to improve fuel efficiency and performance, with degrading exhaust emissions.

174. Moreover, there would have been a reasonable expectation of success combining Robichaux's and Suzuki's teachings. A POSA would have easily implemented Suzuki's dual combustion mode control by modifying the software instructions stored in Robichaux's engine controller such the engine switches

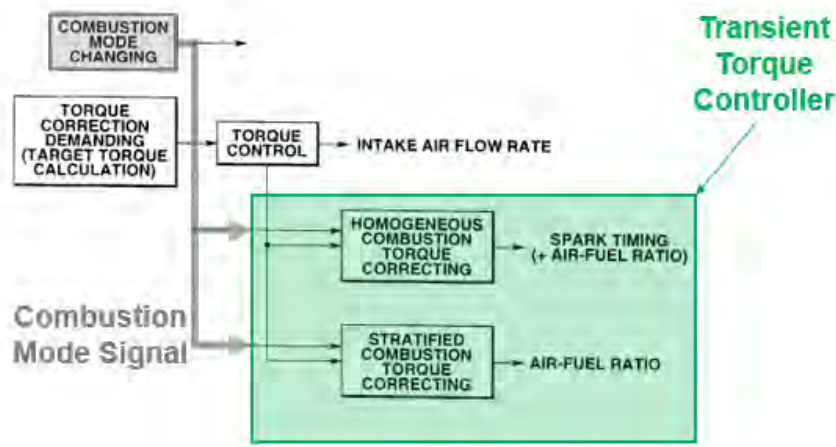
between the stratified combustion mode and the homogeneous combustion mode based on the desired torque. Combining Suzuki's dual combustion mode control with Robichaux's engine controller would have simply been applying a known technique to a known device to yield the predictable result of switching between combustion modes based on load for improved fuel efficiency. Therefore, a POSA would have had a reasonable expectation of success in combining Robichaux and Suzuki.

175. Thus, Robichaux and Suzuki render obvious [4.A].

2. **[4.B] “wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode”**

176. Robichaux and Suzuki render obvious the recited transient torque controller. Although Robichaux does not explicitly disclose the engine controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, Suzuki discloses this feature.

177. Again, Suzuki's stratified torque correction section composes, in part, the “transient torque controller” recited in claim 4. *See supra* Section XII.B.1.



EX1005, FIG. 1B (annotated).

178. Suzuki’s “stratified combustion torque correcting section **corrects at least the air-fuel ratio** to make torque correction **during stratified combustion.**” EX1005, 3:10-22. To correct the air-fuel ratio, Suzuki’s stratified combustion torque correction section adjusts the injection pulse signal (“fuel adjustment signal”) transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 (“[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function.”). Specifically, Suzuki’s control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived ultimately from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*, 6:21-57, 7:35-44, FIG. 6. Thus, in the stratified combustion mode, Suzuki’s stratified torque correction section controls the fuel adjustment signal. Indeed, Suzuki’s stratified torque correction operates in the same manner as

the transient torque controller 21 disclosed by the '565 patent, which generates a transient fuel adjustment signal when the engine 100 is operating in the stratified mode. EX1001, 3:34-50. Thus, Suzuki discloses [4.B].

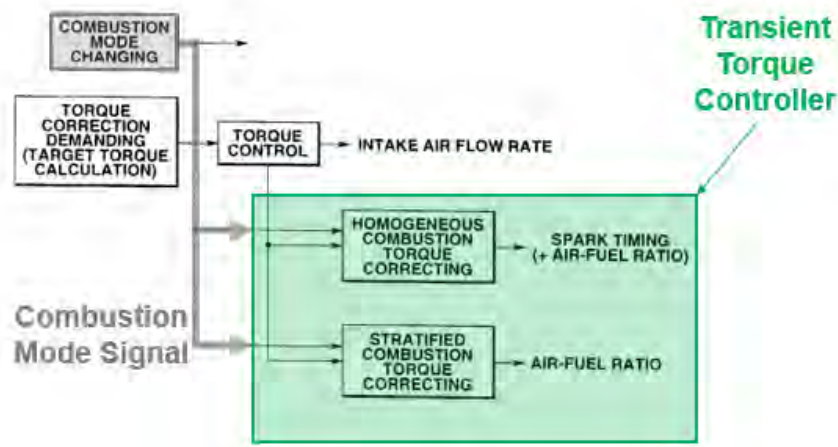
179. As explained above for [4.A], a POSA would have been motivated to combine the teachings of Robichaux, Scherer, and Takahashi for at least the same reasons and would have had a reasonable expectation of success in doing so.

180. Thus, Robichaux and Suzuki render obvious [4.B].

3. [4.C] “wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode”

181. Robichaux and Suzuki render obvious the recited transient torque controller. Although Robichaux does not explicitly disclose the engine controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode, Suzuki discloses this feature.

182. Again, Suzuki’s homogeneous torque correction section composes, in part, the “transient torque controller” recited in claim 4. *See supra* Section XII.B.2.



EX1005, FIG. 1B (annotated).

Suzuki’s “homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response ... during homogenous combustion.” EX1005, 3:10-22. To correct spark (ignition) timing, Suzuki’s homogeneous combustion torque correction section modifies the timing of a command signal (“spark adjustment signal”) transmitted to spark plug 6 based on the spark timing calculation routine shown in Figure 4. *Id.*, 6:7-9, 7:60-8:4 (“The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting function.”). Specifically, Suzuki’s control unit retards or advances the timing of the ignition command signal based on a torque correction factor that is derived directly from the torque shortage signal (“the difference signal”) generated in step S34 of Figure 6. *Id.*, 5:59-65, 7:35-59. Thus, in the homogeneous combustion mode, Suzuki’s homogeneous torque correction section controls the spark adjustment signal. Indeed, Suzuki’s

homogeneous torque correction section operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50. Thus, Suzuki discloses [4.C].

183. As explained above for [4.A.], a POSA would have been motivated to combine the teachings of Robichaux, Scherer, and Takahashi for at least the same reasons and would have had a reasonable expectation of success in doing so.

184. Thus, Robichaux and Suzuki render obvious [4.C].

XIII. GROUND 4: THE COMBINATION OF ROBICHAUX, SCHERER, SUZUKI, AND TAKAHASHI RENDERS OBVIOUS CLAIMS 5-6.

A. Rationale for combining Robichaux, Scherer, Suzuki, and Takahashi

185. As an initial matter, Robichaux, Scherer, Suzuki, and Takahashi are from the same field of endeavor—engine control systems. Similar to Robichaux, Scherer, and Suzuki, Takahashi is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. Like Robichaux, Scherer, and Suzuki, Takahashi's "invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values." EX1008, 1:6-9. Takahashi's electronic control module (ECM) 11 has a control unit, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, an engine water temperature sensor, and an airflow meter. EX1005, 4:17-40, FIG. 2;

EX1008, 3:8-16, FIGS. 1, 13. These components are similar to Robichaux, Scherer, and Suzuki's control components.

186. Combining Takahashi's teachings with Robichaux, Scherer, and Suzuki would have simply involved modifying the engine controller (e.g., reprogramming stored instructions in Robichaux's engine controller) to perform the steps taught in Takahashi—a basic task for a POSA. A POSA would have been motivated to combine the teachings of Robichaux, Scherer, Suzuki, and Takahashi for at least the reasons discussed below and would have had a reasonable expectation of success in doing so.

187. The motivations to combine Robichaux and Scherer discussed above in Section X.B apply here for claims 5 and 6. For example, a POSA would have been motivated to combine Scherer's transient torque controller with Robichaux's broader-purpose engine controller 156 to control torque output during both transient and steady-state conditions. *See supra* Section X.B.

188. The motivations to combine Robichaux and Suzuki discussed above in Section XII.A still apply here for claims 5 and 6. For example, a POSA would have been motivated to incorporate Suzuki's dual combustion mode control into Robichaux's engine controller to improve the fuel efficiency and performance. *See supra* Section XII.A.

189. And the motivations to combine Takahashi's teachings with Robichaux's teachings discussed in Section XI.A apply here for claims 5 and 6. For example, a POSA would have been motivated to combine the teachings of Takahashi with the Robichaux's engine controller to converge torque output to the desired torque output more precisely. *See supra* Section XI.A.

B. Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 5.

190. Claim 5 depends from claim 4 and recites "wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal."

191. As explained above in Section XII, Robichaux, Scherer, and Suzuki render obvious claim 4. And Takahashi in combination with Robichaux, Scherer, and Suzuki renders obvious this limitation of claim 5.

192. Further, as explained in Section XI.B regarding claim 2, which recites the same features, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

193. And a POSA would have been motivated to modify Robichaux's electronic throttle module to receive as signal inputs an air charge demand, a throttle

position, an engine speed, a manifold pressure, and an air charge temperature so that Robichaux's engine controller, including electronic throttle module, estimates the cylinder air charge more accurately. EX1008, 1:43-65, 2:18-24, 10:21-27. Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. *KSR*, 550 U.S. at 416. Accordingly, a POSA would have been motivated to combine the teachings of Takahashi with Robichaux so that Robichaux's controller converges the engine output torque to the demand torque more precisely. EX1008, 2:18-24.

194. Likewise, a POSA would have easily implemented Takahashi's teaching by modifying the software instructions stored in Robichaux's electronic throttle module such that the torque control section receives signals indicating air charge demand, throttle position, engine speed, manifold pressure, and air charge temperature to produce an estimated air charge signal. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux and Takahashi.

195. Thus, Robichaux, in combination with Scherer, Suzuki, and Takahashi, renders obvious claim 5.

C. Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 6.

196. Claim 6 depends from 5 and recites “wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio.”

197. As explained above in Section XIII.B, Robichaux, Scherer, Suzuki, and Takahashi render obvious claim 5. Robichaux, Scherer, Suzuki, and Takahashi also render obvious this limitation of claim 6.

198. As explained above in Section XI.C regarding claim 3, which recites the same limitation as claim 6, Takahashi discloses an air charge demand controller that produces an air charge demand signal and receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio, as recited in claim 6.

199. A POSA would have been motivated to incorporate Takahashi’s an air charge demand controller into Robichaux’s engine controller to generate a demand air charge signal based on the target torque, target air/fuel ratio, and spark advance to provide precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. EX1008, 1:49-57, 2:17-23, 3:24-51 (“Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention ... provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque.”). Such modification would

have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. In sum, a POSA would have been motivated to combine the teachings of Takahashi with Robichaux so that the control unit converges the engine output torque to the demand torque value with more precision. EX1008, 2:17-23.

200. Likewise, a POSA would have easily implemented Takahashi's teaching by modifying the software instructions stored in Robichaux's engine controller such that the demand air charge value is calculated according to Takahashi's teachings. EX1008, 3:30-41. Accordingly, a POSA would have had a reasonable expectation of success in combining Robichaux and Takahashi.

201. Thus, Robichaux, in combination with Scherer, Suzuki, and Takahashi, renders obvious claim 6.

XIV. OBJECTIVE INDICIA DO NOT SUPPORT PATENTABILITY.

202. I understand that the obviousness analysis includes considering evidence of secondary indicia of nonobviousness (if available). I understand that any secondary indicia of nonobviousness must have a nexus, or a close connection, to the novel aspects of the claimed invention. I understand that secondary indicia of nonobviousness include the following: commercial success, long-felt but unmet need, failure of others, copying, praise in the industry, and unexpectedly superior results as compared with the closest prior art.

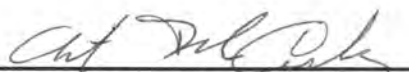
203. Considering the information I have reviewed, my general knowledge of the field of engine control systems, and publications within that and related fields, I am not aware of any objective evidence that might support the patentability of the claims of the '565 patent. Further, from my review of the file history (EX1002) of the '565 patent, I did not see that the applicant raised any secondary indicia of nonobviousness during prosecution. I am not otherwise aware of any publicly available evidence of secondary indicia of nonobviousness. Should any alleged secondary indicia of nonobviousness be presented, I reserve the right to provide an opinion thereon.

XV. CONCLUSION

In signing this Declaration, I recognize that this Declaration will be filed as evidence in an *inter partes* review before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required, I will appear for cross-examination within the United States during the time allotted.

I hereby declare that all statements made herein are made of my own knowledge and are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on this 30th day of January, 2020.


C. Arthur MacCarley, Ph.D., P.E.

Curriculum Vitae

C. Arthur (Art) MacCarley, Ph.D. PE.

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Specializations: Automotive electronics and control systems, electric and alternative fuel vehicles.

Employment

California Polytechnic State University, San Luis Obispo (1988-present)

Professor and former Department Chair, Electrical Engineering

Professor and former Program Director, Computer Engineering

Professor and former Department Head, BioResource and Agricultural Engineering

Director, Cal Poly Transportation Electronics Laboratory

Munich University of Applied Science (Germany)

Adjunct Professor, Mechanical & Electrical Engineering (Summer 2014,16,18,19 and Winter semester 2017)

Registered Professional Engineer, Electrical and Mechanical (Colorado, 1981-present)

Education

Purdue University, West Lafayette, Indiana

Ph.D. Electrical Engineering (Computer Engineering Specialization), 1987. Thesis: Advanced Digital Control.

University of California, Los Angeles, California

M.S. Electrical Engineering, 1978. Thesis: Electronic Fuel Injection Techniques for Hydrogen IC Engines.

B.S. (Cum Laude) Engineering, Mechanical/Alternative Energy Specialization, 1976.

Employment

9/16-1/17 *Munich University of Applied Science (Germany), Adjunct Professor, Mechanical Engineering.* Teach and supervise projects in Electric and Alternative Fuel Vehicles, Solar PV Systems.

3/88 to present *California Polytechnic State University, Professor, Electrical Engineering.*

EE Department Chair 2007-2010, Computer Engineering Program Director 2000- 2003, Dept. Head BioResource and Agricultural Engineering 2014-2015.

Administrative and academic responsibilities, teaching undergraduate and graduate courses in control systems, computer engineering, automotive engineering and alternative energy.

Research funded by NSF, DOE, DOT, Caltrans, PG&E and five industrial firms on advanced highway monitoring and control systems, electric vehicles, electronic engine controls and alternative fuels.

1/11-5/11 *Franklin Olin College of Engineering (Mass), Adjunct Professor of ECE.* Taught multidisciplinary engineering lecture/lab and senior elective "Automotive Technologies for a Sustainable Future".

6/97 to 6/14 *Loragen Corporation, Advanced Technology Group, Principal Engineer*

Automotive and highway safety electronics R&D for US DOE, Caltrans, UC Berkeley, Hughes SBRC.

1/84 to 12/87 *Purdue University, School of Electrical Engineering, David Ross Fellow*

Research in microprocessor-based control systems and advanced indirect sensing methods. Lead teaching assistant for digital laboratory; instructor for two undergrad laboratories; teaching asst. for two grad courses.

8/82 to 9/83 *American Bosch Division of United Technologies, Springfield, MA., Senior Engineer*

Design and optimization of electronic diesel engine controls. Lead engineer, controls group, responsible for development and testing of electronic engine control algorithms.

5/82 to 8/82 *Consulting Engineer in Private Practice, Denver, CO.*

Designed, constructed and tested electronic fuel injection and ignition control system for natural gas fueled engines, for CNG Vehicle Equipment Co., Fort Collins, Colorado.

5/79 to 5/82 *Denver Research Institute, University of Denver, CO., Research Engineer*

Principle investigator on three programs involving the development and testing of alternative fuel engines and vehicles. Designed electronic engine controls and on-board metal-hydride hydrogen fuel storage systems.

9/77 to 5/79 *Hughes Aircraft Co. Digital Communications Lab, El Segundo, CA., Member of Technical Staff*

Design, analysis and computer optimization of circuits for NASA Space Shuttle, GMS2 and GOES satellites.

6/75 to 9/77 *Research Assistant, UCLA School of Engineering and Applied Science*

Designed electronic fuel injection and cryogenic hydrogen fuel storage system under US DOT grant.

Honors and Awards

Deans list, UCLA College of Engineering 1975 and 76.
Outstanding Thesis of the Year, College of Engineering Nominee for University Award 1978
Outstanding Research Paper of the Year, University of Denver Research Institute (1980)
Cal Poly Meritorious Promise and Professional Practice (MPPP) Award, 1990.
Award recipient, DOE/NIST New Invention Competition, 1992.
Most Inspirational Instructor Award, runner-up, 1989 and 1992.
Outstanding Faculty-Student Involvement Award, 1992 and 1993.
Outstanding Faculty Advisor, 1995, 1996, 1997, 1998.
Northrup-Grumman Excellence in Teaching and Applied Research Award, 1997.
Litton Industries Excellence in Research and Development Award, 1997.
SCCA/EVTC Electric Vehicle Racing Series, 4th and 2nd Place National Winner, Stock/modified Class, 1998, 99.
Society of Automotive Engineers "Best Oral Presentation" Award, SAE International Congress, 2000.
Computer Engineering Program Appreciation Plaque for service as Director of Computer Engr. 2000-2003.
Society of Women Engineers Team Tech Competition Project Advisor, Recognition Plaque, 2003.
Electrical Engineering Student Advising and Support Award, 2003.
Caltrans nomination for State of California Award for most cost-effective research of the year, 2004.
Society of Women Engineers Team Tech Competition Project Advisor, Recognition Plaques, 2004 and 2005.
Electrical Engineering Department Appreciation Award for service as Department Chair, 2007-2010
Cal Poly 20-year Service Award, 2008.
EE Student Award for "Best Stories", EE Department Banquet, 2010.
Professional Recognition Plaque from Cal Poly Alumnus Astronaut Greg Chamitoff, 2009.
Recognition pin for service to the disabled community from Rory Cooper, Director of the Human Engineering Research Laboratories, University of Pittsburgh Medical Center, 2010.
BioResource & Agricultural Engineering Department Appreciation Award for service as Dept. Head, 2013-15
Faculty Fellow, Cal Poly College of Agriculture, Food and Environmental Science, AY 2015-16

Professional Society Memberships

Registered Professional Engineer (Electrical and Mechanical), Colorado, 1980-present.
Society of Automotive Engineers (SAE), Senior Member, 1976-present.
International Association for Hydrogen Energy (IAHE), founding member, 1977-1982.
Institute of Electrical and Electronic Engineers (IEEE), Senior Member, 1976-present.
Sigma Xi Scientific Research Society, 1980-present. Cal Poly Chapter President 1991/92.
American Society of Engineering Educators (ASEE), Senior Member, 1989-2010.
American Society of Agricultural and Biological Engineers (ASABE), 2013-2016.

Professional Service

Faculty advisor to 150+ senior projects, 20+ MS theses in electrical and computer engineering, 1988-present.
Faculty advisor of student or team winning the Hewlett Packard Senior Project of the Year Award, 1989, 90, 91, 92, 93, 95, 98, 99, 2000, 2002.
Deployed first EE Central UNIX computer system, using donated systems and components. 1988.
Produced first computer-typeset lab manual in College of Engineering, using UNIX TROFF/EQN, 1988.
Patent Disclosure "Indirect Sensing Method for Diesel Fuel Injection Quantity Control," CP Foundation, 1989.
Specified, deployed and wrote practical users manuals for EE Dept. network of 15 UNIX Workstations, 1990.
Served as UNIX and network system administrator for the EE Dept., 1990-1999.
Presentations for Electrical Engineering Graduate Seminar almost every year since 1989.
Faculty Advisor and Branch Counselor to Cal Poly Student IEEE Chapter, 1990-97.
Cal Poly representative to Chancellor's Technology Transfer Task Force, 1993.
Cal Poly Academic Senator, 1993-95.
Principal Evaluator, US Dept of Transportation Federal Highway Administration Field Operational Test, "Evaluation of Video Intersection Detection System", 1993-06.
Principal Evaluator, US Dept of Transportation Federal Highway Administration Field Operational Test, "Evaluation of Integrated Freeway Ramp Meter and Arterial Control System", 1993-06.
Patent Disclosure "Rapid Battery Interchange," Cal Poly Foundation, 1993.
Invited speaker for IEEE Central Coast Professional Section Meetings, 1995, 1999 and 2007.
Cal Poly Intellectual Property Committee, 1995-97.
Developed modern EE/CPE Embedded Systems Laboratory, teaching both Intel and Motorola MCs, 1996.

Founder and Incorporator of Loragen Corp., San Luis Obispo, CA (consulting and independent evaluation team of Cal Poly faculty and students) 1997.
 Interviewed by KSBY News for technical opinion on ordinance banning cell phone use at gas stations, 1998.
 Co-author of Cal Poly College of Engineering Mission Statement document, 1998.
 Academic Senate Research Committee, College of Engineering Representative, 1996-99.
 College of Engineering Strategic Planning Committee, 1997-98.
 College of Engineering Research and Professional Development Committee, Chair, 1997-99.
 Founder and faculty adviser, Cal Poly Electric Vehicle Engineering Club and Electric Racing Team, national winner of 4th place 1998 and 2nd place 1999. 1996-2012.
 Expert witness for California Department of Transportation Legal Division (1999-present).
 Director of Cal Poly Computer Engineering Program 2000–03.
 Spent June-August of 2000 fundraising for CPE and EE; traveled to 18 companies throughout California. Resultant contacts and donations provide continuing annual support of CPE, EE and CsC.
 Designated by Advancement Office in 2000 as the official contact between the College of Engineering and Bert and Candace Forbes, helping to secure \$3 million dollar donation to Cal Poly CPE, half to the EE Dept.
 Organized and offered the first Computer Engineering Program Banquet, September 2001.
 Created first Industrial Advisory Board for the Computer Engineering Program, December 2001.
 Founder and permanent faculty co-advisor of Cal Poly Computer Engineering Honor Society, Fall 2001-present.
 Created and advised three Computer Engineering Capstone team projects with industrial collaborators.
 Appointee, Caltrans working group on telecommunications, meeting annually 2002-present.
 Raytheon Excellence in Teaching Award Selection Committee, 2004, 05, 06.
 Raytheon Excellence in Applied Research Award Selection Committee, 2004, 05, 06.
 Northrup-Grumman Excellence in Teaching and Research Award Selection Committee, 1999, 2004, 05, 06.
 Developed and continue to operate Caltrans Detector Testbed on I-405 in Irvine, 2002-present.
 Faculty advisor to the SWE *Team Tech* National Competition Team, 2003 (2nd place) and 2004 (1st place)
 Developed “SIBS Bill Analyzer” computer program for Caltrans. Program for auditing and controlling state telecommunications costs, attributed with saving over \$4 million in first year of use, 2004.
 Member and Inter-committee Liaison, TRB Committee on User Information Systems, 2005-present.
 Faculty advisor, Cal Poly Advanced Autonomous Vehicle Club, 2005-present.
 Faculty advisor to the Cal Poly DARPA Grand Challenge Team, (semifinalists) 2005-06.
 Chair of Tenured and Probationary Faculty Committee, Tenured Faculty Committee, and Probationary Review Committee, Cal Poly Electrical Engineering Department, 2005-06.
 Developed Cal Poly EE “Control Systems” educational web site <http://telab.ee.calpoly.edu/~amaccarl>
 Invited participant in the “Baker Forum”, focusing on sustainability issues, 2006.
 Completed short “CDR Certification Course” conducted by Collision Safety Institute, (for qualification as automotive crash data expert witness), Vallejo, CA, July 2006.
 Co-organizer of special session “Next Generation of Driver Information Systems” at 2007 TRB Annual Meeting.
 College of Engineering Domain 5 (Professional Development) Advisory Committee, 2007.
 Member of SurGE, Cal Poly Sustainable Initiatives Working Group.
 Participant in US Congressional Caucus meeting on “Education in Simulation and Modeling,” 2007.
 College of Engineering RPT Committee. Co-author of draft CENG RPT Policy Document, 2007-2009.
 Represented Cal Poly at International Engineering Education Symposium, Seoul, Korea, 2009.
 College of Engineering Project-Based Learning Center Committee, representing CPE, 2006-present.
 College of Engineering Computers and Networks Committee, representing EE and CPE, 2006-present.
 Founder and faculty advisor to interdisciplinary Electric Vehicle Engineering Club, 2007.
 Active in many forums as advocate for improvement of research environment at Cal Poly.
 Published lecture notes and laboratory manuals for 18 Electrical and Computer Engineering courses at Cal Poly, San Luis Obispo.
 Principal Investigator on 36 funded research projects involving various areas of advanced controls and transportation electronics 1989-present, totaling over \$3.5 million in external funding. All projects have involved and provided employment for undergraduate and graduate students. Complete list on request.
 Member, National Academy of Engineering Transportation Research Board User Information Committee, 2006-
 Member, College of Engineering Committee to write new Retention, Probation and Tenure Document, 2006-08.
 Invited Speaker, Cal Poly Focus the Nation campus-wide event. Co-presented “Global Warming: Problems and Solutions, An Engineering Approach”, Jan 31, 2008.
 Invited Speaker, Cal Poly Kennedy Library Science Café. “My Methanol Motorcycle”, Jan 28, 2009.

Department Chair, Electrical Engineering, 2007-2010. Among accomplishments were major fiscal restructuring, implementation of "Promise-keeping Policy" for assured student accommodation in required classes, and guidance of Department through ABET accreditation culminating in visit 2008.

EPIC Course instructor, 2008 and 2009 (solar-powered model car design and competition).

Volunteer GATE course teacher, Nipomo MESA Middle School, every year 2002-present.

Adjunct Professor of Electrical and Computer Engineering at Olin College of Engineering, Needham, MA, during Sabbatical leave 2011. Developed and taught new course on Sustainable Automotive Technologies. Co-developed and taught major revision of freshman introduction course "Real-World Measurements".

Created "Electric Vehicle and Battery Safety Course" with certification examination for Cal Poly Electric Vehicle Engineering Club. Offered course and certification exam to all interested Cal Poly students, Dec. 2011.

Created and taught new Cal Poly multidisciplinary engineering course "Automotive Technologies for a Sustainable Future", Winter quarter, 2012.

Recipient of Chevron Grant for support of student team projects in above course.

Co-recipient (with ME faculty) of Chevron Grant for support of Wind Energy Project.

Currently (2012) PI on Caltrans Division of Innovation and Research advanced detector testbed project.

Safety officer for Cal Poly electrical engineering department (2011-present).

Department Head, BioResources and Agricultural Engineering Department. Administrative duties, oversaw program accreditation 2005, served faculty and College as member of visioning enrollment committees, reactivated Industrial Advisory Board, created Annual Department News Magazine and weekly newsletters.

Assisted in securing the donation of 1060 advanced solar panels from Sunpower Inc, 2013.

Created Solar Photovoltaic System Engineering Course (BRAE 434) and installed Solar PV systems on BRAE office building and Rodeo Arena storage building as course projects, 2013-15.

Faculty Fellow and Technology Consultant to CAFES, 2015-16.

Preliminary design of 70kW Solar PV system for College of Agriculture Swanton Pacific Ranch, 2016.

First electrical engineering professor to exchange with Munich University of Applied Science, Fall 2016.

University Courses Developed

Major course revisions:

EE 342, Control Systems Laboratory. Designed lab, wrote new lab manual, 1988, 1994, 1996, 1998.

EE/CPE 319/359 Digital Design with Laboratory. Introduced PLDs, FPGAs, and CAD logic design methods.

BRAE 335, Internal Combustion Engines. Updated and redesigned Lecture and Laboratory, Winter 2016.

Created new courses:

EE 563 Graduate Seminar, 1989.

EE 514 Advanced Topics in Automatic Control, 1988.

EE/CPE 432 Digital Control Systems, 1989.

EE 434 Automotive Engineering for a Sustainable Future, 2013.

EE/CPE 472 Microprocessor Controls Laboratory, 1989.

EE/CPE 336 Microprocessor Embedded Systems Lecture and Laboratory, 1994.

CPE 350/450 Jointly created (2003), and instructor for CPE 350/450 capstone courses, 2006-2016.

EE470/471 "Automotive Technologies for a Sustainable Future", Winter quarter, 2012, 2013.

BRAE 240-5 Solar Engineering Laboratory Spring 2014

EE/BRAE 434 Alternative Energy Vehicles, Spring 2014,15,16,17,18.

BRAE 470/471 Special Topics "Solar PV Engineering". Fall 2014, 2015.

EE/BRAE 450 Solar Photovoltaic System Engineering, Winter/Spring 2016,17,18, 19.

Munich Univ of Applied Science: "Alternative Energies" Mechanical Engineering, Winter Semester 2016.

Course coordinator and major course redesign:

EE 436 and 336, Embedded Systems Laboratories, 1994-2004.

EE 342 Controls Laboratory 1993-2003, 1988-2000, 2006-2012.

EE/CPE 219,259,319,359 digital area lectures and labs, 1990-1998.

EE 432/472 Digital Control Systems lecture and laboratory. 1990-present.

EE 513, Linear Control Theory, 1988 – 2000.

EE 514, Advanced Topics in Automatic Controls, 1988 – present.

Created "Prof. MacCarley's New Control Systems Web Site" <http://amaccarl.ceng.calpoly.edu/ControlsSystems> , web site for courses EE302, 342, 432, 472, 513 and 514. Continuously updated 1998-present.

Created "Alternative Energy Vehicles" Web Site <http://amaccarl.ceng.calpoly.edu/AltFuels/> courseware and reference web site for course EE/BRAE 434.

Created "Solar Photovoltaic System Engineering", <http://amaccarl.ceng.calpoly.edu/SolarEngineering/> , a public-access courseware and information web site on solar PV system technologies, science, design and permitting.

Journal Publications and Book Chapters

- "Development of a Sodium Borohydride Hydrogen Fuel Storage System for Vehicular Applications," *Physica Status Solidi (A) Applied Research*, pp. 315-321, 1976.
- "Energy Primer", contributed section "Hydrogen Energy", published by Portola Institute, Santa Cruz, CA, 1976.
- "Electronic Fuel Injection Techniques for Hydrogen Powered I.C. Engines," *International Journal of Hydrogen Energy*, V5.2, Pergamon Press, Oxford, England, 1980. Co-author: W.D. VanVorst.
- "Alternative Automotive Fuels Handbook," Publication of National Science Foundation, under Grant No. ISP-8009001, administered by University of Denver Research Institute, 1981.
- "State Feedback Control of Nonlinear Systems," *International Journal of Control*, V.43, No.5, 1986. Co-author: S. H. Zak.
- "An Auxiliary Sensor Processor to Provide Real Time Fuel Delivery Feedback for a Microprocessor Based Diesel Engine Controller," chapter in SAE publication "Recent Advances in Electronic Diesel Engine Control" and 1987 SAE Transactions. Co-author: D. G. Meyer.
- "A Study of Numeric Saturation Effects in Linear Digital Compensators," *Electrical Engineering Technical Journal*, Purdue University, School of Electrical Engineering, 1988. Co-author: D. G. Meyer (thesis advisor).
- "An Indirect Sensing Technique for Closed-Loop Diesel Fuel Quantity Control," *Society of Automotive Engineers Transactions*, 1990. Co-authors: W. Clark and K. Nakae (students).
- "Sample Rate Selection for Discrete Time Switching Controls", *IFAC Journal*, International Assoc. for Mathematics and Computer Simulation and International Federation of Operational Research Societies, Pergamon Press, Inc. 1990
- "Evaluation of Video Image Processing Systems for Traffic Detection," *Transportation Research Record No. 1360*, National Research Council, Wash. DC., 1992. Co-authors: S. Hockaday, D. Need, S. Taff.
- "Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," *Transportation Research Record No. 1410*, National Research Council, Washington D.C., 1993. Co-authors: D. Need, R. Neiman (students).
- "Video Technologies for Roadway Surveillance and Automated Detection," *Society of Automated Engineers, Transactions*, 1995. Co-author: L. Ponce (student).
- "Advanced Imaging Techniques for Traffic Surveillance and Hazard Detection," *Intellimotion (journal)*, Vol 6 No.2, Partners for Advanced Transit and Highways, University of California, Berkeley, March 1997.
- "Evaluation of Infrared and Millimeter-wave Imaging Technologies Applied to Traffic Management," *Society of Automotive Engineers, Transactions*, and chapter in SAE publication "Journal of Passenger Car Electronic and Electrical Systems", 2001.
- "Computer Vision Detection System for Network Model Validation," *Transportation Research Record 01-3442*, National Research Council, Washington D.C., 2001
- "Technical Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test," *Transportation Research Record*, National Research Council, Washington D.C., March 2004. Co-authors: J. E. Moore II, S. P. Mattingly, M. G. McNally.
- "Methods and Metrics of Evaluation of Evaluation of an Automated Real-Time Driver Warning System," *Transportation Research Record*, No. 05-1423, National Research Council, Washington DC, January 2005.
- "A Study of the Response of Highway Traffic to Dynamic Fog Warning and Speed Advisory Messages," *TRB 06-3086*, *Transportation Research Record*, National Research Council, Washington, DC, Feb 2007.
- "Automated Consensus-based Data Verification in the Caltrans Detector Testbed" *Transportation Research Record*, Vol. 1993, No. 1, pp. 124-130, 2007, National Research Council, Washington DC, January 2007.
- "A Spy Under the Hood: Controlling Risk and Automotive EDR" *Risk Management Magazine*, Vol. 55, Issue: February 01, 2008. Co-author: Peter Thom

Conference Papers and Published Articles

- "Development of a Sodium Borohydride Hydrogen Fuel Storage System for Vehicular Applications," *American Society of Aeronautical Engineers Conference on Future Transportation Fuels*, AIAA Proceedings, 1976.)
- "Electronic Fuel Injection Techniques for Hydrogen Powered I.C. Engines," *Proc. Second World Hydrogen Energy Conference*, Zurich, Switzerland, International Association of Hydrogen Energy, Coral Gables, FL, 1978. Co-author: W.D. VanVorst.
- "Hydrogen Fuel Applications for Urban Transit," *Proc. AIAA Society and Aerospace Technology Workshop*, Los Angeles, California, 1979.
- "Development of a High Speed Injection Valve for Electronic Hydrogen Fuel Injection," *Proc. Third World Hydrogen Energy Conference*, Tokyo, Japan, International Association of Hydrogen Energy, Coral Gables, Florida, September, 1980.

"A Study of Factors Influencing Thermally Induced Backfiring in Hydrogen Fueled Engines, and Methods for Backfire Control," Proc. Intersociety Energy Conversion Engineering Conference, American Society of Mechanical Engineers, Atlanta, GA, July, 1981.

"An Auxiliary Sensor Processor to Provide Real Time Fuel Delivery Feedback for a Microprocessor Based Diesel Engine Controller," SAE International Congress, Detroit, Mich., Feb. 1987. Co-author: D. G. Meyer.

"An Indirect Sensing Technique for Closed-Loop Diesel Fuel Quantity Control," Proc. Society of Automotive Engineers International Congress, Detroit, MI, 1990.

"Sample Rate Selection for Discrete Time Switching Controls", Proc. 11th Triennial World Congress of the the International Federation of Automatic Control, Tallinn, Estonia, USSR. International Assoc. for Mathematics and Computer Simulation and International Federation of Operational Research Societies, Pergamon Press, Aug. 13-17, 1990.

"Computer Image Processing Techniques for Highway Traffic Monitoring," Proc. AMSE Workshop on Computer Applications in Transportation, UC Berkeley, California, 1991. Co-author: E. Sullivan.

"Testing and Feasibility of VIPS for Traffic Detection," Proc. Second International Conference on Applications of Advanced Technologies in Transportation Engineering, Minneapolis, MN, American Society of Civil Engineers, August 18-21, 1991.

"Dynamic Extension of Static Traffic Flow Models for Computer Simulation," Proc. IEEE Pittsburgh Simulation and Modeling Conference, Pittsburgh, PA, May 1992. Co-author: E. Sullivan

"Evaluation of Video Image Processing Systems for Traffic Detection," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 1991.

"Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 1992.

"Video Technologies for Roadway Surveillance and Automated Detection," Proc. Society of Automotive Engineers International Congress, Detroit, January, 1995.

"Economic Analysis of Electric Vehicle Configuration," 20th International Conference on Computers and Industrial Engineering, Kyongjo, Korea, 1996. Co-author: A. Seifoddini.

"Electric Vehicles – Promise and Reality", quoted and contributed several pages on the state of the art of battery electric vehicles to US DOE-sponsored Renewable Energy Institute web site (no longer avail) 1996.

"Assessment of an Automated Driver Warning Systems: CAWS", Presentation and published notes for California Department of Transportation, Stockton, California, June 14, 1998.

"EDSRS: Electronic Diesel Smoke Reduction System," Poster Session for the National Conference on Strategic Technologies, US Department of Energy, Office of Industrial Technology, Washington, DC., Jan 7, 1999.

"Infrared and Millimeter-wave Imaging for Traffic Surveillance and Detection," Proc. Transportation Research Board Annual Meeting, National Research Council, Washington D.C., January, 1999.

"Review and Assessment of Battery Interchange Methods for Electric Vehicles," Proc. SAE Future Car Conference 2000, Society of Automotive Engineers, Washington, DC. January 2000.

"Evaluation of Infrared and Millimeter-wave Imaging Technologies Applied to Traffic Management," Proc. SAE International Congress and Exhibition, Society of Automotive Engineers, Detroit, March 2000.

"Battery Interchange Alternatives to In-Vehicle Charging: Technical, Safety and Economic Considerations," Proc. FISITA 2000 World Automotive Congress, Seoul, Korea, June 2000.

"Lessons Learned from Irvine Integrated Freeway Ramp Metering/Arterial Adaptive Signal Control Field Operational Test," Transportation Research Board Annual Meeting, 01-3354, National Research Council, Washington D.C., Jan 2001. Co-authors: S.P. Mattingly (student), M.G. McNally, J.E. Moore

"Computer Vision Detection System for Network Model Validation," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 2000.

"Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics," Transportation Research Board Annual Meeting, No. 02-3920, National Research Council, Washington DC, January 2002.

"Technical Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, March 2003. Co-authors: J. E. Moore II, S. P. Mattingly, M. G. McNally.

"Methods and Metrics of Evaluation of Evaluation of an Automated Real-Time Driver Warning System," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, March 2004.

"A Study of the Response of Highway Traffic to Dynamic Fog Warning and Speed Advisory Messages," Proc. Transportation Research Board Annual Meeting, National Research Council, Washington DC, Jan 2006.

"A Data Fusion Approach to Automated Vehicle Detector Testing" IEEE Digital Signal Processing and DSP in Education Conference, Teton, WY, Sept 2006.

"Automated Consensus-based Data Verification in the Caltrans Detector Testbed," Proc. 2007 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2006.

- "Global Warming: Problems and Solutions, An Engineering Approach", Invited Published Presentation, Focus the Nation, National Academic Initiative for Global Awareness, Jan 31, 2008. Co-authors: Yarrow Nelson, Linda Vanasupa.
- "Adaptive Automatic Ground Truth Generation for Testing of Vehicle Detectors", 2009 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2009.
- "Teaching Sustainability in Cal Poly Electrical and Computer Engineering Programs", Presentation at UC/CSU Conference on Sustainability in Curricula, UC Santa Barbara, June 22, 2009.
- "Retention, Promotion and Tenure Policies in the College of Engineering, California Polytechnic State University, San Luis Obispo", Televised presentation and proceedings publication, International Engineering Education Symposium, Seoul National Technical University, S. Korea, 2009. Co-author: M. L. Noori
- "A Comparison of Real-time and Short-term Aggregated Metrics of Potential Accident Risk and Severity", Published via Digital Commons, California Polytechnic State University, San Luis Obispo, <http://digitalcommons.calpoly.edu> August 2011.
- "Traffic Ground Truth Estimation using a Multi-Sensor Consensus Filter", accepted for publication and presentation at 2011 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2012.
- "Automotive Technologies for a Sustainable Future: Alternative Fuel Engineering Education with Emphasis on DME and Methanol as Transition Fuels," Fifth International DME Conference, Ann Arbor MI, International DME Association, London, England, April 2013.
- "The Cal Poly Rapid Battery Exchange Project: Automated Battery Exchange as an Alternative to Fast-Charging of Electric Vehicles." IEEE Power and Energy Conference, California Polytechnic State University, San Luis Obispo, 2013.

Published Research Reports

- "Development of a Multi-fuel Vehicle using Electronic Fuel Injection," Final Project Report, Regional Technology Advancement grant, US Department of Energy, Region 8, September, 1981.
- "Acceleration of Automobiles Fueled by Natural Gas and Gasoline: A Comparison", Report to the National Science Foundation, Published by Denver Urban Observatory and City of Denver, University of Denver Research Institute, 1982.
- "Evaluation of Image Processing Technology for Application on Highway Operations," Final Report to the California Department of Transportation, TR 91-2, June 1991.
- "Noise-Optimal Control of HEMT LNA's for Compensation of Temperature Deviations," The Telecommunications and Data Acquisition Progress Report, 42-109, NASA JPL/Caltech, May 1992.
Co-authors: J.J. Bautista, P.A. Willis.
- "Evaluation of Closed-Circuit Television Technology for Application in Highway Operations," Final Project Report, Caltrans Contract 51J932, Caltrans Division of New Technology, San Luis Obispo, CA., 1992.
- "Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," Report to the California Dept. of Transportation, Cal Poly Transportation Electronics Laboratory, 1992.
- "Feasibility Study: Rapid Battery Interchange for Electric Vehicles," published study commissioned by Pacific Gas and Electric Co., Transportation Electronics Laboratory, Cal Poly EL/EE Dept. PR93-1, 1993.
- "Rapid Battery Interchange Electric Transit Bus Demonstration, Phase I," final project report (published) to Pacific Gas and Electric Co. Transportation Electronics Laboratory, Cal Poly EE Dept. PR95-5, 1995.
- "Design and Deployment Planning (Phase II), Rapid Battery Interchange Electric Transit Bus" Project report published by California Energy Commission. Cal Poly Transportation Electronics Laboratory PR96-1, 1996.
- "Design Considerations for Automated Electric Vehicle Battery Interchange," Transportation Electronics Laboratory, California Polytechnic State University, SLO, Report published by sponsor Pacific Gas and Electric Company, No. TEL4881a97, January 1997.
- "City of Anaheim / Caltrans / FHWA Advanced Traffic Control System Field Operational Test Evaluation Task C, Video Detection System," final project report, US Dept. of Transportation FHWA and Caltrans agreement No. SA 1272-18286, Partners for Advanced Transit and Highways, UC Berkeley, April 18, 1998.
- "Video-based Vehicle Signature Analysis and Tracking, Phase 1: Verification of Concept and Preliminary Testing," PATH publication based on final project report, Caltrans MOU 262, Cal Poly Transportation Electronics Laboratory Report No. TEL5881a97. Partners for Advanced Transit and Highways, University of California, Berkeley, January 10, 1998.
- "Evaluation of Caltrans District 10 Automated Warning System, First Year Report," Cal Poly Transportation Electronics Laboratory Document TEL5881B98R, published by Partners for Advanced Transit and Highways (PATH), University of California, Berkeley, July 6, 1998.

"Video-based Vehicle Signature Analysis and Tracking, Phase 2: Algorithm Development and Field Testing," final project report, Partners for Advanced Transit and Highways, University of California, Berkeley, 1999.

"Evaluation of Caltrans District 10 Automated Warning System, Second Year Report," Cal Poly Transportation Electronics Laboratory Document TEL5881B99, Published by Partners for Advanced Transit and Highways (PATH), Univ of California, Berkeley, March 4, 1999.

"An Indirect Sensing Technique for Diesel Fuel Quantity Control," Final Report, U.S. Department of Energy, ERIP Project 583 Contract No. DE-FG01-94CE15583 May, 1999.

"Evaluation of SCOOT Performance in the Anaheim Advanced Traffic Control System Field Operational Test," Intellimotion, Published by Partners for Advanced Transit and Highways, University of California, Berkeley, November 1999. Co-authors: J. Moore, R. Jayakrishnan, M. McNally

"Evaluation of Infrared and Millimeter-wave Imaging Technologies," Project Final Report, Partners for Advanced Transportation and Highways, Feb. 2001.

"Documentation of the Irvine Integrated Corridor Freeway Ramp Metering and Arterial Adaptive Control Field Operational Test," California Partnership for Advanced Transit and Highways (PATH) Research Report UCB-ITS-PRR-2001-02, Report for MOU RTA 65V313-5, California Department of Transportation, Office of New Technology, Jan. 2001. Co-authors: M. McNally and J.E. Moore II.

"V2SAT Operators Manual" published project deliverable under University of California Contract No. T01-65A0071-4122-L, California Department of Transportation, August 2002, with major addendum 2003.

"Calnet/SIBS Bill Analyzer Operators Manual", deliverable under contract to Caltrans Division of Research and Innovation Contract, March 2004.

"Caltrans Detector Testbed / V2SAT Technical Report, 2004", deliverable under University of California Purchase Order 0031 P 00 681648, California Department of Transportation, August 2004.

"Instrumentation and Evaluation of District 10 Caltrans Automated Warning System (CAWS)" Volumes 1-5, Document Nos. L-D10-FR-01 through -05, California Office of Traffic Safety (OTS) Grant RS0034, Caltrans Contract 51A0050, distributed by California Office of Traffic Safety, Sacramento, CA., Sept. 2005.

"Video Vehicle Detector Verification System Operators Manual," Project deliverable to California Dept. of Transportation and Univ. of California, Berkeley under Task Order 5327, 2006, and supplement 2007.

"Caltrans Traffic Detection Plan", Published report for the California Dept of Transportation under contract to Cambridge Systemetrics, Washington DC. 2008. Co-authors: Daniel Krechmer, Lawrence Klein.

"My Methanol Motorcycle", web site on my self-designed multi-fuel motorcycle, 1998-present.

"What Your Car Knows About You that You Don't Know – Data Retention in Automotive Electronics". Invited presentation at over ten academic, professional and public forums and events, 2007-10.

"Electric Vehicle Safety", online tutorial at <http://evec.calpoly.edu/ElectricVehicleSafety.pdf>, sponsored by Cal Poly Electric Vehicle Engineering Club, November 2011.

"Methanol Fuel Safety – a Practical Guide", Available online through the Cal Poly State University Digital Commons, http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1345&context=eeng_fac, 2013.

Unpublished Project Reports (list on request)

Author or co-author of over 150 unpublished research reports for DOE, NSF, DOT/ FHWA, Caltrans, California Office of Traffic Safety, Hughes Electronics, UC Berkeley, UC Irvine, Raytheon, Northrup Grumman, and other corporate sponsors, 1979-present.

Proposals Submitted

Author, co-author or major contributor to over 110 research proposals to state, federal and industrial sponsors. Approximately 50% funding success rate. List on request from Cal Poly Sponsored Programs Office.

Journal, Conference and Proposal Reviewer (lists of individual titles on request)

California Partner for Advanced Transportation and Highways, annual reviewer, 1991-present.

Prentice Hall, Academic Publishing Division, contract textbook review, 1995-2000.

Society of Automotive Engineers World Congress and Transactions, annual reviewer, 1995-2003.

Society of Automotive Engineers, Transactions on Automotive Electronics, Associate Editor, 2009-present.

Transportation Research Board, National Academies. Reviewer for committees: Intelligent Transportation Systems, Visibility, Motorcycles and Vulnerable Vehicles, and User Information Systems, 1999-present.

IEEE Transaction on Intelligent Transportation Systems, annual reviewer, 2001-present.

Intelligent Transportation Journal, Pergamon Press, 1998, 99, 2003.

METRANS (Los Angeles Metropolitan Transit), annual reviewer, 2002, 04, 05.

Cal Poly C3RP proposal reviewer, 2005, 2006.

US Patents

"Consensus-based Vehicle Detector Verification System." issued 2012, Assignee Cal Poly Corp.

"Geometric Tactile Information Delivery System for the Visually Impaired." issued 2013, Assignee Cal Poly Corp.

Other Relevant Qualifications

Caltrans-appointed evaluator for HOV-lane enforcement system manufactured by Vehicle Occupancy Detection Systems, (7/13-6/14)

Operator of Cal Poly Alternative Fuel Facility dispensing methanol, DME and SVO (2005-).

Certified Crash Data Recorder (CDR) Analyst, training by Vetronix Div of Robert Bosch (6/06).

Owner/builder of two battery-electric vehicles, used for transportation and education (1998-).

Commute daily with self-constructed methanol-fueled ultra-low-emission vehicle (1988-).

Designer/installer of 4 residential and one commercial solar PV and thermal systems (1988/14).

Expert Witness Experience

Expert witness under three-year contract to the California Department of Transportation. Forensic electronics in highway applications, 1999-2002.

Federal evaluator for FHWA Field Operational Test of Advanced Integrated Traffic Management System for City of Irvine, California, 1995-98.

Federal evaluator for FHWA Field Operational Test of Computer Vision based Intersection Traffic Detection System for City of Anaheim, California, 1995-98.

Evaluator/operator of Caltrans Detector Testbed, Irvine, CA. California Department of Transportation Division of Innovation and Research, for Evaluation of Intersection Video Traffic Detection Systems, 2004-2011.

Shackelford v United Stereo (expert for defendant). Fatality crash allegedly related to cruise control. Litigation against client dropped following my inspection report, 2005.

Savagian v Advantage Ford, et. al. (expert for defendant). Multiple fatality crash allegedly related to vehicle stability enhancement system. Settled, for defendant, 2006-07.

Backe v Mercendes of Nanuet, Massachusetts and Daimler Chrysler Corp. (expert for defendant). Single fatality crash allegedly related to engine management electronics failure. Litigation against client dropped following my inspection, 2007.

Misc. analysis, vehicle inspections and report preparation on multiple cases as subcontractor to Peter Thom and Associates, Orinda, CA., 1990-2008.

Lyon v. Hybrid Technologies Inc./EVii (expert for plaintiff). One of the first electric vehicle Lemon-Law cases litigated in California. Proved multiple defects and FMVSS violations by manufacturer. Settled in full following inspection report, 2009.

Romero v Stowasser et. al. (expert for defendant, engaged by Murchison Cumming LLP). Automotive electrical system failure and resultant vehicle disablement. Lawsuit dropped following my inspection report, 2010.

Combustion Controls Inc. v. Harley-Davidson Corp., Milwaukee, WI. (expert for defendant). Patent infringement case related to electronic fuel injection. Token settlement paid by defendant. 2010 - 2011.

HTI LLC and Network Fleet Inc v. DriveOK, Webtech Wireless Inc, Procon Inc., and Xirgo Technologies LLC. (expert for defendants). Patent infringement related to vehicular wireless technologies. Case settled prior to significant action, 2011.

Vehicle Occupancy Detection Co. USA / Laser Optical Engineering Ltd England. Independent evaluation of HOV lane enforcement detection system. Study/report completed. June 2012 – January 2014.

Zavalla v Randell Equipment & Danfoss Power Solutions (expert for defendant, engaged by Youngerman McNutt LLP), injury accident, electrical system in specialized vehicle. 2013-15, settled favorably 2015.

UUSI/Nartron v. Brose GmbH and Robert Bosch GmbH (expert for defendants, engaged by Kirkland Ellis LLP), patent infringement case related to automotive electric window closure safety technology. Our clients sought IPR invalidation of two patents. 2013-15. Case resolved July 2015 with all contested claims invalidated.

Campana v. Rally Auto Group and State of California (expert for defendants, engaged by Murchison Cumming LLP), automotive fatality case. Found tampered airbag and SRS. Trial testimony. Client exonerated on tampering charges, but settled due to failure to disclose vehicle history. 2013-2016.

Lee/Baldwin v. Volkswagen Group of America, Inc. et. al. (expert for defendants, engaged by Murchison Cumming LLP) – failure of airbag to deploy. Litigation dropped following my inspection report, Jan 2015.

Fountain v. Hyundai Motor Company (expert for plaintiff, engaged by Taylor and English LLP.) Wrongful death, alleged defects of Electronic Power Steering system. Litigation dropped upon my recommendation following vehicle inspection. April 2015-Dec 2016.

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United States Patent [19]
Suzuki et al.

[11] **Patent Number:** **6,006,717**
[45] **Date of Patent:** **Dec. 28, 1999**

[54] **DIRECT-INJECTION SPARK-IGNITION TYPE ENGINE CONTROL APPARATUS**

[75] Inventors: **Keisuke Suzuki**, Kanagawa; **Yuki Nakajima**; **Nobutaka Takahashi**, both of Yokohama, all of Japan

[73] Assignee: **Nissan Motor Co., Ltd.**, Yokohama, Japan

[21] Appl. No.: **09/104,359**

[22] Filed: **Jun. 25, 1998**

[30] **Foreign Application Priority Data**
Jun. 25, 1997 [JP] Japan 9-168419

[51] **Int. Cl.⁶** **F02B 17/00**; F02D 43/04

[52] **U.S. Cl.** **123/295**; 123/406.45; 123/430

[58] **Field of Search** 123/295, 299, 123/300, 305, 406.45, 430

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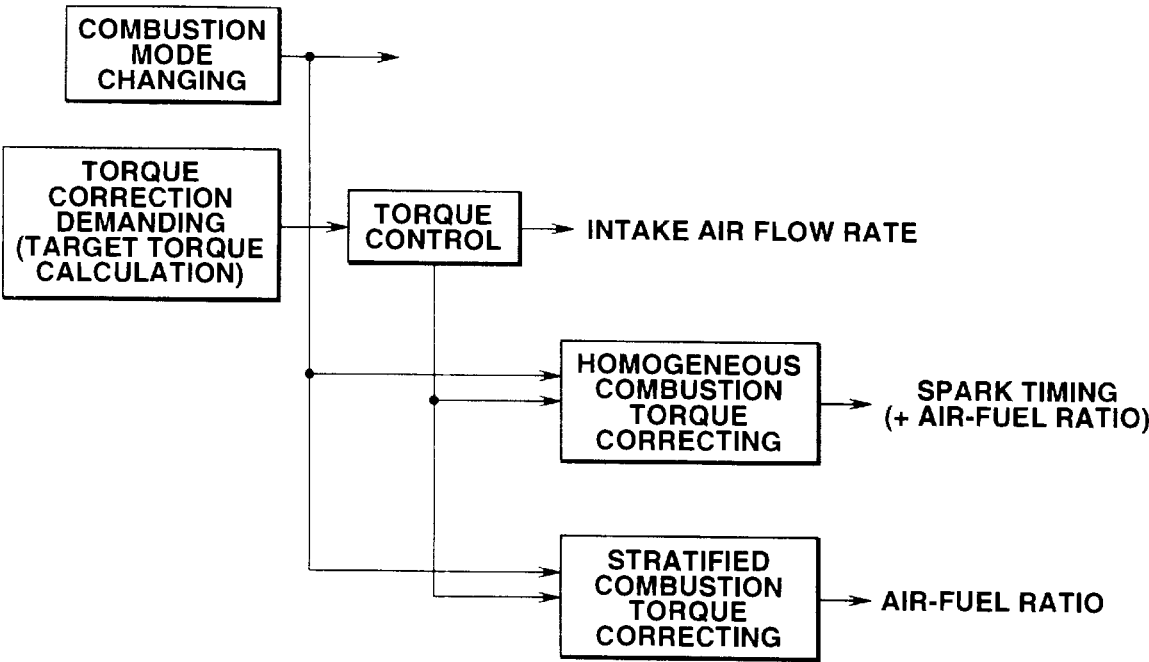
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Primary Examiner—Tony M. Argenbright
Attorney, Agent, or Firm—Foley & Lardner

[57] **ABSTRACT**

The invention provides torque correction during both homogeneous combustion and stratified combustion. Torque correction is made in response to a torque correction demand (produced when, for example, a gear shift is effected, the air conditioner is turned on, or fuel cut recovery is effected) by correcting the spark timing (or the spark timing and air-fuel ratio) during homogeneous combustion and by correcting the air-fuel ratio during stratified combustion.

10 Claims, 25 Drawing Sheets



VW EX1005
U.S. Patent No. 6,581,565

FIG.1(A)

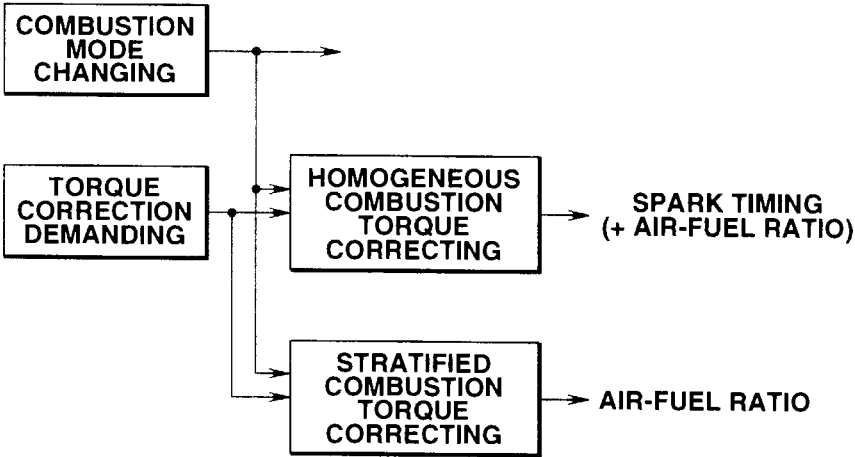


FIG.1(B)

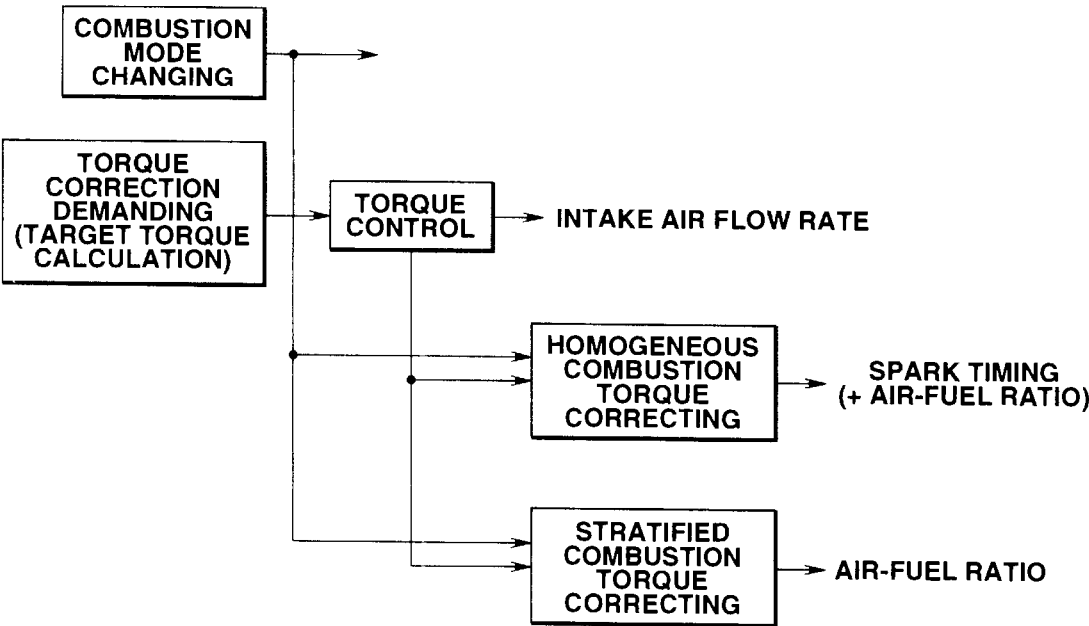


FIG.2

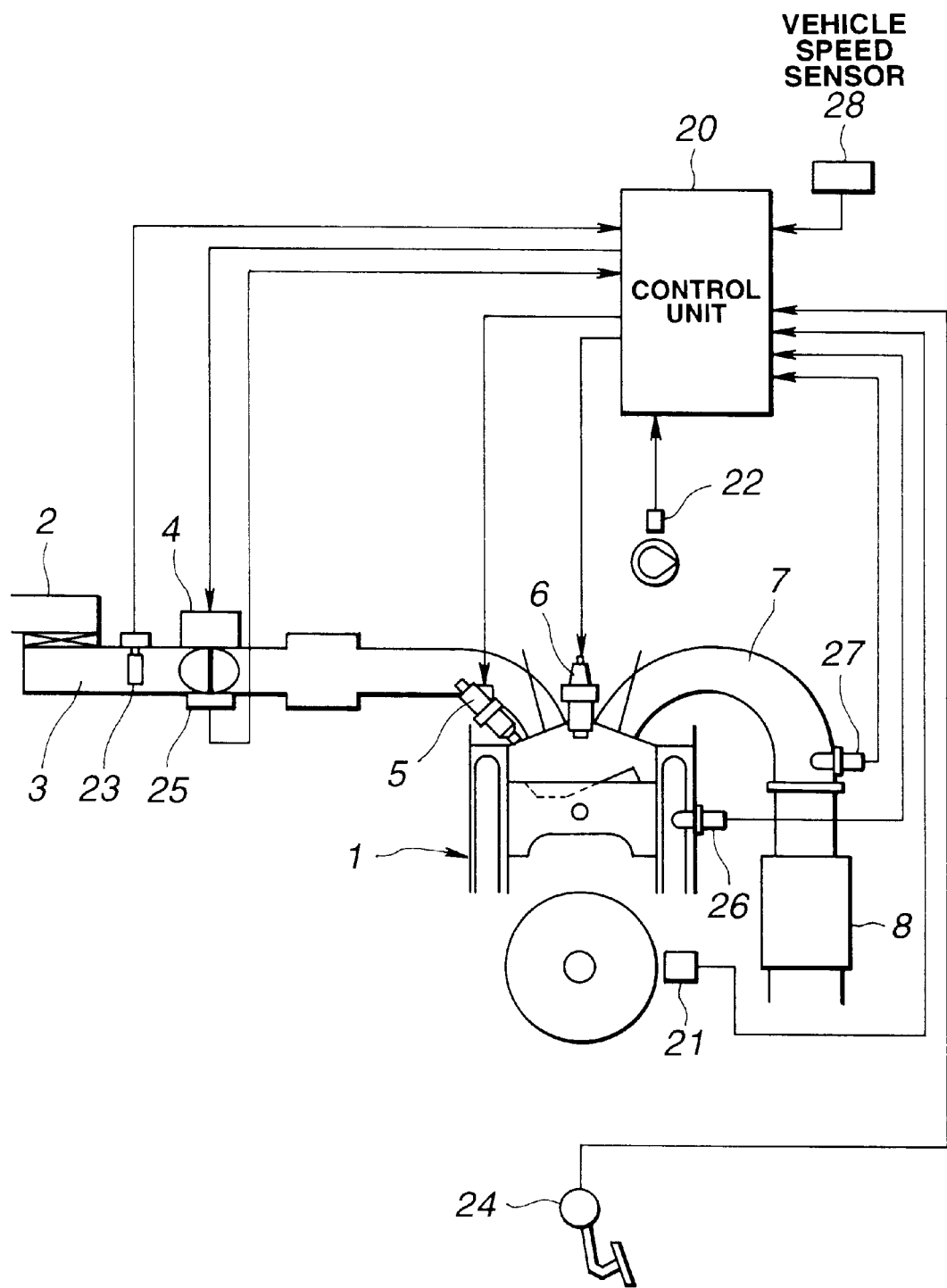


FIG.3

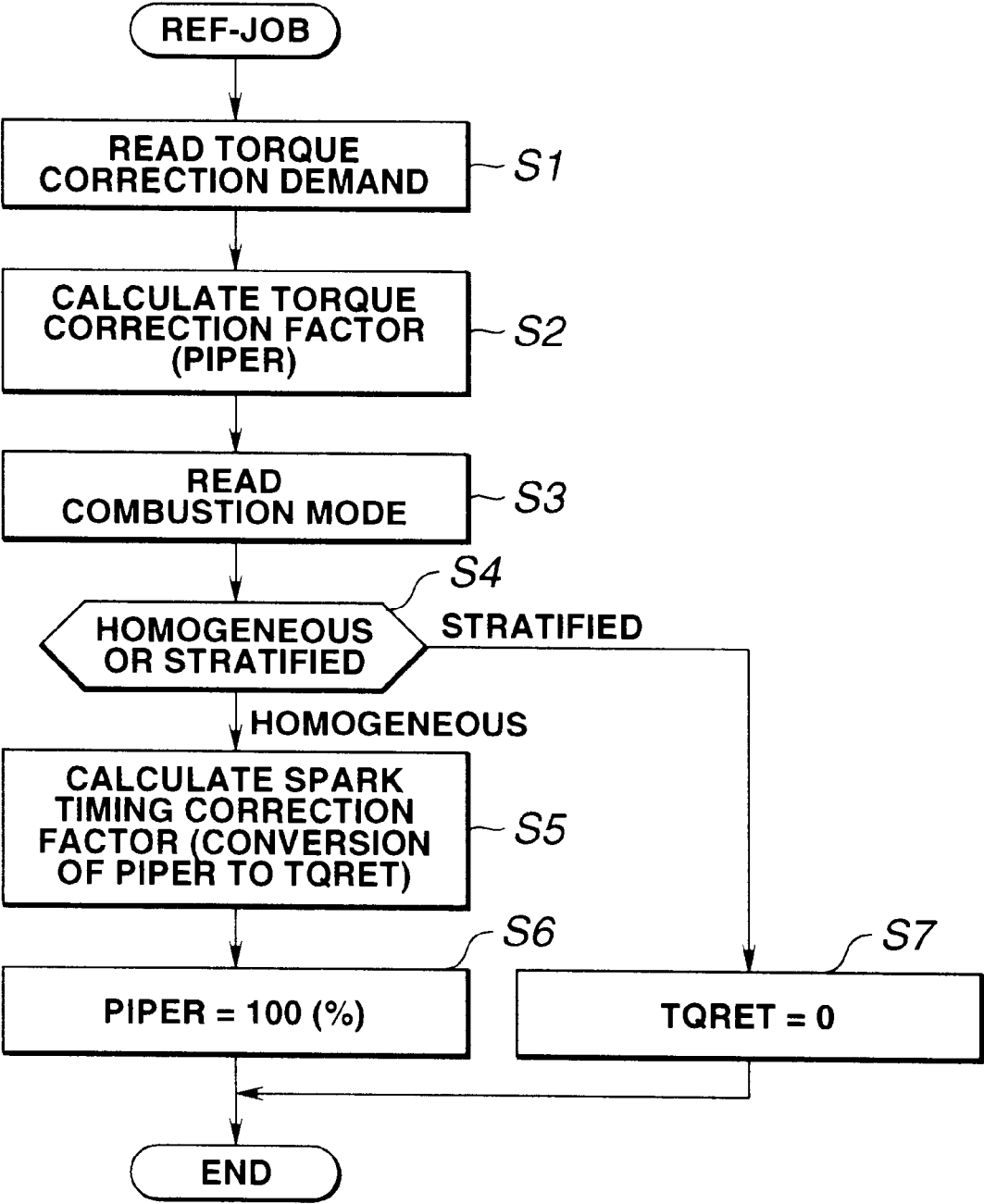


FIG. 4

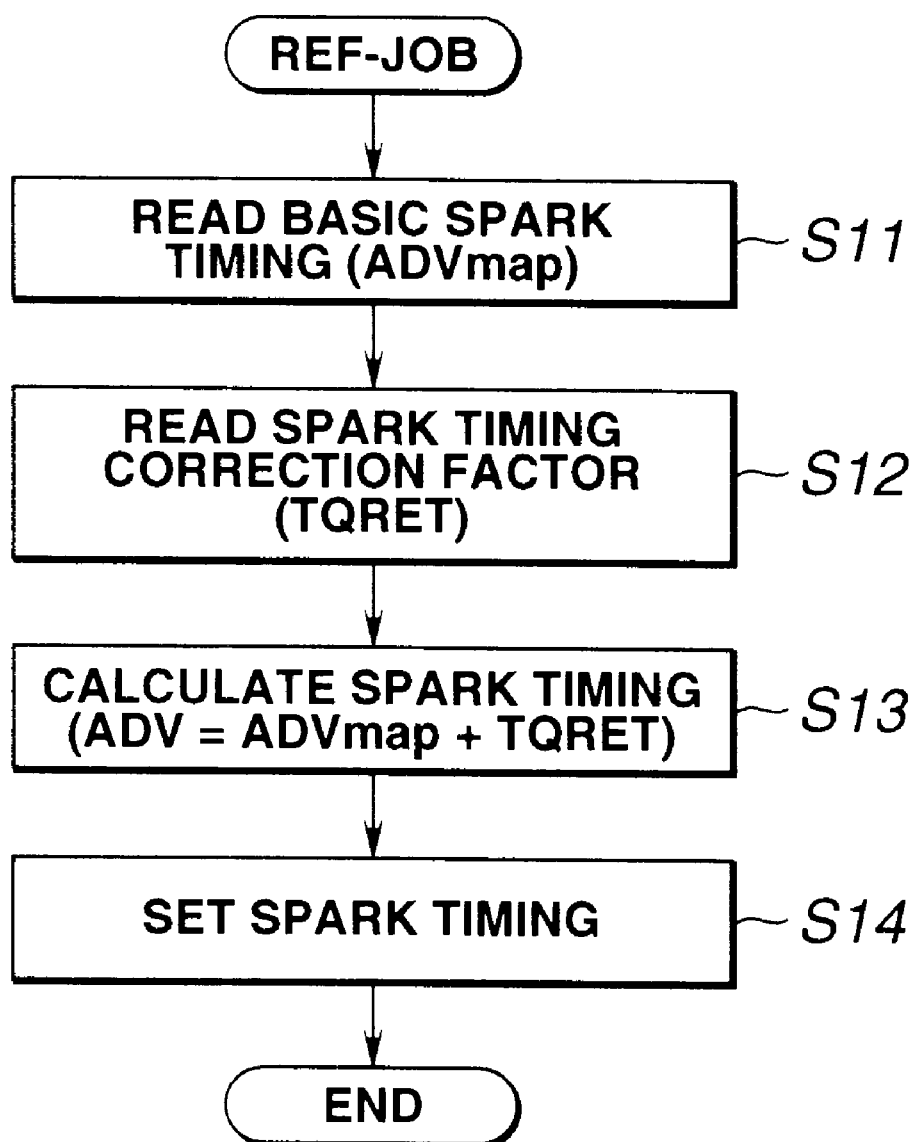


FIG.5

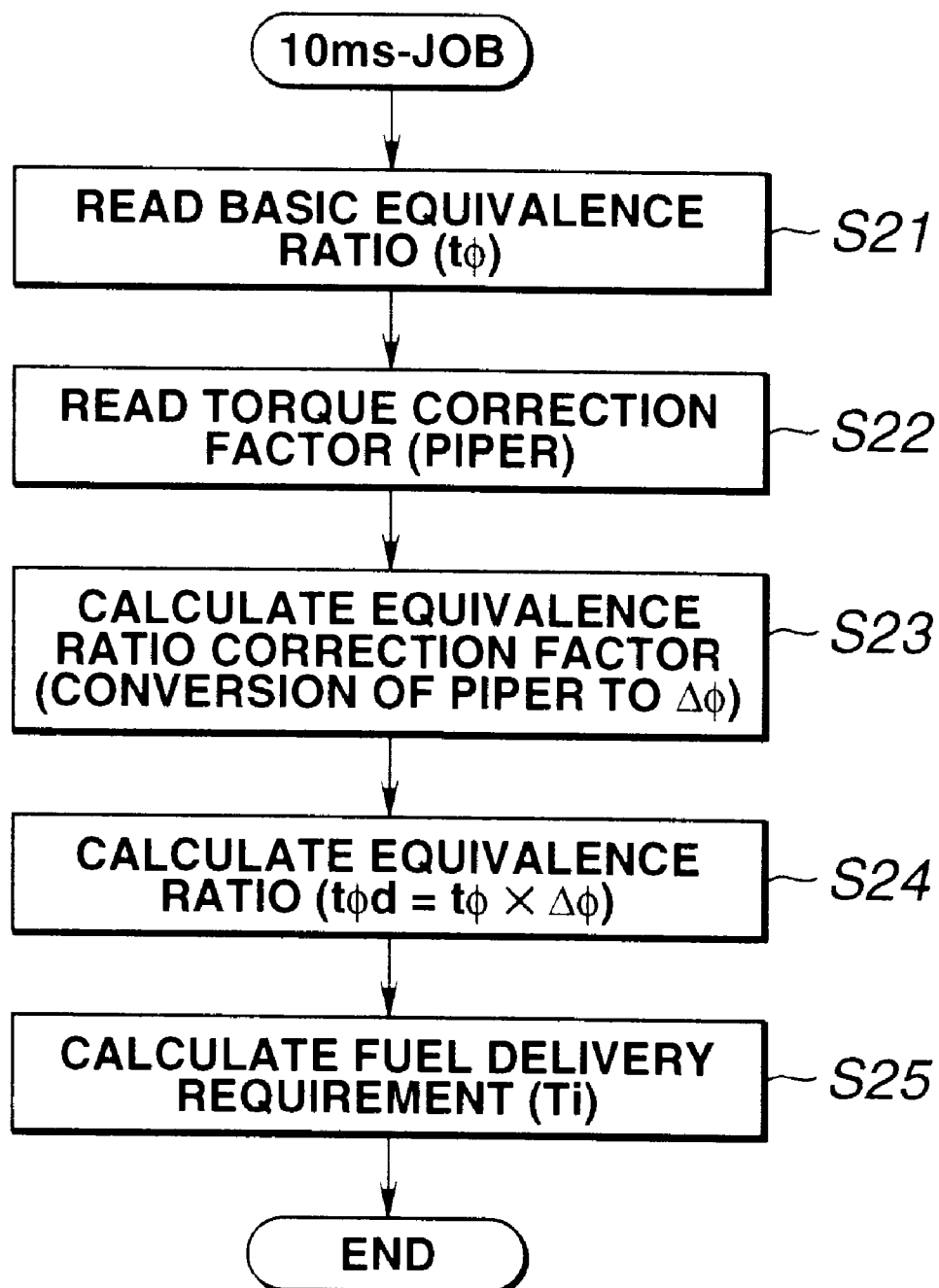


FIG.6

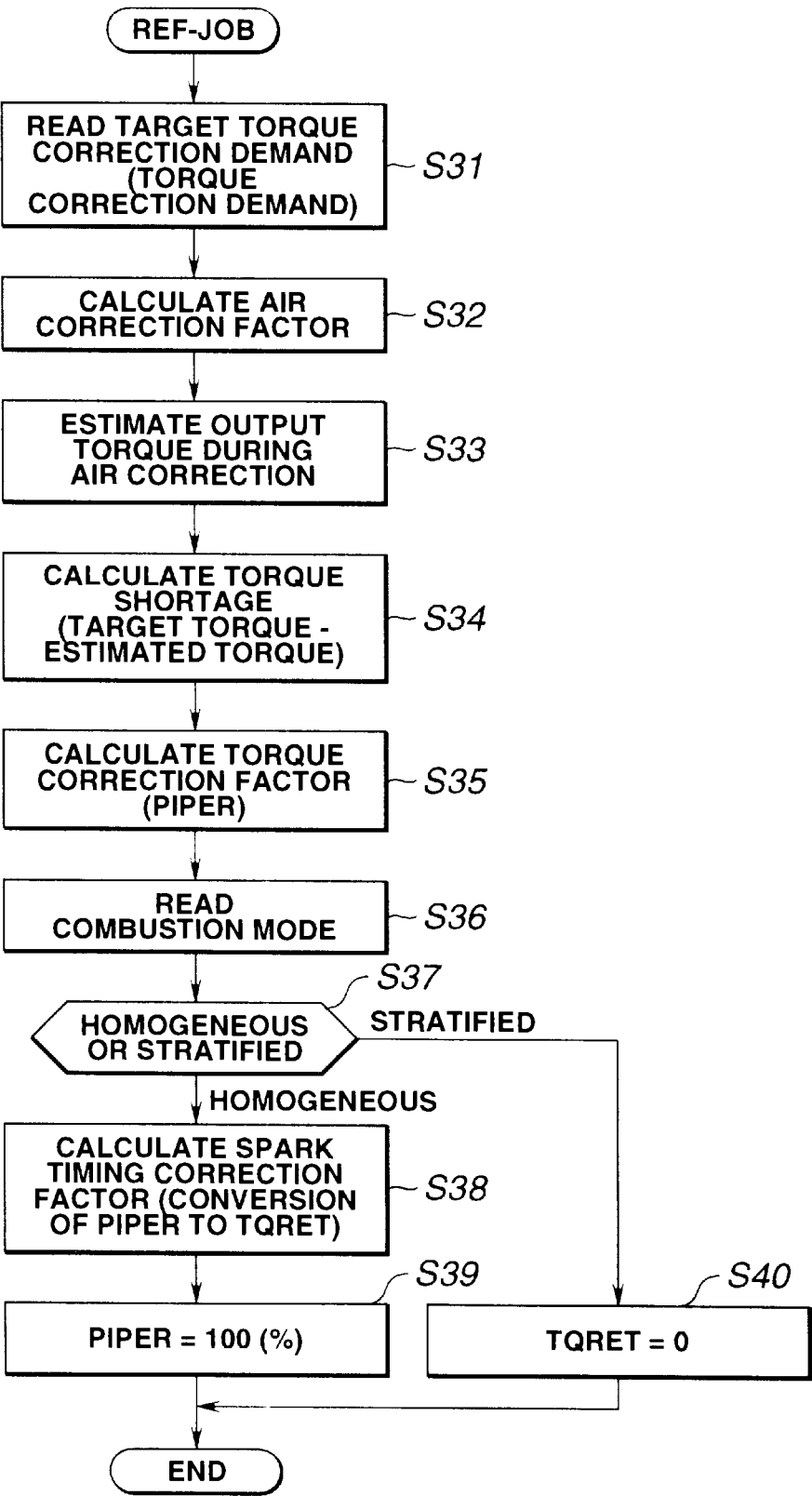


FIG. 7

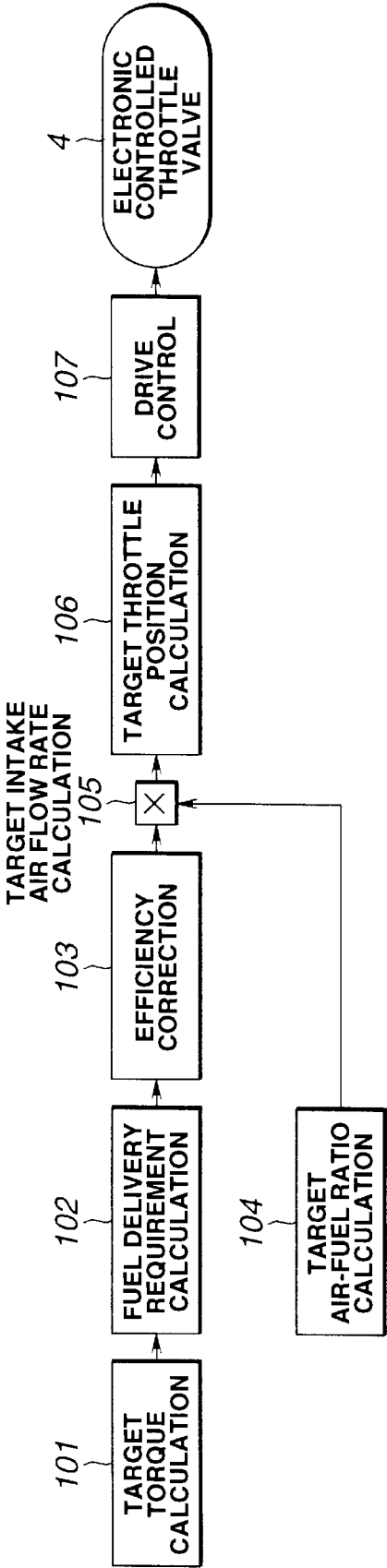


FIG.8

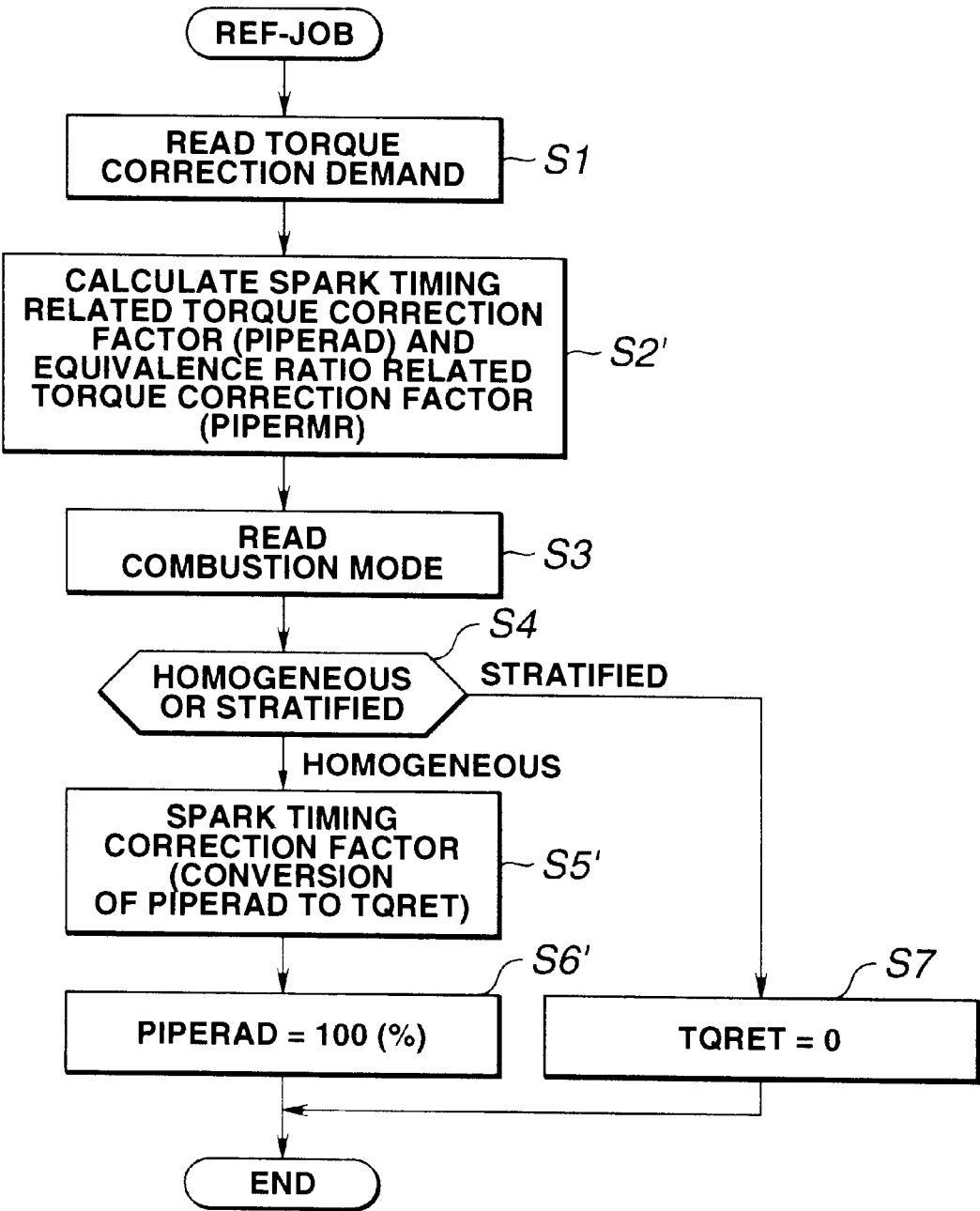


FIG. 9

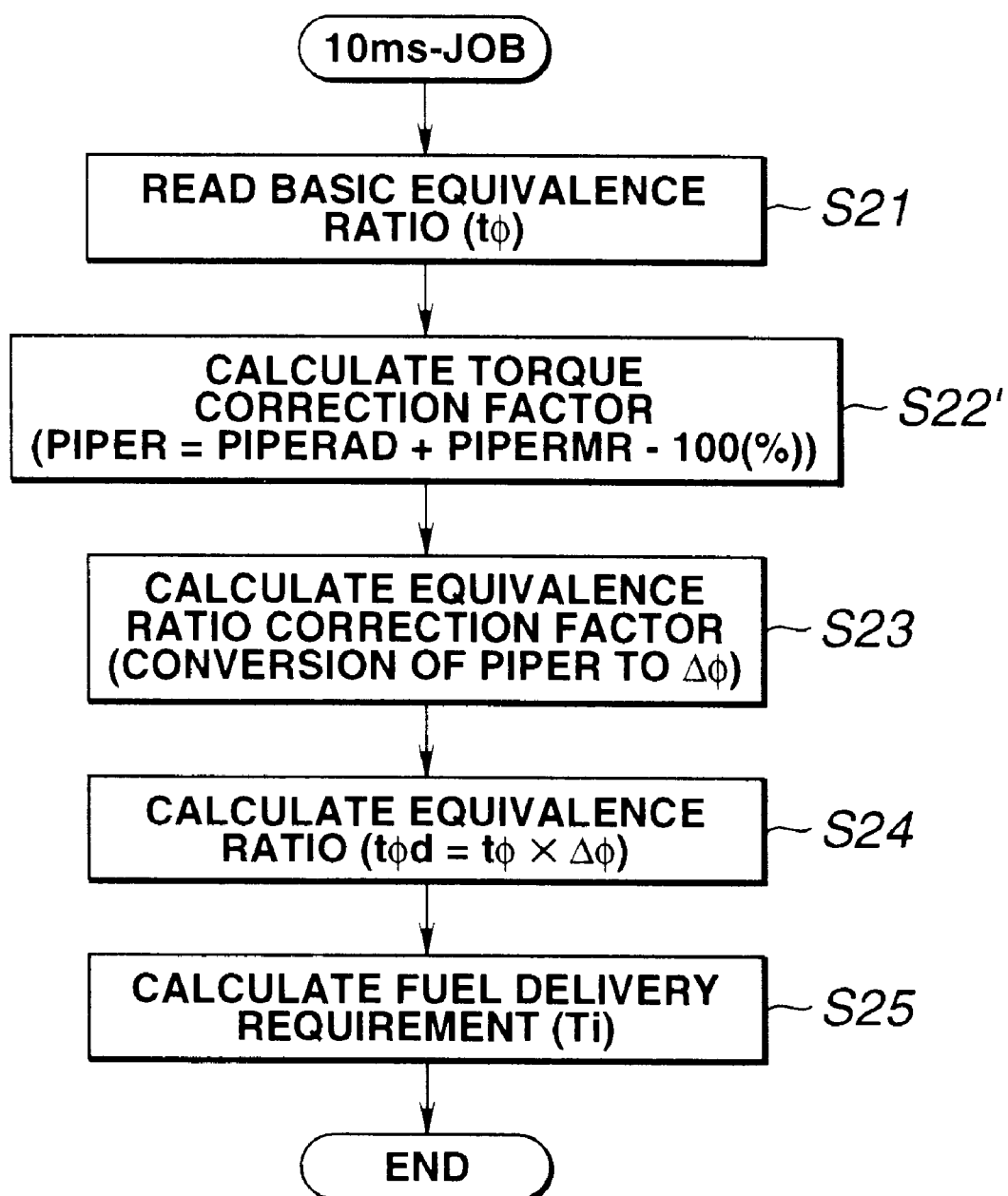


FIG.10

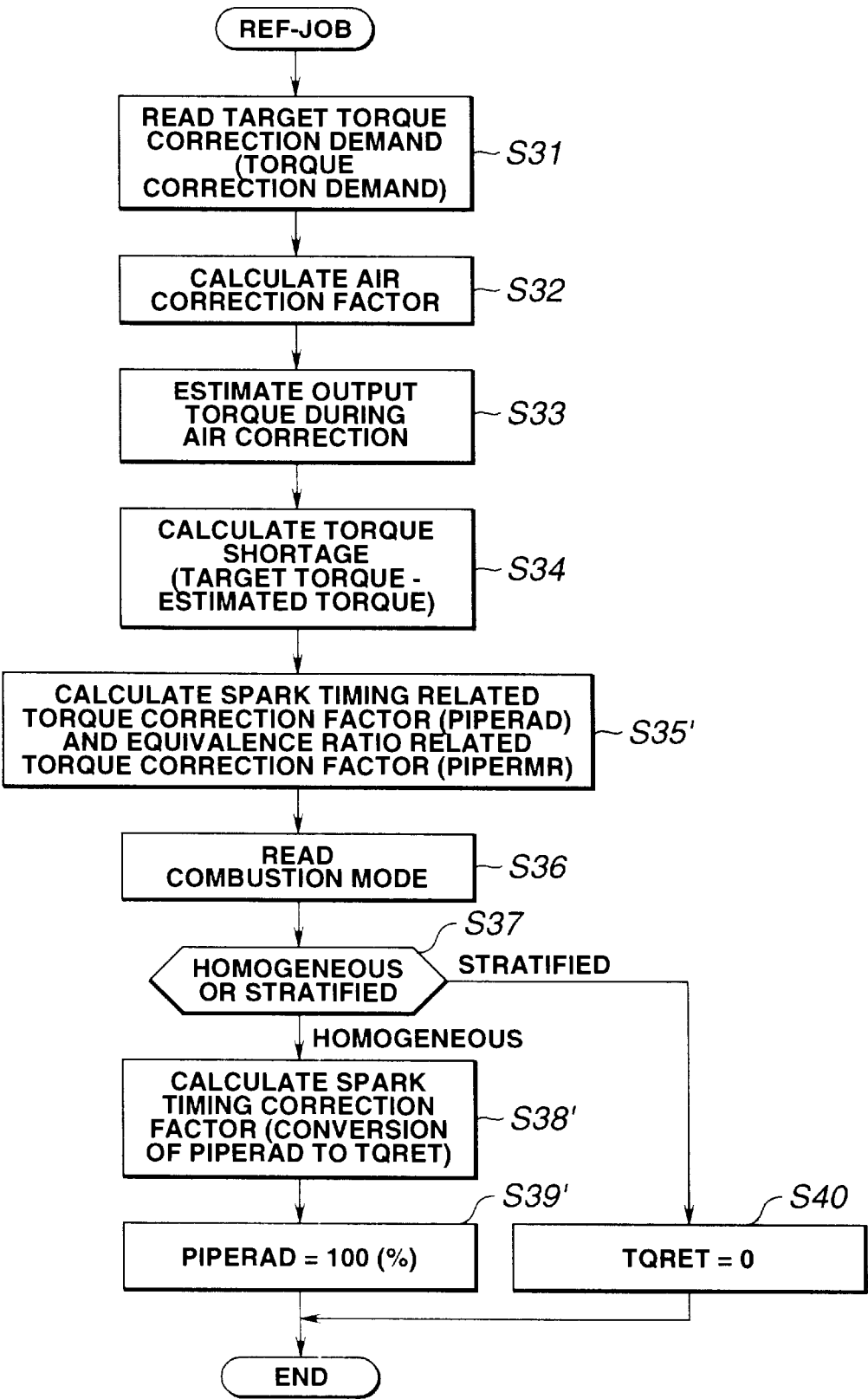


FIG.11

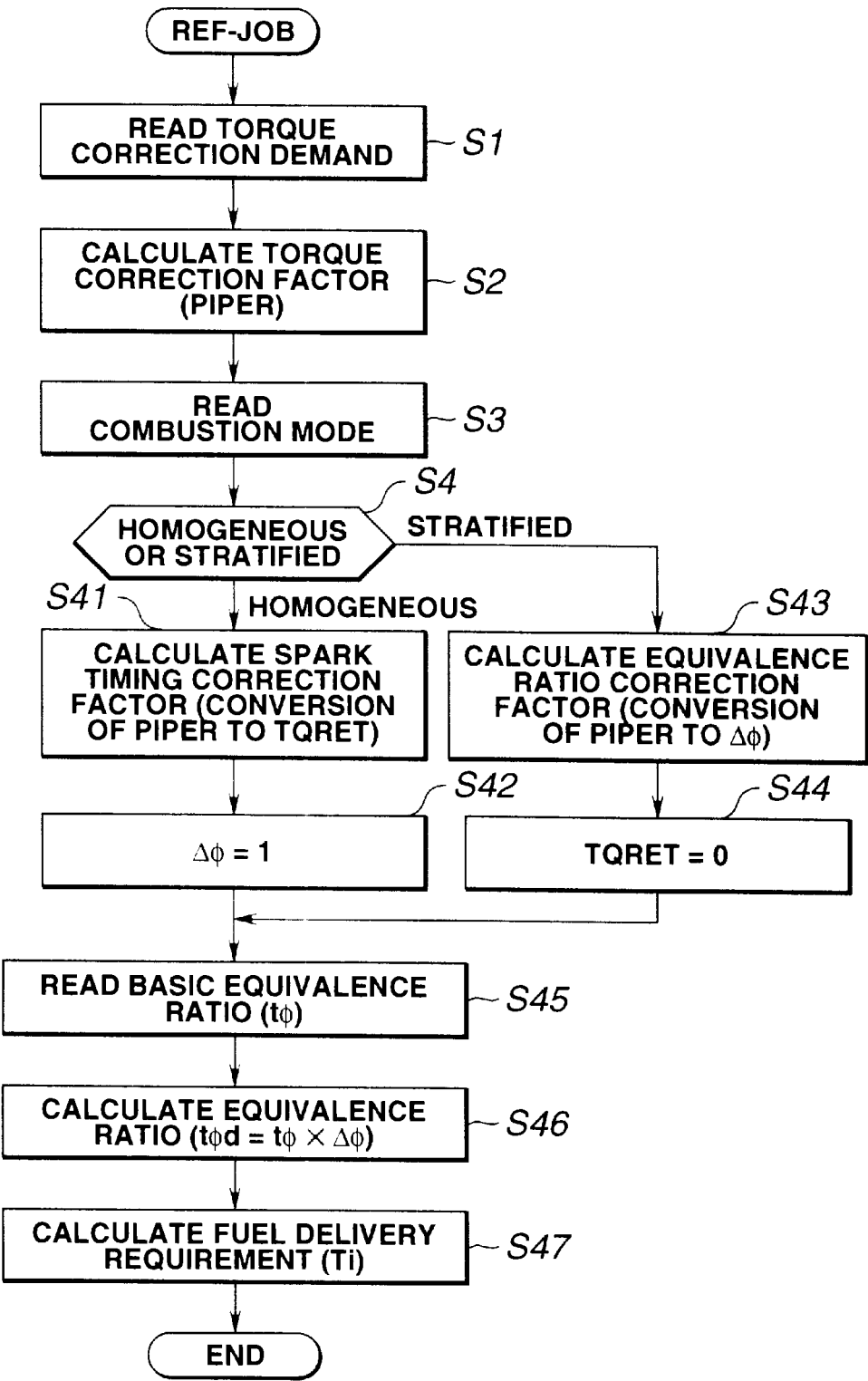


FIG.12

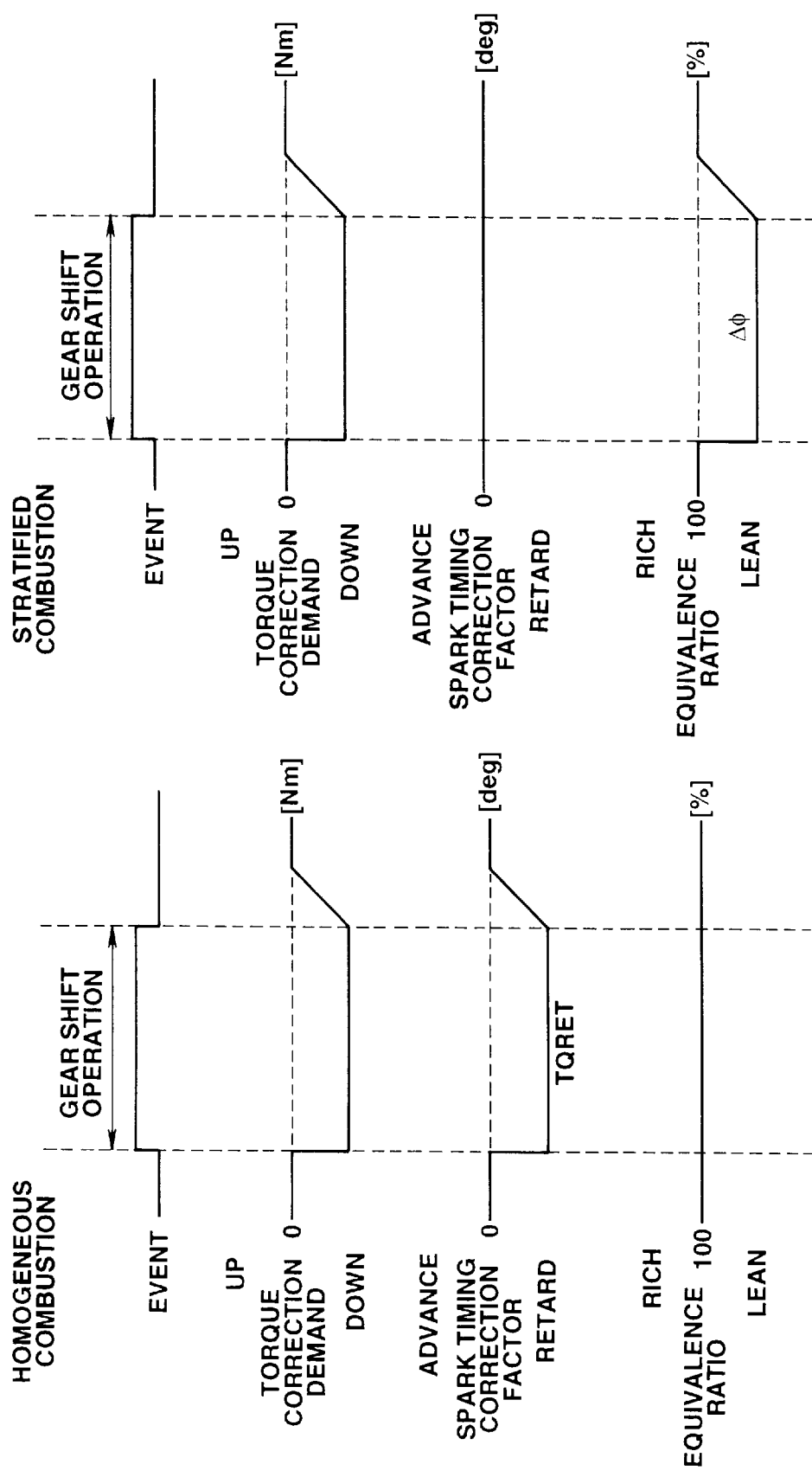


FIG.13

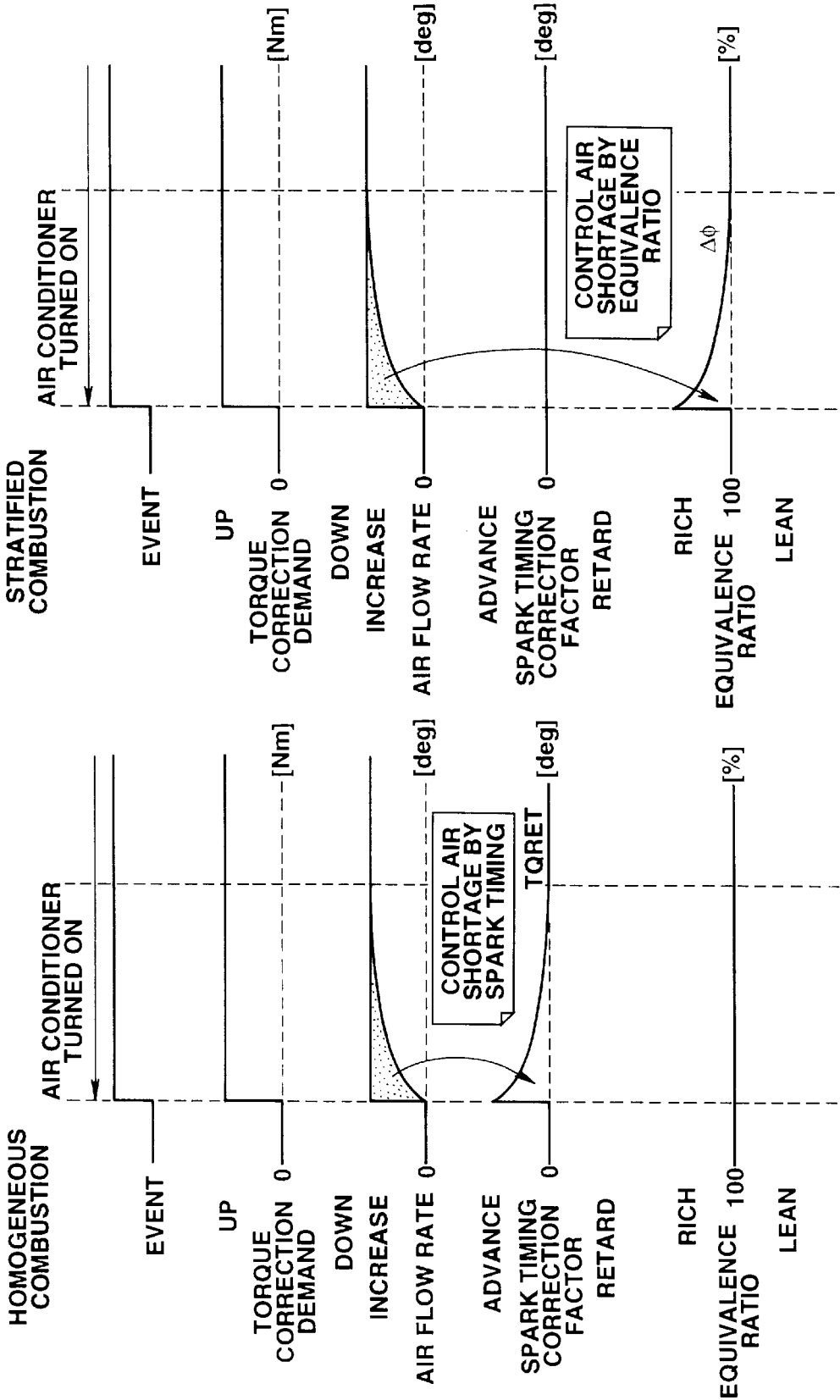


FIG.14

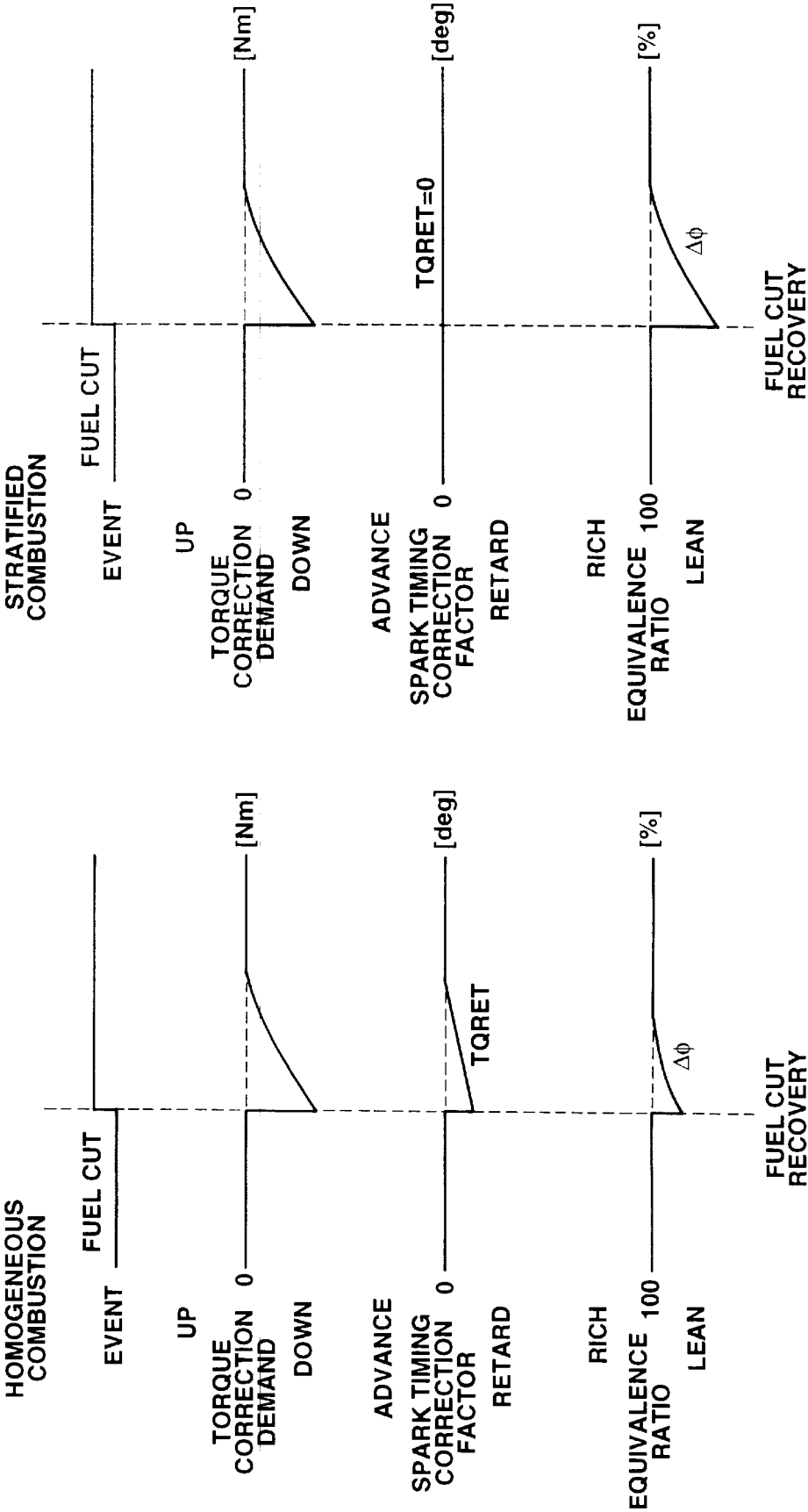


FIG.15

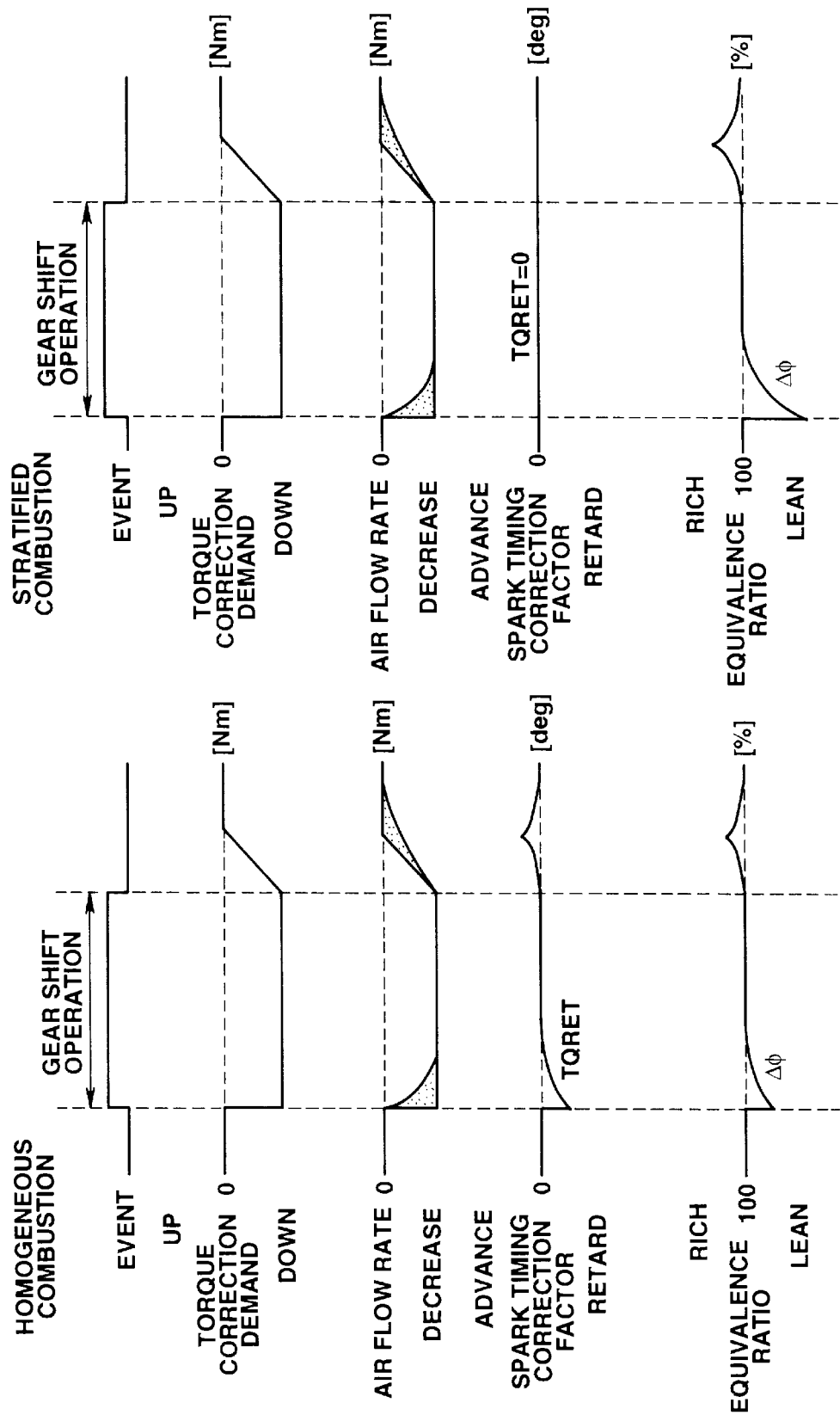


FIG.16

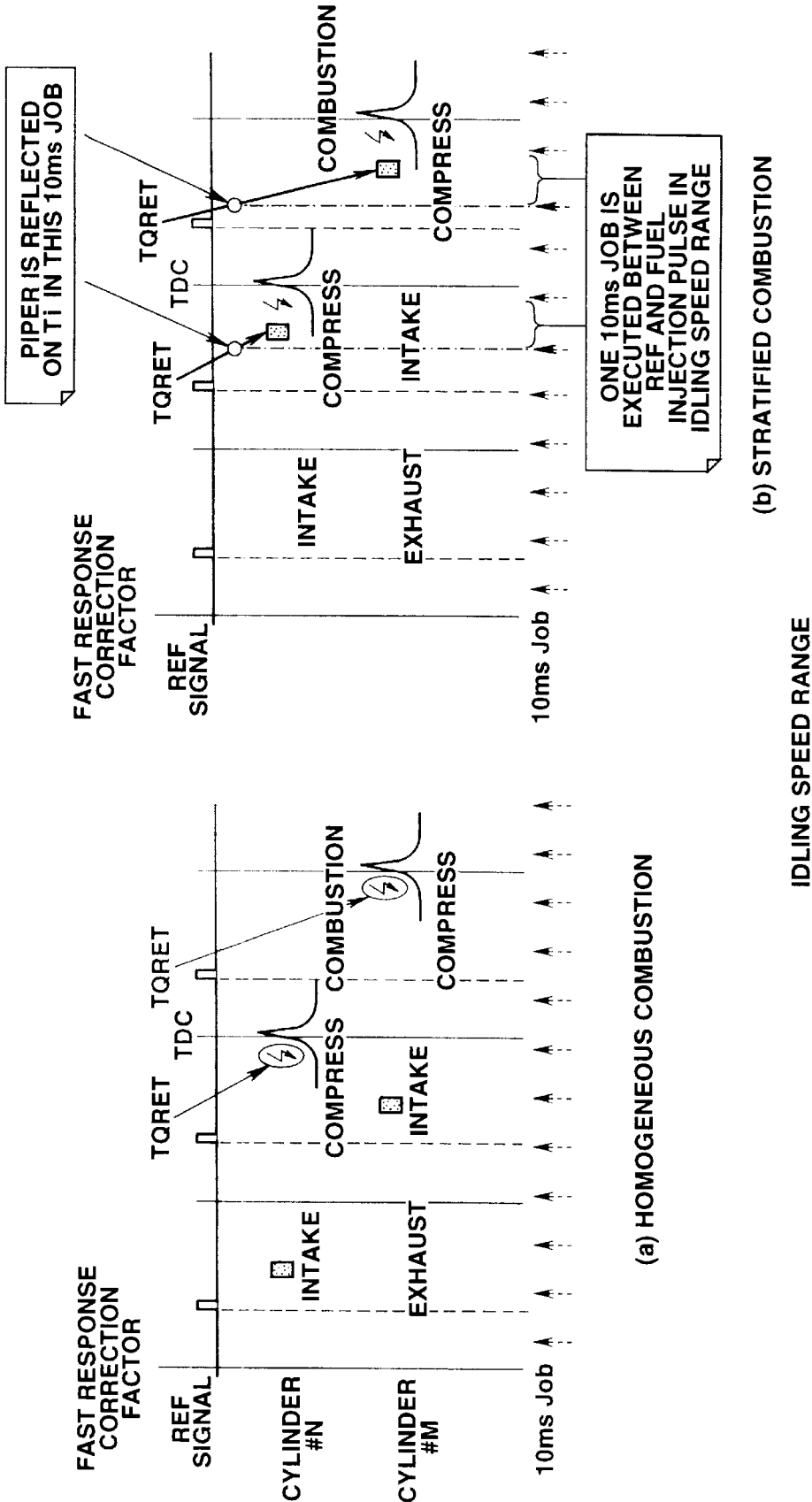


FIG.17

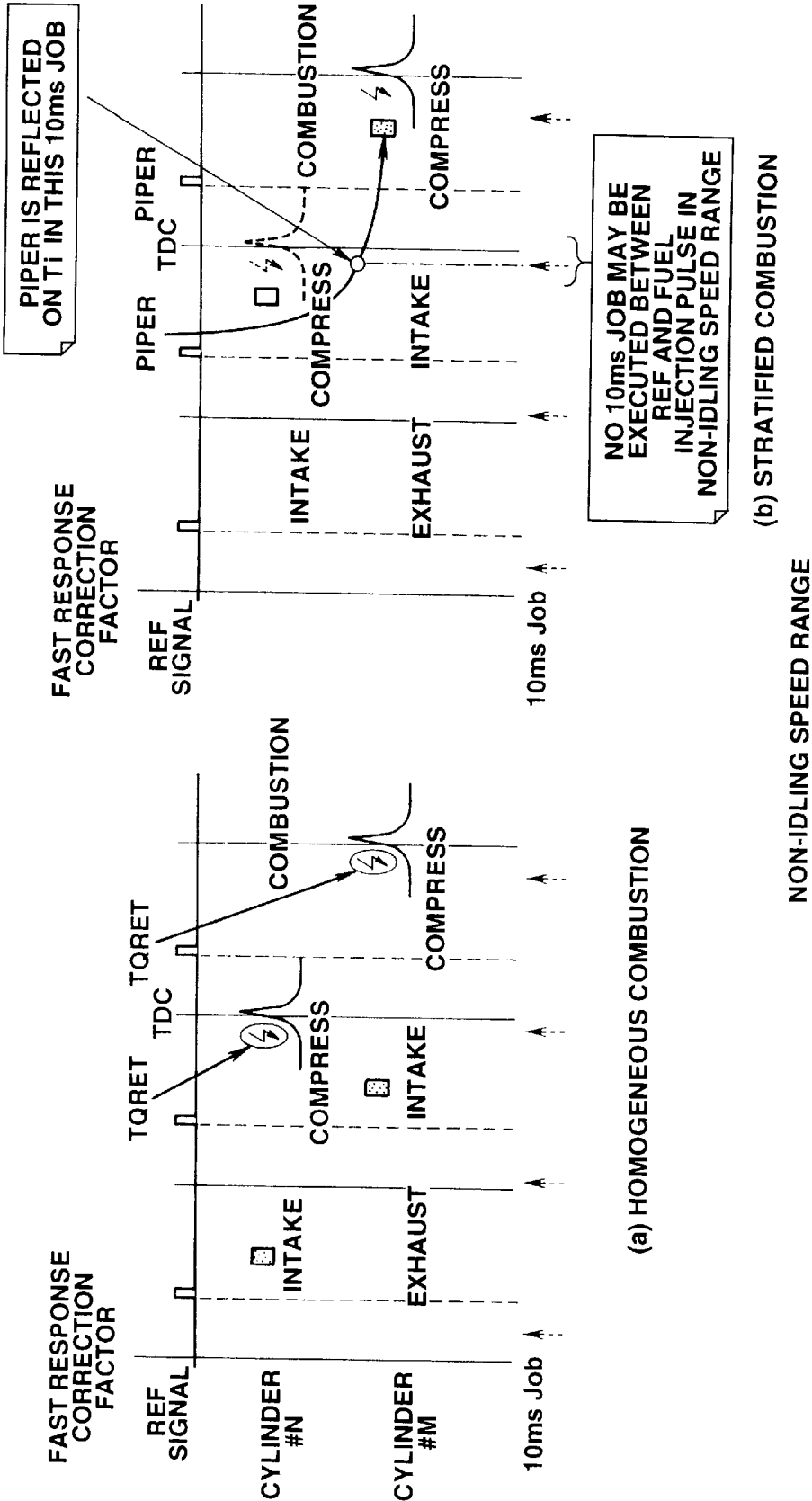
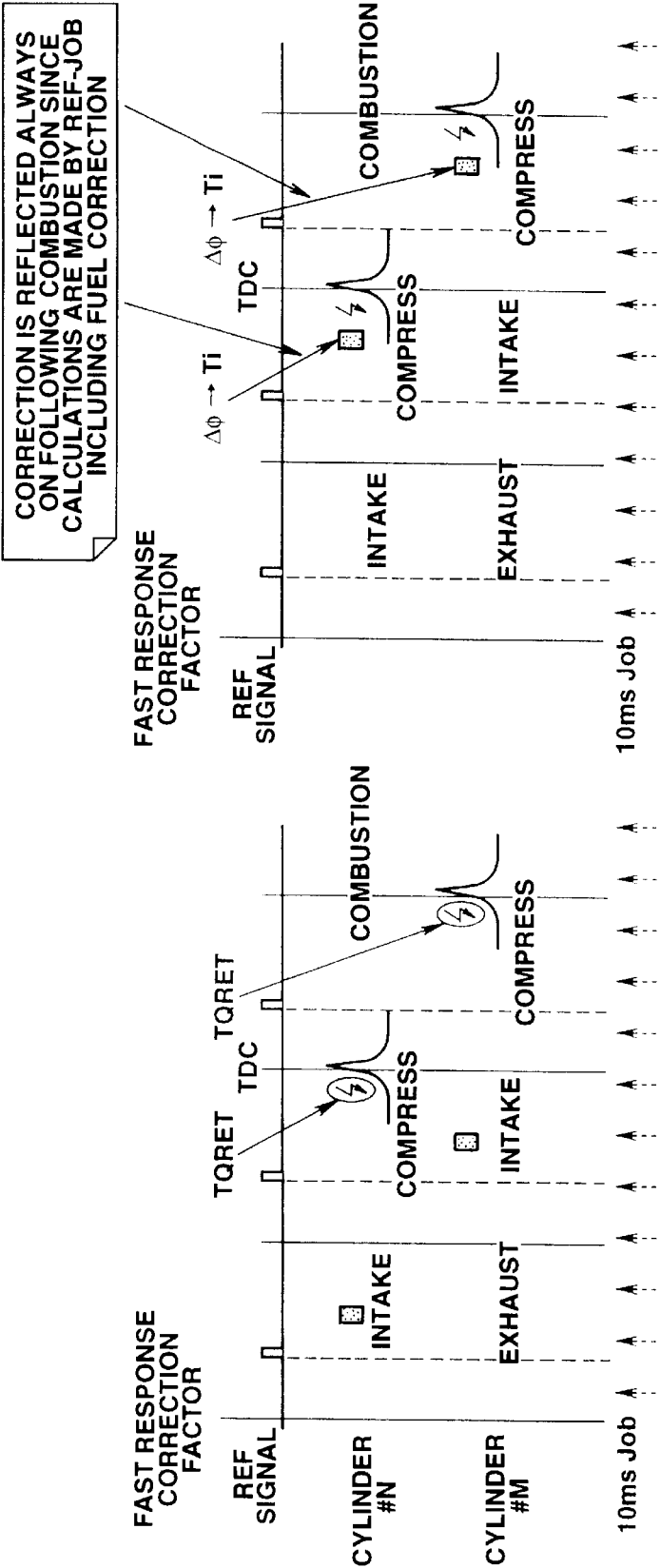


FIG.18



(b) STRATIFIED COMBUSTION

(a) HOMOGENEOUS COMBUSTION

FIG.19

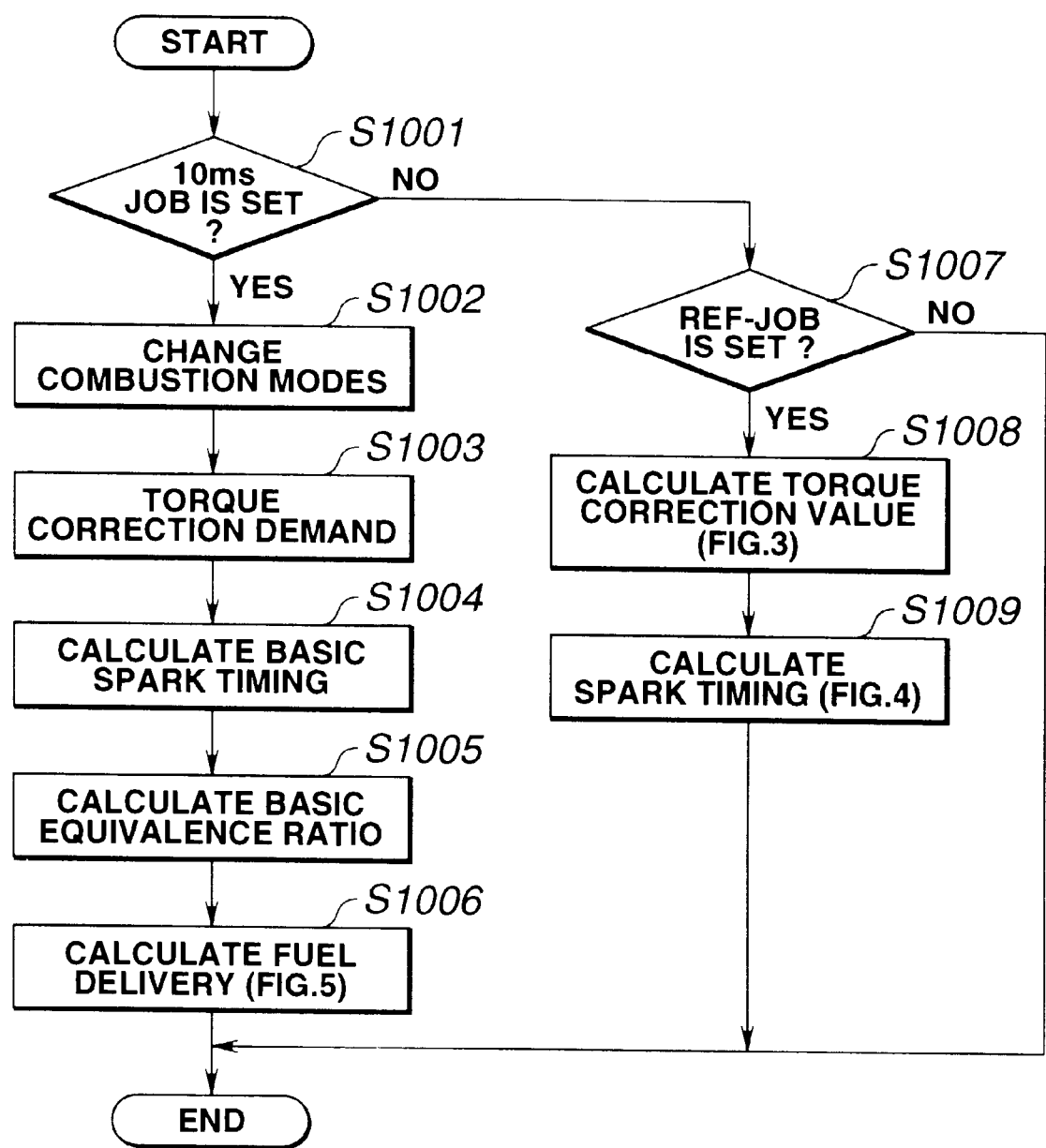


FIG.20

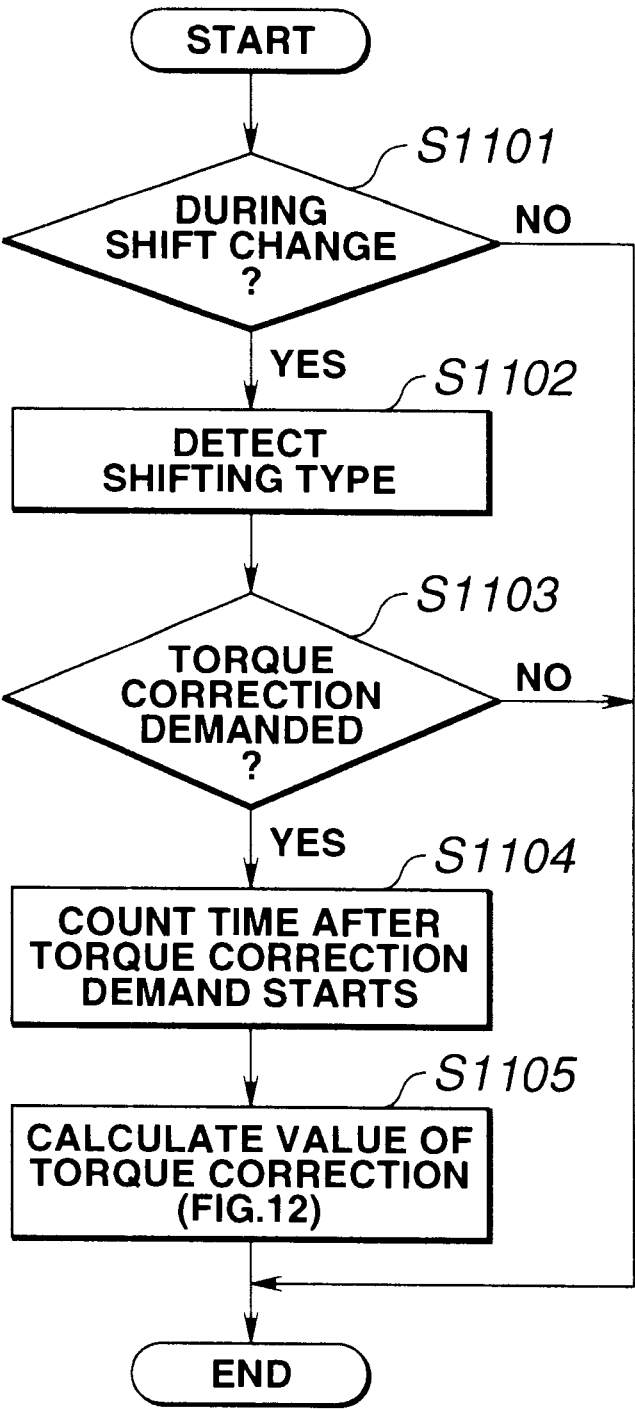


FIG.21

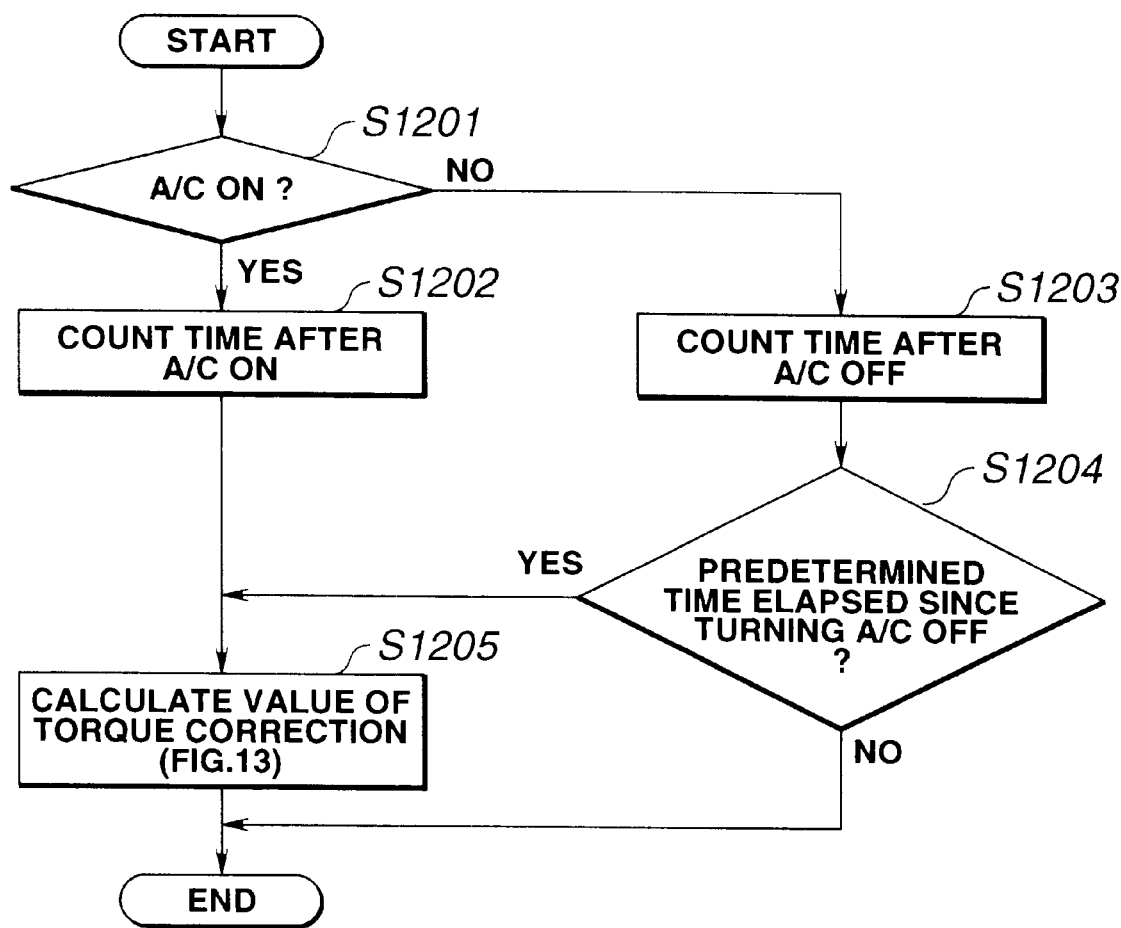


FIG.22

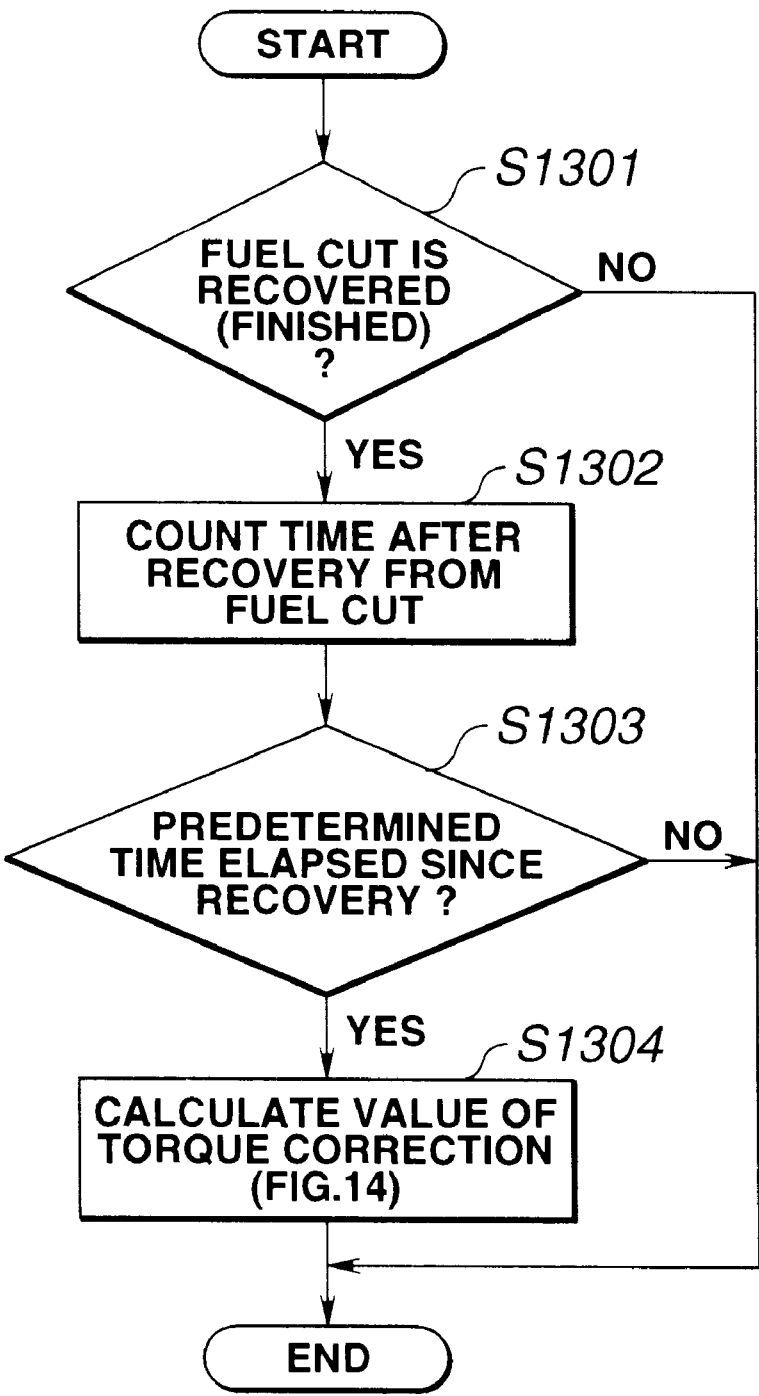


FIG.23

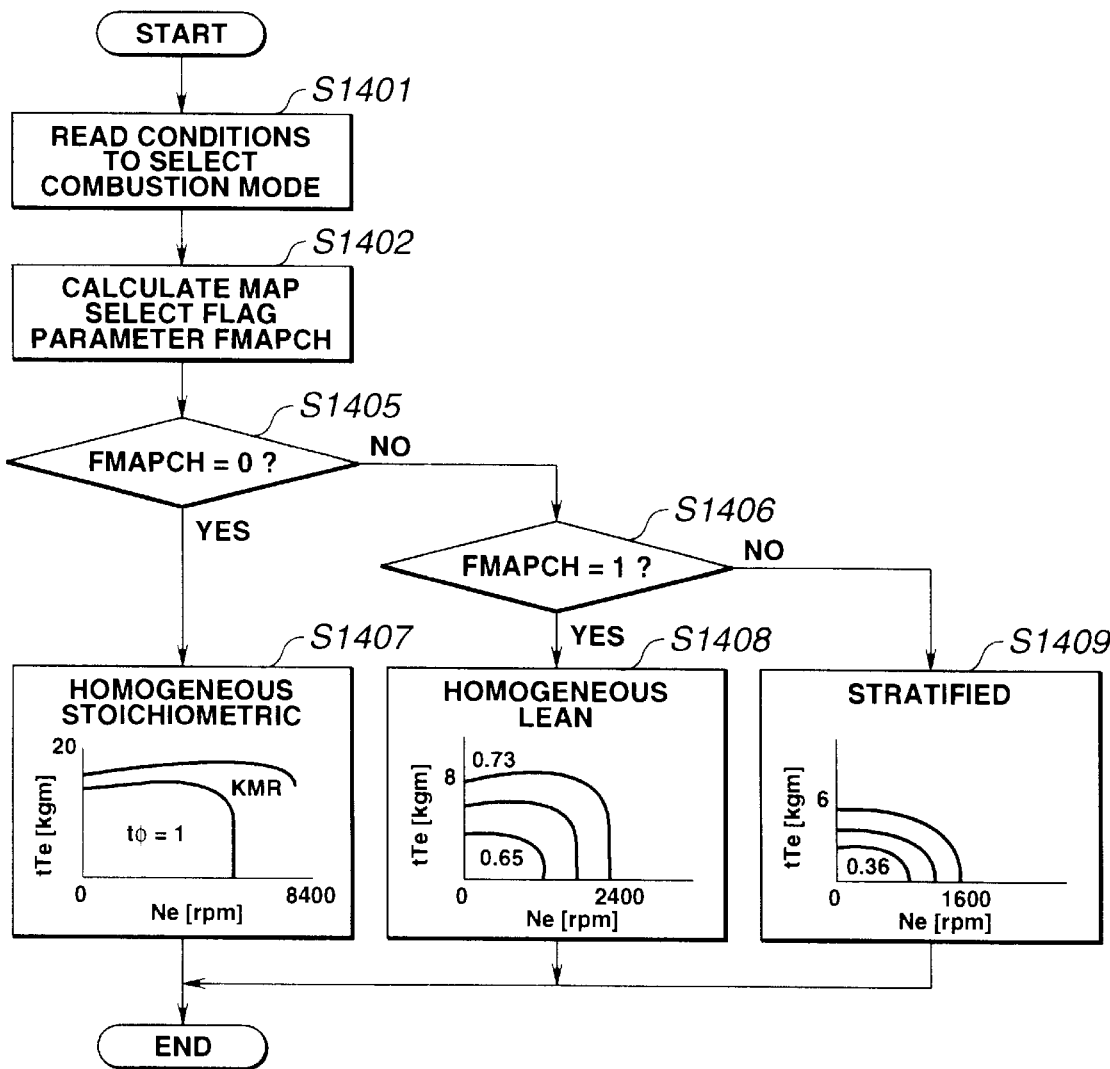


FIG.24

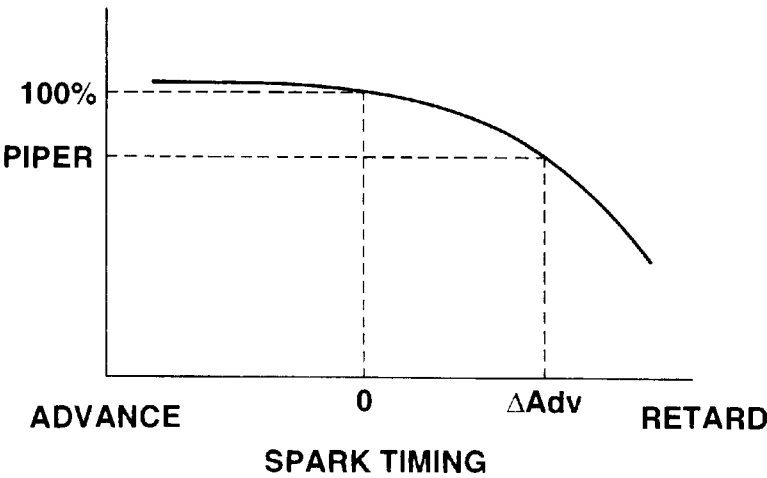


FIG.25

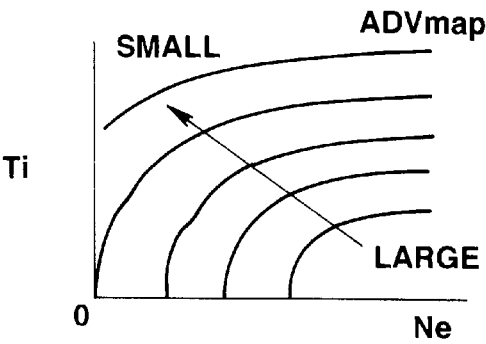


FIG.26

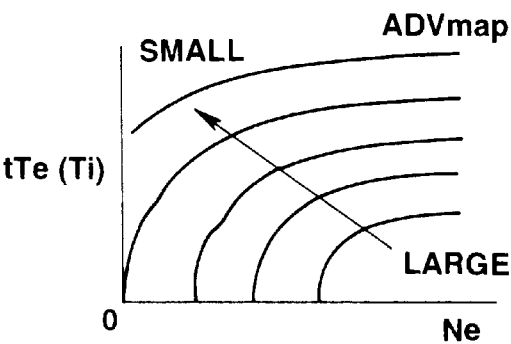
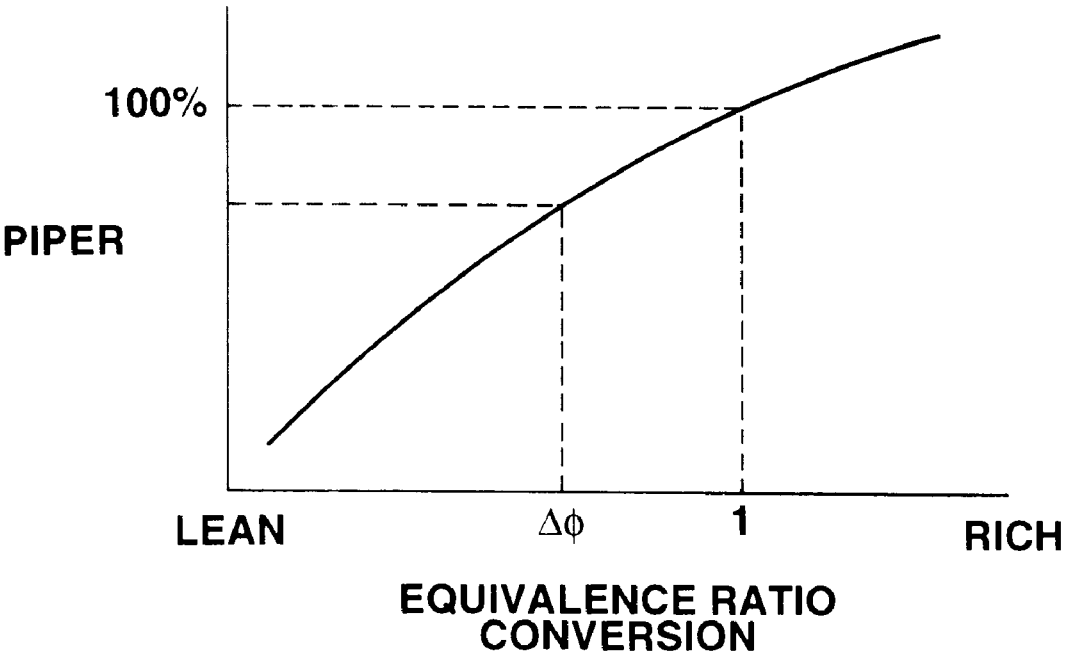


FIG.27



DIRECT-INJECTION SPARK-IGNITION TYPE ENGINE CONTROL APPARATUS

BACKGROUND OF THE INVENTION

This invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions.

It is conventional practice to realize a desired target torque (for example, during a gear shift operation made in an automatic transmission) using feedback control of the intake air flow rate in a manner to converge the engine torque to the target torque while correcting the spark timing according to a difference between the engine torque and the target torque. In order to achieve the target torque, the torque control (torque correction), which requires a faster response than intake air flow rate control can provide, is made by correcting spark timing, as discussed in Japanese Patent Kokai No. 5-163996.

In recent years, direct-injection spark-ignition type engines have attracted special interest. In such a direct-injection spark-ignition type engine, it is the current practice to make a combustion mode change, according to engine operating conditions, between homogeneous combustion (wherein fuel is injected during an intake stroke to diffuse the injected fuel so as to form a homogeneous mixture in the combustion chamber) and stratified combustion (wherein fuel is injected during a compression stroke to form a stratified fuel mixture around the spark plug) as discussed in Japanese Patent Kokai No. 59-37236.

With such a direct-injection spark-ignition type engine, sparks must be produced at a time when the mixture is close to the spark plug if torque correction is to be made by the use of spark timing during stratified combustion. However, the range over which spark timing can be corrected is too narrow to permit sufficient torque correction during stratified combustion. An attempt to correct spark timing to an excessive extent will cause degraded combustion performance and eventually misfire.

SUMMARY OF THE INVENTION

In view of these considerations, the invention has for an object providing a direct-injection spark-ignition type engine control apparatus which can ensure optimum torque correction when the combustion mode is either homogeneous combustion or stratified combustion.

The invention provides desired torque correction regardless of the combustion mode by controlling at least the spark timing to correct torque during homogeneous combustion and by controlling at least the air-fuel ratio to correct torque during stratified combustion. Torque correction is provided with a fast response to a torque correction demand that cannot be followed by intake air flow rate control, regardless of the combustion mode. High speed torque correction is provided when torque demand control (such as the control described in connection with FIG. 7) is used to control the throttle position. Also, the invention widens the range (dynamic range) over which torque can be controlled during homogeneous combustion. It is possible to realize a response during stratified combustion that is about as fast as the response during homogeneous combustion, without increasing the processing load required for calculations during high speed operations. Also, the same response characteristics for operations with stratified and homogeneous combustion can be used over the entire range of engine speed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1(A) and 1(B) illustrate block diagrams showing the overall arrangement of the invention.

FIG. 2 is a system diagram of an engine embodying the invention.

FIG. 3 is a flow diagram showing a torque correction factor calculating routine used in a first embodiment.

FIG. 4 is a flow diagram showing a spark timing calculating routine used in the first embodiment.

FIG. 5 is a flow diagram showing a fuel delivery requirement calculating routine used in the first embodiment.

FIG. 6 is a flow diagram showing a torque correction factor calculating routine used in a second embodiment.

FIG. 7 is a block diagram showing torque demand control used in the second embodiment.

FIG. 8 is a flow diagram showing a torque correction factor calculating routine used in a third embodiment.

FIG. 9 is a flow diagram showing a fuel delivery requirement calculating routine used in the third embodiment.

FIG. 10 is a flow diagram showing a torque correction factor calculating routine used in a fourth embodiment.

FIG. 11 is a flow diagram showing a torque correction factor and fuel delivery calculating routine used in a fifth embodiment.

FIG. 12 shows response waveforms for the first embodiment.

FIG. 13 shows response waveforms for the second embodiment.

FIG. 14 shows response waveforms for the third embodiment.

FIG. 15 shows response waveforms for the fourth embodiment.

FIG. 16 shows time synchronous calculation of the fuel delivery requirement during idling.

FIG. 17 shows time synchronous calculation of the fuel delivery requirement above idling speed.

FIG. 18 shows rotation synchronous calculation of the fuel delivery requirement (fifth embodiment).

FIG. 19 illustrates one arrangement of overall processing.

FIGS. 20 to 22 illustrate torque correction demand processing under various conditions.

FIG. 23 illustrates processing to select a combustion mode and basic equivalence ratio.

FIGS. 24 to 27 are examples of maps employed in the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

FIGS. 1(A) and 1(B) will be used to explain the overall design of the invention.

The invention is directed to a control apparatus, or controller, for a direct-injection spark-ignition type engine. As shown in FIG. 1(A), the invention includes a combustion mode changing section for making a combustion change between homogeneous combustion (wherein fuel is injected during an intake stroke to diffuse the injected fuel so as to form a homogeneous mixture in the combustion chamber) and stratified combustion (wherein fuel is injected during a compression stroke to form a stratified fuel mixture around the spark plug). The invention includes a torque correction demanding section for producing a torque correction demand in accordance with engine operating conditions. The controller also includes a homogeneous combustion torque correcting section, which is responsive to the torque correction demand, for correcting at least the spark timing in order to make a torque correction during homogeneous

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combustion. A stratified combustion torque correcting section is responsive to a torque correction demand and corrects at least the air-fuel ratio in order to make a torque correction during stratified combustion.

FIG. 1(B) shows another overall arrangement of the invention. This arrangement is also directed to a controller for a direct-injection spark-ignition type engine. This design also includes a combustion mode changing section for making a combustion mode change between homogenous combustion and stratified combustion. A torque correction demanding section produces a torque correction demand based on engine operating conditions. A torque control section is responsive to the torque correction demand and controls the amount of air permitted to enter the engine in order to control the torque. Because air intake cannot be changed rapidly, a homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response (compared with the delay associated with intake air flow rate control) during homogenous combustion. A stratified combustion torque correcting section corrects at least the air-fuel ratio to make torque correction during stratified combustion.

FIG. 2 is a system diagram showing a direct-injection spark-ignition engine embodying the invention. Air is introduced through an air cleaner 2 into an intake passage 3 and hence into each of the combustion chambers of engine 1 (installed in a vehicle). Air intake is controlled by an electronic controlled throttle valve 4. The degree of opening of the electronic controlled throttle valve 4 is controlled by, for example, a step motor operable in response to a signal from a control unit 20.

An electro-magnetic fuel injector 5 is provided for direct injection of fuel (gasoline) into the combustion chamber. The fuel injector 5 opens to inject fuel adjusted at a predetermined pressure when its solenoid receives a fuel injection pulse signal outputted from the control unit 20 during an intake or compression stroke, in synchronism with engine rotation, to inject fuel. In the case where the fuel is injected during the intake stroke, the injected fuel diffuses into the combustion chamber to form a homogeneous mixture. In the case where the fuel is injected during the compression stroke, a stratified mixture is formed around a spark plug 6. The spark plug 6 produces a spark to ignite the mixture for combustion (homogeneous combustion or stratified combustion). The combustion modes include homogeneous stoichiometric combustion (at an air-fuel ratio of about 14.6), homogeneous lean combustion (at air-fuel ratios ranging from about 20 to 30), and stratified lean combustion (at air-fuel ratios of about 40), in accordance with air-fuel ratio control. Additional discussion regarding homogeneous combustion and stratified combustion and regarding how the air-fuel ratio can be adjusted for various engine operating conditions is set forth in U.S. patent application Ser. No. 08/901,963, filed Jul. 29, 1997 entitled "Control System for Internal Combustion Engine," and a U.S. Patent Application entitled "Direct Injection Gasoline Engine with Stratified Charge Combustion and Homogeneous Charge Combustion" filed under Attorney Docket No. 040679/625. The entire contents of these applications are incorporated herein by reference.

The exhaust gases discharge from the engine 1 into exhaust passage 7. The exhaust passage 7 has a catalytic converter 8 for purifying the exhaust gases.

The control unit, or controller, 20 includes a microcomputer comprised of a CPU, a ROM, a RAM, an A/D converter and an input/output interface and receives signals

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from various sensors. One suitable control unit is, for example, a Hitachi SH70 series processor, programmed in C and/or machine language. The sections described herein are implemented in hardware, software, or a combination of both, in the control unit 20.

These sensors include angle sensors 21 and 22 for detecting the rotation of the crankshaft or camshaft of the engine 1. The sensors 21 and 22 produce a reference pulse signal REF for each 720°/n of rotation of the shaft (where n is the number of cylinders) at a predetermined shaft position (at a predetermined crankshaft angular position before the compression top dead center of each of the cylinders) and also a unit pulse signal POS at a predetermined number of degrees (1 to 2°) of rotation of the shaft. The engine speed Ne is calculated based on the period of the reference pulse signal REF.

The sensors also include an airflow meter 23 provided in the intake passage 3 at a position upstream of the throttle valve 4 for detecting the intake air flow rate Qa (the amount of air permitted to enter the engine); an accelerator sensor 24 for detecting the accelerator position ACC (the degree to which the accelerator is depressed); a throttle valve sensor 25 (including an idle switch positioned to be turned on when the throttle valve 4 is fully closed) for detecting the degree TVO of opening of the throttle valve 4; a coolant temperature sensor 26 for detecting the temperature Tw of the coolant of the engine 1; an O₂ sensor 27 positioned in the exhaust passage 7 for producing a signal corresponding to the rich/lean composition of the exhaust gas for actual air-fuel ratio determination; and a vehicle speed sensor 28 for detecting the vehicle speed VSP.

The control unit 20 receives the signals fed thereto from the various sensors and includes a microcomputer built therein for making the calculations described herein to control the degree of opening of the electronic controlled throttle valve 4, the amount of fuel injected to the engine by the fuel injector 5, and the spark timing of the spark plug 6.

Torque control (torque correction) will be described with reference to the flow diagrams.

First Embodiment

A first embodiment will be described with reference to the flow diagrams of FIGS. 3 to 5.

FIG. 3 shows a torque correction factor calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB).

In step S1, a torque correction demand (that is, a demand for an increase or decrease in engine torque), which can result from, for example, a gear shift operation, air conditioner turning on operation, or fuel cut recovery, is read. For example, a torque decreasing demand is produced during a gear shift operation; a torque increasing demand is produced when the air conditioner is turned on; and a torque decreasing demand is produced upon fuel cut recovery. Examples of torque correction demand will be described in further detail below in connection with FIGS. 20 to 22.

In step S2, a torque correction factor PIPER (100±α%) is calculated in accordance with the torque correction demand. More specifically:

$$PIPER = \frac{tTeO + \Delta tTe}{tTeO}$$

wherein tTeO is basic target engine torque and ΔtTe is the torque correction value. No correction is made when

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PIPER=100%. A torque increasing demand is when PIPER>100% and a torque decreasing demand is when PIPER<100%.

In step S3, the combustion mode is read. The combustion mode is changed based on engine operating conditions using combustion mode changing maps such as a map which defines the combustion mode (and basic equivalence ratio ϕ or air-fuel ratio) as a function of engine speed Ne and the target engine torque tTe. Maps are prepared for each engine operating condition as defined by, for example, coolant temperature Tw, the time elapsed after the engine starts, and the like. One of homogeneous stoichiometric combustion, homogeneous lean combustion, and stratified lean combustion is set based on the actual engine operating conditions from the map selected according to these conditions. An example of this process will be described below in connection with FIG. 23.

In step S4, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S5 where the torque correction factor PIPER is converted into a spark timing correction factor TQRET according to, for example, a map such as shown in FIG. 24 (TQRET= Δ Adv). As shown in FIG. 24, since advancing the spark timing increases the torque little, the basic spark timing is set retarded in order to obtain a enough torque increase when the spark timing is advanced. The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step S6, the torque correction factor PIPER is returned to 100% and this routine is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S7 wherein the spark timing correction factor TQRET is set at zero (TQRET=0) and this program is ended. In this case, the torque correction factor PIPER is held at the value calculated in step S2. In one embodiment, the calculations in FIG. 3 take several microseconds.

FIG. 4 shows a spark timing calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB).

In step S11, the basic spark timing ADVmap is obtained. The basic spark timing ADVmap for homogeneous combustion [both stoichiometric and lean] is calculated in accordance with MBT control such as disclosed in U.S. Pat. No. 5,070,842. The basic spark timing ADVmap for stratified charge combustion is calculated from a prepared map. FIG. 25 shows an ADVmap for stratified charge combustion which defines the basic spark timing ADVmap as a function of engine speed Ne and fuel delivery, more particularly pulse width for fuel delivery Ti. In FIG. 25, the target torque tTe can also be used instead of fuel delivery Ti.

The spark timing ADVmap for homogeneous combustion can be calculated in accordance with a map as a function of engine speed Ne and one the target torque tTe and fuel delivery Ti (see FIG. 26)

In step S12, the spark timing correction factor TQRET (from the FIG. 3 processing) is read. In step S13, the spark timing correction factor TQRET is added to the basic spark timing ADVmap to calculate the eventual spark timing ADV:

$$ADV=ADVmap+TQRET$$

Since the torque correction factor PIPER is converted to the spark timing correction factor TQRET during homoge-

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neous combustion, this torque correction reflects on the spark timing ADV, and the torque is corrected by adjusting the spark timing. Since the spark timing correction factor TQRET is zero during stratified combustion, no torque correction is made via the spark timing during stratified combustion.

In step S14, the spark timing ADV is set in a predetermined register and a command is produced to generate a spark at the spark timing ADV.

FIG. 5 shows a fuel delivery requirement calculating routine executed at uniform intervals of time, for example, 10 ms (10 ms-JOB).

In step S21, a basic equivalence ratio ϕ (set during execution of another routine for air-fuel ratio control) is read. The basic equivalence ratio ϕ is set according to the combustion mode, as discussed above. The term "equivalence ratio" means a fuel-air ratio represented as 14.6/AFR, where AFR is the air-fuel ratio. An example of this processing will be described in connection with FIG. 23.

In step S22, the torque correction factor PIPER is read.

In step S23, the torque correction factor PIPER is converted to an equivalence ratio correction factor $\Delta\phi$. Since the torque correction factor PIPER is 100% during homogeneous combustion (in this embodiment), the equivalence ratio correction factor $\Delta\phi$ is 1 in this case. Since the torque correction factor PIPER is $100\pm\alpha\%$ during stratified combustion, the equivalence ratio correction factor $\Delta\phi$ is $1\pm\beta$. FIG. 27 shows one suitable map for converting PIPER to $\Delta\phi$.

In step S24, the target equivalence ratio ϕ_d is calculated by multiplying the basic equivalence ratio ϕ by the equivalence ratio correction factor $\Delta\phi$:

$$\phi_d=\phi\times\Delta\phi$$

In step S25, the basic fuel delivery requirement Tp is corrected for the target equivalence ratio ϕ_d and the like to calculate the eventual fuel delivery requirement Ti as follows:

$$Ti=Tp\times\phi_d\times K\alpha+Ts$$

Tp is the basic fuel delivery requirement corresponding to the stoichiometric air-fuel ratio, $Tp=K1\times Qa/Ne$ (K1 is a constant).

K α is an air-fuel ratio feedback correction factor calculated based on the O₂ sensor signal (the correction factor K α is clamped at 1 during lean combustion).

Ts is an ineffective injection time correction factor dependent on the battery voltage.

The fuel delivery requirement Ti calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to the fuel delivery requirement Ti is outputted to each of the fuel injectors 5 for fuel injection in the intake stroke of the corresponding cylinder (during homogeneous combustion) and in the compression stroke of the corresponding cylinder (during stratified combustion).

Thus, the steps S1 to S4, S5, S6, S12 and S13 perform a homogeneous combustion torque correcting function and the steps S1 to S4, S7, and S22 to S25 perform a stratified combustion torque correcting function.

FIG. 12 shows response waveforms for the first embodiment of the invention. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a gear shift, the spark timing is corrected to correct the torque during homogeneous combustion, whereas the equivalence ratio (air-fuel ratio) is corrected, without cor-

recting the spark timing, to correct the torque during stratified combustion.

In this embodiment, the electronic controlled throttle valve 4 is controlled according to the accelerator position ACC.

Second Embodiment

In the second embodiment, torque correction is made as shown in FIG. 6, and spark timing and fuel delivery requirement calculations are made as described above in connection with FIGS. 4 and 5.

FIG. 6 shows a torque correcting routine executed in synchronism with the reference pulse signal REF (REF-JOB).

At step S31, a target torque tTRQ calculated by torque demand control is retrieved. The parameter tTRQ includes a torque correction demand (demand for increasing or decreasing the torque) resulting from gear shifting of the transmission, turning on the air conditioner, recovery from a fuel cut, or the like.

The target torque is represented by the following formula:

$$\text{Target torque } tTE (= tTRQ) = \text{basic target engine torque } (tTeO) + \text{torque correction for intake air } (\Delta tTe_air)$$

In the second and fourth embodiments, torque correction entails correction for the intake air amount. This torque correction is indicated by ΔtTe_air .

In step S32, an air correction factor to obtain the target torque (the torque correction demand) is calculated to control the degree of opening of the electronic controlled throttle valve 4.

In step S33, the output torque during intake air correction is estimated.

In step S34, the estimated torque is subtracted from the target torque (which is based on the torque demand control target torque or the torque correction demand calculated at step S31) to calculate the torque shortage due to the delay involved with changing the amount of intake air.

In step S35, a torque correction factor PIPER ($100 \pm \alpha\%$) is calculated in accordance with the torque shortage. In this case, PIPER=100% indicates no correction. PIPER>100% indicates a torque increase demand, and PIPER<100% indicates a torque decrease demand.

In step S36, the combustion mode is read.

In step S37, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S38 wherein the torque correction factor PIPER is converted to a spark timing correction factor TQRET, as discussed above. The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step S39, the torque correction factor PIPER is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S40 wherein the spark timing correction factor TQRET is set at 0 and this program is ended. In this case, the torque correction factor is held at the value calculated in step S35.

Thereafter, control is made according to the spark timing calculation routine of FIG. 4 and the fuel delivery requirement calculation routine of FIG. 5.

The steps S31 to S37, S38, S39, S12 and S13 perform a homogeneous combustion torque correcting function and the steps S31 to S37, S40 and S22 to S25 perform a stratified combustion torque correcting function.

FIG. 7 is a control block diagram for torque demand control.

A target torque calculation section 101 receives the accelerator position ACC and the engine speed Ne, and outputs a driver demand torque based on a predetermined map which defines the driver demand torque as a function of accelerator position and engine speed. A torque correction demand factor resulting from a gear shift, air conditioner on, fuel cut recovery, or the like is added to the driver demand torque to calculate a target torque tTRQ.

A basic fuel delivery requirement calculation section 102 receives the target torque tTRQ and the engine speed Ne and it outputs a basic fuel delivery requirement tQf based on a predetermined map which specifies the basic fuel delivery requirement tQf as a function of target torque and engine speed.

The combustion efficiency varies when the air-fuel ratio changes over a wide range during operation with homogeneous and stratified combustion. An efficiency correction section 103 corrects the basic fuel delivery requirement tQf based on combustion efficiency. The basic fuel delivery is corrected less as the air/fuel ratio increases (leaner). Under lean conditions, the pumping loss is lower and efficiency is higher; thus less fuel is needed to get a certain torque when the air fuel ratio is leaner.

A target air-fuel ratio calculation section 104 receives the target torque tTRQ and the engine speed Ne and outputs a target air-fuel ratio tAFR from a predetermined map which defines the target air-fuel ratio tAFR as a function of target torque and engine speed.

A target intake air flow rate calculation section 105 includes a multiplier which multiplies the basic fuel delivery requirement tQf by the target air-fuel ratio tAFR to calculate a target intake air flow rate tQcyl=tQf×tAFR.

A target throttle position calculation section 106 receives the target intake air flow rate tQcyl and the engine speed Ne and outputs a target throttle position tTVO from a predetermined map which specifies the target throttle position tTVO as a function of tQcyl and Ne.

A throttle valve drive control section 107 drives, for example, a step motor in a stepped manner in response to a command signal corresponding to the target throttle position tTVO so as to bring the throttle valve 4 to the target throttle position tTVO. Examples of maps referred to above in connection with FIG. 7 are shown in a U.S. Patent Application entitled "Engine Throttle Control Apparatus" and filed under Attorney Docket No. 040679/0629.

FIG. 13 shows response waveforms for the second embodiment. Assuming that a torque correction (torque up) demand is produced when the air conditioner is turned on, the amount of air to the engine increases; however, a torque shortage occurs because of the delay in increasing the actual amount of air to the engine. The spark timing is corrected to correct the torque shortage during homogeneous combustion and the equivalence ratio (air-fuel ratio) is corrected, without correcting the spark timing, to correct the torque shortage during stratified combustion.

Third Embodiment

In the third embodiment, the torque correction factor calculation is made as shown in FIG. 8, the spark timing calculation is made as described above in connection with FIG. 4, and the fuel delivery requirement calculation is made as shown in FIG. 9.

FIG. 8 shows a torque correction factor calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB). FIG. 8 is different from FIG. 3 in steps S2', S5' and S6'.

In step S1, a torque correction demand (increase or decrease demand) resulting from a gear shift, air conditioner on, fuel cut recovery, or the like, is read.

In step S2, a torque correction factor is calculated in accordance with the torque correction demand. The torque correction factor is divided into a spark timing related torque correction factor PIPERAD and an air-fuel ratio related torque correction factor PIPERM, which are independently calculated. When each correction factor is Δt_{Te_AD} , Δt_{Te_MR} :

$$PIPERAD = \frac{t_{TeO} + \Delta t_{Te_AD}}{t_{TeO}}$$

In this case, 100% indicates no correction, greater than 100% indicates a torque increase demand, and less than 100% indicates a torque decrease demand.

In step S3, the combustion mode is read.

In step S4, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to the step S5' wherein the spark timing related torque correction factor PIPERAD is converted to a spark timing correction factor TQRET in accordance with FIG. 24. (TQRET=ΔAdv). The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step S6', the spark timing related torque correction factor PIPERAD is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S7, where the spark timing correction factor TQRET is set at 0. In this case, the spark timing related torque correction factor PIPERAD is held at the value calculated in step S2'.

Thereafter, control is made according to the spark timing calculation routine of FIG. 4.

FIG. 9 shows a fuel injection requirement calculating routine executed at uniform intervals of time, for example, 10 ms (10 ms-JOB). FIG. 9 is different from FIG. 5 in step S22'.

In step S21, a basic equivalence ratio ϕ for air-fuel ratio control is read.

In step S22', the spark timing related torque correction factor PIPERAD and the equivalence ratio related torque correction factor PIPERM are read and added to calculate a total torque correction factor PIPER as follows:

$$PIPER = PIPERAD + PIPERM - 100(\%)$$

Since the spark timing related torque correction factor PIPERAD 100% during homogeneous combustion (after execution of FIG. 8), $PIPER = PIPERM$ during homogeneous combustion.

In step S23, the torque correction factor PIPER is converted to an equivalence ratio correction factor $\Delta\phi$.

In step S24, the equivalence ratio correction factor $\Delta\phi$ is multiplied by the basic equivalence ratio ϕ to calculate a target equivalence ratio ϕ_d as follows:

$$\phi_d = \phi \times \Delta\phi$$

In step S25, the basic fuel delivery requirement T_p is corrected based on the target equivalence ratio ϕ_d to calculate an eventual fuel delivery requirement T_i :

$$T_i = T_p \times \phi_d \times K \alpha + T_s$$

The fuel delivery requirement T_i calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to the fuel delivery requirement T_i is outputted to each of the fuel injectors 5 for fuel injection in the intake stroke of the corresponding cylinder during homogeneous combustion and in the compression stroke of the corresponding cylinder during stratified combustion.

FIG. 14 shows response waveforms for the third embodiment. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a fuel cut, the spark timing and equivalence ratio (air-fuel ratio) are corrected to correct the torque during homogeneous combustion, whereas the equivalence ratio (air-fuel ratio) is corrected to a greater extent, without correcting the spark timing, to correct the torque during stratified combustion.

Fourth Embodiment

In the fourth embodiment, the torque correction is made as shown in FIG. 10, the spark timing calculation is made as described above in connection with FIG. 4, and the fuel delivery requirement calculation is made as described above in connection with FIG. 9.

FIG. 10 shows a torque correcting routine executed in synchronism with the reference pulse signal REF (REF-JOB). FIG. 10 is different from FIG. 6 in steps S35', S38' and S39'.

In step S31, a torque correction demand (increase or decrease demand) resulting from the target torque for torque demand control, a gear shift, the air conditioner being turned on, fuel cut recovery, or the like is read.

In step S32, an air correction factor for the target torque or the torque correction demand is calculated to control the degree of opening of the electronic controlled throttle valve 4.

In step S33, the output torque during air correction is estimated.

In step S34, the estimated torque is subtracted from the target torque (based on the torque demand control target torque or the torque correction demand) to calculate a torque shortage.

In step S35', a torque correction factor is calculated in accordance with the torque shortage. The torque correction factor is divided into a spark timing related torque correction factor PIPERAD and an air-fuel ratio related torque correction factor PIPERM. The spark timing related torque correction factor and the air-fuel ratio related torque correction factor are calculated based on the torque shortage from step S34 in the following manner:

under stratified combustion:

$$PIPERAD : PIPERM = 0 : 100$$

under homogeneous combustion:

$$PIPERAD : PIPERM = x : (100 - x)$$

a value retrieved from a map based on the driving condition (engine speed, torque). In this case, 100% indicates no correction, more than 100% indicates a torque increase demand and less than 100% indicates a torque decrease demand.

In step S36, the combustion mode is read.

In step S37, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S38' wherein the spark timing related torque correction factor PIPERAD is converted to a spark timing correction factor TQRET. In step S39', the spark timing related torque correction factor PIPERAD is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S40 wherein the spark timing correction factor TQRET is set at 0 and this program is ended. In this case, the spark timing related torque correction factor PIPERAD is held at the value calculated in step S35'.

Thereafter, control is made according to the spark timing calculation routine of FIG. 4 and the fuel delivery requirement calculation routine of FIG. 9.

FIG. 15 shows response waveforms for the fourth embodiment. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a gear shift, the amount of air to the engine is decreased; however, too much torque occurs because of the delay in air flow rate control. In order to correct the torque excess, the spark timing and equivalence ratio (air-fuel ratio) are corrected to correct the torque during homogeneous combustion. The equivalence ratio (air-fuel ratio) is corrected to a greater extent, without correcting the spark timing, to correct the torque during stratified combustion.

Fifth Embodiment

In the fifth embodiment, calculations for the torque correction factor and fuel delivery requirement are made as shown in FIG. 11, and the spark timing calculation is made as described above in connection with FIG. 4.

In step S1, the torque correction demand (demand for increase or decrease) which can result from a gear shift operation, air conditioner turning on operation, or fuel cut recovery, or the like, is read.

In step S2, a torque correction factor PIPER ($100 \pm \alpha\%$) is calculated in accordance with the torque correction demand. In this case, no correction is made when PIPER=100%, a torque increasing demand correction is made when PIPER>100%, and a torque decreasing demand correction is made when PIPER<100%.

In step S3, the combustion mode is read.

In step S4, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S41 wherein the torque correction factor PIPER is converted to the spark timing correction factor TQRET. In step S42, the equivalence ratio correction factor $\Delta\phi$ is set to 1. Following this, the program proceeds to steps S45 to S47.

If the combustion mode is stratified combustion, then the program proceeds to step S43 wherein the torque correction factor PIPER is converted to an equivalence ratio correction factor $\Delta\phi$, and then to step S44 wherein the spark timing correction factor TQRET is set to 0. Following this, the program proceeds to steps S45 to S47.

In step S45, the basic equivalence ratio $t\phi$ (set in another routine) is read for air-fuel ratio control.

In step S46, the target equivalence ratio $t\phi d$ is calculated by multiplying the basic equivalence ratio by the equivalence ratio correction factor $\Delta\phi$ as follows:

$$t\phi d = t\phi \times \Delta\phi$$

In step S47, the basic fuel delivery requirement Tp is corrected for the target equivalence ratio $t\phi d$ and the like to calculate the eventual fuel delivery requirement Ti according to the following equation

$$Ti = Tp \times t\phi d \times K\alpha + Ts$$

The fuel delivery requirement Ti calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to Ti is outputted to each of the fuel injectors 5 to inject fuel in the intake stroke of the corresponding cylinder during homogeneous combustion and in the compression stroke of the corresponding cylinder during stratified combustion.

Control of spark timing is made according to the spark timing calculation routine of FIG. 4.

In the fifth embodiment, the fuel delivery requirement calculation is made in synchronism with engine rotation (REF-JOB) like the torque correction factor calculation.

Differences between fuel delivery requirement calculation made in synchronism with time (10 ms-JOB) as described above in connection with the first to fourth embodiments and fuel delivery requirement calculation made in synchronism with engine rotation (REF-JOB) as described in connection with the fifth embodiment will now be described.

Assuming that calculations made in synchronism with rotation (REF-JOB) are for a four-cylinder engine, the period of the reference pulse signal REF produced for each 180° of crankshaft rotation will change with engine speed approximately as follows:

1000 rpm . . . 30 ms
3000 rpm . . . 10 ms
5000 rpm . . . 6 ms
6000 rpm . . . 5 ms

Thus, the processing load required for the calculations is as great as compared to the 10 ms-JOB at 3000 rpm or more and double the 10 ms-JOB at 6000 rpm. This tendency increases for 6 and 8 cylinder engines.

For this reason, the processing load required for the calculations is decreased, in the first to fourth embodiments, by executing the fuel delivery requirement calculation in synchronism with time (10 ms-JOB). The reason why the response speed during stratified combustion is not degraded by making the calculations in synchronism with time is as follows.

At low loads (1200 rpm or less) during stratified combustion, 10 ms-JOB is executed between the time at which the torque correction factor is calculated (in synchronism with rotation) and the time at which fuel is injected. Thus, it is possible to realize the same response characteristic as realized with spark timing adjustment during homogeneous combustion.

The reflection of the torque correction factor on the fuel delivery requirement is made in synchronism with time (10 ms-JOB) even at greater engine speeds, and the control is made at uniform intervals of 10 ms. However, sufficient control can be made for torque correction demands on such a time scale.

FIGS. 16 to 18 show the timing chart of the operation as to two cylinders of the engine. A Z-shape arrow represents

a spark timing, a shaded rectangle shows a fuel delivery, and a triangular wave shows a pressure in the cylinder raised by the combustion.

Referring to FIG. 16, the influence on performance is dependent on whether the reflection of the correction factor is delayed one combustion at low engine speeds, for example, at idling speeds. Since the correction factor (TQRET) is calculated by REF-JOB during homogeneous combustion and reflected immediately on spark timing set by the REF signal during homogeneous combustion (when the correction factors (TQRET, PIPER) are calculated by REF-JOB and the reflection on the fuel delivery requirement is made by 10 ms-JOB), it is possible to reflect the correction factor on the combustion just after the REF signal. Homogeneous combustion might be used while idling if, for example, accessory loads are high and the engine is cold. Although the correction factor (PIPER) is calculated by REF-JOB during stratified combustion, at least one 10 ms-JOB is executed between the time at which a REF signal is produced and the time at which a fuel injection pulse is produced at low engine speeds. Thus, the correction factor can be reflected on the combustion just after the REF signal, like operation with homogeneous combustion.

It is, therefore, possible to make torque corrections with the same response characteristics for both stratified combustion and homogeneous combustion in the low engine speed range, such as the idling speed range.

As shown in FIG. 17, at engine speeds above idling speeds, if the correction factors (TQRET, PIPER) are calculated by REF-JOB and the reflection on the fuel delivery requirement is made by 10 ms-JOB, the correction factor (TQRET) is calculated by REF-JOB and reflected immediately on the spark timing set by the REF signal during homogeneous combustion so that the correction factor is reflected on the combustion just after the REF signal.

Although the correction factor (PIPER) is calculated by REF-JOB during stratified combustion, no 10 ms-JOB routine can be executed between the time at which the REF signal is produced and the time at which a fuel injection pulse is produced, in this engine speed range. In this case, the calculated correction factor is reflected on the next combustion.

Thus, the time at which the correction factor is reflected may be delayed during stratified combustion as compared to homogeneous combustion. However, this manner of calculation can reduce the processing load required for the calculations of REF-JOB and can prevent an increase in the processing load required for calculations made in synchronism with rotation when the engine speed is increasing.

Since it is sufficient for a greater part of the correction demand values to be handled in synchronism with time, and the reflection timing is not severe at engine speeds except for idling speeds, there is no performance reduction problem if the corrected fuel delivery values are reflected at time intervals of 10 ms.

It is, therefore, possible to correct the torque with sufficient response regardless of whether homogeneous or stratified combustion is occurring, while also preventing an increase in the processing load required for calculations made in synchronism with rotation at engine speeds above idling speeds.

FIG. 18 illustrates the effect of the fifth embodiment. Both the correction factor TQRET and the fuel delivery requirement Ti can be calculated by REF-JOB when the control unit has a sufficiently great processing ability. The correction of the amount of fuel to the engine during stratified combustion is reflected on the combustion just after the REF signal, like the correction to spark timing made during homogeneous combustion.

It is thus possible to realize torque correction with a sufficient response regardless of whether the combustion mode is homogeneous combustion or stratified combustion, over the entire engine speed range.

FIG. 19 illustrates one arrangement for overall processing. This processing includes the torque correction calculations of FIG. 3, the spark timing calculations of FIG. 4, and the fuel delivery calculations of FIG. 5. This processing also includes torque correction demand processing, change of combustion mode processing, basic spark timing calculation processing and processing for calculating basic equivalence ratio ϕ .

In step S1001, a determination is made as to whether a 10 ms job is set. A counter in the control unit 20 outputs a clock signal every 10 ms. If the clock signal was output between the last process and the current process, a "YES" determination is made and the processing proceeds on to step S1002. The general flow of FIG. 19 itself is processed under a 1 or 2 ms job.

In step S1002, the combustion mode is changed. For example, stratified charge combustion or homogeneous charge combustion can be selected. Selection of the combustion mode based on various conditions is described, for example, in a U.S. Patent Application entitled "Direct Injection Gasoline Engine with Stratified Charge Combustion and Homogeneous Charge Combustion" filed under Attorney Docket Number 040679/0625. In step S1003, torque correction demand processing is performed and in step S1004 basic spark timing is calculated.

In step S1005, the basic equivalence ratio is calculated, as discussed above. In step S1006, fuel delivery is calculated as discussed above in connection with FIG. 5.

In step S1007, a determination is made as to whether REF-JOB is set. If the REF signal is output between the last process and the current process, "YES" is obtained and the processing proceeds to step S1008. In step S1008, a torque correction value is calculated, as discussed above in connection with FIG. 3. In step S1009, spark timing is calculated, as discussed above in connection with FIG. 4.

FIGS. 20-22 show torque correction demand processing under various conditions. FIG. 20 shows the processing for a shift change. FIG. 21 shows the processing for the air conditioner compressor being turned on/off. FIG. 22 shows the processing for fuel cut recovery.

In FIG. 22, a determination is made in step S1101 as to whether a shift change is occurring. If yes, the processing proceeds to step S1102. Otherwise, the processing proceeds to the end. In step S1102, the shifting type is detected. In step S1103, a determination is made as to whether torque correction is demanded. If yes, the processing proceeds to step S1104. Otherwise, the processing proceeds to the end.

In step S1104, the time after the torque correction demand starts is counted. In step S1105, the value of torque correction is calculated and torque is corrected as shown in FIG. 12.

In FIG. 21, step S1201, a determination is made as to whether the air conditioner is on. If the air conditioner is on, the processing proceeds to step S1202. Otherwise, the processing proceeds to step S1203. In step S1202, the time after the air conditioner has been turned on is counted. In step S1203, the time after the air conditioner has been turned off is counted. After step S1203, the processing proceeds to step S1204. In step S1204, a determination is made as to whether a predetermined time has elapsed since turning the air conditioner off. If yes, the processing proceeds to step S1205. Otherwise, the processing proceeds to the end. In step S1205, the value of the torque correction is calculated and torque is corrected as shown in FIG. 13.

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In FIG. 22, step S1301 makes a determination as to whether a fuel cut is recovered (finished). If no, the processing proceeds to the end. Otherwise, the processing proceeds to step S1302. In step S1302, the time after the recovery from the fuel cut is counted. In step S1303, a determination is made as to whether a predetermined time has elapsed since recovery. If no, the processing proceeds to the end. Otherwise, the processing proceeds to step S1304. In step S1304, the value of torque correction is calculated and torque is corrected as shown in FIG. 14.

FIG. 23 is a flowchart which shows an example of processing to select the combustion mode and basic equivalence ratio ϕ . As discussed above, this processing is employed in connection with step S3 of FIG. 3, and step S21 of FIG. 5.

In step S1401, the conditions to select a combustion mode are read. These conditions can include, for example, water temperature, the time from engine starting, driving conditions such as engine revolution speed Ne and target torque, and the like.

In step S1402, a map select flag parameter FMAPCH is calculated in accordance with a combustion mode selected. Steps S1405 and S1406 select the appropriate map based on the combustion mode, according to FMAPCH. The processing proceeds to step S1407 for the homogeneous stoichiometric combustion condition. The processing proceeds to step S1408 for the homogeneous lean condition. The processing proceeds to step S1409 for the stratified combustion condition. In each of steps S1407 to S1409, the basic equivalence ratio ϕ is selected from a map based on engine speed Ne and target torque ($rTe=rTeO$).

The entire contents of Japanese patent application No. 9-168419 (filed Jun. 25, 1997) and Press Information entitled "Nissan Direct-Injection Engine" (Document E1-2200-9709 of Nissan Motor Co., Ltd., Tokyo, Japan) are incorporated herein by reference.

Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings. For example, the characteristic curves shown in the Figures are merely examples and other curves and techniques can be employed. The scope of the invention is defined with reference to the following claims.

What is claimed is:

1. A controller for an engine which operates in a homogeneous combustion mode and a stratified combustion mode, the controller comprising:

a detector to detect whether the engine is operating in a homogeneous combustion mode or a stratified combustion mode; and

a torque correction section, coupled to the detector, which receives a torque correction demand and produces a torque correction output in response to the torque correction demand, the torque correction output varying spark timing when the detector detects that the engine is in the homogeneous combustion mode and

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varying a ratio of air and fuel when the detector detects that the engine is in the stratified combustion mode.

2. A controller as set forth in claim 1, wherein the torque correction output varies a ratio of air and fuel but not spark timing when the detector detects that the engine is in the stratified combustion mode.

3. A controller as set forth in claim 1, wherein the torque correction output varies spark timing and a ratio of air and fuel when the detector detects that the engine is in the homogeneous combustion mode.

4. A controller as set forth in claim 1, wherein the torque correction section calculates an intake air flow amount to satisfy the torque correction demand and produces an air flow amount output corresponding thereto, and wherein the torque correction section varies spark timing when the detector detects that the engine is in a homogeneous combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output, and varies the ratio of air and fuel when the detector detects that the engine is in a stratified combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output.

5. A controller as set forth in claim 4, wherein the torque correction section varies spark timing and a ratio of air and fuel when the detector detects that the engine is in a homogeneous combustion mode to compensate for the delay in actual air flow reaching air flow specified by the air flow amount output.

6. A controller as set forth in claim 1, further comprising a fuel delivery calculation section, wherein the fuel delivery calculation section performs fuel delivery calculations in a loop having a constant repetition time, and wherein the torque correction section performs its calculations in a loop whose repetition time varies with engine speed.

7. A controller as set forth in claim 1, wherein the torque correction section calculates an intake air flow amount to satisfy the torque correction demand and produces an air flow amount output corresponding thereto, and wherein the torque correction section varies spark timing when the detector detects that the engine is in a homogeneous combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output.

8. A controller as set forth in claim 2, wherein the torque correction output varies spark timing and a ratio of air and fuel when the detector detects that the engine is in the homogeneous combustion mode.

9. A controller as set forth in claim 4, wherein the torque correction section varies a ratio of air and fuel but not spark timing when the detector detects that the engine is in the stratified combustion mode.

10. A controller as set forth in claim 1, further comprising a fuel delivery calculation section performing fuel delivery calculations, and wherein the fuel delivery calculation section and the torque correction section perform the calculations in loops, each having repetition time varying with engine speed, respectively.

* * * * *



US005241855A

United States Patent [19]
Cullen et al.

[11] Patent Number: 5,241,855
[45] Date of Patent: Sep. 7, 1993

[54] METHOD AND APPARATUS FOR
INFERRING ENGINE TORQUE

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[21] Appl. No.: 786,229

[22] Filed: Oct. 31, 1991

[51] Int. Cl.⁵ G01M 15/00
[52] U.S. Cl. 73/117.3
[58] Field of Search 73/116, 117.3;
364/431.03, 431.04

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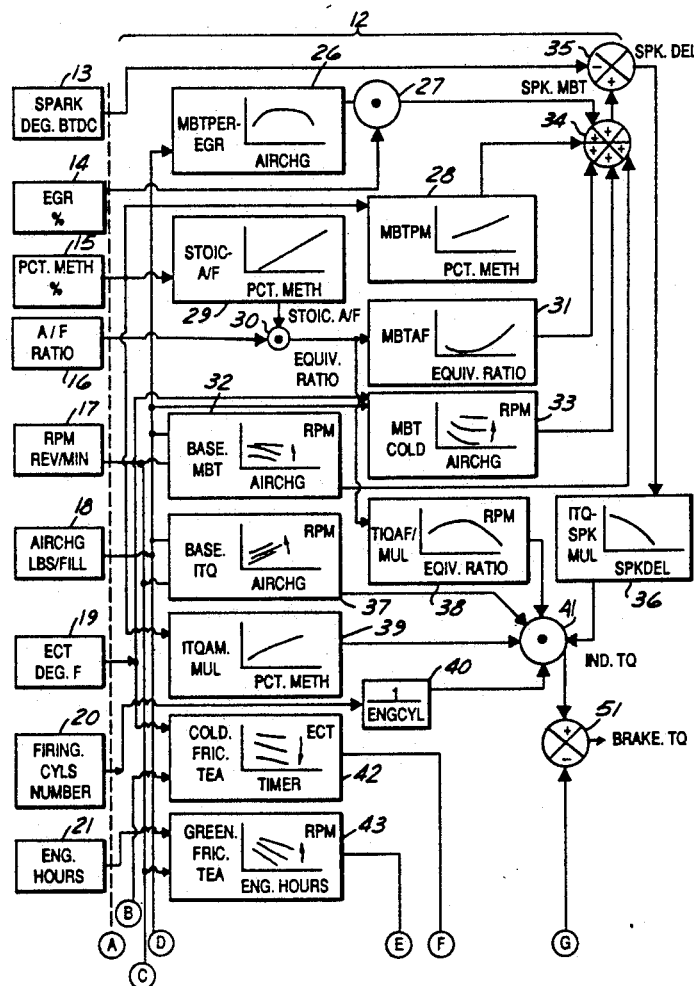
Attorney, Agent, or Firm—Peter Abolins; Roger L. May

[57]

ABSTRACT

A method of inferring and predicting engine torque uses a function of a speed/load table, air/fuel ratio and spark advance. The effects of the magnitudes of engine spark retard, rich or lean air/fuel ratios and exhaust gas recirculation are accounted for using a series of multipliers. Friction torque is accounted for through a speed/air charge table look-up.

7 Claims, 10 Drawing Sheets



VW EX1006
U.S. Patent No. 6,581,565

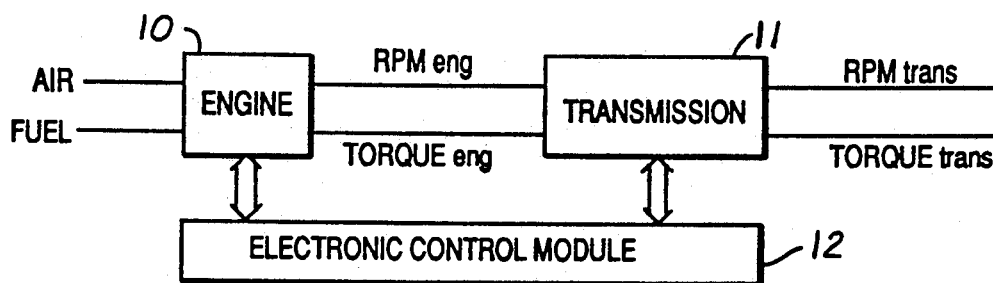
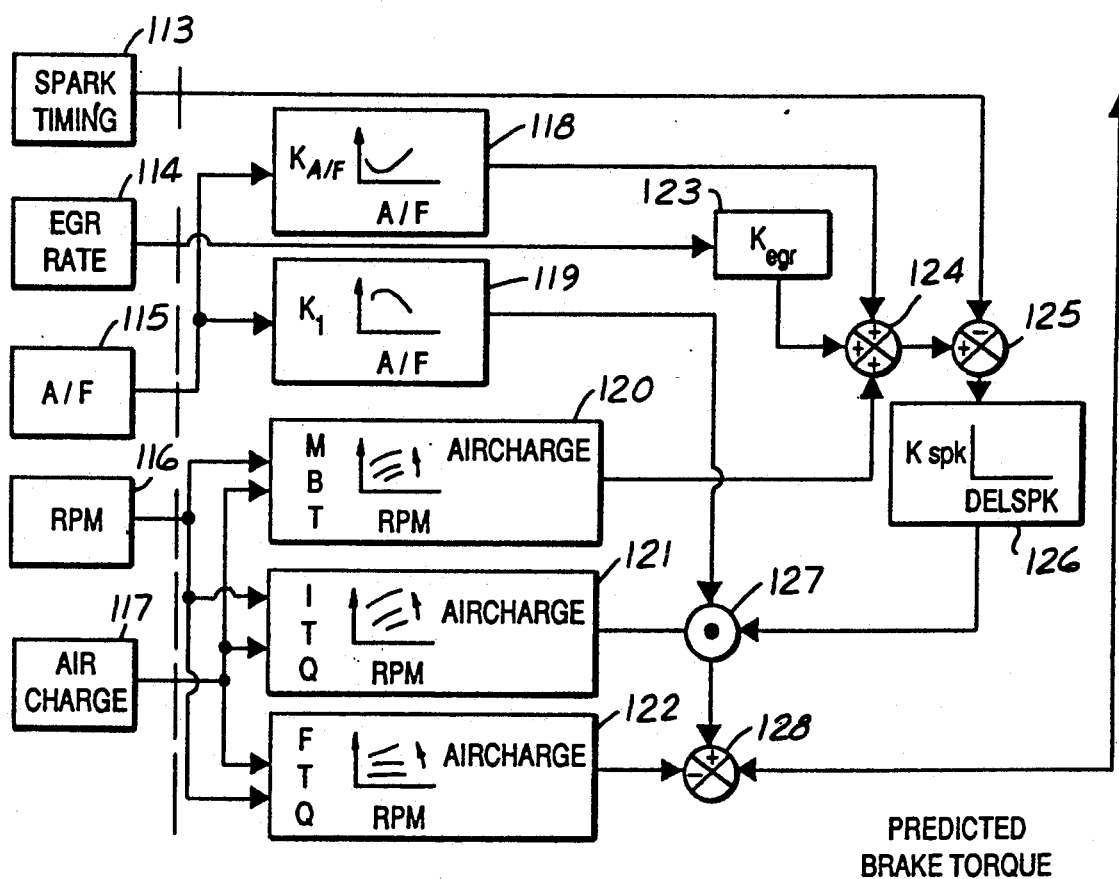


FIG. 1



(PRIOR ART)

FIG. 2

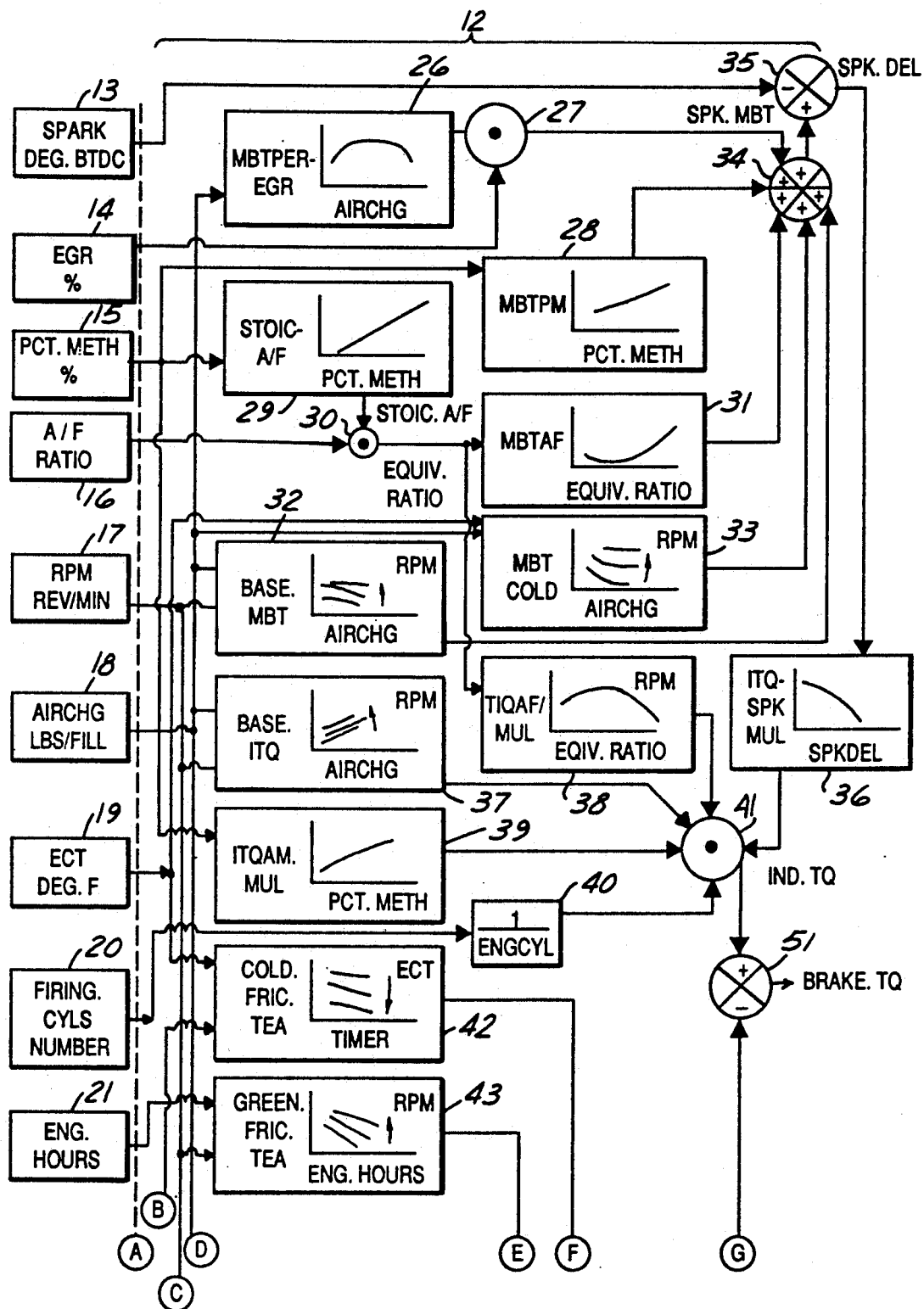


FIG. 3

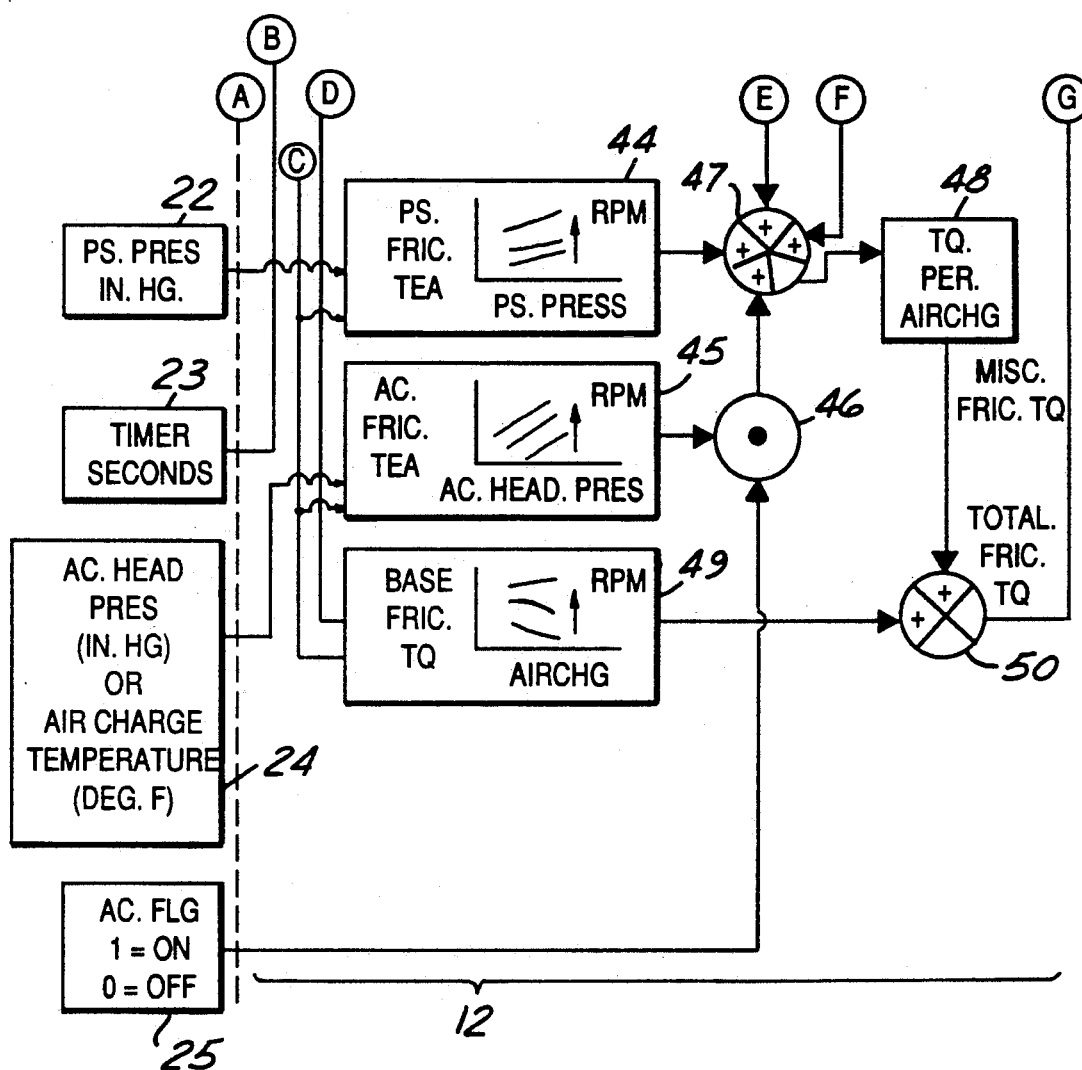


FIG.3A

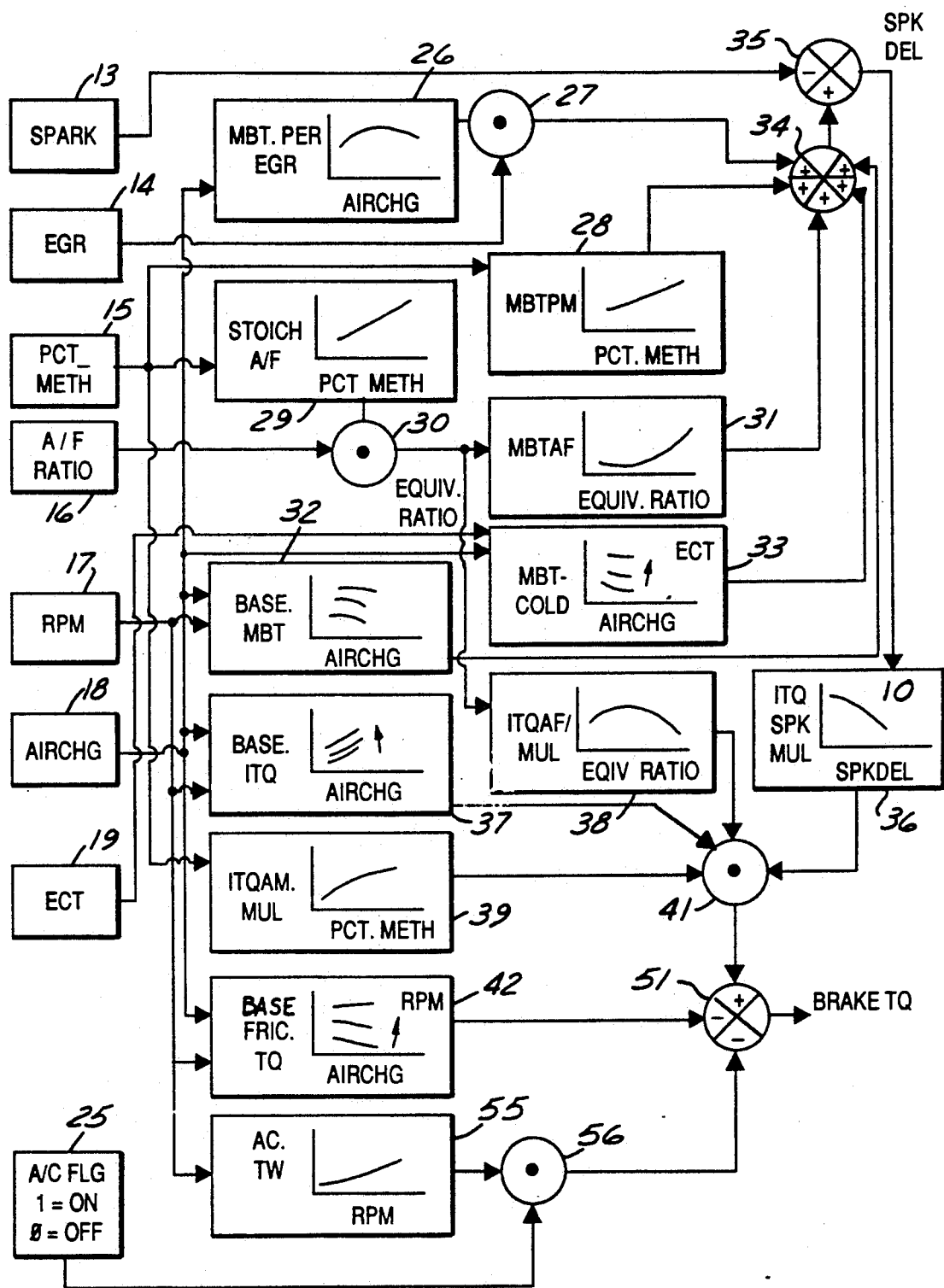


FIG. 4

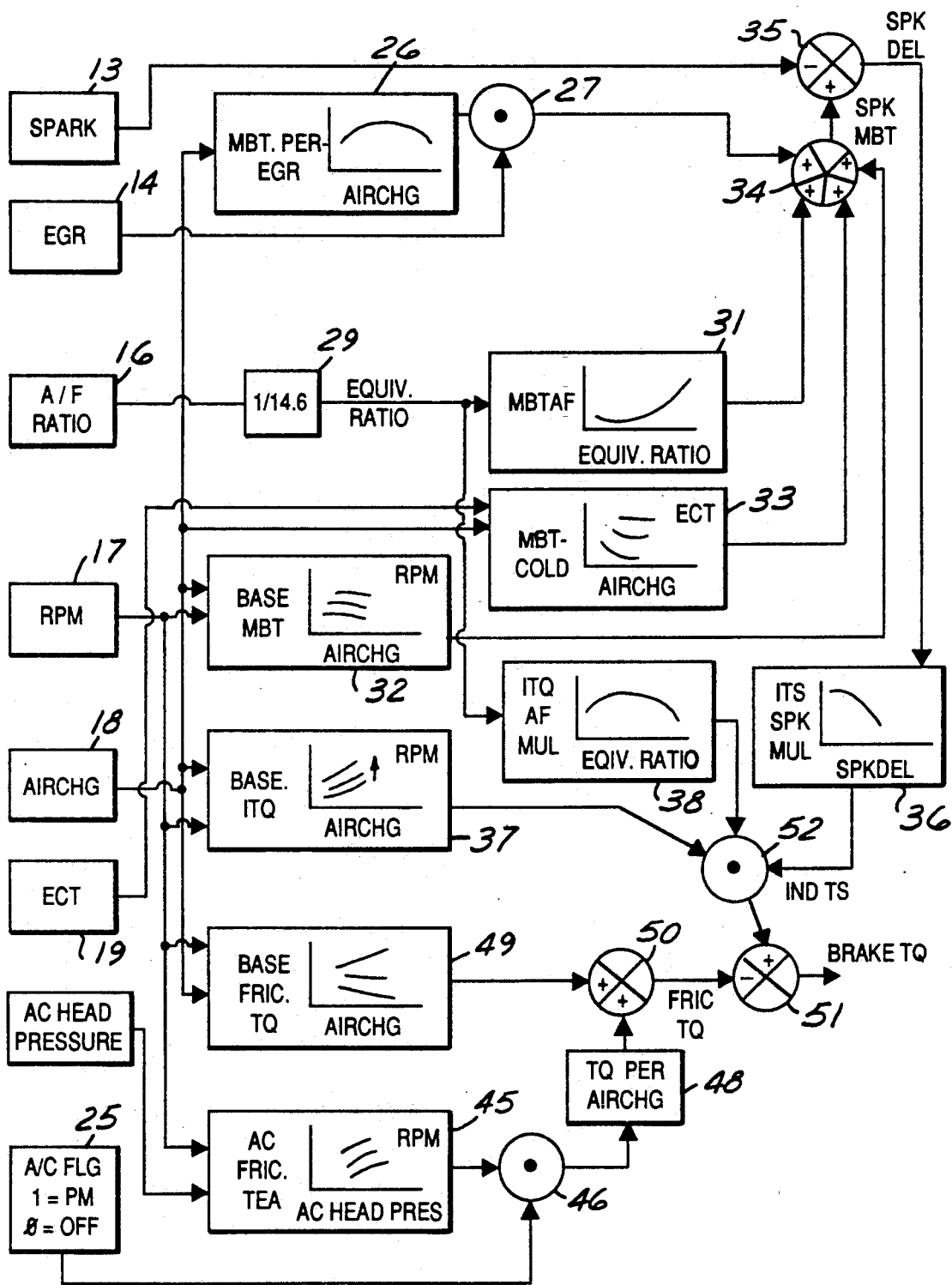


FIG.5

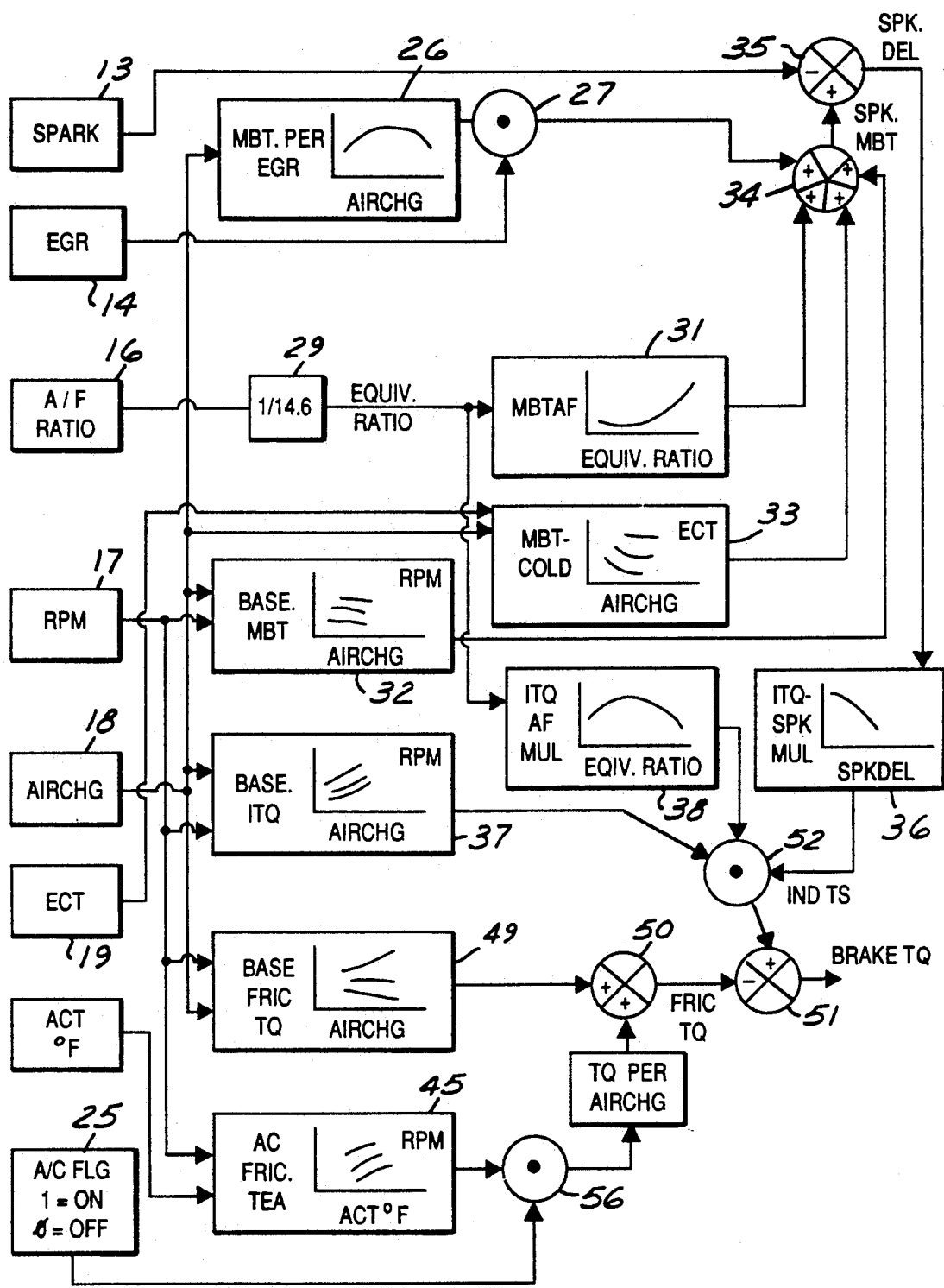


FIG.6

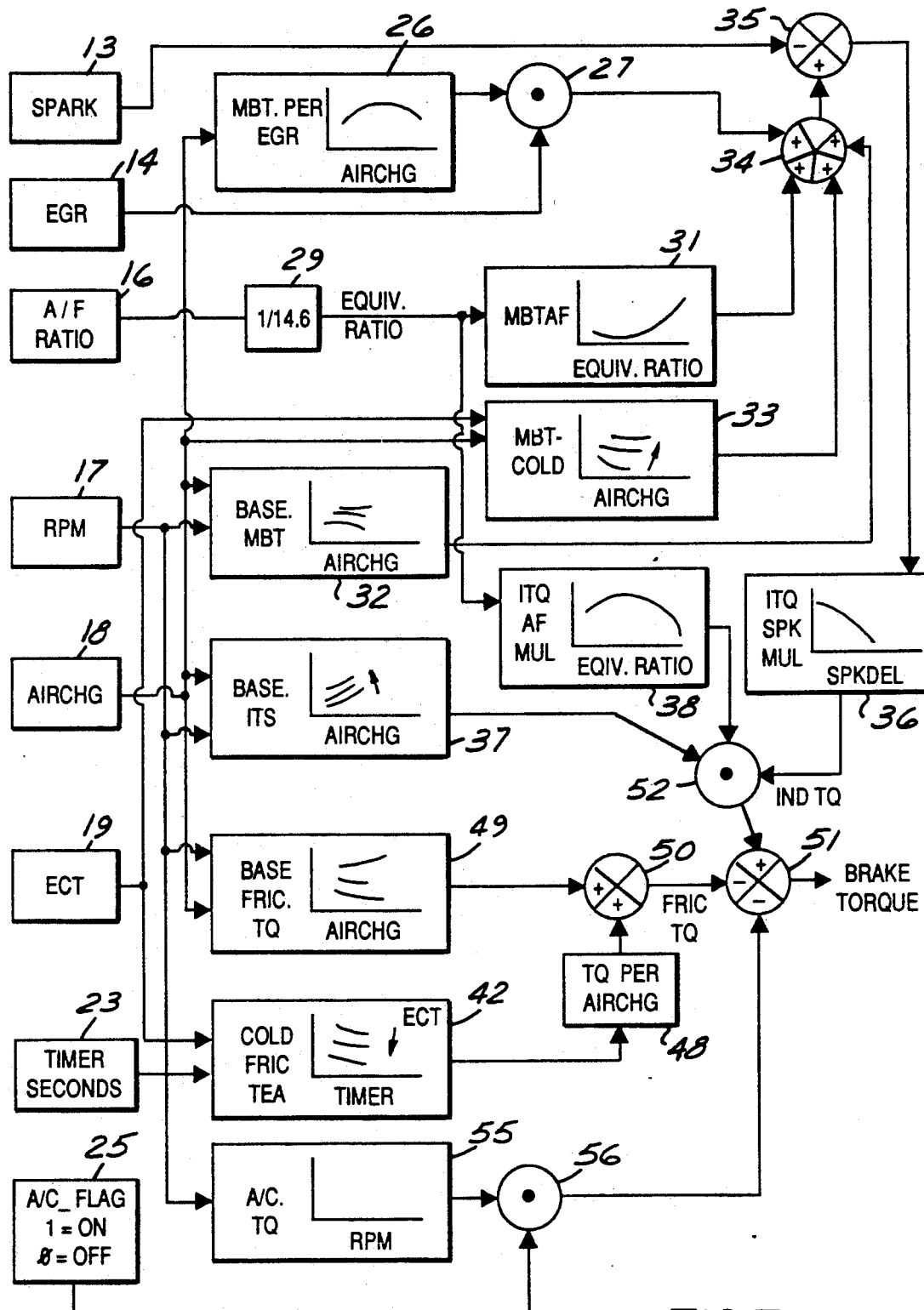


FIG.7

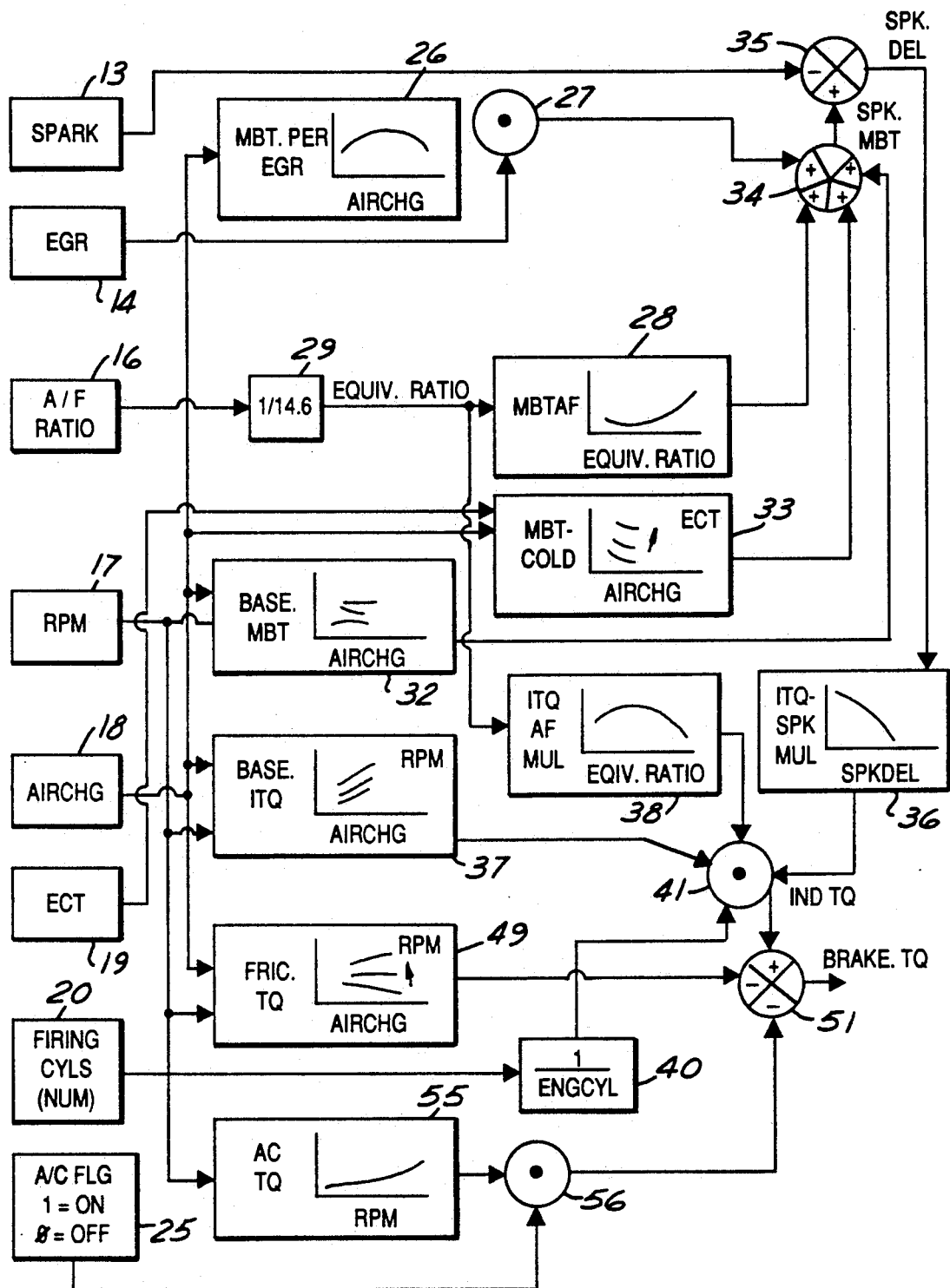


FIG. 8

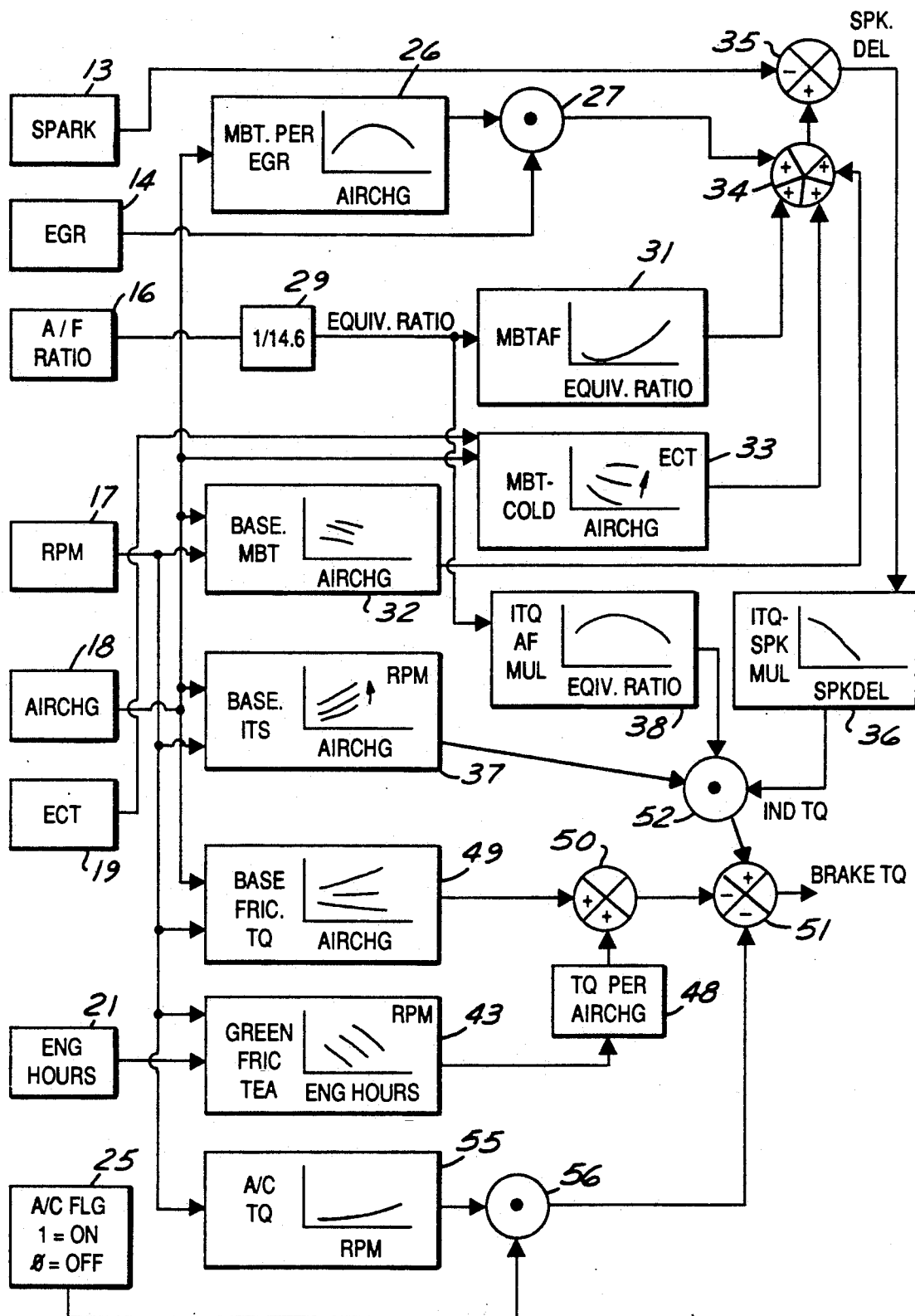


FIG. 9

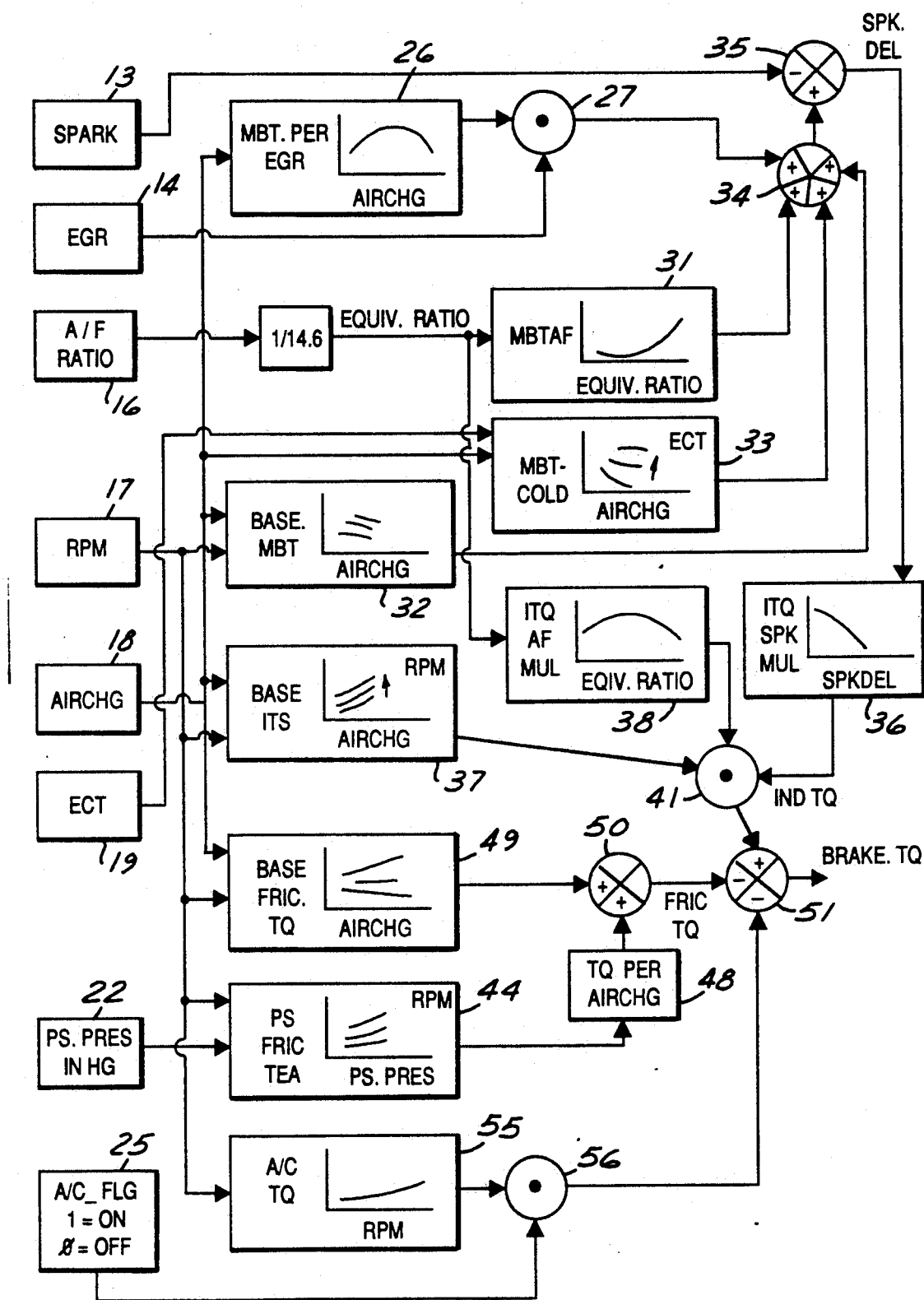


FIG.10

METHOD AND APPARATUS FOR INFERRING ENGINE TORQUE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to engines and in particular to inferring the torque produced by an engine. One use of such an inferred engine torque is as an input parameter for a control system governing operation of an automatic transmission associated with the engine.

2. Prior Art

Knowledge of engine torque is required as an input for automatic transmission control strategies and transmission failure mode management strategies.

Direct measurement of engine torque is not currently practical so various inferences have been used over the years in both mechanically controlled powertrains and microprocessor controlled powertrains.

Known mechanical transmission control systems predicted torque from throttle angle or engine intake manifold vacuum and an aneroid atmospheric pressure sensor.

These mechanical systems suffered from many sources of error including the influence of exhaust gas recirculation rate on the prediction, changes in accessory torque losses, and changes in friction torque during the warmup period or over the life of the engine.

Known microprocessor based powertrain control systems inferred engine torque from engine speed and engine airflow. For systems equipped with a manifold pressure sensor the airflow was calculated after accounting for the influence of exhaust gas recirculation. Thus this source of error was minimized. A lookup function of air conditioning torque versus engine speed was used to adjust the predicted torque when the air conditioner clutch was enabled by the microprocessor.

These early microprocessor based torque prediction systems were subject to the effect of changes in spark advance, EGR percent, and air/fuel ratio which occur over various barometric pressures, ambient temperatures and time since engine startup.

Referring to FIG. 2, also known in the prior art is an electronic engine control module including a stored table 118 which is a MBT spark adjustment for air/fuel read only memory function and has an input from air/fuel ratio input 115. A block 119 is an indicated torque adjustment for air/fuel ratio and has an input from air/fuel ratio input 115. A block 120 has a stored table for an unadjusted MBT spark and has inputs from engine speed rpm input 116 and air charge input 117. A block 121 is an unadjusted indicated torque round table and has inputs from engine speed rpm input 116 and engine air charge input 117. A block 122 has a stored table indicating friction torque read only memory table and has inputs from air charge input 117 and engine speed rpm indicator input 116. A block 123 is a MBT spark adjustment for EGR, read only memory scalar and has an input from engine EGR rate input 114.

A summer 124 has positive inputs from block 118, block 123, and block 120 to provide an adjusted MBT spark which is the sum of the outputs of blocks 118, 123 and 120. A summer 125 has a negative input from spark timing input 113 and a positive input from adder 124 to determine the difference between MBT and actual spark advance. The output of summer 125 is applied to a table storing the indicated torque adjustment for spark retard in a block 126. The output of block 126 is applied

to a multiplier 127 which also has inputs from block 119 and block 121. Multiplier 127 provides an adjusted indicated torque which is the product of blocks 119, 121, and 126. The output of multiplier 127 is applied to a summer 128. As an output of block 128, brake torque is indicated less friction torque. The output of summer 128 is applied to a coupling to transmission 111.

This level of microprocessor based control system had inaccuracies due to air conditioning head pressure, power steering torque requirements, cold engine friction, green engine friction, intentional or otherwise known cylinder shutdown (via spark or injector turn-off), and the influence of non-gasoline fuels like methanol/gasoline blends in flexible fuel vehicles.

A real time torque calculation is accomplished by determining the distance (i.e., actual spark advance) from MBT spark (SPK_DELTA) by looking up MBT spark (FN1617) and adjusting it for EGR (MBTEGR) and LAMBSE (FN730) then subtracting the actual current spark (SAFTOT). Indicated (COMBUSTION) engine torque is then looked up from a table of RPM and LOAD (FN1615A) and multiplied by a function of SPK_DELTA (FN621) and a function of LAMBSE (FN623).

Thus an improved torque prediction algorithm would be desirable to account for operating variables which influence torque output including engine coolant temperature and air conditioning friction.

SUMMARY OF THE INVENTION

This invention recognizes that a predicted torque calculation can be made more accurate by predicting the air conditioning torque requirement versus head pressure, power steering torque requirements versus power steering pressure switch, cold engine friction versus time since start and engine coolant temperature, green engine friction versus total engine revolutions since new, and the influence of non-gasoline fuels like methanol measured by a percent methanol sensor. The effect of intentional or otherwise known engine cylinder shutdown is also accounted for.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a means for inferring engine torque in accordance with an embodiment of this invention;

FIG. 2 is a logic flow diagram of the operation of an electronic engine control module in accordance with the prior art; and

FIGS. 3 and 3A is a logic flow diagram of the operation of an electronic engine control module in accordance with an embodiment of this invention.

FIG. 4 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating percent methanol fuel;

FIG. 5 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating air conditioning head pressure;

FIG. 6 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating air charge temperature;

FIG. 7 is a logical diagram of the operation of the electronic control module in accordance with an em-

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bodiment of this invention including an input indicating engine cooling temperature and a timer input;

FIG. 8 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating firing cylinders;

FIG. 9 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating engine operating hours; and

FIG. 10 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating power steering pressure.

DETAILED DESCRIPTION OF THE INVENTION

Torque calculation in accordance with an embodiment of this invention advantageously uses a speed/load table of indicated engine torques for 100% gasoline, all engine cylinders enabled, a stoichiometric air/fuel ratio, MBT spark, and 0% exhaust gas recirculation rate (EGR). The effects of percentage methanol, number of cylinders firing, spark retard, rich or lean air/fuel ratios, and EGR are accounted for through a series of multipliers. The calculations are based on indicated torque because the effects above act on top of the pistons, independently of various frictional losses which subtract from the indicated torque before it impacts the transmission. This formulation thus allows the effects to be accounted for with relatively simple indicated torque multipliers.

Alternately, the base indicated torque tables could be defined for a fuel other than gasoline, and the percent methanol modified could be for other flexible fuels like propane.

Torque calculation in accordance with an embodiment of this invention advantageously uses a speed/AIRCHG table of friction torques for a warmed up engine, with friction stabilized (no longer reducing with engine hours), air conditioning clutch disabled, and power steering at straight ahead pressure level. Additional friction due to deviation from the above conditions always add to the friction torque.

The effect of cold engine friction is predicted from a table of engine coolant temperature and the time since the engine was started. Alternately, an oil temperature sensor replaces the engine coolant temperature sensor.

The effect of air conditioning torque requirements are predicted first from a flag indicating that the microprocessor has enabled the air conditioner clutch, and then from a table of torque requirements versus air conditioning head pressure and engine speed. Alternately, if the vehicle is not equipped with a head pressure sensor, inlet air temperature is a suitable predictor for head pressure and the table of torque requirements is a function of engine speed and inlet air temperature.

The effect of power steering torque requirements are predicted from a table of torque requirements versus power steering pressure level and engine speed. In its simplest form the power steering pressure is a two position switch indicating high and low pressure. Alternately, it is a continuous measurement.

The effect of green engine friction is predicted from an engine hour meter if the vehicle is so equipped. Alternately total engine revolutions could be used. The green engine friction torque losses are contained in a lookup table versus engine speed and engine hours.

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In summary, the designations for inputs used in the torque calculation are:

RPM—engine speed (revolutions/minute), a sensor input.

AIRCHG—air charge lbs/cylinder-filling) which equals an estimate of air mass flow, (AM lbs/minute) divided by the number of cylinder fillings per minute: $AIRCHG = AM / (RPM * ENG CYL / 2)$ AM may be a direct output of an air meter or calculated in speed-density system.

SPK—final spark advance (degree BTDC), calculated and output by the microprocessor.

A/F—air/fuel ratio, a calculation modified by a feedback sensor.

EGR—actual EGR percent (%), a sensor input.

AC_FLG—air conditioning flag (1=A/C clutch engaged, 0=A/C clutch freewheeling), an output of the microprocessor.

ECT—engine coolant temperature (degrees Fahrenheit), a sensor input.

ACT—inlet air temperature (degrees Fahrenheit), a sensor input.

AC_PRES—air conditioning head pressure (inches Mercury), a sensor input.

PS_PRES—power steering pressure (inches Mercury), a sensor input.

TIMER—time since engine was started, a calculation.

PCT_METH—percent methanol in fuel (%), a sensor input.

FIRING_CYLS—number of cylinders firing which can be less than the number available, ENG CYL, for instance during decel fuel shutoff modes, a calculation by the microprocessor.

The designation for the output used in the torque calculation is:

BRAKE_TQ—brake engine torque (Fft-lbs)

The designations for calibration items used in the torque calculation are:

ENG CYL—number of engine cylinder available (=8 for 8 cylinder engine).

BASE_ITQ(RPM,AIRCHG)—a table containing indicated torque at MBT spark, stoichiometric air/fuel ratio 0% EGR, 100% gasoline, all cylinders firing.

ITQSPKMUL(SPKDEL)—indicated torque multiplier versus degrees of spark retard from MBT.

STOIC_A/F(PCT_METH)—the stoichiometric A/F ratio corresponding to the percent methanol.

ITQAFMUL(EQUIV_RATIO)—indicated torque multiplier versus equivalence ratio (air/fuel ratio divided by stoichiometric equivalence ratio for given percent methanol).

ITQPMUL(PCT_METH)—indicated torque multiplier versus percent methanol.

BASE_MBT(RPM,AIRCHG)—a table of MBT spark values values corresponding to BASE_ITQ.

MBTAF(EQUIV_RATIO)—adder to BASE MBT due to deviation from stoichiometric equivalence ratio.

MBTPEREGR(AIRCHG)—number which when multiplied by percent EGR produces an adder to BASE_MBT.

MBTPM(PCT_METH,AIRCHG)—adder to BASE_MBT which accounts for less than 100% gasoline (percent methanol).