Robert Bosch LLC and Daimler AG.,
Petitioner
v.
Orbital Australia PTY LTD,
Patent Owner

Cases IPR2015-01258, 01259

U.S. Patent No. 5,655,365

Witness Notes Prepared by Dr. Ron Matthews

Summary of Instituted Grounds

IPR 2015-01258

Reference(s)	Basis	Challenged Claim(s)
Bernhardt	§102 (b)	1, 2, 5, 10, 12, 13, 18
Bernhardt and Onishi	§103 (a)	9
Bernhardt and Griese	§103 (a)	14
Eichler '791 and Bernhardt	§103 (a)	1, 2, 5, 10, 12-14, 18
Eichler '791, Bernhardt, and Onishi	§103 (a)	9

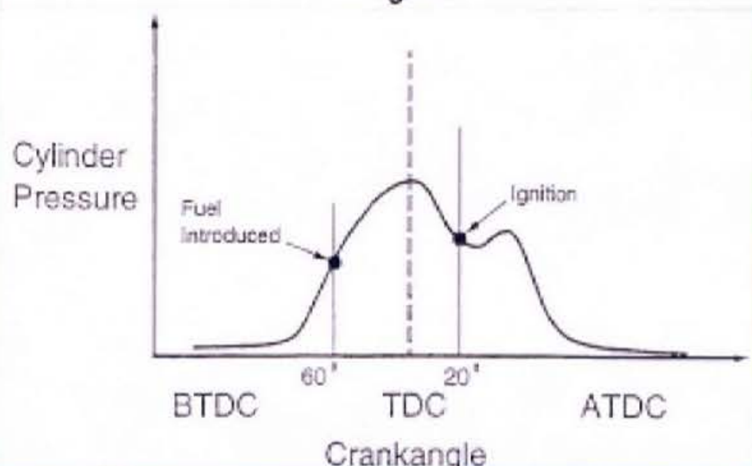
IPR 2015-01259

Reference(s)	Basis	Challenged Claim(s)
Hitomi and Onishi	§103 (a)	1, 9, 10, 13, 14, 18
Hitomi, Onishi, and Eichler '089	§103 (a)	5
Hitomi, Onishi, and Takada	§103 (a)	12
Griese, Eichler '791, and Onishi	§103 (a)	1, 2, 5, 9, 10, 13, 14, 18
Griese, Eichler '791, Onishi, and Takada	§103 (a)	12

Asserted Patent – Claim 1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



Asserted Patent – Claim 2

2. A method according to claim **1** wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

cylinder engine. Preferably, the fuelling rate (measured in mg/cylinder/cycle) is greater than 50% of the fuelling rate at maximum load, and more preferably is up to about 80% of the fuelling rate at maximum load. However, if desired, the fuelling rate can be in excess of 100% of the fuelling rate at maximum engine load. However, the selected fuelling rate is conveniently the minimum rate which will ensure that the desired exhaust gas temperature is achieved. The fuel may

'365 patent at 2:3-10

Referring initially to FIG. **1**, in a typical direct injected two-stroke internal combustion engine, the fuel is introduced to the cylinder at approximately 60° before top dead centre (BTDC) with ignition within the cylinder occurring prior to top dead centre at approximately 35° BTDC. The solid curve of the graph of FIG. **1** shows the cylinder pressure crankangle characteristics where ignition has occurred. The dashed curve shows the situation where ignition does not occur.

'365 patent at 2:59-67

In the method according to the invention and as shown in an exemplary embodiment in FIG. **2**, while the fuel is introduced to the cylinder at between 60° and 80° BTDC, the ignition within the cylinder is retarded and occurs at up to about −30° BTDC, ie. 30° after top dead centre (ATDC). The curve of the graph of FIG. **2** shows the cylinder pressure crankangle characteristics where the fuel is introduced to the cylinder at 60° BTDC and ignition thereof occurs at −20° BTDC.

'365 patent at 3:1-12

Asserted Patent – Claim 5

5. A method according claim **1** wherein the ignition is retarded up to about 30° ATDC.

Conveniently, ignition can be retarded up to about −30° BTDC (i.e 30° ATDC) and is preferably of the order of −20° BTDC (i.e 20° ATDC). The ignition retardation may alter-

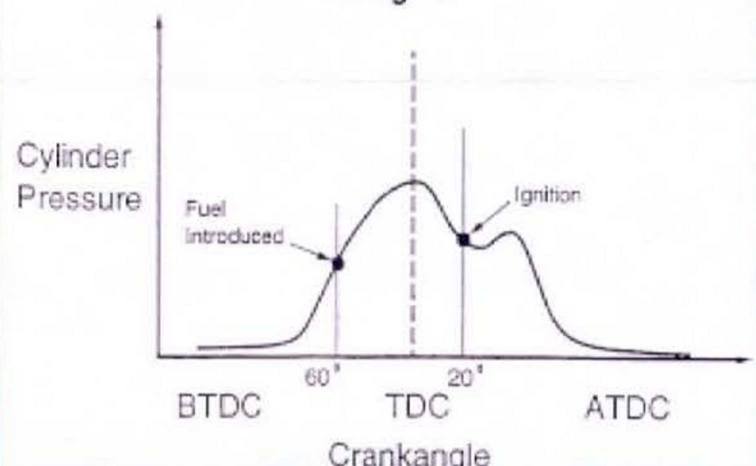
natively be variable, preferably between 15° ATDC to 30° ATDC in the case of a multi cylinder engine such as a three cylinder engine. Preferably, the fuelling rate (measured in

'365 patent at 1:65-2:3

In the method according to the invention and as shown in an exemplary embodiment in FIG. 2, while the fuel is introduced to the cylinder at between 60° and 80° BTDC, the ignition within the cylinder is retarded and occurs at up to about −30° BTDC, ie. 30° after top dead centre (ATDC). The curve of the graph of FIG. 2 shows the cylinder pressure crankangle characteristics where the fuel is introduced to the cylinder at 60° BTDC and ignition thereof occurs at −20° BTDC.

'365 patent at 3:1-9

Fig. 2



Asserted Patent – Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

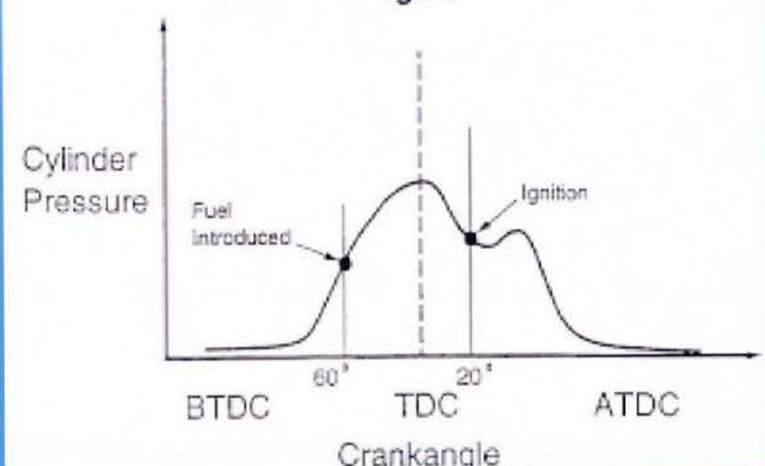
desired exhaust gas temperature is achieved. The fuel may be introduced to the combustion chamber before top dead centre (BTDC) and most preferably at 60° to 80° BTDC in the case of a direct injected engine. It is however also envisaged that the fuel be introduced to the cylinder after top dead centre (ATDC) under certain conditions or situations.

'365 patent at 2:9-14

In the method according to the invention and as shown in an exemplary embodiment in FIG. **2**, while the fuel is introduced to the cylinder at between 60° and 80° BTDC, the ignition within the cylinder is retarded and occurs at up to about –30° BTDC, ie. 30° after top dead centre (ATDC). The curve of the graph of FIG. **2** shows the cylinder pressure crankangle characteristics where the fuel is introduced to the cylinder at 60° BTDC and ignition thereof occurs at –20° BTDC.

'365 patent at 3:1-9

Fig. 2



Asserted Patent – Claim 10

10. A method according to claim **1** wherein the engine includes in an exhaust system thereof a catalytic treatment means supporting a catalytic material therein.

FIG. **3** shows an internal combustion engine **1** with an associated exhaust system **2** connecting the engine exhaust ports **6** to a catalytic treatment means **3**. Catalytic material **4** is supported within the catalytic treatment means **3**. A flame arrester **5** is located upstream of the catalytic treatment means **3** between the exhaust ports **6** and the treatment means **3**.

'365 patent at 3:13-19

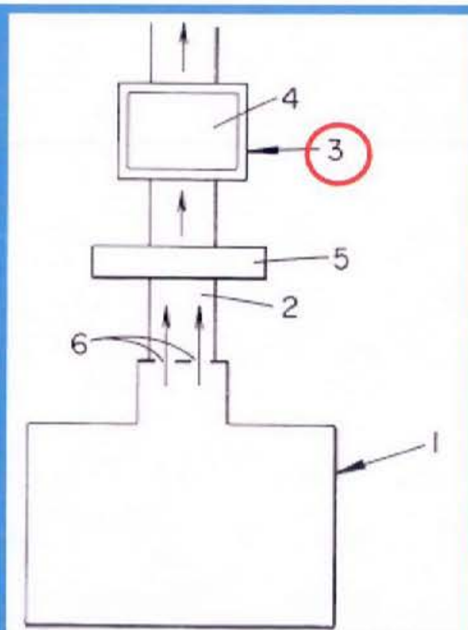


Fig. 3

Asserted Patent – Claim 12

12. A method according to claim **10** wherein additional air is introduced upstream of the catalytic treatment means.

FIG. **3** shows an internal combustion engine **1** with an associated exhaust system **2** connecting the engine exhaust ports **6** to a catalytic treatment means **3**. Catalytic material **4** is supported within the catalytic treatment means **3**. A

'365 patent at 3:13-16

protect it from contact with any flames. Where necessary, and as alluded to hereinbefore, excess air may be introduced to the exhaust system to promote the catalytic oxidation of the exhaust gases.

'365 patent at 4:32-35

If desired, additional oxygen containing gas, such as air, may be introduced upstream of the catalytic treatment means provided in the exhaust system of the engine, for example, by use of an air pump, thus ensuring the introduction of excess oxygen to the exhaust system enabling catalytic conversion of any contaminants in the exhaust gas. In many cases, it will be desirable that the throttle or air control means for the air supply to the combustion chamber with retarded ignition be set at a "wide open" or near "wide open" value such as to maximise air supply to that combustion chamber, thus allowing higher fuelling rates to be used. However, in the case that the air control system serves more than one cylinder, then the air flow rate must be established such that the combustion efficiency of the combustion chamber(s) without retarded ignition is not adversely affected.

'365 patent at 4:1-16

Asserted Patent – Claims 13 and 14

13. A method according to claim **10** wherein the engine is operated according to said method during cold start of the engine.

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

The method can be operated during cold start of the engine. Alternatively or in addition, the method is operated when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

'365 patent at 2:26-29

is a substantial increase in operator demand. The method of operating the engine according to the present invention can therefore be initiated, both during cold start of the engine, and when the temperature of catalytic material is sensed or determined to be below the required light-off operating temperature any time during the running of the engine.

'365 patent at 5:41-46

Asserted Patent – Claim 18

18. A method according to claim 1 wherein after a predetermined operating condition has been sensed or determined, said engine reverts back to normal operation.

It will be appreciated that where an engine start-up occurs after only a short period of time after shut-down of the engine, the catalytic treatment means may still be at a sufficiently high temperature to immediately light-off on restarting the engine and hence it may be undesirable to further heat the catalytic treatment means by way of the present invention. However, this condition can be determined by appropriate sensing of other engine parameters such as the temperature of the engine in general, cooling water temperature or the temperature of the exhaust system in the vicinity of the catalytic treatment means. Accordingly, sensing of these and/or other engine parameters may be effected and the specific ignition retarding and high fuelling rate conditions only implemented if for example, the sensed temperature condition of the engine and/or exhaust system indicates that the temperature of the catalytic treatment means is at a level which would necessitate assistance in achieving prompt light-off thereof.

'365 patent at 4:62-5:12

When the appropriate sensor or sensors detect that the engine parameter, for example the exhaust system temperature, is again above the acceptable value, the engine management system may then cease to effect the ignition retard and high fuelling rate conditions and return the cylinder to normal ignition timing and fuelling rates. Where

'365 patent at 5:24-29

Claim Constructions Addressed by the Board

Term	Board Preliminary CC*	Petitioner's Construction	Patent Owner Construction
"the timing of the introduction of fuel … being maintained at …BTDC""	The start of injection of the fuel begins at BTDC – "we need not and do not reach at this time the issue of whether the claims require all fuel to be injected BTDC."	"maintained" requires that all fuel be injected at BTDC**	"Introduction" refers to the start of injection Fuel injection begins BTDC but does not require that the addition of fuel end in the BTDC range
"while said ignition is so retarded"	"The engine is in a period 'while said ignition is so retarded [to ATDC]' at all crankangle positions when the retarded-ignition condition is enabled, including those times during the cycle when the crankangle is before top dead center. Thus, when the engine is operated in a condition where ignition is at a retarded angle after top dead center and all fuel is injected before the crankangle reaches top dead center, it still would be true that the fuel was injected while the ignition was 'so retarded.'"	[*Not explicitly construed by Petitioner in the Petition*] The Board's construction is correct.	The period of time when the crankangle position during a given cycle is ATDC.

* Institution Decision at 7-9. **Petition at 5-6.

Claim Construction – Claim 1

"the timing of introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC)" (Claim 1)

37.

at 6:15-17. In light of the specification and prosecution history, this phrase should be construed to mean "all fuel introduced into the at least one cylinder during a combustion cycle is controlled to occur BTDC." *See e.g.*, Ex. 1001 at 2:9-14, 2:59-63, 3:1-9, Figs. 1, 2. Ex. 1008 at 74-76 (11/13/1995 Office Action), 83-85 (03/08/1996 Response), 91-93 (04/25/1996 Office Action), 106-07 (07/25/1996 Amendment). I have been informed that in the pending litigation, the PO has construed this term to mean "the start of injection occurs in the window between 80 to 60 degrees before top dead center." Under such a construction, however, the terms "being maintained" are rendered superfluous. The '365 patent describes that, in typical engines fuel is introduced at approximately 60° BTDC with ignition occurring at approximately 30° BTDC. Ex. 1001 at 2:59-63. It then describes the method "according to the invention" where fuel is still introduced BTDC (at between 60° and 80° BTDC), while the ignition is retarded at up to about 30° ATDC. *Id.* at 3:1-9. In other words, ignition is retarded to ATDC, but the timing of introduction of fuel is left unchanged as compared to the timing of fuel introduction in "typical engines"—i.e., it is "maintained at" BTDC. *Compare id.* at

Claim Construction – Claims 1 and 2

37.

"fuelling rate" (Claims 1 and 2)

Independent claim 1 and dependent claim 2 recite "fuelling rate." Ex. 1001 at 6:12-14. In light of the specification, this phrase should be construed to mean "the amount of fuel introduced into a cylinder during a combustion cycle." *See e.g., Id.* at 2:3-6, 2:7-10, 2:59-3:12, Figs. 1, 2. Ex. 1010 at 1:8-14.

Claim Construction – Claim 2

37.

"maximum load" (Claim 2)

Dependent claim 2 recites "maximum load." Ex. 1001 at 6:19-20. In light of the specification, this term should be construed to mean "maximum load of the engine," <u>which equates to the peak torque output of the engine</u>. *See e.g.*, Ex. 1001 at 1:26-40, 2:3-8, 3:10-12, 5:50-57. *See also*, Ex. 1010 at 2:19-22.

Claim Construction – Claim 5

37. **"up to about 30° ATDC" (Claim 5)**

Independent claim 1 recites "up to about 30° ATDC." Ex. 1001 at 6:25-26. In light of the specification, this phrase should be construed to mean "between 15° and about 30° ATDC." *See, e.g.*, Ex. 1001 at 1:65-2:3, 3:1-9, 3:20-27, 3:41-47, Fig. 2. The patent's specification does not disclose an engine in which retarded ignition occurs between TDC and 15 ATDC. Rather, all that is supported is engine operation in which ignition is delayed to between 15° and about 30° ATDC. Further, there is no disclosure in the specification explaining if, or how, retarding ignition to between TDC and 15° ATDC meets the object of the invention of increasing exhaust gas temperature to achieve light-off in a sufficiently reduced amount of time. *See, e.g., id.* at 1:65-2:3, 3:1-9, 3:20-47.

PO contends that no explicit construction is necessary, but argues that "up to about 30°" encompasses all crankangles between 0° and 30°.

Claim Construction – Claim 12

37. **"additional air is introduced upstream" (Claim 12)**

Dependent claim 12 recites "additional air is introduced upstream." Ex. 1001 at 6:43-44. In light of the specification, this term should be construed to mean "additional air is introduced into the exhaust system between the exhaust ports of the engine and the catalytic treatment means." *See e.g.*, Ex. 1001 at 3:13-19, 4:1-16, 4:32-35, Fig. 3.

Claim Construction – Claim 14

37. **"required operating temperature" (Claim 14)**

Dependent claim 14 recites "required operating temperature." Ex. 1001 at 6:48-51. In light of the specification, this term should be construed to mean "the temperature at which the catalytic material within the catalytic treatment means is 50% efficient." *See e.g.*, Ex. 1001 at 1:10-19, 4:62-5:46.

"sensed or determined" (Claim 14)

Dependent claim 14 recites "sensed or determined." Ex. 1001 at 6:48-51. In light of the specification, this term should be construed to mean "measured by a sensor." *See e.g.*, Ex. 1001 at 4:62-5:46.

Claim Construction – Claim 18

37. "predetermined operating condition" (Claim 18)

Dependent claim 18 recites "predetermined operating condition." Ex. 1001 at 6:60-62. In light of the specification, this term should be construed to mean "a threshold value, set in advance." *See e.g.*, Ex. 1001 at 4:62-5:12, 5:24-29.

Claim Construction – Claim 9

37. "fuel is introduced at between 60° to 80° BTDC" (Claim 9)

Claim 9 recites that "fuel is introduced at between 60° to 80° BTDC." Ex. 1001 at 6:35-36. In light of the specification, this term should be construed to mean "all fuel for a combustion cycle is introduced into a cylinder between 80° and 60° BTDC." *See e.g.*, Ex. 1001 at 2:9-14, 2:59-63, 3:1-9, Figs. 1, 2. Ex. 1008 at 74-76 (11/13/1995 Office Action), 83-85 (03/08/1996 Response), 91-93 (04/25/1996 Office Action), 106-07 (07/25/1996 Amendment). I have been informed that in the pending litigation, the PO has construed this term to mean "the start of injection occurs in the window between 80 to 60 degrees before top dead center." As described above in relation to the "the timing of introduction of fuel" limitation of claim 1, the '365 patent describes, and claim 1 requires, that all fuel is introduced into the cylinder BTDC. Because claim 9 depends from, and cannot be broader than, claim 1, in my opinion, a POSITA would construe "fuel is introduced at between 60° to 80° BTDC" to require ***all*** fuel to be injected at between 80° and 60° BTDC. There is no fair reading of this language, or support in the specification, for a construction that provides for fuel to be injected after 60° as long as injection began between 80° and 60°, as allowed for in PO's proposed construction.

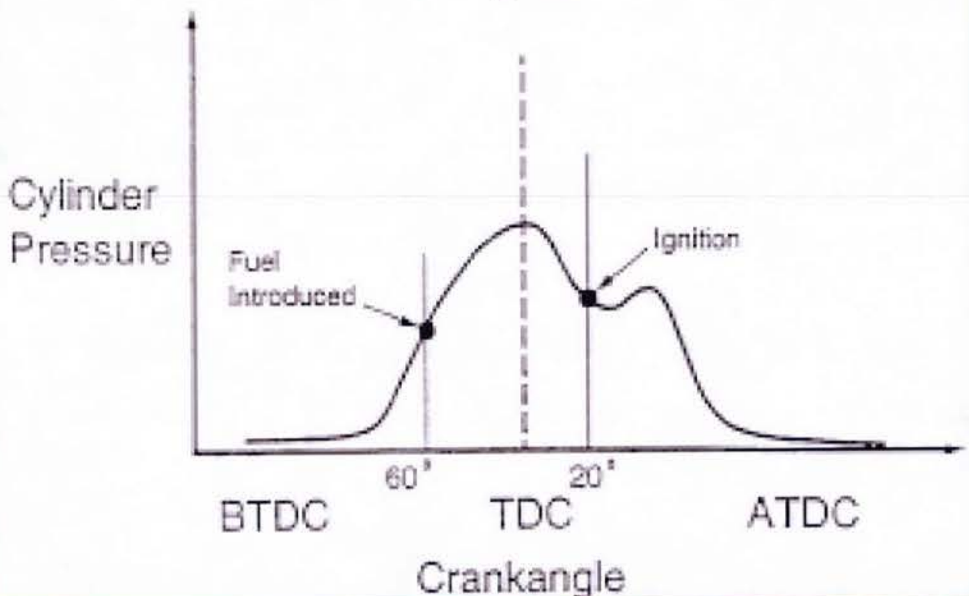
← Petitioner's Construction

← Patent Owner's Construction

Bernhardt

Reference(s)	Basis	Challenged Claim(s)
Bernhardt	§102 (b)	1, 2, 5, 10, 12, 13, 18
Bernhardt and Onishi	§103 (a)	9
Bernhardt and Griese	§103 (a)	14

Fig. 2



'365 patent at FIg. 2

Bernhardt

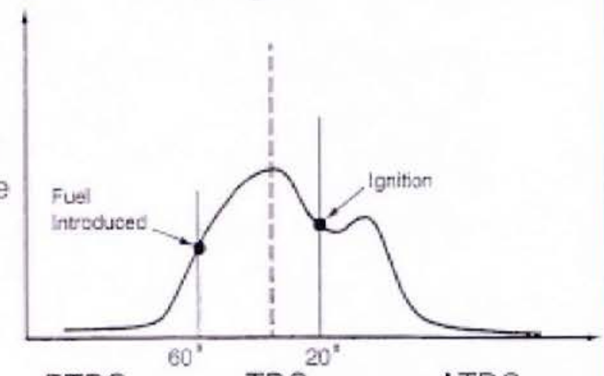
Reference(s)	Basis	Challenged Claim(s)
Bernhardt	§102 (b)	1, 2, 5, 10, 12, 13, 18

Bernhardt Discloses All Elements Of Claims 1, 2, 5, 10, 12, 18

Mapping of Bernhardt to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2

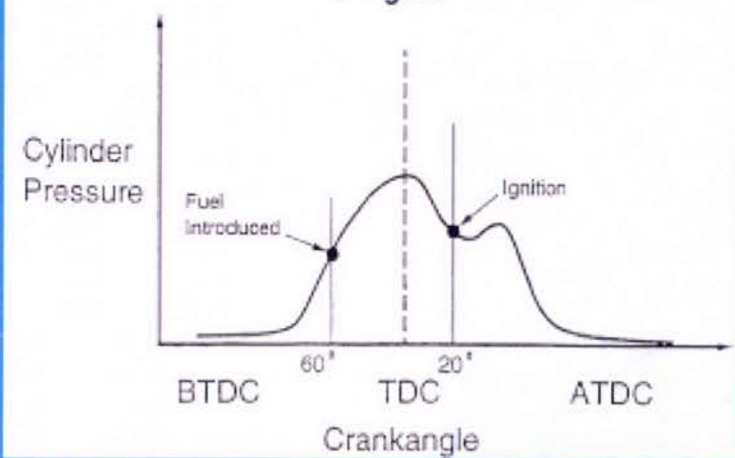


39. *Bernhardt* discloses a method for operating an internal combustion engine incorporating a catalytic system for treating exhaust gases exiting the combustion chamber. The method uses the engine as a preheater for the catalytic system by retarding ignition of the air and fuel mixture in at least one cylinder of the engine until ATDC. *Id.* at p. 8, col. 2, ¶1; p. 10, col. 2, ¶2. *Bernhardt* also discloses that while the ignition is being retarded to ATDC, an increase in fuel flow raises the exhaust gas enthalpy (*i.e.*, the amount of heat content of the exhaust gas in a system at constant pressure). In particular, *Bernhardt* discloses that during spark retard there is an "increased idling speed of the engine," the engine may operate with a "fully opened throttle," and may operate with a "reciprocal equivalence ratio of 1.0." *Id.* at p. 12, col. 1, ¶¶ 2, 5; *Id.* at p. 8, col. 2, ¶1.

Mapping of Bernhardt to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



47. *Bernhardt* discloses that "the total chemical energy of the exhaust gases can be used to increase the exhaust gas enthalpy if the shaft work is zero ($W_{12} = 0$). . . . In an engine the condition $W_{12} = 0$ can be attained by altering the ignition timing to 'retard'. In this case the energy release rises very late so that the work done on the piston becomes less." *Id.* at p. 8, col. 2, ¶3.

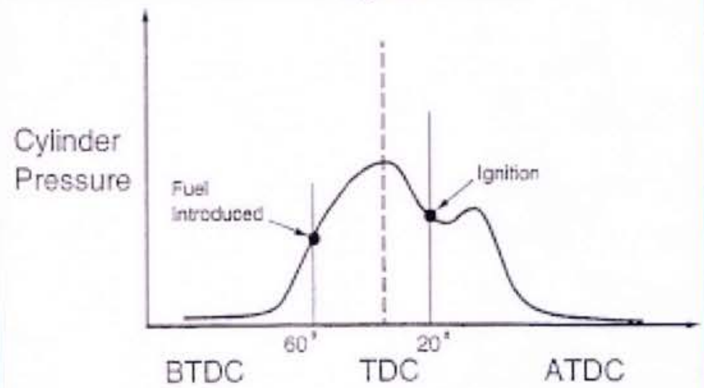
48. *Bernhardt* further discloses that "[a]s expected the exhaust gas temperature increased very rapidly when the ignition timing was retarded to a region after T.D.C.[2]" *Id.* at p. 10, col. 2, ¶2.

'See also, Bernhardt at p. 10, col. 2, par. 2.

Mapping of Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2

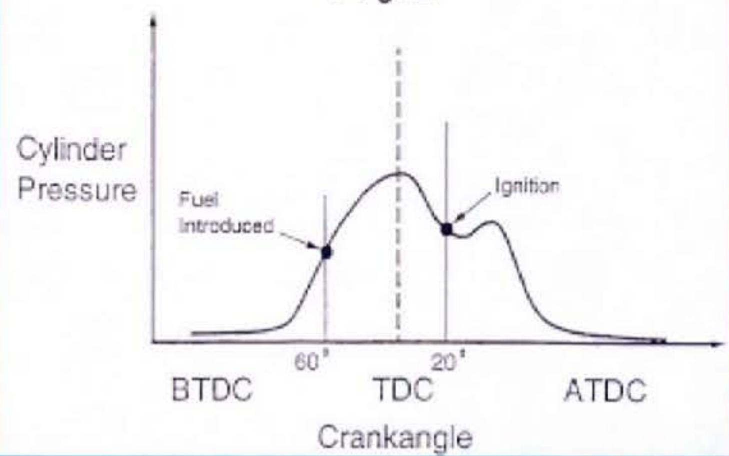


39. *Bernhardt* discloses a method for operating an internal combustion engine incorporating a catalytic system for treating exhaust gases exiting the combustion chamber. The method uses the engine as a preheater for the catalytic system by retarding ignition of the air and fuel mixture in at least one cylinder of the engine until ATDC. *Id.* at p. 8, col. 2, ¶1; p. 10, col. 2, ¶2. *Bernhardt* also discloses that while the ignition is being retarded to ATDC, an increase in fuel flow raises the exhaust gas enthalpy (*i.e.*, the amount of heat content of the exhaust gas in a system at constant pressure). In particular, *Bernhardt* discloses that during spark retard there is an "increased idling speed of the engine," the engine may operate with a "fully opened throttle," and may operate with a "reciprocal equivalence ratio of 1.0." *Id.* at p. 12, col. 1, ¶¶ 2, 5; *Id.* at p. 8, col. 2, ¶1.

Mapping of Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2

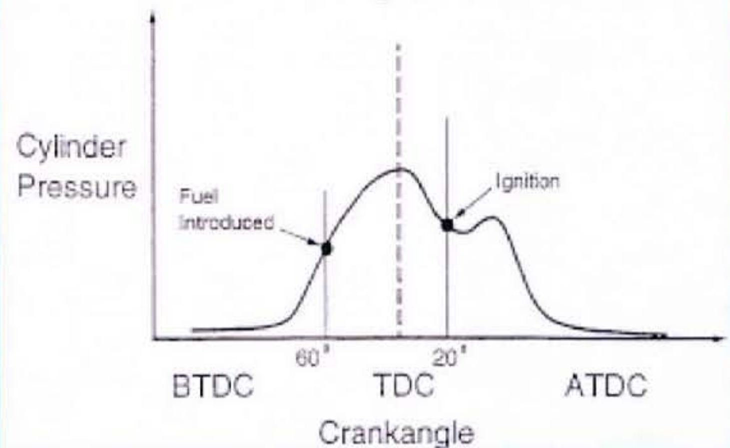


50. *Bernhardt* explicitly discloses that "the increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id* at p. 12, col. 1, ¶5. *Bernhardt* further discloses that this increase in fuel flow occurs during "spark retard," while there is "increased idling speed of the engine," "fully opened throttle," and a reciprocal equivalence ratio equals 1.0 (which occurs at a maximum exhaust gas temperature). Thus, in my opinion, a POSITA would recognize that *Bernhardt* discloses "increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally."

Mapping of Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



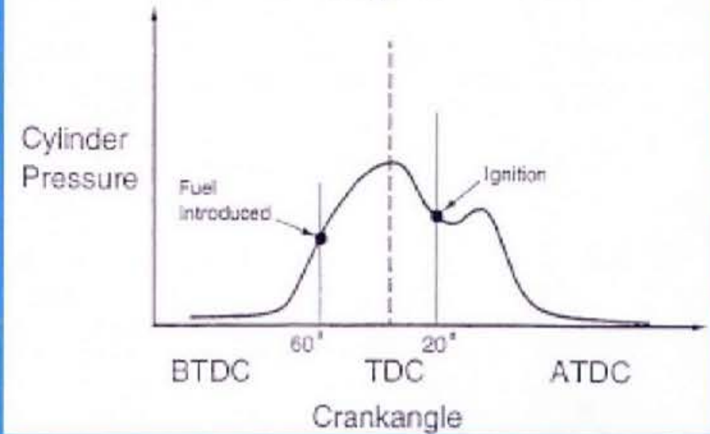
51. *Bernhardt* discloses a "very elegant method to achieve a rapid warm-up is the use of extreme spark retard from the moment of engine start-up by which an increased exhaust gas flow rate with high exhaust enthalpy is secured when the engine operates with stoichiometric mixtures ($1/\Phi = 0.95$-1.05) and fully opened throttle." *Id.* at p. 22, col. 2, ¶2.

52. *Bernhardt* discloses that in "order to keep the engine running the cylinder charge was repeatedly increased as the timing became more retarded until finally the throttle was fully open." *Id.* at p. 10, col. 2, ¶2.

Mapping of Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



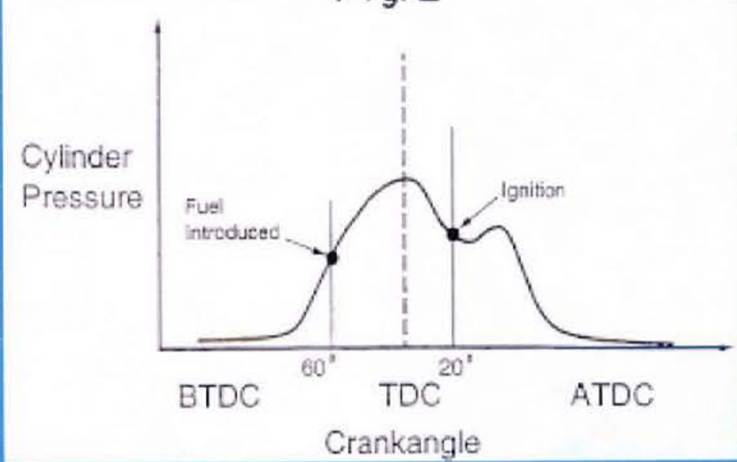
53. *Bernhardt* discloses that "curves of constant volumetric efficiency have the same tendency as the curves of constant exhaust gas temperature so that the desired objective of providing the hottest possible exhaust gas in largest possible quantities is achieved by the spark retard. . . . The increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id.* at p. 12, col. 1, ¶5.

54. *Bernhardt* discloses that the "exhaust gas temperature diagram in Figure 11 illustrates the influence of the air/fuel ratio and the ignition timing on the exhaust gas temperature. The exhaust gas temperature reaches its maximum at a reciprocal equivalence ratio of $1/\Phi = 1.0$ because the combustion temperature is highest at stoichiometric mixtures. *Id.* at p. 12, col. 1, ¶2.

Mapping of Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2

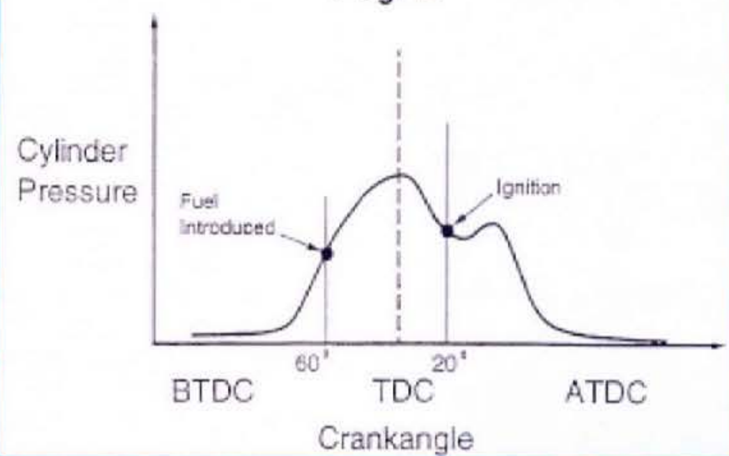


55. Bernhardt discloses that it "has been found that under appropriate operating conditions the engine itself is able to act as a preheater for the catalytic system. Warm-up spark retard and an increased idling speed of the engine with full open throttle lead to higher exhaust temperatures and thereby to a greater enthalpy of the exhaust gases, so that the after burning system could be brought rapidly up to its operating temperature." *Id.* at p. 8, col. 2, ¶1. Again, *Bernhardt* refers to exhaust catalysts in disclosing "after burning systems" *Id.* at p. 1, col. 2, ¶1.

Mapping of Bernhardt to Claim 1.2

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



40. *Bernhardt* discloses implementing conventional internal combustion engines[1], such as a VW 1.6 liter single cylinder engine with a production type combustion chamber, in which fuel and air are mixed prior to ignition, a POSITA would recognize that *Bernhardt* discloses an engine which operates in a manner in which "the timing of the introduction of fuel into the at least one cylinder [is] maintained at BTDC."

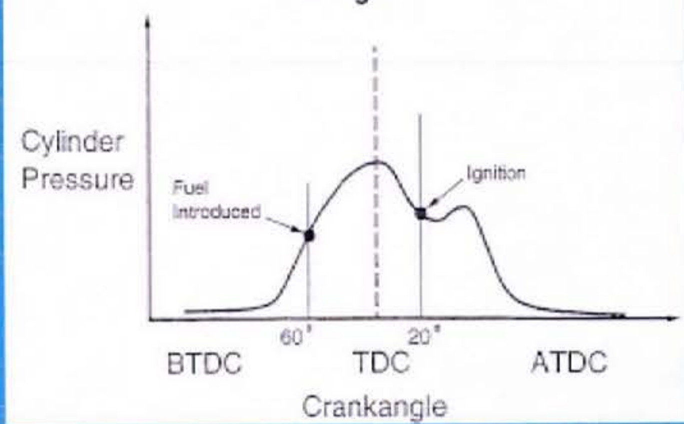
41. In conventional port fuel injected engines, such as the engine disclosed in *Bernhardt*, all fuel is introduced before the start of the compression stroke, which is typically at about 180° BTDC.

See also, Bernhardt at p. 10, col. 1, par. 2.

Mapping of Bernhardt to Claim 1.2

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, **the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).**

Fig. 2



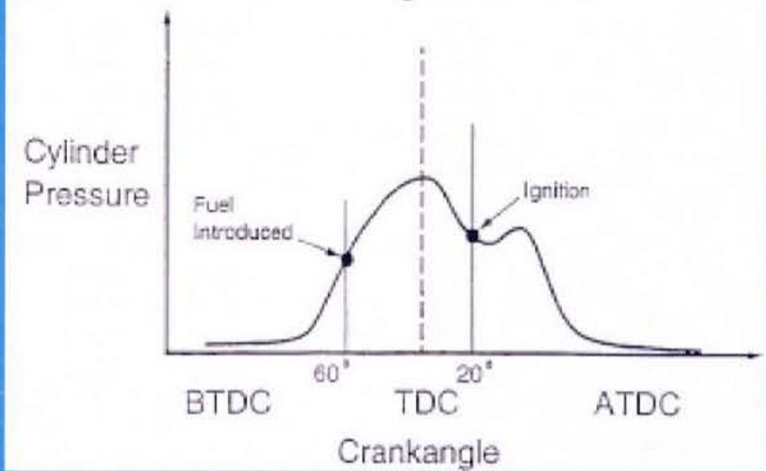
57. *Bernhardt* discloses that to "achieve the emission targets . . . a number of emission concepts with conventional internal combustion engines and emission control systems have been examined." *Id.* at introduction.

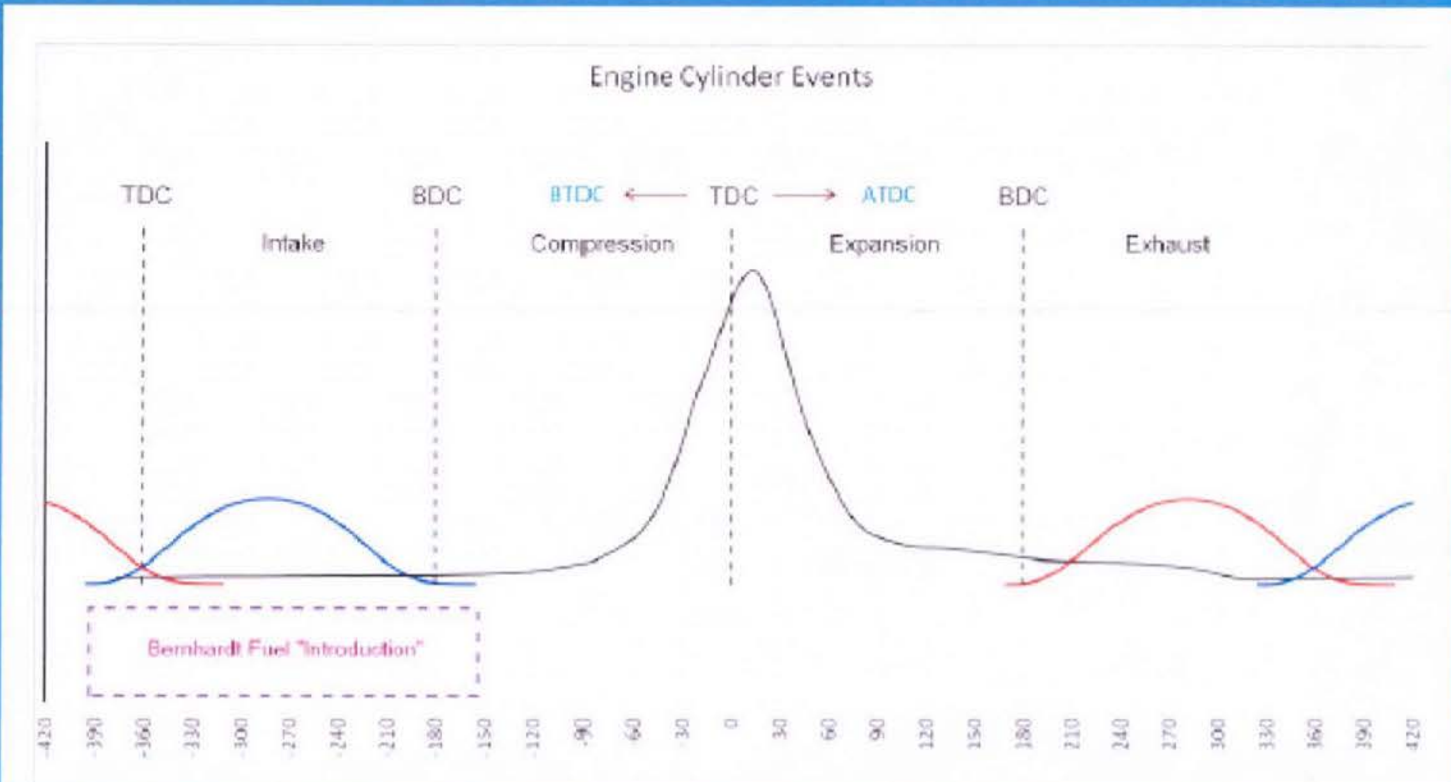
58. Because *Bernhardt* discloses implementing conventional internal combustion engines, in which fuel and air are mixed prior to ignition, in my opinion, a POSITA would recognize that *Bernhardt* discloses an engine which operates such that "the timing of the introduction of fuel into the at least one cylinder being maintained at BTDC," and in which all fuel in a combustion cycle is injected while the cylinder is at BTDC. The engine disclosed in *Bernhardt* employed a port fuel injection system where fuel is mixed with air in the intake port and introduced into the combustion chamber when the intake valve is opened and the fresh charge is drawn in during the intake stroke. As shown in the figure below, this necessarily occurs BTDC.

Mapping of Bernhardt to Claim 1.2

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2





Mapping of Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

59. *Bernhardt* discloses that the engine may operate at full throttle (which is the equivalent of the fuelling rate at maximum load at the instantaneous engine speed) during ignition retard. Ex 1002 at p. 22, col. 2, ¶2; p. 10, col. 2, ¶2; p. 12, col. 1, ¶2, ¶5; p. 12, Fig. 11.

60. *Bernhardt* discloses a "very elegant method to achieve a rapid warm-up is the use of extreme spark retard from the moment of engine start-up by which an increased exhaust gas flow rate with high exhaust enthalpy is secured when the engine operates with stoichiometric mixtures ($1/\Phi = 0.95\text{-}1.05$) and fully opened throttle." (Emphasis added.) *Id.* at page 22, col. 2, ¶2. *Bernhardt* also discloses that in "order to keep the engine running the cylinder charge was repeatedly increased as the timing became more retarded until finally the throttle was fully open." *id.* at p. 10, col. 2, ¶2, and that the "increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id.* at p. 12, col. 1, ¶5. *Bernhardt* further discloses that the "exhaust gas temperature reaches its maximum at a reciprocal equivalence ratio of $1/\Phi = 1.0$ because the combustion temperature is highest at stoichiometric mixtures. *Id.* at p. 12, col. 1, ¶2.

Mapping of Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

61. *Bernhardt* discloses that the "curves of constant volumetric efficiency have the same tendency as the curves of constant exhaust gas temperature so that the desired objective of providing the hottest possible exhaust gas in largest possible quantities is achieved by the spark retard. . . . The increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id.* at p. 12, col. 1, ¶5. (Emphasis added.)

62. *Bernhardt* discloses that the "exhaust gas temperature diagram in Figure 11 illustrates the influence of the air/fuel ratio and the ignition timing on the exhaust gas temperature. The exhaust gas temperature reaches its maximum at a reciprocal equivalence ratio of $1/\Phi = 1.0$ because the combustion temperature is highest at stoichiometric mixtures." *Id.* at p. 12, col. 1, ¶2.

Mapping of Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

63. Because *Bernhardt* discloses that during "spark retard," there is "increased idling speed of the engine," "fully opened throttle," and a reciprocal equivalence ratio of 1.0, a POSITA would recognize that *Bernhardt* discloses "increasing the fuelling rate greater than 50% of the fueling rate at maximum load wherein maximum load refers to wide open throttle operation of the engine. Specifically, it was well known to a POSITA that the fueling rate scales linearly with the product of the volumetric efficiency and the reciprocal equivalence ratio, that the wide open throttle volumetric efficiency was approximately 0.85 for normal fuel rich operation at the engine speed for which the volumetric efficiency was maximized prior to intake tuning and cam phasers (2200 rpm for *Bernhardt's* engine), that the volumetric efficiency was approximately 0.15 for closed throttle no load conditions, and that the reciprocal equivalence ratio was ~1.0. However, to achieve 1500 rpm at no load, the throttle would have to be opened further to yield a volumetric efficiency of ~0.3 for no load at 1500 rpm. For wide open throttle operation at 1500 rpm, the volumetric efficiency would be lower than the peak of ~0.85, approximately 0.8. It was also well known to a POSITA that normal wide open throttle operation involves using a rich mixture to maximize torque and minimize the chance that engine knock would be encountered, such that $1/\Phi \sim 1.2$. Thus, the increase in fueling rate from no load to full load at 1500 rpm for a normally operating engine is approximately $0.8*1.2/(0.3*1.0) \sim 3.2$. For *Bernhardt's* no load operating conditions with advanced ignition timing (BTDC), $1/\Phi \sim 1$, and a partially opened throttle (to achieve 1500 rpm and no load), Figure 11 in *Bernhardt* reveals a volumetric efficiency of approximately 0.3. For *Bernhardt's* full load operating conditions with retarded ignition timing (35° ATDC), $1/\Phi \sim 1$, and wide open throttle, Figure 11 in *Bernhardt* reveals a volumetric efficiency of approximately 0.8. Thus the ratio for the fueling rate for *Bernhardt's* wide open throttle operation to his no load fueling rate is approximately $0.8/0.3 \sim 2.67$. Therefore, *Bernhardt's* data reveals that his retarded ignition, wide open throttle, no load condition for rapidly warming up the catalyst requires $100*2.67/3.2 \sim 83\%$ of the fuelling rate at maximum load. Obviously, this is more than the "50% of the fuelling rate at maximum load" specified in claim 2 of the '365 patent.

Mapping of Bernhardt to Claim 5

5. A method according claim 1 wherein the ignition is retarded up to about 30° ATDC.

64. *Bernhardt* discloses retarding ignition up to about 30° ATDC, and in particular, between 15° and 30°. Ex. 1002 at p. 8, col. 2, ¶4. *Bernhardt* characterizes, for example, that the entire operating regime at 1500 rpm which includes ignition timing events from ~25° BTDC to ~35° ATDC with air-fuel ratios (in terms of the reciprocal equivalence ratio) from 0.7 to 1.2. *Id.* at Figs. 11 and 12. In Fig. 12 (below), *Berhmardt* shows the relationship between exhaust gas enthalpy and ignition timing from 25° BTDC to 35° ATDC.

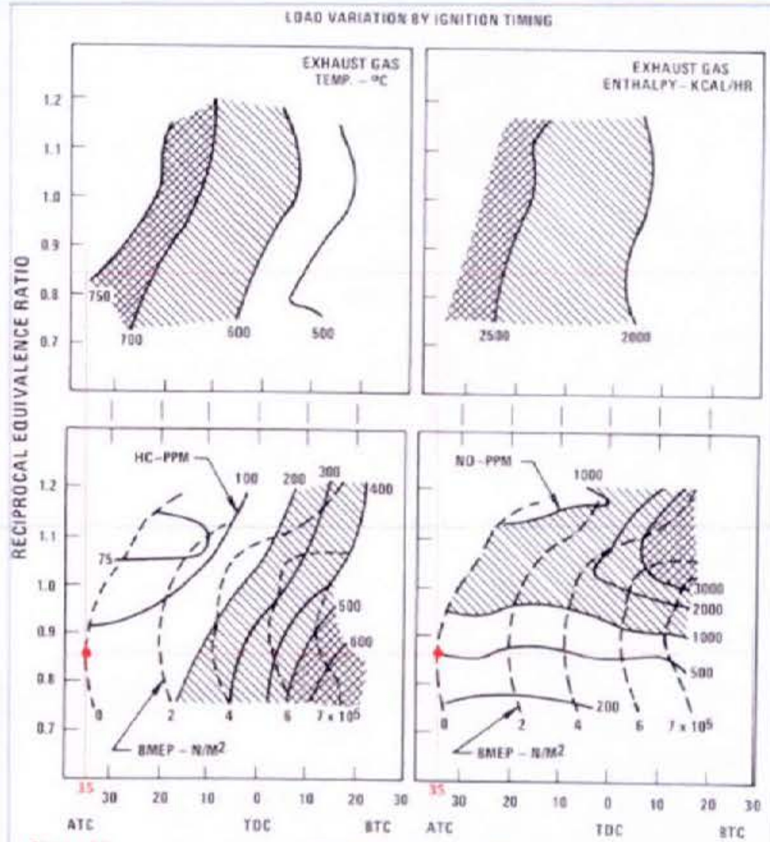


Figure 12

Mapping of Bernhardt to Claim 10

10. A method according to claim **1** wherein the engine includes in an exhaust system thereof a catalytic treatment means supporting a catalytic material therein.

66. *Bernhardt* discloses that "[d]uring vehicle cold start, emissions, mass flow rates, and catalytic converter space velocities vary by orders of magnitude. Therefore, catalytic exhaust control systems must be designed to operate at high efficiency almost from the moment of engine start-up. Catalysts must reach their operating temperature as quickly as possible. Therefore, the utility of different methods of improving the warm-up characteristics of catalytic systems is illustrated." *Id.* at Abstract. *Bernhardt* also discloses that the "utility of different methods for improving the warm-up characteristics of catalytic systems was illustrated and the necessity of concurrent and stringent control of NOx and HC/CO emissions, particularly during the first two minutes after vehicle start-up was discussed." *Id.* at p. 22, col. 2, ¶1. *Bernhardt* further discloses that "[c]atalytic emission control systems described in this paper operate mainly with the dual-bed catalytic process. The first bed contains the reduction catalyst which reduces the oxides of nitrogen (NO_x) by carbon monoxide (CO), hydrogen (H_2), and hydrocarbons (HC) which are present in the exhaust gases." *Id.* at p. 2, col. 1, ¶1.

Mapping of Bernhardt to Claim 12

12. **A method according to claim 10 wherein additional air is introduced upstream of the catalytic treatment means.**

67. *Bernhardt* discloses introduction of additional air upstream of the catalyst in the exhaust system between the exhaust ports and the catalytic treatment means. Ex. 1002 at p. 2, col. 2, bullet 4; p. 3, col. 2, ¶3-p. 4, col. 1, ¶1; p. 12, col. 1, ¶6, p. 3, Figure 2, p. 2, Figure 1. For example, Bernhardt discloses that "One method which promises success is a thermal reactor acting as a 'preheater' for improving catalytic converter performance. The thermal reactor is located at the cylinder heads. . . . In this system, secondary air is introduced in front of the thermal reactor at the cylinder head, and the reduction catalyst works as an oxidation catalyst in the starting phase. Due to the burning of high HC and CO emission levels directly after start-up a rapid warmup of the after burning system and therefore a rapid attainment of operating temperature is ensured." *Id.* at p. 3, col. 2, ¶3-p. 4, col. 1, ¶1.

Mapping of Bernhardt to Claim 12

12. A method according to claim **10** wherein additional air is introduced upstream of the catalytic treatment means.

68. *Bernhardt* discloses that the "chemical energy still contained in the exhaust gas, particularly when there is a shortage of air, is not taken into account. By the use of appropriate devices (i.e., thermal reactor with secondary air injection) this energy can be used to warm-up the converters in the start-up phase." *Id.* at p. 12, col. 1, ¶6. *Bernhardt* also discloses a specific example involving introducing secondary air upstream of a first bed in a dual bed catalytic converter without using a thermal reactor. "Introduce secondary air in front of the first bed during the initial 120 seconds after cold engine start-up; then switch the secondary air to the connecting pipe between NO_x and HC/CO beds (staged secondary air)," as depicted in Fig. 1. *Id.* at p. 2, col. 2, bullet 4; Fig. 2.

Mapping of Bernhardt to Claim 13

13. A method according to claim 10 wherein the engine is operated according to said method during cold start of the engine.

69. *Bernhardt* discloses that the engine is operated according to the method during cold start of the engine. *Id.* at p. 22, col. 2, ¶1; p. 22, col. 2, ¶2; title. Bernhardt also discloses that the "utility of different methods for improving the warm-up characteristics of catalytic systems was illustrated and the necessity of concurrent and stringent control of NO_x and HC/CO emissions, particularly during the first two minutes after vehicle start-up was discussed." *Id.* at p. 22, col. 2, ¶1. Bernhardt further discloses a "very elegant method to achieve a rapid warm-up is the use of extreme spark retard from the moment of engine start-up by which an increased exhaust gas flow rate with high exhaust enthalpy can be obtained." *Id.* at p. 22, col. 2, ¶2. *Bernhardt* further discloses that "[i]n place of the thermal reactors, monolithic noble metal catalysts could be employed as warm-up elements because the majority of the HC and CO emissions produced by an engine are emitted in the first two minutes of the 42-min. CVS cold-hot test" *Id.* at p. 6, col. 2, ¶2.

Mapping of Bernhardt to Claim 18

18. A method according to claim 1 wherein after a predetermined operating condition has been sensed or determined, said engine reverts back to normal operation.

70. *Bernhardt* discloses that after a predetermined operation condition has been sensed or determined, the engine reverts back to normal operation. Ex. 1002 at p. 22, col. 2, ¶2. Bernhardt also discloses that from "the standpoint of fuel consumption it is necessary to change the warm-up spark retard as soon as possible to normal operation." *Id.* In my opinion, a POSITA would understand that while ignition is being retarded, fuel efficiency and fuel consumption are suffering within an engine, as is the torque. In order to improve fuel efficiency and consumption and to recover torque, it is important for the engine to revert to normal operation as quickly as possible after the predetermined condition, *e.g.*, catalyst light-off temperature, is met.

Bernhardt

Reference(s)	Basis	Challenged Claim(s)
Bernhardt and Onishi	§103 (a)	9

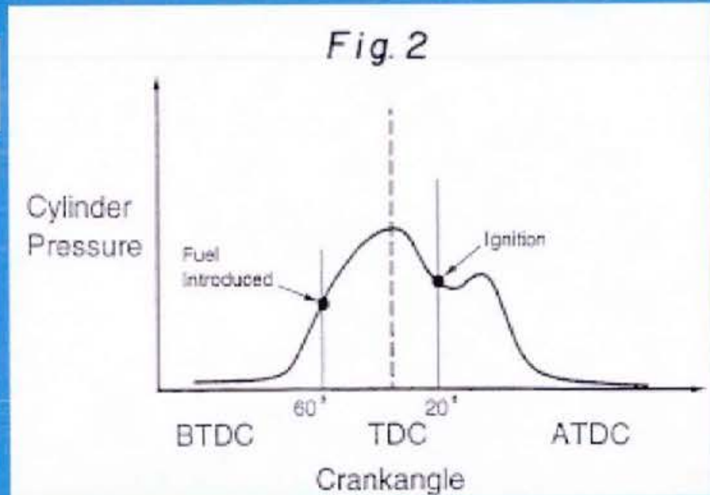
Obviousness of Bernhardt in Combination with Onishi Over Claim 9

Mapping of Bernhardt and Onishi to Claim 9

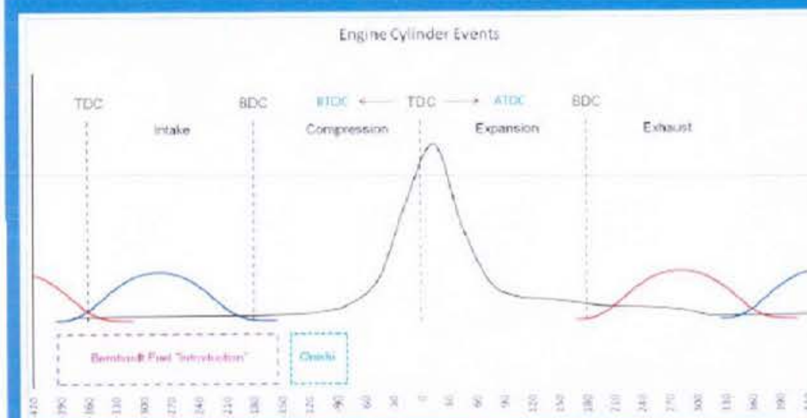
9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

71. I have been informed that claim 9 depends from independent claim 1 and requires that "the fuel is introduced at between 60° to 80° BTDC." Ex. 1001 at 6:35-36. As explained below, in my opinion, the teachings of *Bernhardt* in combination with the teachings of *Onishi* would render claim 9 of the '365 patent obvious to a POSITA.

72. As discussed above, *Bernhardt* discloses an internal combustion engine in which all fuel is injected into a cylinder during a cycle at BTDC. This is because *Bernhardt's* engine employed a port fuel injection system where the fuel is introduced into the cylinder along with air during the intake valve event. This was state-of-the-art for automotive fuel injection systems in SI engines at the time *Bernhardt* was published. In the figure below, the timing of fuel introduction into the cylinder is shown for *Bernhardt* and the timing of the start of fuel injection is shown for *Onishi*. In my opinion, and as discussed in more detail below, with the "rise" of direct injection in passenger car SI engines, it would have been obvious to a POSITA to inject all fuel into a cylinder during a cycle at between 80° to 60° BTDC using a "direct" fuel injection system.



'365 patent at Fig. 2



Mapping of Bernhardt and Onishi to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

73. In my opinion, it was well known in the art to inject all fuel at between 80° to 60° BTDC during operation of an internal combustion engine comprising a fuel injection system and catalytic system was well known in the art. For example, U.S. Patent No. 3,572,298 to Onishi ("*Onishi*"), Ex. 1005, which issued on March 23, 1971, and which I have been informed is prior art under 35 U.S.C. § 102(b), discloses injecting all fuel in a combustion cycle in at least one cylinder between about 80° and 60° BTDC. *Onishi* discloses that the inventive fuel injection method may be carried out over a range from idling (no load) to full-load conditions, *id.* at 4:6-8, and when the engine is cold. *Id.* at 9:46-52.

74. *Onishi* discloses that ignition timing can be independent of fuel injection timing and further discloses that the start of fuel injection may occur at about 80° BTDC. In particular, *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure." Ex. 1005 at 9:65-74. *Onishi* also discloses that the fuel injection initiation timing may vary "over extensive ranges," and thus a POSITA would have understood that fuel injection in a cylinder of the *Onishi* engine could begin at a crank angle slightly after 80° BTDC. *Id.* at 10:6-9.

Mapping of Bernhardt and Onishi to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

75. Moreover, under certain conditions, such as idle, in which the engine of *Onishi* is operating at a no load, or in a low load condition, and is also operating at low speed, the length of injection time, and in turn, the change in the crank shaft angle during injection will be minimal during a combustion cycle. It was well known in the art at the time of the '365 patent invention, for example, that a port fuel injector could have a minimum pulse width (i.e., the length of time the fuel injector is open in a particular cycle) as short as approximately 2.0 ms and a direct injector could have a minimum pulse width of approximately 1.5 ms. The following calculation shows that at an engine speed of 600 rpm, which a POSITA would understand is typical for port injected engines at idle (low end of the idle speed range), and for a crank shaft angle change of 20° (i.e., from 80° to 60° BTDC), there would be 5.56 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/600 revolutions)*(60 s/min)*(1000 ms/s)] =
5.56 ms

A similar calculation made at an engine speed of 800 rpm, which a POSITA would understand is typical for port injected engines at idle (high end of the idle speed range), shows that there would be 4.17 ms to inject all fuel under such conditions.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/800 revolutions)*(60 s/min)*(1000 ms/s)] =
4.17 ms

Finally, at an engine speed of 1200 rpm there would be 2.78 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/1200 revolutions)*(60 s/min)*(1000 ms/s)] =
2.78 ms

Thus, in my opinion, a POSITA would understand that at each of these exemplary engine speeds <u>all</u> fuel would be injected during the 20° crank shaft angle change under low load or no load conditions, because the minimum pulse width is less than the time available to inject all fuel (based on a crank shaft angle range of 20°). Therefore, under such circumstances in the engine disclosed in *Onishi*, if fuel injection started at about 80° BTDC, a POSITA would have understood that all fuel could have been injected by 60° BTDC over at least a portion of the engine operating range. Even in the case of 1500 rpm, as explicitly disclosed in *Bernhardt*, and a 2.0 ms minimum injection pulse width, the injection event can be accomplished within the 20° window.

Mapping of Bernhardt and Onishi to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

76. In my opinion, a POSITA would understand that the timing of the injection event is somewhat dependent on the shape of the piston, the flow conditions created by the inlet port geometry and combustion chamber shape, the design of the injector, and the engine designer's objective for a particular set of operating conditions. Since the '365 patent discloses no information on the combustion chamber, port shapes, flow field conditions, or injection system design it is impossible to know the optimal injection timing for the hypothetical engine in the '365 patent. Nevertheless, in my opinion, a POSITA would have been motivated to explore the optimal injection timing for several combustion chamber system configurations and would also have been motivated to begin the development process with implementation of the fuel injection range of *Bernhardt* with the fuel introduction range of *Onishi* (which includes injecting all fuel in a cycle between about 80° and 60° BTDC) so as to provide a more optimal air/fuel mixture leading to more assured and stable combustion, as disclosed by *Onishi*. Ex. 1005 at 4:50-73. Moreover, a POSITA would have understood *Onishi* to disclose some embodiments in which all fuel is injected into a cylinder within the claimed introduction range of between 80° and 60° BTDC. In my opinion, through routine experimentation, a POSITA would have concluded that injecting all fuel in a cycle between 80° and 60° BTDC would have resulted in a more optimal mixture of the air/fuel mixture prior to ignition, which *Bernhardt* discloses may be retarded to ATDC for some operating conditions.

Bernhardt

Reference(s)	Basis	Challenged Claim(s)
Bernhardt and Griese	§103 (a)	14

Bernhardt and Griese Disclose All Elements Of Claim 14

Mapping of Bernhardt and Griese to Claim 14

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

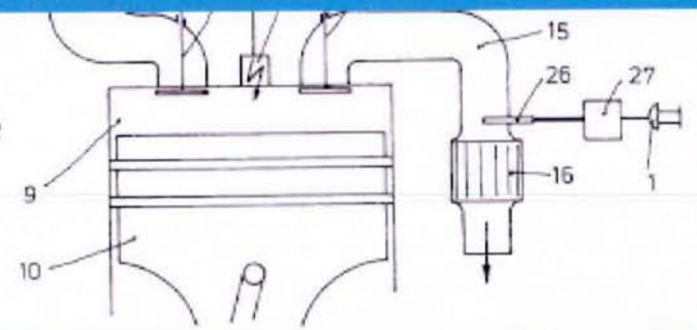
77. I have been informed that claim 14 depends from independent claim 1 and dependent claim 10 and requires that "the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature." Ex. 1001 at 6:48-51. As discussed above, I understand that this claim term means that the catalytic temperature is measured by a sensor. *Bernhardt* discloses all features of dependent claim 10 and independent claim 1, including a combustion engine having a fuel injection system and a catalytic treatment means comprising a catalytic material. *Bernhardt* further discloses that "[a]fter the exhaust gas has attained the operating temperature required by the catalyst the ignition system will revert to normal." Ex. 1002 at p. 4, col. 2, ¶3. While *Bernhardt* discloses the measurement or determination of the catalytic material temperature, it does not explicitly disclose that the temperature is measured by a sensor.[4]

Mapping of Bernhardt and Griese to Claim 14

14. A method according to claim 10 wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

78. In my opinion, it would have been obvious to measure the temperature of catalytic material using a sensor, in order to evaluate whether the temperature is below a required operating temperature. As explained below, in my opinion, the teachings of *Bernhardt* in combination with the teachings of *Griese* would render claim 14 of the '365 patent obvious to a POSITA. In my opinion, it was well known in the art to measure the temperature of the catalytic material in an exhaust system with a sensor. For example, *Griese*, which issued on March 26, 1974, and I have been informed is prior art under 35 U.S.C. § 102(b), discloses a thermostat for measuring the temperature of the catalytic material to determine whether it is below a required operating temperature. For example, *Griese* discloses that the "thermostat 27 measures the temperature at a location indicated by 26 which, for example, can be in the form of a thermo-element placed, as indicated, into the exhaust gas conduit 15, directly before the exhaust gas cleaning arrangement 16. The thermostat 27 operates then the switching means 1 as described in connection with FIG. 1." *Id.* at 5:23-29. *Griese* also discloses that "[d]uring a cold start of the combustion engine, at which the exhaust gas cleaning arrangement 16 is also cold, the thermostat 27 will keep the switch 1 closed," *id.* at 5:33-35, and "[a]s soon as the required temperature has been attained, by the cleaning arrangement 16, the thermostat 26, 27 will open the switch 1." *Id.* at 5:63-67.

Fig. 2



Mapping of Bernhardt and Griese to Claim 14

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

79. In my opinion, it would have been obvious for a POSITA to combine the thermostat of *Griese*, which senses the temperature of the catalytic material and controls the operation of a switch relating to the same, with the internal combustion engine disclosed in *Bernhardt* in order to control the operation of the engine to increase the exhaust gas temperature and improve efficiency the exhaust system. In my opinion, a POSITA would have been motivated to implement the thermostat of *Griese* into the engine and fuel injection system disclosed in *Bernhardt* would have been to efficiently manage the emission of exhaust gases in a fuel injection system by increasing the temperature of the exhaust gases. The use of automatic temperature sensing would increase the reliability and consistency of fuel injected engine operation and would control and avoid the release of hazardous substances into the atmosphere via exhaust gases.

80. I have also been informed that the PO has proposed to define this claim feature to mean that the catalytic temperature is measured or identified. Under such a construction, as discussed above, *Bernhardt* discloses this claim feature. Thus, under the PO's proposed construction, claim 14 would be anticipated by *Bernhardt*.

Eichler '791

Reference(s)	Basis	Challenged Claim(s)
Eichler '791 and Bernhardt	§103 (a)	1, 2, 5, 10, 12-14, 18
Eichler '791, Bernhardt, and Onishi	§103 (a)	9

Eichler '791

Reference(s)	Basis	Challenged Claim(s)
Eichler '791 and Bernhardt	§103 (a)	1, 2, 5, 10, 12-14, 18

Obviousness of Eichler '791 in Combination with Bernhardt Over Claims 1, 2, 5, 10, 12-14, 18

Mapping of Eichler '791 to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

85. *Eichler* '791 discloses a method of operating an internal combustion engine having an electrically controlled, petrol injection system. Ex 1003 at 1:9-11, 1:86-89.

86. *Eichler* '791 discloses retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to ATDC in respect of the combustion cycle of said at least one cylinder of the engine. Ex. 1003 at 5:3-12, 4:100-112.

Mapping of Eichler '791 to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

87. *Eichler* '791 discloses a device for acting upon the internal combustion engine during overrun, which device comprises a control valve for auxiliary air arranged in a circuit by-passing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C." *Id.* at 5:3-12.

88. *Eichler* '791 also discloses that "[w]hen the servo valve 75 is switched on by the control system 60, the negative pressure in the spark timing adjusting element 77 moves an actuating rod 95, connected to the mounting plate 54, in the direction of the arrow and thereby rotates the mounting plate 52 so far that the firing instant is moved 15° to 20° in the spark retard direction from its basic setting, namely, approximately 5° A.T.D.C. The ignition processes are then triggered at a crankshaft angle of 20° to 25° A.T.D.C." *Id.* at 4:100-112.

Mapping of Eichler '791 and Bernhardt to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

89. *Eichler '791* discloses that while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder. Ex. 1003 at 3:86-93, 5:69-76. In particular, *Eichler '791* discloses "which a temperature sensor, provided in the exhaust system of the internal combustion engine, operates in parallel with the engine speed transducer and at low exhaust gas temperatures retards the spark timing device and opens the auxiliary air valve during slow idling." *Id.* at 5:70-76. *Eichler '791* also discloses that "the auxiliary air necessary to maintain combustion in the cylinders of the internal combustion engine is supplied by the auxiliary air valve 50 which then switches to its open position. *Id.* at 3:86-93.

Mapping of Eichler '791 and Bernhardt to Claim 1.1

90. As discussed above, *Bernhardt* also discloses that while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine. Ex. 1002 at p. 22, col. 2, ¶2; p. 10, col. 2, ¶2; p. 12, col. 1, ¶2, ¶5; p. 8, col. 2, ¶1, Fig. 11.

91. *Bernhardt* also explicitly discloses that "the increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Bernhardt* further discloses that this increase in fuel flow occurs during "spark retard" (at idle), while there is "increased idling speed of the engine," "fully opened throttle," and a reciprocal equivalence ratio equals 1.0 (which occurs at a maximum exhaust gas temperature). Thus, in my opinion, a POSITA would further recognize that *Bernhardt* discloses "increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally."

92. In addition, *Bernhardt* discloses a "very elegant method to achieve a rapid warm-up is the use of extreme spark retard from the moment of engine start-up by which an increased exhaust gas flow rate with high exhaust enthalpy is secured when the engine operates with stoichiometric mixtures ($1/\Phi = 0.95$-1.05) and fully opened throttle." *Id.* at p. 22, col. 2, ¶2. Bernhardt also discloses that "[i]n order to keep the engine running the cylinder charge was repeatedly increased as the timing became more retarded until finally the throttle was fully open." *Id.* at p. 10, col. 2, ¶2. Bernhardt further discloses that the "curves of constant volumetric efficiency have the same tendency as the curves of constant exhaust gas temperature so that the desired objective of providing the hottest possible exhaust gas in largest possible quantities is achieved by the spark retard. . . . The increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id.* at p. 12, col. 1, ¶5

93. *Bernhardt* also discloses that the "exhaust gas temperature diagram in Figure 11 illustrates the influence of the air/fuel ratio and the ignition timing on the exhaust gas temperature. The exhaust gas temperature reaches its maximum at a reciprocal equivalence ratio of $1/\Phi = 1.0$ because the combustion temperature is highest at stoichiometric mixtures. *Id.* at p. 12, col. 1, ¶2. In addition, *Bernhardt* discloses that "under appropriate operating conditions the engine itself is able to act as a preheater for the catalytic system. Warm-up spark retard and an increased idling speed of the engine with full open throttle lead to higher exhaust temperatures and thereby to a greater enthalpy of the exhaust gases, so that the after burning system could be brought rapidly up to its operating temperature." *Id.* at p. 8, col. 2, ¶1.

Mapping of Eichler '791 and Bernhardt to Claim 1.2

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

94. *Bernhardt* discloses that the timing of the introduction of fuel into the at least one cylinder is maintained at BTDC.[5] Ex. 1002 at . 10, col. 1, ¶2, col. 2, ¶2, introduction.

95. *Bernhardt* discloses that in "order to keep the engine running the cylinder charge was repeatedly increased as the timing became more retarded until finally the throttle was fully open." *Id.* at p. 10, col. 2, ¶2.

96. *Bernhardt* discloses that to "achieve the emission targets . . . a number of emission concepts with conventional internal combustion engines and emission control systems have been examined." *Id.* at introduction.

97. Because *Bernhardt* discloses implementing conventional internal combustion engines, in which fuel and air are mixed prior to ignition, in my opinion, a POSITA would recognize that *Bernhardt* discloses an engine which operates such that "the timing of the introduction of fuel into the at least one cylinder being maintained at BTDC," and in which all fuel in a combustion cycle is injected while the cylinder is at BTDC.

Mapping of Eichler '791 and Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is <u>greater than 50% of the fuelling rate at maximum load</u>.

98. *Bernhardt* discloses that the engine may operate at full throttle (which is the equivalent of the fuelling rate at maximum load at the instantaneous engine speed) during ignition retard. Ex 1002 at p. 22, col. 2, ¶2; p. 10, col. 2, ¶2; p. 12, col. 1, ¶2, ¶5; p. 12, Fig. 11.

99. Because *Bernhardt* discloses that during "spark retard," there is "increased idling speed of the engine," "fully opened throttle," and a reciprocal equivalence ratio of 1.0, in my opinion, a POSITA would recognize that *Bernhardt* discloses "increasing the fuelling rate to greater than 50% of the fueling rate at maximum load," wherein maximum load refers to that of the engine at the instantaneous engine speed.

100. *Bernhardt* discloses that a "very elegant method to achieve a rapid warm-up is the use of extreme spark retard from the moment of engine start-up by which an increased exhaust gas flow rate with high exhaust enthalpy is secured when the engine operates with stoichiometric mixtures ($1/\Phi = 0.95\text{-}1.05$) <u>and fully opened throttle</u>." (Emphasis added). *Id.* at page 22, col. 2, ¶2. (Emphasis added.)

101. *Bernhardt* discloses that the "curves of constant volumetric efficiency have the same tendency as the curves of constant exhaust gas temperature so that the desired objective of providing the hottest possible exhaust gas in largest possible quantities is achieved by the spark retard. . . . The increase in fuel flow corresponding to the increase in volumetric efficiency with spark retard raises the exhaust gas enthalpy." *Id.* at p. 12, col. 1, ¶5.

102. *Bernhardt* discloses that the "exhaust gas temperature diagram in Figure 11 illustrates the influence of the air/fuel ratio and the ignition timing on the exhaust gas temperature. <u>The exhaust gas temperature reaches its maximum at a reciprocal equivalence ratio of $1/\Phi = 1.0$ because the combustion temperature is highest at stoichiometric mixtures</u>." *Id.* at p. 12, col. 1, ¶2. (Emphasis added.)

Mapping of Eichler '791 and Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

103. Because *Bernhardt* discloses that during "spark retard," there is "increased idling speed of the engine," "fully opened throttle," and a reciprocal equivalence ratio of 1.0, a POSITA would recognize that *Bernhardt* discloses "increasing the fuelling rate greater than 50% of the fueling rate at maximum load," wherein maximum load refers to wide open throttle operation of the engine. Specifically, it was well known to a POSITA that the fueling rate scales linearly with the product of the volumetric efficiency and the reciprocal equivalence ratio, that the wide open throttle volumetric efficiency was approximately 0.85 for normal fuel rich operation at the engine speed for which the volumetric efficiency was maximized prior to intake tuning and cam phasers (2200 rpm for *Bernhardt's* engine), that the volumetric efficiency was approximately 0.15 for closed throttle no load conditions, and that the reciprocal equivalence ratio was ~1.0. However, to achieve 1500 rpm at no load, the throttle would have to be opened further to yield a volumetric efficiency of ~0.3 for no load at 1500 rpm. For wide open throttle operation at 1500 rpm, the volumetric efficiency would be lower than the peak of ~0.85, approximately 0.8. It was also well known to a POSITA that normal wide open throttle operation involves using a rich mixture to maximize torque and minimize the chance that engine knock would be encountered, such that $1/\Phi \sim 1.2$. Thus, the increase in fueling rate from no load to full load at 1500 rpm for a normally operating engine is approximately $0.8*1.2/(0.3*1.0) \sim 3.2$. For *Bernhardt's* no load operating conditions with advanced ignition timing (BTDC), $1/\Phi \sim 1$, and a partially opened throttle (to achieve 1500 rpm and no load), Figure 11 in *Bernhardt* reveals a volumetric efficiency of approximately 0.3. For *Bernhardt's* full load operating conditions with retarded ignition timing (35° ATDC), $1/\Phi \sim 1$, and wide open throttle, Figure 11 in *Bernhardt* reveals a volumetric efficiency of approximately 0.8. Thus the ratio for the fueling rate for *Bernhardt's* wide open throttle operation to his no load fueling rate is approximately $0.8/0.3 \sim 2.67$. Therefore, *Bernhardt's* data reveals that his retarded ignition, wide open throttle, no load condition for rapidly warming up the catalyst requires $100*2.67/3.2 \sim 83\%$ of the fuelling rate at maximum load. Obviously, this is more than the "50% of the fuelling rate at maximum load" specified in claim 2 of the '365 patent.

Mapping of Eichler '791 and Bernhardt to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

104. In my opinion, a POSITA would have recognized that *Eichler '791* discloses the concern over the cooling down of the combustion chamber and exhaust system during overrun due to the substantial power drop and increase in noxious hydrocarbon content of the exhaust gases that can be expected on the next acceleration operation. Ex. 1003 at 1:43-54. Thus, a POSITA would have been motivated to increase fuelling rate to greater than 50% of the fuelling rate at maximum load, as taught by *Bernhardt*, during ignition retard, because during ignition retard the amount of torque generated by a cylinder in the engine is reduced. Increasing the fuelling rate in turn increases the amount of torque generated, because the cylinder is able to operate at a higher than normal equivalence ratio.

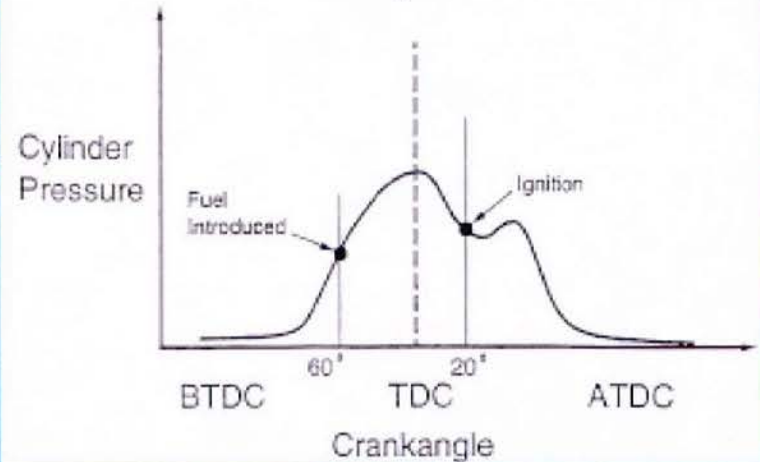
Mapping of Eichler '791 and Bernhardt to Claim 5

5. A method according claim 1 wherein the ignition is retarded up to about 30° ATDC.

105. *Eichler '791* discloses retarding ignition up to about 30° ATDC, and in particular, to between 15° and 30° ATDC. Ex. 1002 at p. 8, col. 2, ¶4. In particular, *Eichler '791* discloses a device for acting upon the internal combustion engine during overrun, which device comprises a control valve for auxiliary air arranged in a circuit by-passing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C." *Id.* at 5:3-12 (emphasis added).

106. *Eichler '791* also discloses that "[w]hen the servo valve 75 is switched on by the control system 60, the negative pressure in the spark timing adjusting element 77 moves an actuating rod 95, connected to the mounting plate 54, in the direction of the arrow and thereby rotates the mounting plate 52 so far that the firing instant is moved 15° to 20° in the spark retard direction from its basic setting, namely, approximately 5° A.T.D.C. The ignition processes are then triggered at a crankshaft angle of 20° to 25° A.T.D.C." *Id.* at 4:100-112 (emphasis added).

Fig. 2



'365 patent at Fig. 2

Mapping of Eichler '791 and Bernhardt to Claim 10

10. A method according to claim **1** wherein the engine includes in an exhaust system thereof a catalytic treatment means supporting a catalytic material therein.

107. *Eichler '791* discloses that the engine includes in an exhaust system thereof a catalytic reactor (the claimed "catalytic treatment means") supporting a catalytic material therein. Ex. 1003 at 3:130-4:7, Fig. 1. *Eichler '791* also discloses that "[w]hen the exhaust gases of the internal combustion engine are passed through a thermal and/or catalytic reactor, which is not shown in the drawings, it is often desired to heat such a reactor quickly during the warming-up phase of the internal combustion engine and thereby cause it to operate." *Id.*

Mapping of Eichler '791 and Bernhardt to Claim 12

12. A method according to claim **10** wherein additional air is introduced upstream of the catalytic treatment means.

108. *Bernhardt* also discloses this claim feature. In particular, *Bernhardt* discloses that the "chemical energy still contained in the exhaust gas, particularly when there is a shortage of air, is not taken into account. By the use of appropriate devices (i.e., thermal reactor with secondary air injection) this energy can be used to warm-up the converters in the start-up phase." *Id.* at p. 12, col. 1, ¶6. *Bernhardt* also discloses a specific example involving introducing secondary air upstream of a first bed in a dual bed catalytic converter. This example operates by "[i]ntroduc[ing] secondary air in front of the first bed during the initial 120 seconds after cold engine start-up; then switch the secondary air to the connecting pipe between NO_x and HC/CO beds (staged secondary air)," as depicted in Fig. 1. *Id.* at p. 2, col. 2, bullet 4; Fig. 1.

109. In my opinion, it would have been obvious to a POSITA to combine the catalytic treatment means and introduction of additional air to the exhaust system of *Bernhardt* with the internal combustion engine disclosed in *Eichler '791* in order to treat the exhaust gases and improve efficiency the exhaust system. The motivation to implement the catalytic treatment means and introduction of air of *Bernhardt* into the engine in *Eichler '791* would have been to efficiently manage the emission of exhaust gases in a fuel injection system by aiding an increase in the temperature of the exhaust gases and diluting the concentration of harmful hydrocarbons in the exhaust gases.

Mapping of Eichler '791 and Bernhardt to Claim 13

13. A method according to claim **10** wherein the engine is operated according to said method during cold start of the engine.

110. *Eichler '791* discloses that the engine is operated during cold start of the engine. Ex. 1003 at 4:7-10. In particular, *Eichler '791* discloses that "when the internal combustion engine is cold, retardation of the spark can be effected not only during overrun but also during slow idling." *Id.*

Mapping of Eichler '791 and Bernhardt to Claim 14

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

111. *Eichler '791* discloses that the engine is operated when the temperature of the catalytic materials is sensed or determined to be below a required operating temperature. Ex. 1003 at 5:69-76. In particular, *Eichler '791* discloses that "a temperature sensor, provided in the exhaust system of the internal combustion engine, operates in parallel with the engine speed transducer and at low exhaust gas temperatures retards the spark timing device and opens the auxiliary air valve during slow idling." *Id.*

Mapping of Eichler '791 and Bernhardt to Claim 18

18. A method according to claim 1 wherein after a predetermined operating condition has been sensed or determined, said engine reverts back to normal operation.

112. *Bernhardt* discloses that after a predetermined operation condition has been sensed or determined, the engine reverts back to normal operation. Ex. 1002 at p. 22, col. 2, ¶2. Bernhardt also discloses that from "the standpoint of fuel consumption it is necessary to change the warm-up spark retard as soon as possible to normal operation." *Id.* In my opinion, a POSITA would understand that while ignition is being retarded, fuel efficiency and fuel consumption are suffering within an engine, as is the torque. In order to improve fuel efficiency and consumption and to recover torque, it is important for the engine to revert to normal operation as quickly as possible after the predetermined condition, *e.g.*, catalyst light-off temperature, is met.

Eichler '791

Reference(s)	Basis	Challenged Claim(s)
Eichler '791, Bernhardt, and Onishi	§103 (a)	9

Obviousness of Eichler '791 in Combination with Bernhardt and Onishi Over Claim 9

Mapping of Eichler '791, Bernhardt, and Onishi to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

113. As discussed above, I have been informed that claim 9 depends from independent claim 1 and requires that "the fuel is introduced at between 60° to 80° BTDC." Ex. 1001 at 6:35-36. As further explained above, under a claim construction wherein this claim element requires all fuel to be injected in a cycle within a cylinder at between 60° to 80° BTDC, it is my opinion that the teachings of *Eichler '791* in combination with *Bernhardt* and *Onishi* would render claim 9 of the '365 patent obvious to a POSITA.

114. As discussed above, *Eichler '791* and *Bernhardt* disclose all features of independent claim 1, including introducing fuel BTDC. As also discussed above, in my opinion, it was well known in the art to inject all fuel in a cycle at between 80° and 60° BTDC during operation of an internal combustion engine comprising a fuel injection system and catalytic system was well known in the art. For example, U.S. Patent No. 3,572,298 to Onishi ("*Onishi*"), Ex. 1005, which issued on March 23, 1971, and which I have been informed is prior art under 35 U.S.C. § 102(b), discloses injecting all fuel in a combustion cycle in at least one cylinder between about 80° and 60° BTDC.

115. *Onishi* discloses that ignition timing can be independent of fuel injection timing and further discloses that the start of fuel injection may occur at about 80° BTDC. In particular, *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure." Ex. 1005 at 9:65-74. *Onishi* also discloses that the fuel injection initiation timing may vary "over extensive ranges," and thus a POSITA would have understood that fuel injection in a cylinder of the *Onishi* engine could begin at a crank angle slightly after 80° BTDC. *Id.* at 10:6-9.

Mapping of Eichler '791, Bernhardt, and Onishi to Claim 9

116. Moreover, under certain conditions, such as idle, in which the engine of *Onishi* is operating at a no load, or in a low load condition, and is also operating at low speed, the length of injection time, and in turn, the change in the crank shaft angle during injection will be minimal during a combustion cycle. *See* ¶75, above. It was well known in the art at the time of the '365 patent invention, for example, that a port fuel injector could have a minimum pulse width (i.e., the length of time the fuel injector is open in a particular cycle) as short as approximately 2.0 ms and a direct injector could have a minimum pulse width of approximately 1.5 ms. *Id.* The following calculation shows that at an engine speed of 600 rpm, which a POSITA would understand is typical for port injected engines at idle (low end of the idle speed range), and for a crank shaft angle change of 20° (i.e., from 80° to 60° BTDC), there would be 5.56 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/600 revolutions)*(60 s/min)*(1000 ms/s)] = **5.56 ms**

A similar calculation made at an engine speed of 800 rpm, which a POSITA would understand is typical for port injected engines at idle (high end of the idle speed range), shows that there would be 4.17 ms to inject all fuel under such conditions.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/800 revolutions)*(60 s/min)*(1000 ms/s)] = **4.17 ms**

Finally, at an engine speed of 1200 rpm there would be 2.78 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/1200 revolutions)*(60 s/min)*(1000 ms/s)] = **2.78 ms**

Thus, a POSITA would understand that at each of these exemplary engine speeds all fuel would be injected during the 20° crank shaft angle change under low load or no load conditions, because the minimum pulse width is less than the time available to inject all fuel (based on a crank shaft angle range of 20°).

58

Therefore, under such circumstances in the engine disclosed in *Onishi*, if fuel injection started at about 80° BTDC, a POSITA would have understood that all fuel could have been injected by 60° BTDC over at least a portion of the engine operating range. Even in the case of 1500 rpm, as explicitly disclosed in *Bernhardt*, and a 2.0 ms minimum injection pulse width, the injection event can be accomplished within the 20° window.

Mapping of Eichler '791, Bernhardt, and Onishi to Claim 9

117. In my opinion, a POSITA would understand that the timing of the injection event is somewhat dependent on the shape of the piston, the flow conditions created by the inlet port geometry and combustion chamber shape, the design of the injector, and the engine designer's objective for a particular set of operating conditions. Since the '365 patent discloses no information on the combustion chamber, port shapes, flow field conditions, or injection system design it is impossible to know the optimal injection timing for the hypothetical engine in the '365 patent. Nevertheless, in my opinion, a POSITA would have been motivated to explore the optimal injection timing for several combustion chamber system configurations and would also have been motivated to begin the development process with implementation of the fuel injection range of *Bernhardt* with the fuel introduction range of *Onishi* (which includes injecting all fuel in a cycle between about 80° and 60° BTDC) so as to provide an optimal air/fuel mixture leading to more assured and stable combustion, as disclosed by *Onishi*. Ex. 1005 at 4:50-73. Moreover, a POSITA would have understood *Onishi* to disclose some embodiments in which all fuel is injected into a cylinder within the claimed introduction range of between 80° and 60° BTDC. In my opinion, through routine experimentation, a POSITA would have concluded that injecting all fuel in a cycle between 80° and 60° BTDC would have resulted in a more optimal mixture of air and fuel prior to ignition, which *Bernhardt* and *Eichler '791* disclose may be retarded to ATDC for some operating conditions.

118. In my opinion, it would have been obvious to a POSITA to implement the ignition timing retard of *Eichler '791* with the increased fuelling rate of *Bernhardt* and the fuel introduction range of *Onishi* (which includes introducing all fuel in a cycle between about 80° and 60° BTDC) so as to provide a more optimal air/fuel mixture leading to more assured and stable combustion (ex. 1005 at 4:50-73), in part, because *Bernhardt* discloses to heat the catalytic converter using variations in ignition timing and *Onishi* discloses that ignition and fuel injection may be varied independently during engine idle after cold start. Ex. 1005 at 9:65-10:2. In my opinion, through routine experimentation, a POSITA would have concluded that injecting all fuel in a cycle between 80° and 60° BTDC would have resulted in a more optimal mixture of the air/fuel mixture prior to ignition, which *Eichler '791* discloses may be retarded to ATDC for some operating conditions.

Hitomi

Reference(s)	Basis	Challenged Claim(s)
Hitomi and Onishi	§103 (a)	1, 9, 10, 13, 14, 18
Hitomi, Onishi, and Eichler '089	§103 (a)	5
Hitomi, Onishi, and Takada	§103 (a)	12

Hitomi

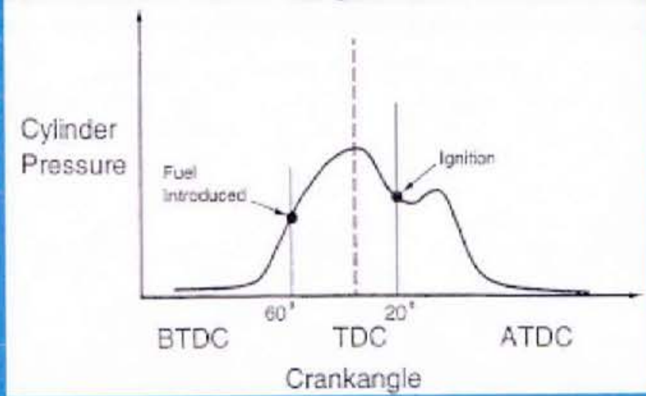
Reference(s)	Basis	Challenged Claim(s)
Hitomi and Onishi	§103 (a)	1, 9, 10, 13, 14, 18

Obviousness of Hitomi in Combination with Onishi Over Claims 1, 9, 10, 13, 14, 18

Mapping of Hitomi and Onishi to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

Fig. 2



'365 patent at FIG. 2

51. *Hitomi* discloses a method of operating an internal combustion engine that includes an exhaust control system. Ex. 1002 at title.

52. *Hitomi* discloses retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to ATDC in respect of the combustion cycle of said at least one cylinder of the engine. Ex. 1002 at 7:3-9; 11:6-12, Fig. 5.

53. *Hitomi* discloses that "During the warming-up ignition control, the standard advance angle is computed based on the engine speed signal Sn. The temperature signal Sa is subjected to a retard correction with a predetermined value of retardation, which is an angle between 10 and 20 degrees from a top dead center position of the piston in a compression stroke. (Emphasis added). *Id.* at 7:3-9.

54. *Hitomi* discloses that "[i]gnition takes place . . . at a time Tc, also represented by a crank angle, after the top dead center position TDC when the engine has not yet warmed up." *Id.* at 11:6-12.

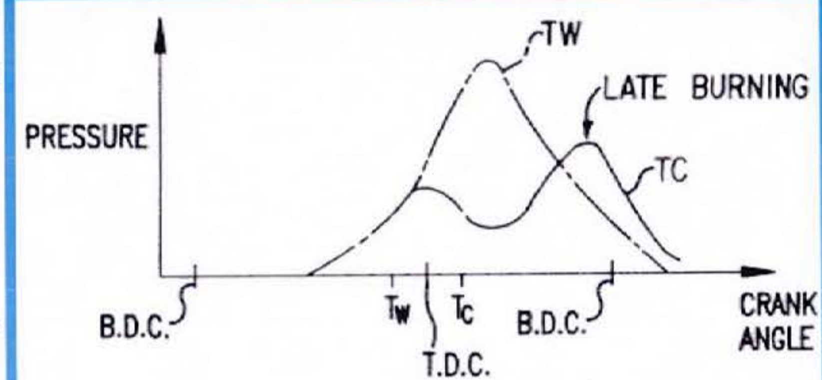


FIG.5

Hitomi at FIG. 5

Mapping of Hitomi and Onishi to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

55. *Hitomi* discloses that increasing the fuelling rate of said at least one cylinder while retarding ignition. Ex. 1002 at 7:28-33; 11:21-28; 12:12-19.

56. *Hitomi* discloses that "[w]hen the engine temperature is still low, the control unit 50 controls the idle speed control valve 29 so that it opens wide and increases a rate of fuel injection in order to compensate for increased work required of the engine for discharging exhaust gases together with closing the shutter valve 40." *Id.* at 7:28-33. "Also, both before and during warming up of the engine, an increase in the rate at which intake air is admitted into the engine, and hence, an increase in the quantity of fuel admitted into the engine are achieved due to an increased opening of the idle speed control valve 28 so as to compensate for an increased discharging load of the engine resulting from throttling of the shutter valve 40." *Id.* at 11:21-28.

57. *Hitomi* discloses that "[s]hutter valve 40 is closed so that its opening is smaller before and during warming up of the engine. This is because closing of the shutter valve 40 causes the idle speed controller valve 29 to open wide in order to compensate for an increase in exhaust load on the engine, which is accompanied by an increase in the quantity of intake air and, hence, of fuel admitted into the engine." *Id.* at 12:12-19.

Mapping of Hitomi and Onishi to Claim 1.2

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

58. *Onishi* discloses that all fuel for at least one cylinder is maintained at before top dead centre (BTDC), as explained in detail in ¶¶123-125 above. Ex. 1005 at 9:63-10:9; 10:62-75.

59. *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said [top dead] center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure." *Id.* at 9:63-75.

Mapping of Hitomi and Onishi to Claim 1.2

60. *Onishi* also discloses that "the engine may be handled almost like an internal combustion engine of electric ignition type and, in addition, can be operated rationally by varying the above factors over extensive ranges." *Id.* at 10:6-9.

61. *Onishi* discloses that in "the practice of the present invention, the wide allowance between the fuel injection and ignition and formation of air stream also provides a fairly high degree of flexibility against inadequate injection conditions such as clogging of the injection nozzle for fuel supply. Thus, minor deterioration of the injective conditions cannot have an appreciably adverse effect upon the performance, and it is another factor contributory to the improved reliability of the engine. As a result, the timing for the initiation of fuel injection can be fully advanced and the effective injection crank angle can be increased thereby to form a suitable mixture without any interruption in the main air stream of the swirling flow in the cylinder." *Id.* at 10:62-75.

62. Even under an alternative claim construction, like the one that I have been informed the Patent Owner ("PO") has advanced during a pending litigation, i.e., that the introduction of fuel claim feature means that the "start of injection for at least one cylinder is before top-dead center," *Onishi* clearly discloses this claim feature under the PO's broad construction, because if all fuel is injected at BTDC, then the start of fuel injection must inherently occur at BTDC as well. In addition, *Hitomi* also discloses this feature under the PO's proposed construction. *Hitomi* discloses that "[i]ntake valve 10 is specifically timed so as to open at an angular position of 5 degrees before the top dead center (TDC) position and close at an angular position of 50 degrees after the bottom dead center (BDC) position." Ex. 1002 at 12:59-63. Thus, *Hitomi* clearly discloses that the start of fuel injection occurs at BTDC.

Mapping of Hitomi and Onishi to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

65. As discussed above at ¶¶ 40-46, *Hitomi* discloses injecting all fuel BTDC. To the extent that *Hitomi* does not disclose injecting all fuel in a cylinder at between 80° and 60° BTDC, *Onishi* discloses this feature. *Id.*

40. *Hitomi* also discloses the introduction of fuel in a combustion cycle being BTDC, *id.* 12:59-63, and in particular, injection of all fuel within a combustion cycle occurring at BTDC. See, e.g. Fig. 1, in which Hitomi discloses a port fuel injected engine. A POSITA would have understood that all fuel is injected BTDC in a typical port fuel injected engine. *Hitomi* does not, however, disclose introducing all fuel within at least one cylinder during a combustion cycle at between 60° to 80° BTDC. It would have been obvious to a POSITA, however, to inject all fuel BTDC, as recited in claim 1, and in particular for a direct injected engine, at between 80° and 60° BTDC, as recited in claim 9 for some low speed, low load operating conditions.

41. In my opinion, injecting all fuel at between 80° and 60° BTDC during operation of a combustion engine comprising direct injected fuel injection and catalytic systems was well known in the art. For example, U.S. Patent No. 3,572,298 to Onishi ("*Onishi*"), Ex. 1005, which issued on March 23, 1971, and is thus prior art under 35 U.S.C. § 102(b), discloses, as discussed in detail below, injecting all fuel in a combustion cycle in at least one cylinder between about 80° and 60° BTDC. *Onishi* discloses that the inventive fuel injection method may be carried out over a range from idling (no load) to full-load conditions, *id.* at 4:6-8, and when the engine is cold. *Id.* at 9:46-52.

Mapping of Hitomi and Onishi to Claim 9

42. *Onishi* discloses that ignition timing can be independent of fuel injection timing and further discloses that the start of fuel injection may occur at about 80° BTDC. Ex. 1005 at 9:65-10:2. In particular, *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure." Ex. 1005 at 9:65-74. *Onishi* also discloses that the fuel injection initiation timing may vary "over extensive ranges," and thus, in my opinion, a POSITA would have understood that fuel injection in a cylinder of the *Onishi* engine could begin at a crank angle slightly after 80° BTDC.

43. Moreover, a POSITA would recognize that under certain conditions, such as idle, in which the engine of *Onishi* is operating at a no load, or in a low load condition, and is also operating at low speed, the length of injection time, and in turn, the change in the crank shaft angle during injection will be minimal during a combustion cycle. It was well known in the art at the time of the '365 patent invention, for example, that a port fuel injector could have a minimum pulse width (i.e., the length of time the fuel injector is open in a particular cycle) as short as approximately 2.0 ms and a direct injector could have a minimum pulse width of approximately 1.5 ms.

44. The following calculation shows that at an engine speed of 600 rpm, which a POSITA would understand is typical for port injected engines at idle (low end of the idle speed range), and for a crank shaft angle change of 20° (i.e., from 80° to 60° BTDC), there would be 5.56 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/600 revolutions)*(60 s/min)*(1000 ms/s)] = **5.56** ms

A similar calculation made at an engine speed of 800 rpm, which a POSITA would understand is typical for port injected engines at idle (high end of the idle speed range), shows that there would be 4.17 ms to inject all fuel under such conditions.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/800 revolutions)*(60 s/min)*(1000 ms/s)] = **4.17** ms

Finally, at an engine speed of 1200 rpm there would be 2.78 ms to inject all fuel.

[(20 crank angle deg)*(1 revolution/360 deg)*(1 min/1200 revolutions)*(60 s/min)*(1000 ms/s)] = **2.78** ms

45. Thus, in my opinion, a POSITA would understand that at each of these exemplary engine speeds <u>all</u> fuel would be injected during the 20° crank shaft angle change under low load or no load conditions, because the minimum pulse width is less than the time available to inject all fuel (based on a crank shaft angle range of 20°). Therefore, under such circumstances in the engine disclosed in *Onishi*, if fuel injection started at about 80° BTDC, a POSITA would have understood that all fuel could have been injected by 60° BTDC over at least a portion of the engine operating range.

Mapping of Hitomi and Onishi to Claim 9

46. In my opinion, a POSITA would understand that the timing of the injection event is somewhat dependent on the shape of the piston, the flow conditions created by the inlet port geometry and combustion chamber shape, the design of the injector, and the engine designer's objective for a particular set of operating conditions. Since the '365 patent discloses no information on the combustion chamber, port shapes, flow field conditions, or injection system design it is impossible to know the optimal injection timing for the hypothetical engine in the '365 patent. Nevertheless, in my opinion, a POSITA would have been motivated to explore the optimal injection timing for several combustion chamber system configurations and would also have been motivated to begin the development process with implementation of the fuel injection range of *Hitomi* with the fuel introduction range of *Onishi* (which includes injecting all fuel in a cycle between about 80° and 60° BTDC) so as to provide a stratified mixture leading to more assured and stable combustion, as disclosed by *Onishi*. Ex. 1005 at 4:50-73. Moreover, a POSITA would have understood *Onishi* to disclose some embodiments in which all fuel is injected into a cylinder within the claimed introduction range of between 80° and 60° BTDC. In my opinion, through routine experimentation, a POSITA would have concluded that injecting all fuel in a cycle between 80° and 60° BTDC would have resulted in a more optimal mixture of air and fuel prior to ignition, which *Hitomi* discloses may be retarded to ATDC for some operating conditions.

Mapping of Hitomi and Onishi to Claim 10

10. A method according to claim **1** wherein the engine includes in an exhaust system thereof a catalytic treatment means supporting a catalytic material therein.

66. *Hitomi* discloses that the engine includes in an exhaust system 30 thereof a secondary three-way catalytic device 37 (the claimed "catalytic treatment means") supporting a catalytic material therein. Ex. 1002 at 3:57-4:1, 14-20, Fig. 1.

67. *Hitomi* discloses that "[i]ndividual exhaust passages 15 are respectively connected to the cylinders 5 and form an upstream portion of an exhaust system 30. A downstream portion of the exhaust system 30 is formed by a common exhaust passage 31. A primary three-way catalytic device 32, such as a catalytic converter including rhodium, and a silencer 33 are disposed in the common exhaust passage 31 a pair of branched exhaust passages 35 are respectively connected to the plurality of the individual exhaust passages 15. A secondary three-way catalytic device 37, such as another catalytic converter including rhodium, and a shutter valve 40 are disposed in each branched exhaust passage 35." *Id.* at 3:57-4:1.

68. *Hitomi* further discloses that "[d]uring the warming-up the engine, the secondary catalytic device 37 is activated first so as to perform exhaust gas purification. Then, the exhaust gas heated by the secondary catalytic device 37 is led to the primary catalytic device 32 so as to promote activation of the primary catalytic device 32." *Id.* at 4:14-20.

Mapping of Hitomi and Onishi to Claim 13

13. A method according to claim 10 wherein the engine is operated according to said method during cold start of the engine.

69. *Hitomi* discloses that the engine that is operated during cold start of the engine with ignition ATDC and extra fuel. Ex 1002 at 4:11-20; 7:28-33; 11:6-12, 21-28. In particular, "[i]gnition takes place . . . at a time Tc, also represented by a crank angle, after the top dead center position TDC when the engine has not yet warmed up." *Id.* at 11:6-12.

70. *Hitomi* also discloses that "[w]hen the engine temperature is still low, the control unit 50 controls the idle speed control valve 29 so that it opens wide and increases a rate of fuel injection in order to compensate for increased work required of the engine for discharging exhaust gases together with closing the shutter valve 40." *Id.* at 7:28-33. "Also, both before and during warming up of the engine, an increased in the rate at which intake air is admitted into the engine, and hence, an increase in the quantity of fuel admitted into the engine are achieved due to an increased opening of the idle speed control valve 28 so as to compensate for an increased discharging load of the engine resulting from throttling of the shutter valve 40." *Id.* at 11:21-28. *See also* 57, *supra* (*Id.* at 4:14-20).

Mapping of Hitomi and Onishi to Claim 14

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

71. *Hitomi* discloses that the engine is operated when the temperature of the catalytic materials is sensed or determined to be below a required operating temperature. Ex 1002 at 5:35-43, 56-61. In particular, *Hitomi* discloses that the "control unit 50 receives various signals, such as . . . a temperature signal Sg, indicative of the temperature of the secondary catalytic device 37, from a temperature sensor 44 associated with one of the two secondary catalytic devices 37." *Id.* at 5:35-43.

72. *Hitomi* further discloses that in the "control of the actuator 38 by the control unit 50, when the ignition key switch 45 provides an ignition signal Si, indicating engine cranking, a temperature signal Sg rom the temperature sensor 44 indicates that a temperature Tc of the secondary catalytic device 37 is still below an active temperature Tco." *Id.* at 5:56-61.

Mapping of Hitomi and Onishi to Claim 18

18. A method according to claim 1 wherein after a predetermined operating condition has been sensed or determined, said engine reverts back to normal operation.

73. *Hitomi* discloses that after a predetermined operating condition has been sensed or determined, the engine reverts back to normal operation. Ex 1002 at 12:28-33. In particular, *Hitomi* discloses that "[i]n order to improve starting of the vehicle, an ignition timing is changed from a retarded ignition timing when the engine operates in the region I to an advanced ignition timing after the vehicle starts." *Id.* In my opinion, a POSITA would understand that while ignition is being retarded, fuel efficiency and fuel consumption are suffering within an engine, as is the torque. In order to improve fuel efficiency and consumption and to recover torque, it is important for the engine to revert to normal operation as quickly as possible after the predetermined condition, *e.g.*, catalyst light-off temperature, is met.

Hitomi

Reference(s)	Basis	Challenged Claim(s)
Hitomi, Onishi, and Eichler '089	§103 (a)	5

Obviousness of Hitomi in Combination with Onishi and Eichler '089 Over Claim 5

Mapping of Hitomi, Onishi, and Eichler '089 to Claim 5

5. A method according claim 1 wherein the ignition is retarded up to about 30° ATDC.

74. I have been informed that claim 5 depends from independent claim 1 and requires that "the ignition is retarded up to about 30° ATDC." Ex. 1001 at 6:25-26. As explained below, in my opinion, the teachings of *Hitomi* and *Onishi* in combination with the teachings of *Eichler '089* would render claim 5 of the '365 patent obvious to a POSITA.

75. As discussed above, *Hitomi* and *Onishi* disclose all features of independent claim 1, including retarding ignition to "between 10 and 20 degrees from a top dead center position of the piston." Ex. 1002 at 7:5-9. As further discussed above, this feature of claim 5 should be construed to mean "between 15° and 30° ATDC."

76. In my opinion, retarding ignition up to about 30° ATDC, including between 15° and 30° ATDC, in an internal combustion engine comprising a fuel injection system and catalytic system was well known in the art. For example, U.S. Patent No. 3,865,089 to Eichler et al. ("*Eichler '089*"), which issued on February 11, 1975, and which I have been informed is prior art under 35 U.S.C. § 102(b), discloses retarding ignition to about 10° to 25° ATDC. Ex. 1003 at 3:33-36.

Mapping of Hitomi, Onishi, and Eichler '089 to Claim 5

77. In my opinion, a POSITA would have been motivated to apply the further ignition retardation range (i.e., to about 10° to 25° ATDC) of *Eichler '089* to the engine operation method and parameters of *Hitomi* and *Onishi* so as to more efficiently heat the exhaust gas with less mechanical work, as disclosed by *Eichler '089*. A POSITA would have recognized that by retarding ignition to a point further ATDC, the beginning and end of the combustion process are in turn delayed longer. The longer delay in the start of the combustion process results in more energy being freed by the burning air/fuel mixture later in the cycle. This delay in combustion results in less time available for heat loss and consequently heats up the exhaust gas and catalyst to its operating temperature faster.

78. It was also known in the art that "when the ignition delay of the air-fuel mixture of the combustion within the operating cylinder is increased, the temperature of the exhaust gases increases, however, the power delivered by the combustion engine will decrease. The energy which is freed by burning an air-fuel mixture becomes, under conditions of increasing the ignition delay, converted to a lesser extent into mechanical work, and becomes converted, to a greater extent, into heat present in the exhaust gas." U.S. Patent No. 3,799,134 to *Griese*.

79. In my opinion, a POSITA with knowledge of *Hitomi* and *Onishi* and the fact that ignition could be retarded to ATDC would have been motivated to determine the optimal range of crank angles ATDC at which to ignite the fuel/air mixture in a combustion engine. Thus, it would have been obvious to consider further retarding ignition to about 10° to 25° ATDC, as disclosed in *Eichler '089*. Moreover, a POSITA would have been motivated to optimize the ignition timing disclosed in *Eichler '089*, potentially covering crank angles outside the range disclosed in *Eichler '089*, and doing so would have required no more than routine experimentation by a POSITA.

Hitomi

Reference(s)	Basis	Challenged Claim(s)
Hitomi, Onishi, and Takada	§103 (a)	12

Obviousness of Hitomi in Combination with Onishi and Takada Over Claim 12

Mapping of Hitomi, Onishi, and Takada to Claim 12

12. A method according to claim **10** wherein additional air is introduced upstream of the catalytic treatment means.

80. I have been informed that claim 12 depends from independent claim 1 and dependent claim 10 and requires that "additional air is introduced upstream of the catalytic treatment means." Ex. 1001 at 6:43-45. As discussed above, *Hitomi* discloses all features of dependent claim 10 and independent claim 1, including a combustion engine having a fuel injection system and a catalytic treatment means comprising a catalytic material. In my opinion, it would have been obvious to introduce additional air into the exhaust system between the exhaust ports and the inlet of the catalytic treatment means. As explained below, in my opinion, the teachings of *Hitomi* in combination with the teachings of U.S. Patent No. 4,276,745 to Takada et al. ("*Takada*"), which I have been informed is prior art to the '365 patent, would render claim 12 of the '365 patent obvious to a POSITA.

81. In my opinion, it was well known in the art to introduce additional air into the exhaust system between the exhaust ports and the inlet of the catalytic treatment means. For example, *Takada* discloses an exhaust gas control system including a specific example of introducing additional air downstream of the engine cylinder between the exhaust ports and the inlet of the catalytic treatment means. This example involves "secondary air [being] supplied, depending on the idling signal and the water temperature signal, to the upstream side of the 3-way catalyst for reducing the CO content, thus satisfactorily effecting the original performance of the catalyst." *Id.* at 3:29-33.

82. In my opinion, it would have been obvious for a POSITA to provide the engine of *Hitomi* with the additional air system of *Takada* in order to reduce CO emissions and improve efficiency of the catalytic treatment means. In my opinion, the motivation to implement the introduction of air disclosed in *Takada* into the engine in *Hitomi* would have been to efficiently manage the emission of exhaust gases in an engine with a fuel injection system by aiding an increase in the temperature of the exhaust gases and catalytic material and diluting the concentration of harmful hydrocarbons in the exhaust gases by increasing the oxygen content in the exhaust gases. *Id.*

Griese

Reference(s)	Basis	Challenged Claim(s)
Griese, Eichler '791, and Onishi	§103 (a)	1, 2, 5, 9, 10, 13, 14, 18
Griese, Eichler '791, Onishi, and Takada	§103 (a)	12

Griese

Reference(s)	Basis	Challenged Claim(s)
Griese, Eichler '791, and Onishi	§103 (a)	1, 2, 5, 9, 10, 13, 14, 18

Obviousness of Griese in Combination with Eichler '791 and Onishi Over Claims 1, 2, 5, 9, 10, 13, 14, 18

Mapping of Griese, Onishi, and Eichler '791 to Claim 1.0

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

90. *Griese* discloses retarding ignition to bring the exhaust gas cleaning arrangement 16 up to its operating temperature especially during a cold start of the combustion engine. Ex 1006 at 1:22-33, 57-68-2:10, 13-20, 63-68; 3:5-9; 4:39-50; 5:1-13, 32-68-6:6. In my opinion, because *Griese* discloses delaying ignition timing "as a function of the temperature of the exhaust gas cleaning arrangement" until "energy which is freed by the combustion of the enriched air-fuel mixture" is "converted . . . into heat within the exhaust gas with a high enthalpy," it would have been obvious to one having ordinary skill in the art that *Griese* discloses "retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine."

91. *Griese* discloses a combustion engine system of operation that "is capable of adjusting the ignition timing for 'delayed,' as a function of the temperature of the exhaust gas cleaning arrangement, and at the same time to provide for a maximum possible fuel supply during the idle run or cold start of a combustion engine." *Id.* at 2:13-20.

92. *Griese* also discloses that "with the help of the control arrangement according to the present invention to deliver an additional quantity to the combustion engine and to set the ignition timing for 'delayed' so that the energy which is freed by the combustion of the enriched air-fuel mixture will be converted to a greater extent into heat within the exhaust gas with a high enthalpy and to a lesser extent, it becomes converted into mechanical work." *Id.* at 3:2-9.

Mapping of Griese, Onishi, and Eichler '791 to Claim 1.0

93. *Eichler* '791 also discloses retarding the ignition of a gas/fuel mixture until after top dead center. Ex. 1010 at 5:3-12; 4:100-112. In particular, *Eichler '791* discloses that "[w]hen the exhaust gases of the internal combustion engine are passed through a thermal and/or catalytic reactor, which is not shown in the drawings, it is often desired to heat such a reactor quickly during the warming-up phase of the internal combustion engine and thereby cause it to operate." *Id.* at 3:130-4:7. *Eichler '791* also discloses a "device for acting upon the internal combustion engine during overrun, which device comprises a control valve for auxiliary air arranged in a circuit by-passing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C." *Id.* at 5:3-12. In addition, *Eichler '791* discloses that when the "servo valve 75 is switched on by the control system 60, the negative pressure in the spark timing adjusting element 77 moves an actuating rod 95, connected to the mounting plate 54, in the direction of the arrow and thereby rotates the mounting plate 52 so far that the firing instant is moved 15° to 20° in the spark retard direction from its basic setting, namely, approximately 5° A.T.D.C. The ignition processes are then triggered at a crankshaft angle of 20° to 25° A.T.D.C." *Id.* at 4:100-112.

94. As discussed above, it would have been obvious to one having ordinary skill in the art to further retard ignition of the engine disclosed in *Griese* to beyond ATDC (i.e., between 15° to 25° ATDC), as explicitly disclosed in *Eichler '791* so as to more effectively convert more energy from the combustion into heat within the exhaust gas with a high enthalpy, and doing so with less mechanical work, as recognized by *Griese* and further disclosed by *Eichler '791*.

Mapping of Griese, Onishi, and Eichler '791 to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine. the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

95. *Griese* discloses an increase in fuelling rate while the ignition is retarded in order to assist in increasing the exhaust gas temperature. Ex. 1006 at 2:13-19; 4:39-49. In particular, *Griese* discloses that "the exhaust gas cleaning arrangement 16 could be brought quickly to its operating temperature when the combustion engine is started up in a cold state" and that "when the engine is in its idle run, an abnormally high quantity of fuel-air mixture should be burned in the operating cylinder 9 of the combustion engine." *Id.* at 4:39-49.

Mapping of Griese, Onishi, and Eichler '791 to Claim 1.1

1. A method of operating an internal combustion engine comprising retarding the ignition of a gas/fuel mixture within at least one cylinder of the engine to after top dead centre (ATDC) in respect of the combustion cycle of said at least one cylinder of the engine and, while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally to thereby assist in increasing the exhaust gas temperature of the engine, the timing of the introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC).

96. *Eichler '791* discloses a conventional engine in which all fuel is injected into a cylinder at BTDC. Ex. 1003 at 2:44-50, Fig. 1.

97. In my opinion, because *Eichler '791* discloses a conventional internal combustion engine incorporating a port fuel injection system, in which fuel and air are mixed in the port outside the combustion chamber prior to ignition, a POSITA would recognize that *Eichler '791* discloses a port fuel injected engine which operates in a manner in which "the timing of the introduction of fuel into the at least one cylinder being maintained at BTDC." Moreover, in my opinion, a POSITA would understand that *Eichler '791* discloses that all fuel must be injected into the at least one cylinder at BTDC.

Mapping of Griese, Onishi, and Eichler '791 to Claim 1.2

98. If, however, this claim term was to be construed to mean the "start of injection for at least one cylinder is BTDC," as I understand the PO has proposed in a pending litigation, *Eichler '791* discloses this feature for at least the reasons discussed above in ¶ 102.

99. *Onishi* discloses that timing of the introduction of fuel into the at least one cylinder is maintained at before top dead centre (BTDC). Ex. 1005 at 9:63-10:9; 10:62-75. In particular, *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said [top dead] center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure. *Id.* at 9:63-75.

100. *Onishi* further discloses that the "engine may be handled almost like and internal combustion engine of electric ignition type and, in addition, can be operated rationally by varying the above factors over extensive ranges." *Id.* at 10:6-9.

Mapping of Griese, Onishi, and Eichler '791 to Claim 2

2. A method according to claim 1 wherein the fuelling rate is greater than 50% of the fuelling rate at maximum load.

101. *Griese* discloses that the fueling rate is greater than 50% of the fuelling rate at maximum load. Ex 1006 at 2:13-19; 4:39-49. In particular, *Griese* discloses an "arrangement which is capable of adjusting the ignition timing for 'delayed,' as a function of the temperature of the exhaust gas cleaning arrangement and, at the same time to provide for a maximum possible fuel supply during the idle run or cold start of a combustion engine." *Id.* at 2:13-19. *Griese* also discloses that "[i]n order that the exhaust gas cleaning arrangement 16 could be brought quickly to its operating temperature when the combustion engine is started up in a cold state, the invention provides that, under the condition, when the engine is in its idle run, an abnormally high quantity of fuel-air mixture should be burned in the operating cylinder 9 of the combustion engine." *Id.* at 4:39-49.

102. In my opinion, because *Griese* discloses providing "for a maximum possible fuel supply" and "an abnormally high quantity of fuel-air mixture" a POSITA would recognize that *Griese* discloses "increasing the fuelling rate greater than 50% of the fueling rate at maximum load."

Mapping of Griese, Onishi, and Eichler '791 to Claim 5

5. A method according claim 1 wherein the ignition is retarded up to about 30° ATDC.

103. *Eichler '791* discloses retarding ignition up to about 30° ATDC, and in particular, to between 15° and 30° ATDC. Ex. 1010 at p. 5, ll. 3-12; p. 4, ll. 100-112. In particular, *Eichler '791* discloses that "[w]hen the exhaust gases of the internal combustion engine are passed through a thermal and/or catalytic reactor, which is not shown in the drawings, it is often desired to heat such a reactor quickly during the warming-up phase of the internal combustion engine and thereby cause it to operate." *Id.* at 3:130-4:7. *Eichler '791* also discloses a "device for acting upon the internal combustion engine during overrun, which device comprises a control valve for auxiliary air arranged in a circuit by-passing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C." *Id.* at p. 5, ll. 3-12.

104. *Eichler '791* also discloses that "[w]hen the servo valve 75 is switched on by the control system 60, the negative pressure in the spark timing adjusting element 77 moves an actuating rod 95, connected to the mounting plate 54, in the direction of the arrow and thereby rotates the mounting plate 52 so far that the firing instant is moved 15° to 20° in the spark retard direction from its basic setting, namely, approximately 5° A.T.D.C. The ignition processes are then triggered at a crankshaft angle of 20° to 25° A.T.D.C." *Id.* at 4:100-112. (Emphasis added.)

Mapping of Griese, Onishi, and Eichler '791 to Claim 9

9. A method according to claim 1 wherein the fuel is introduced at between 60° to 80° BTDC.

105. *Griese* and *Eichler '791* do not disclose injecting all fuel into a cylinder during a cycle between 80° and 60° BTDC. In my opinion, it would have been obvious to a POSITA to inject all fuel into a cylinder of a direct injected engine during a cycle between 80° and 60° BTDC.

106. In my opinion, it was well known in the art to inject all fuel at between 60° to 80° BTDC during operation of an internal combustion engine comprising a fuel injection system and catalytic system was well known in the art. For example, as discussed above, *Onishi* discloses injecting all fuel in a combustion cycle in at least one cylinder between about 80° and 60° BTDC. *Onishi* discloses that the inventive fuel injection method may be carried out over a range from idling (no load) to full-load conditions, ex. 1005 at 4:6-8, and when the engine is cold. *Id.* at 9:46-52.

107. *Onishi* discloses that ignition timing can be independent of fuel injection timing and further discloses that the start of fuel injection may occur at about 80° BTDC. In particular, *Onishi* discloses that "while the initiation angle of fuel injection is varied from 140 deg. ahead of the top dead center to 80 deg. ahead of the same center, i.e., over a range of 60 deg. in terms of the crank angle, the ignition timing may be varied independently thereof and the ignition and operation are made possible without any undesirable outcome, over a range from about 40 deg. ahead of the top dead center to a point past the said center, though it is accompanied by some fluctuations of the maximum pressure and mean effective pressure." Ex. 1005 at 9:65-74. *Onishi* also discloses that the fuel injection initiation timing may vary "over extensive ranges," and thus a POSITA would have understood that fuel injection in a cylinder of the *Onishi* engine could begin at a crank angle slightly after 80° BTDC. *Id.* at 10:6-9.

Mapping of Griese, Onishi, and Eichler '791 to Claim 9

108. Moreover, under certain conditions, such as idle, in which the engine of *Onishi* is operating at a no load, or in a low load condition, and is also operating at low speed, the length of injection time, and in turn, the change in the crank shaft angle during injection will be minimal during a combustion cycle. It was well known in the art at the time of the '365 patent invention, for example, that a direct fuel injector could have a minimum pulse width (i.e., the length of time the fuel injector is open in a particular cycle) as short as approximately 1.5 ms. The following calculation shows that at an engine speed of 600 rpm, which a POSITA would understand is typical for port injected engines at idle (low end of the idle speed range), and for a crank shaft angle change of 20° (i.e., from 80° to 60° BTDC), there would be 5.56 ms to inject all fuel.

> [(20 crank angle deg)*(1 revolution/360 deg)*(1 min/600 revolutions)*(60 s/min)*(1000 ms/s)] =
> **5.56 ms**

A similar calculation made at an engine speed of 800 rpm, which a POSITA would understand is typical for port injected engines at idle (high end of the idle speed range), shows that there would be 4.17 ms to inject all fuel under such conditions.

> [(20 crank angle deg)*(1 revolution/360 deg)*(1 min/800 revolutions)*(60 s/min)*(1000 ms/s)] =
> **4.17 ms**

Finally, at an engine speed of 1200 rpm there would be 2.78 ms to inject all fuel.

> [(20 crank angle deg)*(1 revolution/360 deg)*(1 min/1200 revolutions)*(60 s/min)*(1000 ms/s)] =
> **2.78 ms**

Thus, a POSITA would understand that at each of these exemplary engine speeds all fuel would be injected during the 20° crank shaft angle change under low load or no load conditions and at low engine speeds, because the minimum pulse width is less than the time available to inject all fuel (based on a crank shaft angle range of 20°).

Therefore, under such circumstances in the engine disclosed in *Onishi*, if fuel injection started at about 80° BTDC, a POSITA would have understood that all fuel could have been injected by 60° BTDC over at least a portion of the engine operating range.

Mapping of Griese, Onishi, and Eichler '791 to Claim 9

109. In my opinion, a POSITA would have been motivated to experimentally explore the fuel injection range of *Griese* with the fuel introduction range of *Onishi* (which includes injecting all fuel in a cycle between about 80° and 60° BTDC) so as to provide an optimal air/fuel mixture leading to more stable combustion, in part, because *Griese* discloses a method for operating an engine during engine idle using ignition timing retard, (Ex. 1006 at Abstract), while *Onishi* discloses a method for operating an engine exhibiting no-load conditions, such as engine idle, (Ex. 1004 at 4:6-8), and after cold start, (Ex. 1004 at 9:46-52), in which ignition timing and fuel inject timing may be varied independently. Ex. 1004 at 10:1-2. Moreover, a POSITA would have understood *Onishi* to disclose some embodiments in which all fuel is introduced to a cylinder within the claimed introduction range of between 60° to 80° BTDC. In my opinion, through routine experimentation, a POSITA would have come concluded that injecting all fuel in a cycle between 80° and 60° BTDC would have resulted in a more optimal mixture of the air/fuel mixture prior to ignition, which Bernhardt discloses may be retarded to ATDC.

Mapping of Griese, Onishi, and Eichler '791 to Claim 10

10. A method according to claim 1 wherein the engine includes in an exhaust system thereof a catalytic treatment means supporting a catalytic material therein.

110. *Griese* discloses an engine which includes in an exhaust system thereof an exhaust gas cleaning arrangement 16 (the claimed "catalytic treatment means") supporting a catalytic material therein. Ex. 1006 at 4:34-38; 5:23-29, Fig. 2. In particular, the "cylinder has an input valve 13 and an exhaust valve 14 which passes the exhaust gases into an exhaust gas conduit 15, into which an exhaust gas cleaning arrangement 16, such as an exhaust gas cleaning catalyzator is coupled." *Id.* at 4:34-38. *Griese* also discloses that the "thermostat 27 measures the temperature at a location indicated by 26 which, for example, can be in the form of a thermos-element placed, as indicated, into the exhaust gas conduit 15, directly before the exhaust gas cleaning arrangement 16. The thermostat 27 operates then the switching means 1 as described in connection with FIG. 1." *Id.* at 5:23-29.

Mapping of Griese, Onishi, and Eichler '791 to Claim 13

13. A method according to claim **10** wherein the engine is operated according to said method during cold start of the engine.

111. *Griese* discloses operating an engine (in accordance with claim 10) during cold start of the engine. Ex 1006 at 4:34-38; 5:23-29; 5:33-35. *See also* ¶110 above. In addition, *Griese* discloses that "[d]uring a cold start of the combustion engine, at which the exhaust gas cleaning arrangement 16 is also cold, the thermostat 27 will keep the switch 1 closed." *Id.* at 5:33-35.

Mapping of Griese, Onishi, and Eichler '791 to Claim 14

14. A method according to claim **10** wherein the engine is operated according to said method when the temperature of the catalytic material is sensed or determined to be below a required operating temperature.

112. *Griese* discloses operating an engine when the temperature of the catalytic material is sensed or determined to be below a required operating temperature. Ex 1006 at 4:34-38; 5:23-29; 5:33-35, 63-67. *See also* ¶110 above. In addition, *Griese* discloses that as "soon as the required temperature has been attained, by the cleaning arrangement 16, the thermostat 26, 27 will open the switch 1." *Id.* at 5:63-67. Thus, a POSITA would recognize that in order for the thermostat to respond to a required temperature being achieved, the system of *Griese* must inherently sense or measure the temperature.

Mapping of Griese, Onishi, and Eichler '791 to Claim 18

18. A method according to claim **1** wherein after a predetermined operating condition has been sensed or determined, said engine reverts back to normal operation.

113. *Griese* discloses that after a predetermined operation condition has been sensed or determined, the engine reverts back to normal operation. Ex 1006 at 4:34-38; 5:23-29; 5:33-35, 63-67. In particular, *Griese* discloses that "[a]s as the required temperature has been attained by the cleaning arrangement 16, the thermostat 26, 27 will open the switch 1. *Id.* at 5:63-67.

Griese

Reference(s)	Basis	Challenged Claim(s)
Griese, Eichler '791, Onishi, and Takada	§103 (a)	12

Obviousness of Griese in Combination with Eichler '791, Onishi, and Takada Over Claim 12

Mapping of Griese, Onishi, and Eichler '791 to Claim 12

12. A method according to claim **10** wherein additional air is introduced upstream of the catalytic treatment means.

114. I understand that claim 12 depends from independent claim 1 and dependent claim 10 and requires that "additional air is introduced upstream of the catalytic treatment means." Ex. 1001 at 6:43-45. As discussed above, *Griese*, *Eichler '791*, and *Onishi* disclose all features of dependent claim 10 and independent claim 1, including a combustion engine having a fuel injection system and a catalytic treatment means comprising a catalytic material. None of these references discloses introducing additional air upstream of the catalytic treatment means and downstream of the exhaust ports. This feature, however, was well known in the art and it would have been obvious to introduce additional air into the exhaust system between the exhaust ports and the inlet of the catalytic treatment means.

115. *Takada*, for example, explicitly discloses an exhaust gas control system including a specific example of introducing additional air downstream of the engine cylinder between the exhaust ports and the inlet of the catalytic treatment means. This example involves "secondary air [being] supplied, depending on the idling signal and the water temperature signal, to the upstream side of the 3-way catalyst for reducing the CO content, thus satisfactorily effecting the original performance of the catalyst." *Id.* at 3:29-33.

116. In my opinion, it would have been obvious for a POSITA to provide the engine containing the features disclosed in *Griese*, *Eichler '791*, and *Onishi* with the additional air system of *Takada* in order to reduce CO emissions and improve efficiency of the exhaust system. In my opinion, the motivation to implement the introduction of air disclosed in *Takada* into the engine in *Griese* would have been to efficiently manage the emission of exhaust gases in an engine with a fuel injection system by aiding an increase in the temperature of the exhaust gases and catalytic material and diluting the concentration of harmful hydrocarbons in the exhaust gases by increasing the oxygen content in the exhaust gases.

Patent Owner Arguments to Bernhardt

In response to argument that Bernhardt discloses "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder," PO says:

1. Bernhardt does not disclose "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder."

Claim 1 does not merely provide that "fuelling rate is higher than that required when the engine is operating normally." Rather, the plain language of this *method* claim specifically recites the step of "increas*ing* the fuelling rate" to this higher level "while said ignition is so retarded [i.e., after top dead centre (ATDC)]." As discussed above with reference to the proper construction of "the timing of introduction of fuel into the at least one cylinder being maintained at before top dead centre (BTDC)," Petitioner frames the issues in this proceeding as being a mere choice between the start of injection being BTDC (as proffered by Patent Owner) and the injection of all fuel BTDC (as alleged by Petitioner), thereby enabling Petitioner to summarily conclude in its invalidity analysis that "[i]f Bernhardt discloses that all fuel is injected at BTDC, it inherently discloses that the start of fuel injection occurs at BTDC." *See* Ex. 1006 at ¶58 (footnote 3), cited by Paper 3 at 14. Petitioner's analysis, however, obfuscates claim 1's other requirement regarding the timing of fuel injection. That is, though the start of fuel injection in a combustion cycle must occur before TDC, claim 1 also *requires* that fuel injection occurs after TDC (i.e., "while said ignition is so retarded") so as to increase the fuelling rate (mg/cylinder/cycle) to a level higher than that required when the engine is operating normally.

Whereas a petitioner must demonstrate that all of a claim's limitations are disclosed in the prior art and arranged as in the challenged claim to make a showing of anticipation, none of the passages of Bernhardt cited by the Petitioner discloses or suggests the step of increasing fuel occurs "while said ignition is so retarded," as required by claim 1. In fact, in doubling down on its improper claim construction, Petitioner and its expert explicitly assert that Bernhardt requires all fuel to be injected BTDC. For example, Petitioner alleges that "a POSITA would recognize that Bernhardt discloses an engine . . . in which all fuel in a combustion cycle is injected while the cylinder is at BTDC" and that "[i]n conventional port fuel injected engines, such as the engine disclosed in Bernhardt, all fuel is introduced before the start of the compression stroke, which is typically at about 180° BTDC." Paper 3 at 13-14 (emphasis added). Petitioner's expert Dr. Matthews concurs, concluding that in "a port fuel injection system where fuel is mixed with air in the intake port," the injection of all fuel into the combustion chamber "necessarily occurs BTDC." Ex. 1006 at ¶58.

Clearly, injection of *all fuel* at BTDC, as alleged by Petitioner to be disclosed in Bernhardt, would preclude increas*ing* the fuelling rate at ATDC. Thus, Petitioner's (and Dr. Matthew's) contention that *all* fuel must be injected *before* TDC in Bernhardt necessarily prohibits Petitioner from demonstrating that Bernhardt discloses increasing the fuelling rate *after* TDC while ignition is so retarded. Accordingly, Bernhardt cannot disclose or suggest "while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally…" because according to Petitioner all of the fueling in Bernhardt is completed BTDC.

Patent Owner Arguments to Bernhardt

My response:

1.

In my opinion, Patent Owner's proposed construction of "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder" is not correct. The timing of ignition and fuel introduction of the claimed invention are expressed in terms of whether they occur at a crankangle before or after top dead center. However, the timing limitations of claim 1, in general, refer to engine operating conditions—the operating conditions of the claimed invention and normal operating conditions—not with reference to the crankangle during a given cycle as implied by Patent Owner's proposed constructions. Instead, the Specification refers to "ignition retard" and "high fuelling rate" as "conditions" and as distinct from normal conditions. Ex. 1001, col. 5, ll. 24–29 (emphasis added); *see also id.*, col. 3, ll. 26–27.

The phrase "while said ignition is so retarded" is not, as Patent Owner suggests, limited to the period of time when the crankangle position during a given cycle is after top dead center. The engine is in a period "while said ignition is so retarded [to ATDC]" at all crankangle positions when the retarded-ignition condition is enabled, including those times during the cycle when the crankangle is before top dead center. Thus, when the engine is operated in a condition where ignition is at a retarded angle after top dead center and all fuel is injected before the crankangle reaches top dead center, it still would be true that the fuel was injected while the ignition was "so retarded."

Patent Owner impliedly argues that fueling rate refers to quantity per unit-time (i.e. milligrams per second) and that that rate must be increased during each cycle. *See* Prelim. Resp. 28–29. However, claim 1 refers to "fuelling rate" as the quantity of fuel injected in a cylinder during a single cycle not the change in the quantity injected within a given cycle. *See* Ex. 1001, col. 2, ll. 3–4 ("the fuelling rate (measured in mg/cylinder/cycle)"). The language of independent claim 1 defines the fueling rate level relative to that "when the engine is operating normally." Ex. 1001, col. 6, ll. 11–14.

Patent Owner's position that the claim 1 "*requires* that fuel injection occurs after TDC (i.e., 'while said ignition is so retarded')" is its sole opposition to the sufficiency of the Bernhard anticipation arguments. *Id.* at 27. As discussed above, I disagree with Patent Owner's proposed claim construction. Patent Owner, in its Preliminary Response, does not otherwise dispute Petitioner's contentions regarding the disclosures of Bernhardt.

Patent Owner Arguments to Bernhardt (not published)

In response to our argument that Bernhardt anticipates the '365 patent, PO says,

2. Bernhardt is not a prior art printed publication.

Here, Bernhardt is an unauthenticated reference purported by Petitioner, without support, to be a publication from February 1, 1972. Paper 3 at 42. Exhibit 1002 contains a cover sheet which appears to be a webpage printout dated January 20, 2015 from the website http://papers.sae.org/720481/. Though the cover sheet lists a "[p]ublished" date of "1972-02-01" (presumably the date cited in the Petition), the reference itself which begins on page 2 of Exhibit 1002 does not contain a publication date nor any marking indicative of a vehicle for publication/distribution (e.g., a periodical title). *Id.* at 2. The only date on the Bernhardt reference itself appears to be a header inserted on the top of pages 2-25 as follows: "Downloaded from SAE International by Bianca Hamilton, Wednesday, January 21, 2015," a day after the date contained on the cover page. The information on Exhibit 1002 itself is therefore insufficient to establish publication, let alone the date alleged by Petitioner.

Patent Owner Arguments to Bernhardt (published)

My response:

2.

In my opinion, Bernhardt was properly published and available by the February 1, 1972. Exhibit 1002 is a cover page with an article attached. The cover page appears to be from an SAE International website describing and offering for the purchase of a technical paper titled "Methods for Fast Catalytic System Warm-Up During Vehicle Cold Starts" by Volkswagonwerk AG's W. Bernhardt and E. Hoffmann. The cover page identifies the paper number as 720481 and as "Published: 1972-02-01." Ex. 1002, cover page. On the second page of the exhibit begins what appears to be a technical article bearing the same title, authors, and paper number (the latter handwritten under the title).

When asked by counsel for Petitioner whether I had any evidence that the Bernhardt technical paper was published prior to the earliest priority date of the '365 patent, which I understand to be January 25, 1993, I searched my internal files and came across the same copy of the Bernhardt technical paper labeled as Ex. 1002. In addition, I found a Cumulative Index of SAE Technical Papers published from 1965-1978. See Ex. 1015 (IPR2015-01258). The index is labeled as the 5th edition and includes subject and author information for each technical paper listed (and published), and the papers are listed in chronological order in the index. The index was published in August 1979 by the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096. In addition, the index was submitted to the Library of Congress and contains, on its face, Library of Congress Card Catalog Number: 79-90723. Moreover, the index provides instructions for ordering a copy of all SAE technical papers listed in the index. Finally, and in particular, the index includes, at p. 782, a citation to paper 720481 (SP-370) Methods for Fast Catalytic System Warm-Up During Vehicle Cold Starts. W. E. Bernhardt and E. Hoffman, Volkswagenwerk AG. SAE Trans. Vol. 81. In my opinion, which is based in part on a comparison of the title, authors, paper number, and publication information, this citation in the index corresponds to the Bernhardt technical paper labeled as Ex. 1002.

Patent Owner Arguments to Eichler '791

In response to argument that Eichler '791 discloses "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder," PO says:

1. **Eichler '791 does not disclose "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder."** **[under PO's claim construction]**

First, with regard to Eichler '791, Petitioner does not allege that Eichler '791 discloses increasing fuel at ATDC as required by claim 1. To the contrary, the Petition's claim chart reproduces two passages of Eichler '791 to summarily conclude that "Eichler '791 discloses that while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder." Paper 3 at 33 [element 1.1]. Though the Petition in IPR2015-01258 is devoid of analysis, Petitioner's expert Dr. Matthews explicates in Petitioner's parallel proceeding against the '365 Patent (IPR2015-01259) that "Eichler '791 discloses a conventional engine in which all fuel is injected into a cylinder at BTDC." Ex. 2005 at 45/117 (¶96). Specifically, Dr. Matthews contends that: "[B]ecause Eichler '791 discloses a conventional internal combustion engine incorporating a port fuel injection system, in which fuel and air are mixed in the port outside the combustion chamber prior to ignition, a POSITA would recognize that Eichler '791 discloses a port fuel injected engine which operates in a manner in which "the timing of the introduction of fuel into the at least one cylinder being maintained at BTDC. Moreover, in my opinion, a POSITA would understand that Eichler '791 discloses that all fuel must be injected into the at least one cylinder at BTDC." *Id.* at 45/117 (¶97) (original emphasis removed, underlining added).

In light of Dr. Matthews' analysis concluding that in Eichler '791's port injection system "all fuel *must be* injected into the at least one cylinder at BTDC," Petitioner cannot demonstrate that Eichler '791 discloses or suggests "while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder…" as recited in claim 1. Rather, because injection of *all fuel* must be completed prior to BTDC according to Dr. Matthews' analysis, Eichler '791 would preclude an increase in the fuelling rate at ATDC.

Patent Owner Arguments to Eichler '791

My response:

1.

In my opinion, Patent Owner's proposed construction of "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder" is not correct. The timing of ignition and fuel introduction of the claimed invention are expressed in terms of whether they occur at a crankangle before or after top dead center. However, the timing limitations of claim 1, in general, refer to engine operating conditions—the operating conditions of the claimed invention and normal operating conditions—not with reference to the crankangle during a given cycle as implied by Patent Owner's proposed constructions. Instead, the Specification refers to "ignition retard" and "high fuelling rate" as "conditions" and as distinct from normal conditions. Ex. 1001, col. 5, ll. 24–29 (emphasis added); *see also id.*, col. 3, ll. 26–27.

The phrase "while said ignition is so retarded" is not, as Patent Owner suggests, limited to the period of time when the crankangle position during a given cycle is after top dead center. The engine is in a period "while said ignition is so retarded [to ATDC]" at all crankangle positions when the retarded-ignition condition is enabled, including those times during the cycle when the crankangle is before top dead center. Thus, when the engine is operated in a condition where ignition is at a retarded angle after top dead center and all fuel is injected before the crankangle reaches top dead center, it still would be true that the fuel was injected while the ignition was "so retarded."

Patent Owner impliedly argues that fueling rate refers to quantity per unit-time (i.e. milligrams per second) and that that rate must be increased during each cycle. *See* Prelim. Resp. 28–29. However, claim 1 refers to "fuelling rate" as the quantity of fuel injected in a cylinder during a single cycle not the change in the quantity injected within a given cycle. *See* Ex. 1001, col. 2, ll. 3–4 ("the fuelling rate (measured in mg/cylinder/cycle)"). The language of independent claim 1 defines the fueling rate level relative to that "when the engine is operating normally." Ex. 1001, col. 6, ll. 11–14.

Patent Owner's position that the claim 1 "*requires* that fuel injection occurs after TDC (i.e., 'while said ignition is so retarded')" is its sole opposition to the sufficiency of the Eichler '791 obviousness arguments. *Id.* at 37-39. As discussed above, I disagree with Patent Owner's proposed claim construction. Patent Owner, in its Preliminary Response, does not otherwise dispute Petitioner's contentions regarding the disclosures of Eichler '791.

Patent Owner Arguments to Hitomi/Onishi

In response to argument that Hitomi discloses "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder," PO says:

1. **Hitomi does not disclose "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder."**

Petitioner and its expert explicitly assert that Hitomi and Onishi require all fuel to be injected BTDC. For example, Petitioner's expert asserts that "Hitomi also discloses the introduction of fuel in a combustion cycle being BTDC, ..., and in particular, injection of all fuel within a combustion cycle occurring at BTDC. See, e.g. Fig. 1, in which Hitomi discloses a port fuel injected engine. A POSITA would have understood that all fuel is injected BTDC in a typical port fuel injected engine." See Ex. 1008 at 21-22.

Clearly, Hitomi's disclosure of injecting "all fuel" at before TDC precludes increas*ing* the fuelling rate at after TDC. Accordingly, by the Petitioner's expert's own admission, Hitomi does not disclose or suggest "while said ignition is so retarded, increasing the fuelling rate of said at least one cylinder to a level higher than that required when the engine is operating normally...," as recited in claim 1.

Though Petitioner does not rely on Onishi's teachings for meeting the recitation of "while said ignition is so retarded, increasing the fuelling rate. . ." (*see* Paper 3 at 18-19 [element 1.1]), Patent Owner submits that Onishi nonetheless fails to cure the deficiencies of Hitomi in this regard. Indeed, Petitioner asserts that Onishi, like Hitomi, discloses that *all fuel is injected BTDC*. *See* Paper 3 at 19 [element 1.2]. Petitioner cites to various passages of Onishi and, relying on the Declaration of Dr. Matthews, presents a calculation of the length of timecorresponding to a 20 degree change in crankangle at various engine speeds. *See* Paper 3 at 14-15; Ex. 1008 at ¶¶42-45. Ultimately, Petitioner concludes that all fuel will be injected BTDC in Onishi because the length of time a fuel injector is open in a particular cycle is less than the length of time orresponding to a 20 degree change in crankangle. *See* Paper 3 at 15. It will be appreciated that Petitioner's contention that all fuel is injected in BTDC in Onishi likewise precludes Petitioner from establishing that Onishi discloses increasing the fuelling rate at ATDC while ignition is retarded to ATDC.

Patent Owner Arguments to Hitomi/Onishi

My response:

1.

In my opinion, Patent Owner's proposed construction of "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder" is not correct. The timing of ignition and fuel introduction of the claimed invention are expressed in terms of whether they occur at a crankangle before or after top dead center. However, the timing limitations of claim 1, in general, refer to engine operating conditions—the operating conditions of the claimed invention and normal operating conditions—not with reference to the crankangle during a given cycle as implied by Patent Owner's proposed constructions. Instead, the Specification refers to "ignition retard" and "high fuelling rate" as "conditions" and as distinct from normal conditions. Ex. 1001, col. 5, ll. 24–29 (emphasis added); *see also id.*, col. 3, ll. 26–27.

The phrase "while said ignition is so retarded" is not, as Patent Owner suggests, limited to the period of time when the crankangle position during a given cycle is after top dead center. The engine is in a period "while said ignition is so retarded [to ATDC]" at all crankangle positions when the retarded-ignition condition is enabled, including those times during the cycle when the crankangle is before top dead center. Thus, when the engine is operated in a condition where ignition is at a retarded angle after top dead center and all fuel is injected before the crankangle reaches top dead center, it still would be true that the fuel was injected while the ignition was "so retarded."

Patent Owner impliedly argues that fueling rate refers to quantity per unit-time (i.e. milligrams per second) and that that rate must be increased during each cycle. *See* Prelim. Resp. 28–29. However, claim 1 refers to "fuelling rate" as the quantity of fuel injected in a cylinder during a single cycle not the change in the quantity injected within a given cycle. *See* Ex. 1001, col. 2, ll. 3–4 ("the fuelling rate (measured in mg/cylinder/cycle)"). The language of independent claim 1 defines the fueling rate level relative to that "when the engine is operating normally." Ex. 1001, col. 6, ll. 11–14.

Patent Owner's position that the claim 1 "*requires* that fuel injection occurs after TDC (i.e., 'while said ignition is so retarded')" is its sole opposition to the sufficiency of the Hitomi and Onishi obviousness arguments. *Id.* at 26-29. As discussed above, I disagree with Patent Owner's proposed claim construction. Patent Owner, in its Preliminary Response, does not otherwise dispute Petitioner's contentions regarding the disclosures of Hitomi/Onishi.

Patent Owner Arguments to Griese

In response to argument that Griese discloses "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder," PO says:

1. **Griese does not disclose "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder."**

As discussed and shown above in FIG. 2 of Griese, Griese provides a portinjected combustion engine in which the fuel is mixed with air in the intake manifold upstream of the intake valve combustion chamber: "The combustion engine cylinder is supplied with fuel mixture through a suction pipe 11 in which a choke or butterfly valve 12 is arranged and is connected for operation by an accelerator pedal. The fuel supply itself is shown only schematically at 17 and which is supplied in a quantity which is a function of the air quantity passing through the suction pipe 11." Ex. 1006 at 4:23-33 (emphasis added).

Though Petitioner asserts that Griese "does not explicitly disclose that all fuel is introduced BTDC," Petitioner asserts that "it was well known in the art, however, to introduce all fuel into a cylinder of an internal combustion engine BTDC. In fact, it was conventional to introduce all fuel in a fuel injected engine BTDC to achieve an optimal air/fuel mixture prior to ignition." Paper 3 at 29. Additionally, Petitioner's expert has averred that "[a] POSITA would have understood that *all fuel is injected BTDC in a typical port fuel injected engine.*" Ex. 1008 at ¶40 (emphasis added). Griese, like Hitomi and Eichler '791, is such an engine. Indeed, as correctly pointed out by Petitioner's expert, in a port fuel injected engine, fuel and air are mixed prior to introduction into the combustion chamber through the intake valve. Once introduced during the intake stroke (i.e., BTDC), the intake valve must close to seal the fuel mixture into the combustion chamber to enable compression by the piston during the compression stroke.

Patent Owner Arguments to Griese

My response:

1.

In my opinion, Patent Owner's proposed construction of "while said ignition rate is so retarded, increasing the fueling rate of said at least one cylinder" is not correct. The timing of ignition and fuel introduction of the claimed invention are expressed in terms of whether they occur at a crankangle before or after top dead center. However, the timing limitations of claim 1, in general, refer to engine operating conditions—the operating conditions of the claimed invention and normal operating conditions—not with reference to the crankangle during a given cycle as implied by Patent Owner's proposed constructions. Instead, the Specification refers to "ignition retard" and "high fuelling rate" as "conditions" and as distinct from normal conditions. Ex. 1001, col. 5, ll. 24–29 (emphasis added); *see also id.*, col. 3, ll. 26–27.

The phrase "while said ignition is so retarded" is not, as Patent Owner suggests, limited to the period of time when the crankangle position during a given cycle is after top dead center. Rather, the engine is in a period "while said ignition is so retarded [to ATDC]" at all crankangle positions when the retarded-ignition condition is enabled, including those times during the cycle when the crankangle is before top dead center. Thus, when the engine is operated in a condition where ignition is at a retarded angle after top dead center and all fuel is injected before the crankangle reaches top dead center, it still would be true that the fuel was injected while the ignition was "so retarded."

Patent Owner impliedly argues that fueling rate refers to quantity per unit-time (i.e. milligrams per second) and that that rate must be increased during each cycle. *See* Prelim. Resp. 28–29. However, claim 1 refers to "fuelling rate" as the quantity of fuel injected in a cylinder during a single cycle not the change in the quantity injected within a given cycle. *See* Ex. 1001, col. 2, ll. 3–4 ("the fuelling rate (measured in mg/cylinder/cycle)"). The language of independent claim 1 defines the fueling rate level relative to that "when the engine is operating normally." Ex. 1001, col. 6, ll. 11–14.

Patent Owner's position that the claim 1 "*requires* that fuel injection occurs after TDC (i.e., 'while said ignition is so retarded')" is its sole opposition to the sufficiency of the Griese obviousness arguments. *Id.* at 35-38. As discussed above, I disagree with Patent Owner's proposed claim construction. Patent Owner, in its Preliminary Response, does not otherwise dispute Petitioner's contentions regarding the disclosures of Griese.