UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

FORD MOTOR COMPANY

Petitioner,

v.

PAICE LLC & ABELL FOUNDATION, INC.

Patent Owner.

U.S. Patent No. 7,104,347 to Severinsky et al.

IPR Case No.: IPR2014-00579

DECLARATION OF DR. GREGORY DAVIS IN SUPPORT OF *INTER PARTES* REVIEW UNDER 35 U.S.C. § 311 *ET SEQ*. AND 37 C.F.R. § 42.100 *ET SEQ.* (CLAIMS 1, 7, 8, 18, 21, 23, 37 OF U.S. PATENT NO. 7,104,347)

FORD EXHIBIT 1108

Table of Contents

Exhibit List

Petition Exhibits			
Exhibit No.	Description	Date	Identifier
1101	U.S. Patent No. 7,104,347	n/a	The ’347 Patent
1102	’347 Patent File History	n/a	’347 Patent File History
1103	Bumby, J.R. et al. “Computer modelling of the automotive energy requirements for internal combustion engine and battery electric-powered vehicles” - IEE Proc. A 1985(5)	Sept. 1985	Bumby I
1104	Bumby, J.R. et al. “Optimisation and control of a hybrid electric car” - IEE Proc. A 1987, 134(6)	Nov. 1987	Bumby II
1105	Bumby, J.R. et al. “A Hybrid Internal Combustion Engine/Battery Electric Passenger Car for Petroleum Displacement” – Proc Instn Mech Engrs Volume 202 (D1), 51-65	Jan. 1988	Bumby III
1106	Bumby, J.R. et al. “A Test-Bed Facility for Hybrid IC Engine-Battery Electric Road Vehicle Drive Trains” - Trans Inst Meas & Cont 1988 Vol. 10(2)	Apr. 1, 1988	Bumby IV
1107	Bumby, J.R. et al. “Integrated Microprocessor Control of a Hybrid i.c. Engine/Battery-Electric Automotive Power Train” - Trans Inst Meas & Cont 1990 Vol. 12:128	Jan. 1, 1990	Bumby V

Declaration Exhibits			
Exhibit No.	Description	Date	Identifier
1118	Curriculum Vitae of Gregory Davis		Declaration Ex.
1119	Innovations in Design: 1993 Ford Hybrid Electric Vehicle Challenge	Feb. 1994	Declaration Ex.
1120	1996 Future Car Challenge	Feb. 1997	Declaration Ex.
1121	1997 Future Car Challenge	Feb. 1998	Declaration Ex.
1122	History of the Electric Automobile – Hybrid Electric Vehicles	1998	Declaration Ex.
1123	Hybrid Vehicle for Fuel Economy		Declaration Ex.
1124	Hybrid/Electric Vehicle Design Options and Evaluations	Feb. 24-28, 1992	Declaration Ex.
1125	Challenges for the Vehicle Tester in Characterizing Hybrid Electric Vehicles	April 9-11, 1997	Declaration Ex.
1126	Electric and Hybrid Vehicles Program	April 1995	Declaration Ex.
1127	Technology for Electric and Hybrid Vehicles	Feb. 1998	Declaration Ex.
1128	Strategies in Electric and Hybrid Vehicle Design	Feb. 1996	Declaration Ex.
1129	Hybrid Vehicle Potential Assessment	Sept. 30, 1979	Declaration Ex.
1130	Final Report Hybrid Heat Engine / Electric Systems Study	June 1, 1971	Declaration Ex.
1131	Transactions of the Institute of Measurements and Control: A microprocessor controlled gearbox for use in electric and hybrid-electric vehicles	Sept. 1, 1988	Declaration Ex.
1132	Propulsion System Design of Electric Vehicles	1996	Declaration Ex.
1133	Propulsion System Design of Electric and Hybrid Vehicles	Feb. 1997	Declaration Ex.
1134	Bosch Handbook	Oct. 1996	Declaration Ex.
1135	Design Innovations in Electric and Hybrid Electric Vehicles	Feb. 1995	Declaration Ex.
1136	U.S. Patent No. 6,209,672	Apr. 3, 2001	Declaration Ex.

Declaration Exhibits			
Exhibit No.	**Description**	**Date**	**Identifier**
1137	Introduction to Automotive Powertrains (Davis Textbook)		Declaration Ex.
1138	Yamaguchi article: Toyota Prius, Automotive Engineering International	Jan. 1998	Declaration Ex.
1139	60/100095 Provisional Application	Filed Sept. 11, 1998	Declaration Ex.

I, Gregory Davis, hereby declare as follows:

1. I am making this declaration at the request of Ford Motor Company in the matter of *Inter Partes* Review of U.S. Patent No. 7,104,347 (“the ’347 Patent”) to Severinsky et al.

2. I am being compensated for my work in this matter at a rate of $315/hour. My compensation in no way depends on the outcome of this proceeding.

3. In preparation of this declaration, I have studied the exhibits as listed in the Exhibit List shown above in my report.

4. In forming the opinions expressed below, I have considered:

(1) The documents listed above as well as additional patents and documents referenced herein;

(2) The relevant legal standards, including the standard for obviousness provided in *KSR International Co. v. Teleflex, Inc.*, 550 U.S. 398 (2007), and any additional documents cited in the body of this declaration; and

(3) My knowledge and experience based upon my work and study in this area as described below.

I. QUALIFICATIONS AND PROFESSIONAL EXPERIENCE

5. I have provided my full background in the curriculum vitae that is

attached as Exhibit 1118.

6. I received my Bachelor of Science Degree in Mechanical Engineering from the University of Michigan, Ann Arbor in 1982 and my Master of Science Degree in Mechanical Engineering from Oakland University in 1986.

7. I further am a licensed "Professional Engineer" in the state of Michigan.

8. As shown in my resume, most of my career has been in the field of automotive engineering that includes numerous positions in both the academia and industry settings.

9. After receiving my Master's degree, I began work at General Motors where I had several assignments involving automotive design, advanced engineering and manufacturing. Over the course of my years at General Motors, I was involved in all aspects of the vehicle design process, from advanced research and development to manufacturing.

10. Specifically, my work at General Motors included aspects of engine and fuel system design relating to the production of fuel sending units, and modeling the effects of fuels and EGR on vehicle performance and emissions.

11. After leaving General Motors, I returned to the University of Michigan where I was awarded a Ph.D. in Mechanical Engineering in 1991. My thesis was directed to automotive engineering including the design and

development of systems and models for understanding combustion in automotive engines.

12. Upon completion of my Ph.D., I joined the faculty of the U.S. Naval Academy where I led the automotive program in mechanical engineering. As part of my responsibilities while at the Academy, I managed the laboratories for Internal Combustion Engines and Power Systems.

13. I further taught automotive and mechanical engineering courses while at the U.S. Naval Academy. Some of the courses I taught were directed specifically to design and operation of internal combustion engines in both conventional and hybrid vehicles. I also taught courses pertaining to the design and operation of hybrid vehicles.

14. In addition to my work at the U.S. Naval Academy, I also served as faculty advisor for the USNA Society of Automotive Engineers (SAE). During this time I served as project director for the research and development of hybrid electric vehicles.

15. My work with regards to hybrid electric vehicles included extensive design and modifications of the powertrain, chassis, and body systems. This development work included the design, modifications and implementation of alternate fuel delivery and injection systems.

16. The hybrid electric vehicle work that I worked on at the U.S. Naval

Academy was published in a bound 1994 SAE special publication. (Ex. 1116 at 6-11.)

17. While at the Naval Academy, I also taught classes in mechanical engineering at Johns Hopkins University.

18. In 1995, I joined the faculty of Lawrence Technological University where I served as Director of the Master of Automotive Engineering Program and Associate Professor in the Mechanical Engineering Department.

19. The master's program in automotive engineering is a professionally oriented program aimed at attracting and educating practicing engineers in the automotive industry.

20. In addition to teaching and designing the curriculum for undergraduate and graduate students, I also worked in the automotive industry closely with Ford Motor Company on the development of a hybrid electric vehicle.

21. Specifically, I served as project director on a cooperative research project to develop and design all aspects of a hybrid electric vehicle. While in many instances we used standard Ford components, we custom designed many automotive subsystems. As part of this project, we completely redesigned and replaced the existing powertrain including the fuel storage, delivery and injection systems. We also did analytical and actual testing of the systems.

22. While at Lawrence Technological University, I also served as the

faculty advisor on several student based hybrid vehicle competitions that were sponsored primarily by Ford Motor Company, General Motor Company, and Chrysler Corporation.

23. These competitions required the complete design of hybrid vehicle, including the design of the power train. These competitions also required the complete design of the software and hardware required to control the hybrid vehicle.

24. Attached as Exhibits 1120 and 1121 are the competition papers that were submitted for the 1996 and 1997 competitions for which I served as the faculty advisor. (Ex. 1120 & Ex. 1121.)

25. During my time at Lawrence Technological University, I further served as advisor for 145 automotive graduate and undergraduate project students. Many of the graduate students whom I advised were employed as full time engineers in the automotive industry. This service required constant interaction with the students and their automotive companies which included the major automotive manufacturers (e.g., Ford, Chrysler, General Motors, Toyota, etc.) along with many automotive suppliers, including those that supply fuel delivery systems (e.g., Denso, Delphi and Bosch.)

26. Currently, I am employed as a Professor of Mechanical Engineering & Director of the Advanced Engine Research Laboratory (AERL) at Kettering

University—formerly known as “General Motors Institute.”

27. At Kettering University I develop curriculum and teach courses in mechanical and automotive engineering to both undergraduate and graduate students.

28. Since coming to Kettering, I have advised over 90 undergraduate and graduate theses in automotive engineering. Further, I actively pursue research and development activities within automotive engineering.

29. My work requires constant involvement with my students and their sponsoring automotive companies which have included not only those mentioned above, but also Walbro, Nissan, Borg Warner, FEV, Inc., U.S. Army Automotive Command, Denso, Honda, Dana, TRW, Tenneco, Navistar, and ArvinMeritor.

30. As is further shown by resume, I have published over 50 peer reviewed technical articles and presentations involving topics in automotive engineering.

31. Automotive and mechanical engineering topics covered in these articles include development of hybrid vehicles, mechanical design and analysis of components and systems, vehicle exterior design including aerodynamics, development of alternative fueled vehicles and fuel systems, thermal and fluid system design and analysis, selection and design of components and sub-systems for optimum system integration, and system calibration and control.

32. I have also chaired or co-chaired sessions in automotive engineering at many technical conferences including sessions involving powertrain development and control in automotive engineering.

33. Additionally, while acting as director of the AERL, I am responsible for numerous laboratories and undergraduate and graduate research projects, which include On-road and Off-road engine and chassis testing laboratories. Projects have included the design and development of fuel injection systems for off-road vehicles, fuel compatibility studies of vehicle storage and delivery systems, modification of fuel delivery systems to accommodate alternative fuels, and other extensive modifications and development of vehicular powertrains.

34. I also serve as faculty advisor to the Society of Automotive Engineers International (SAE) at the national level, on the local Student Branch and for the "SAE Clean Snowmobile Challenge." I have served as a director on the SAE Board of Directors, the Engineering Education Board, and the Publications Board.

35. Further, I have chaired the Engineering Education Board and several of the SAE Committees.

36. I also actively develop and teach Continuing Professional Development (CPD) courses both for SAE and directly for corporate automotive clients. These CPD courses are directed to automotive powertrain, exterior body systems, hybrid electric vehicle design, and include extensive engine performance,

emissions, and economy considerations. These courses are taught primarily to engineers who are employed in the automotive industry.

37. Finally, I am a member of the Advisory Board of the National Institute for Advanced Transportation Technology at the University of Idaho. In addition to advising, I also review funding proposals and project reports of the researchers funded by the center.

II. RELEVANT LEGAL STANDARDS

38. I have been asked to provide opinions on the claims of the ’347 Patent in light of the prior art.

39. It is my understanding that a claimed invention is unpatentable under 35 USC § 102 if a prior art reference teaches every element of the claim. Further, it is my understanding that a claimed invention is unpatentable under 35 U.S.C. § 103 if the differences between the invention and the prior art are such that the subject matter as a whole would have been obvious at the time the alleged invention was made to a person having ordinary skill in the art to which the subject matter pertains. I also understand that an obviousness analysis takes into factual inquiries including the level of ordinary skill in the art, the scope and content of the prior art, and the differences between the prior art and the claimed subject matter.

40. It is my understanding that the Supreme Court has recognized several rationales for combining references or modifying a reference to show obviousness

of the claimed subject matter. Some of these rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to obtain predictable results; a predictable use of prior art elements according to their established functions; applying a known technique to a known device to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

III. QUALIFICATIONS OF ONE OF ORDINARY SKILL IN THE ART

41. I have reviewed the ’347 Patent, those patents cited in the ’347 Patent as well as the prior art documents. Based on this review and my knowledge of hybrid electric vehicles, including my work on multiple hybrid vehicles during the course of the 1990’s, it is my opinion that a person of ordinary skill in the art would have either: (1) a graduate degree in mechanical, electrical or automotive engineering with at least some experience in the design and control of combustion engines, electric or hybrid electric vehicle propulsion systems, or design and control of automotive transmissions, or (2) a bachelor's degree in mechanical, electrical or automotive engineering and at least five years of experience in the

design of combustion engines, electric vehicle propulsion systems, or automotive transmissions.

42. I understand that this determination is made at the time of the invention, which I understand that the patentee purports as being the September 14, 1998 filing of U.S. Provisional Application No. 60/100,095 ("the '095 Provisional," Ex. 1136). As I also discussed in my "Qualifications and Professional Experience" (¶¶5-37) above, I am familiar with the level of knowledge and the abilities of a person having ordinary skill in the art at the time of the claimed invention based on my experience in the industry (both as an employee and as a professor).

IV. STATE OF THE ART

43. Hybrid-Electric Vehicles (hybrid vehicle) were conceived over 100 years ago in an attempt to combine the power capabilities of electric motors and internal combustion engines[1] (ICE) to satisfy all the driver demand required to propel a vehicle. (Ex. 1122 at 11).

44. I am aware that one of the first functioning hybrid vehicles was designed and built by Justus Entz in May 1897. (Ex. 1122 at 11-13).

45. I am also aware that hybrid vehicle patents extend as far back as 1909

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[1] An engine could also be referred to as a "heat engine" and is commonly known to be a part of the overall "Auxiliary Power Unit" of a hybrid vehicle (i.e., "APU").

for U.S. Patent No. 913,846 to Pieper that was granted for a "Mixed Drive Auto Vehicle."

46. I am aware that the hybrid vehicle disclosed by the Pieper patent was likewise assembled as a functioning hybrid vehicle that was publically used. (Ex. 1122 at 13-14).

47. I am also aware of well-known hybrid vehicles that were built and publically used by Baker and Woods in 1917. (Ex. 1122 at 21-23).

48. While these early hybrid vehicles did not include the complex microprocessor based control strategies found in present-day hybrid vehicles, it has always been known that one goal of hybrid vehicles is the possibility of operating the engine at its "optimum efficiency."

> From almost the beginning of the Automotive Age, various combinations of drive systems have been tried in order to achieve vehicle performance characteristics superior to those that can be obtained using a single type of drive. **These efforts have been made in the name of many worthwhile goals such as increased vehicle acceleration capability, audible noise reduction, operation of an engine or turbine at optimum efficiency, reduction of noxious emissions, and improved fuel economy**.

(Ex. 1123 at 1; emphasis added).

49. It was not until events in the 1970's, however, that a renewed interest in hybrid vehicles emerged as a means to combat the U.S. dependency on oil and

to meet increased air pollution reduction goals. (*See e.g.*, Ex. 1124 at 3; Ex. 1125 at 3).

50. For instance, in 1976 the U.S. government enacted Public Law 94-413 pertaining to the "Electric and Hybrid Vehicle Research, Development, and Demonstration Act" that was to "encourage and support accelerated research into, and development of electric and hybrid vehicle technologies." (Ex. 1026 at 4).

51. As a result of this law, multiple fully functional hybrid and electric vehicles were developed by automotive corporations. (Ex. 1026 at 4).

52. I am specifically aware that Ford Motor Company and Toyota Motor Company invested considerable time and money into developing both hybrid and electric vehicles. (*See e.g.,* Ex. 1123 at 1; Ex. 1127 at 4).

53. Further collegiate competitions intensified during the 1990's starting with the 1993-1995 Ford Hybrid Electric Vehicle Challenge. The 1993 Ford Hybrid Electric Vehicle Challenge is attached as Exhibit 1116. By 1994 these competitions had grown to include teams from over 38 universities representing more than 800 students. (Ex. 1126 at 10).

54. As I mentioned in my "Qualifications and Professional" section above, I was personally involved with the U.S. Naval Academy's hybrid vehicle design that was entered in the 1993 "Ford Hybrid Vehicle" competition. (Ex. 1119 at 6).

55. I was also personally involved with Lawrence Technological University's hybrid vehicle design that was entered in the 1996 and 1997 "Future Car" hybrid vehicle competitions. (Ex. 1120 at 6; Ex. 1121 at 9).

56. Based upon the level of research and development prior to 1998, numerous hybrid vehicle "architectures" were well-known. (*See e.g.*, Ex. 1128 at 4 & 7-8). As I explain in detail below, known hybrid vehicle "architectures" included what was commonly referred to as: (1) "series" hybrid vehicles (¶¶61-69 below); and (2) "parallel" hybrid vehicles (¶¶70-72 below). As I further explain in detail below, "parallel" hybrid vehicle architectures were further known to include: (1) one motor "parallel" hybrid vehicle architectures (¶¶73-86 below); and (3) two motor "parallel" hybrid vehicle architectures (¶¶87-107 below).

57. As I explain further below, these varying hybrid vehicle architectures differed in how the powertrain (i.e., the engines and motors) was arranged and connected to the wheels. The various architectures were done in order to achieve many of the goals I mentioned above in paragraph 48, including operating the engine at its peak efficiency. (*See e.g.*, Ex. 1123 at 1; Ex. 1128 at 4 & 7).

58. Due to the rapid advancement of computers starting in the 1970's, each of these hybrid vehicles included microprocessor based control strategies for properly controlling the engine, motor(s), transmission, and/ clutching mechanisms used. (*See e.g.,* Ex. 1127 at 4).

59. While the control strategies varied based on the architecture being employed, the primary goal still focused on operating the engine within its "sweet spot" or "optimum efficiency range." (*See e.g.,* Ex. 1123 at 1; Ex. 1127 at 4).

60. Such efficient engine control strategies were desired so as to meet the Federal government's reduced air pollution goals of 1976 and to meet California's "Low Emissions Vehicle" regulation that was enacted in 1990. (Ex. 1125 at 3).

A. "Series" Hybrid Vehicle

61. A person of ordinary skill in the art knew well-prior to September 1998 of the design and operational advantages of "series" hybrid vehicle architectures. (Ex. 1124 at 6-7; Ex. 1128 at 7).

62. In fact, by 1979 it was well-known that "series" hybrid vehicles could be designed in various arrangements that could include one or more electric motors.[2] (Ex. 1129 at 17).

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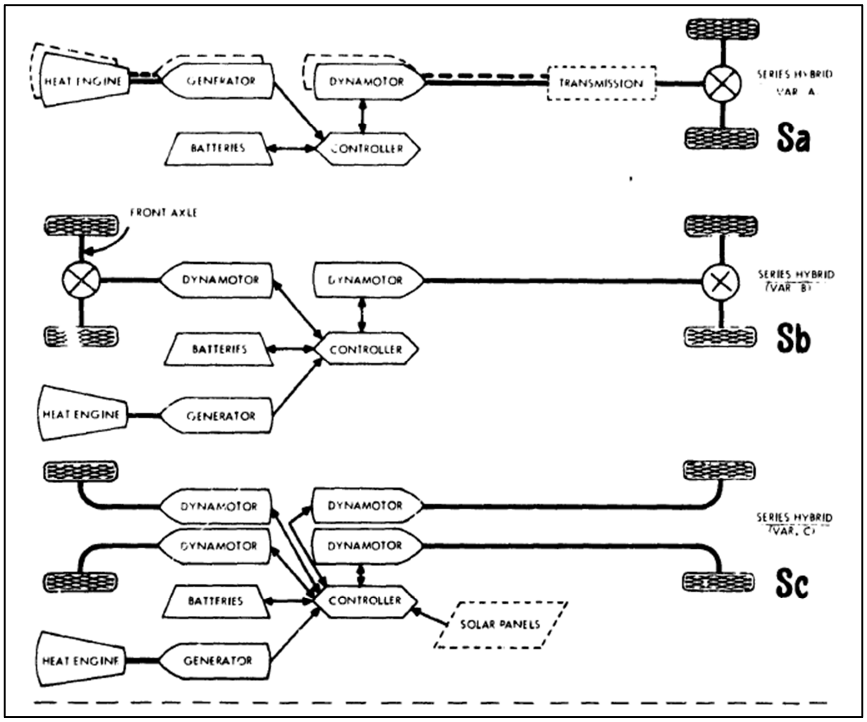
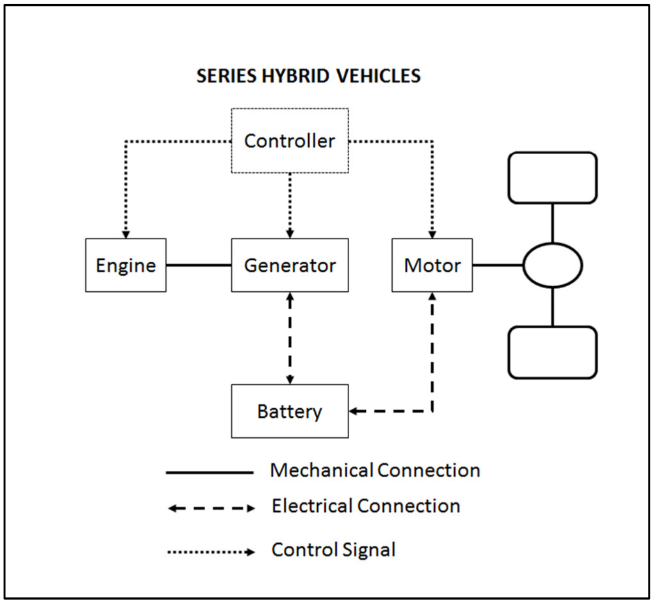
[2] The term "dynamotor" was commonly used to describe an electric motor that was capable of operating both as (1) a motor for propulsion; and (2) as a generator that converts mechanical torque into electrical energy that is stored in the battery.



(Ex. 1129 at 17-Fig. 7)

63. Although multiple configurations were known, I have provided the following exemplary figure to explain the general architecture and operation of a "series" hybrid vehicle.



64. As I illustrated, the motor is always connected to the road wheels. (*see also* Ex. 1124 at 6; Ex. 1128 at 7-8).

65. In other words, the **motor alone** provides the torque required to propel the vehicle. (Ex. 1124 at 6; Ex. 1128 at 15).

66. The engine, on the other hand, is **not mechanically connected** to the wheels and the engine is therefore controlled independently of driving conditions. (Ex. 1124 at 6; Ex. 1128 at 7).

67. In other words, the engine does not provide any of the torque required to propel the vehicle; rather, the engine powers the generator to produce electrical energy that is stored in the battery and/or used by the motor.

68. The primary reason for the engine in a "series" hybrid vehicle was to overcome the limited driving range associated with "pure" electric vehicles. By including an engine, drivers were able to "fill up" at gas-stations that are common throughout the United States. Without the engine, drivers would have needed to find an electrical source to recharge the battery. Not only were electrical sources less common than gas stations, it could also require hours to fully charge the battery.

69. Because the engine is controlled independently of the torque requirements of the vehicle, it was well known that the engine would be designed to operate at its optimum efficiency and low emission ranges during the majority of

operation. However, during conditions of low battery state of charge, the engine could be operated above its "sweet spot." Such efficient operation was performed for the sole purposes of operating the generator illustrated by the figure in paragraph 63. (Ex. 1124 at 6-7; Ex. 1128 at 7).

B. "Parallel" Hybrid Vehicle

70. A person of ordinary skill in the art was also aware that prior to September 1998 "parallel" hybrid vehicle architectures existed. (Ex. 1124 at 7-8; Ex. 1128 at 7-8).

71. Again, by 1979 it was well-known that "parallel" hybrid vehicles could be designed in various arrangements that could include one or more electric motors.[3] (Ex. 1129 at 18).

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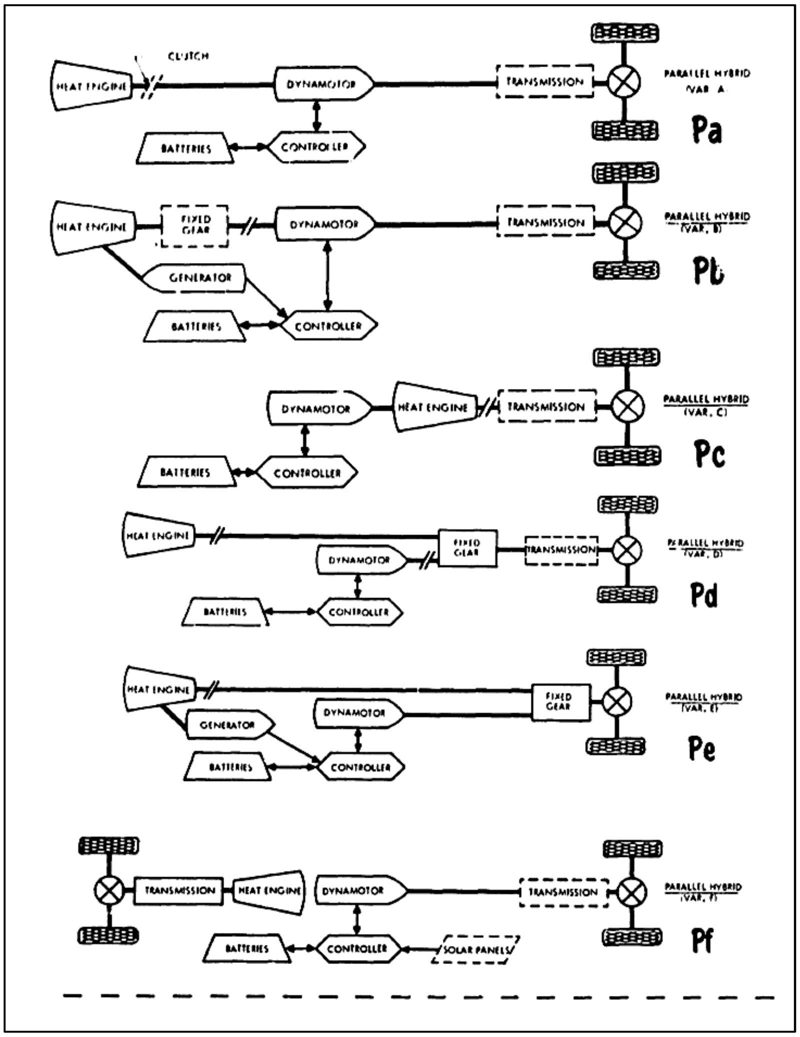
[3] The term "dynamotor" was commonly used to describe an electric motor that was capable of operating both as (1) a motor for propulsion; and (2) as a generator that converts mechanical torque into electrical energy that is stored in the battery.



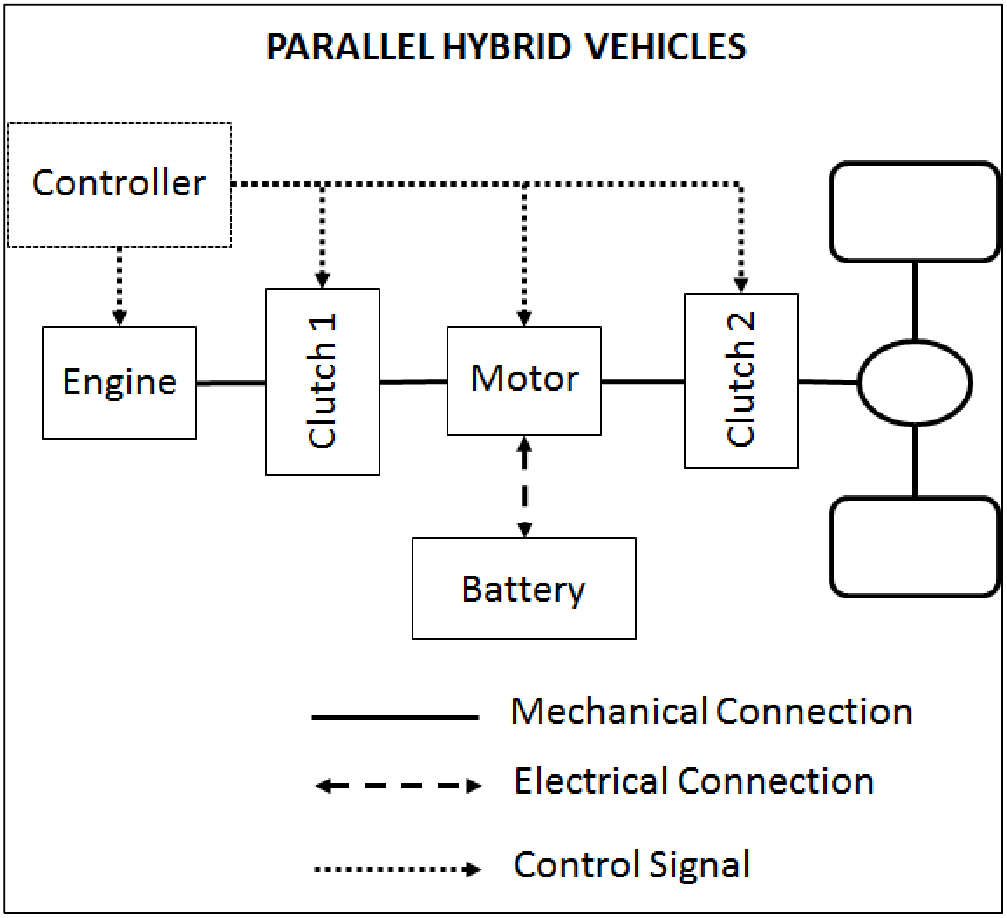
(Ex. 1129 at 18-Fig.7 (cont))

72. As illustrated above, there existed three generally known "parallel" hybrid vehicle architectures. The first architecture was a one-motor "parallel" hybrid vehicle as illustrated by "Pa," "Pc," and "Pd." The second architecture is a two-motor "parallel" hybrid vehicle as illustrated by "Pb" and "Pe." (Ex. 1129 at

18).[4]

a. One-Motor "Parallel" Hybrid Vehicle

73. Although multiple various configurations existed, I have provided the following exemplary figure in order to assist in explaining the general architecture and operation of a one-motor "parallel" hybrid vehicle.



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[4] The third type of "parallel" hybrid vehicle illustrated was an all-wheel drive platform that used a motor and engine to power both the front and rear wheels as shown by "Pf."

74. As I illustrated, “parallel” hybrid vehicles typically included one or more “clutches” that were controlled by a microprocessor (i.e., controller).[5] These clutches selectively enabled either or both the engine and motor to provide drive torque to the wheels of the vehicle.

75. Generally, “parallel” hybrid vehicles were known to include a single traction motor that could be operated to provide torque required to propel the vehicle as explained, for example, by the following 1992 SAE paper.

> The parallel hybrid (Figure 5) [is one] in which both the electric motor and the engine provide torque to the wheels either separately or together and the motor can be used as a generator to recharge the batteries when the engine can produce more power than is needed to propel the vehicle… (Ex. 1124 at 5).

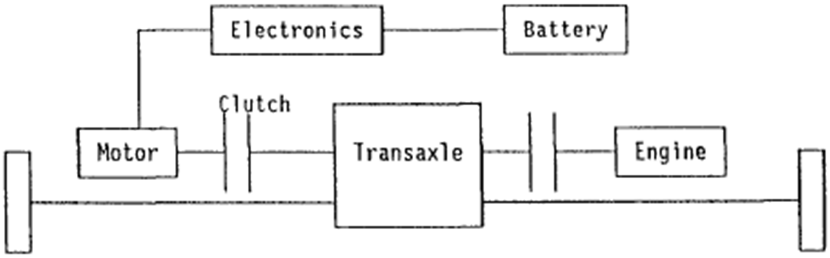

Figure 5. Parallel hybrid driveline schematics. (Ex. 1124 at 25-Fig. 5)

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[5] It was also known that a transmission and/or fixed gear ratio could be used between the motors or engine and the wheels.

76. With reference back to my exemplary figure illustrated in paragraph 73, “parallel” hybrid vehicles engage the motor and/or engine by operating one or more clutches. For example, the controller could engage “clutch 1” which would connect the engine to the road wheels.

77. Alternatively, the controller could engage “clutch 2” which would connect the motor to the road wheels. Both “clutch 1” and “clutch 2” could be engaged in order to connect both the motor and engine to the road wheels.

78. In another configuration of a “parallel” hybrid vehicle, either “clutch 1” or “clutch 2” could be removed from the system so that its respective power source (i.e., the engine or motor) became the “prime mover” that is connected to the wheels at all times, with the additional power source being selectively connected/disconnected to the road wheels using a clutch.

79. For instance, the motor could be directly coupled to the wheels with the engine being selectively connected/disconnected to the wheels using a clutch.

80. It was also known prior to September 1998 that the engine in a “parallel” hybrid vehicle could be downsized and controlled to run only at speed and load conditions where engine operation was most efficient (e.g., steady state or highway cruising).

81. It was also known that the traction motor would be used to provide the extra power required for vehicle acceleration so that the engine could be restricted

solely to its most efficient operating region (i.e., low or minimum specific fuel consumption region).

82. The typical operation of a one-motor "parallel" hybrid vehicle is confirmed by the following 1976 SAE article.

> The engine used in the [parallel] hybrid is operated in regions of minimum specific fuel consumption during a much greater portion of its operating time than in conventional drives. The engine is sized more for steady-state (constant speed) driving conditions than for vehicle acceleration requirements. The electrical system serves a function somewhat analogous to that of an infinitely variable transmission and also adds power during vehicle acceleration and stereo power during braking.

(Ex. 1123 at 17).

83. In other words, by September 1998 it was known that "parallel" hybrid vehicles could be controlled like a conventional vehicle except the engine would operate "much less frequently at low power, because the electric driveline will provide the power at low vehicle speeds and light loads." (Ex. 1124 at 7-8)

84. It was further known by September 1998 that efficient engine operation was typically accomplished using multiple "operating modes" in a control strategy. For instance, a well-known and commonly-cited SAE publication from 1976 discloses a then-novel control strategy for a "parallel" hybrid vehicle that accounted for the overall efficiency with respect to the torque required to

propel the vehicle. (Ex. 1123 at 3-4). This 1976 control strategy disclosed a five-mode operating strategy, as shown below, that was used to improve the efficiency and fuel economy over a conventional vehicle.

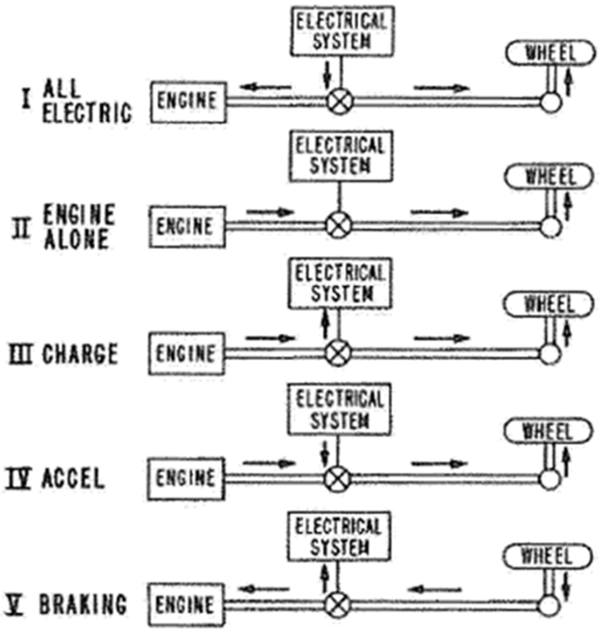


Fig.2 -Five hybrid modes of operation

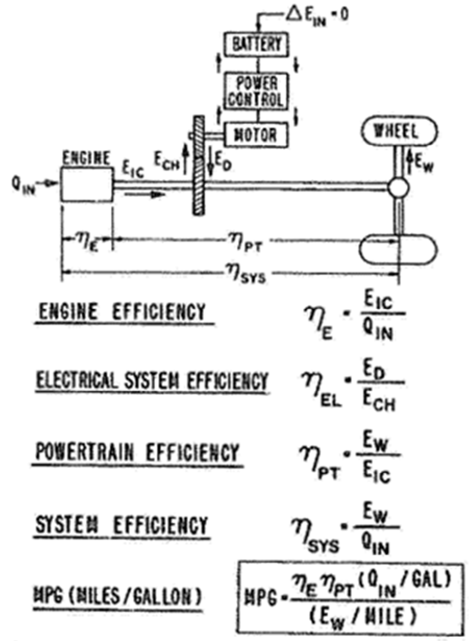


Fig.4 -Average fuel economy for a hybrid vehicle in terms of system efficiencies and energies

(Ex. 1123 at 3-4, Fig. 2 & 4)

85. This disclosure confirms that the control strategy increased the fuel economy over conventional vehicles by only operating the engine in regions of "minimum specific fuel consumption during a much greater portion of its operating time." (Ex. 1123 at 17). In other words, the engine operated at "higher load factors" which provides "increased efficiencies." (Ex. 1123 at 4).

86. It was also known prior to September 1998 that a typical control strategy for a "parallel" hybrid vehicle would operate the motor alone at low loads

and speeds where engine operation was inefficient. (Ex. 1123 at 17).

b. Two-Motor "Parallel" Hybrid Vehicle

87. As was illustrated in paragraph 72 above, two-motor "parallel" hybrid vehicles were also well known in the art. (Ex. 1129 at 18; Ex. 1128 at 8).

88. In fact, I have provided below an illustration from a 1971 Department of Energy report that describes a well-known two motor "parallel" hybrid vehicle configuration. (Ex. 1130 at 20).

(Ex. 1130 at 20-Fig. 10-7)

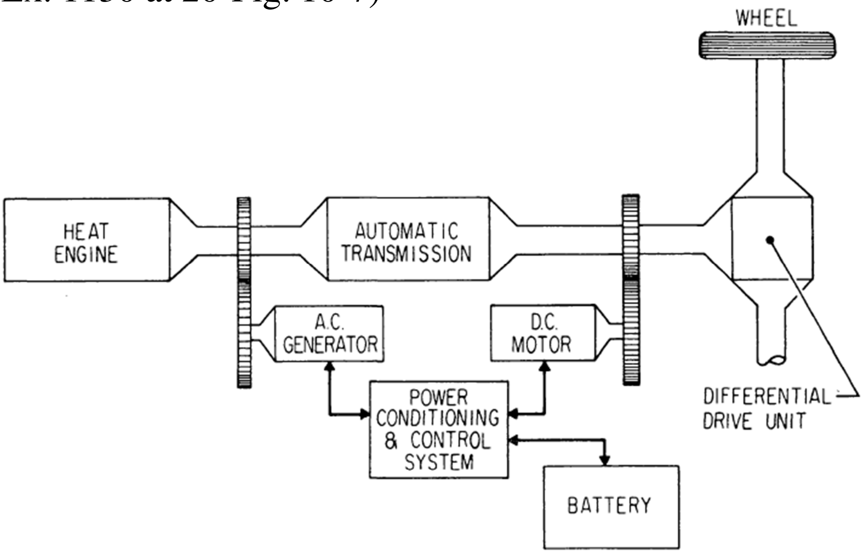


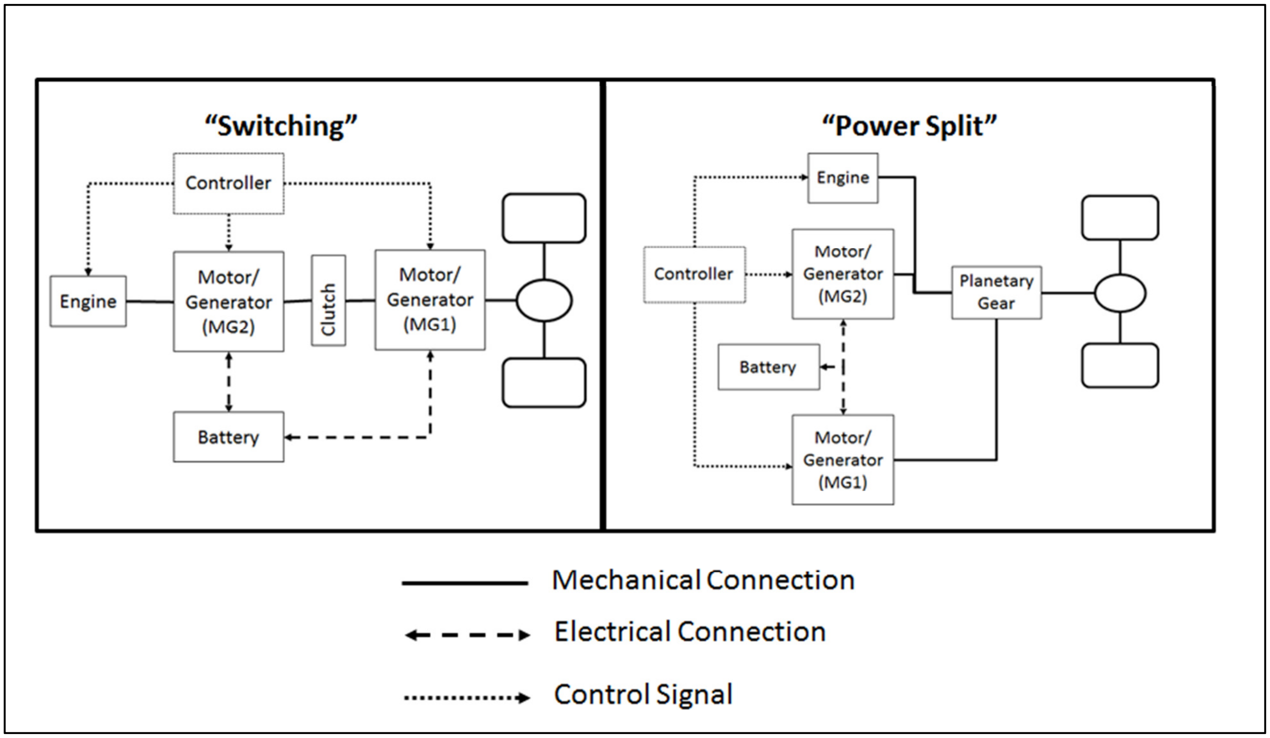
Figure 10- 7. Selected Baseline Parallel Configuration Concept

89. One known advantage of two-motor "parallel" hybrid vehicle architecture illustrated above is that the "generator can supply power to the batteries when heat engine power is in excess of wheel demand." (Ex. 1130 at 19).

90. In other words, it was known that a second motor could be operated as

a generator to charge the battery when the engine torque required to propel the vehicle is greater than the actual torque needed to propel the vehicle.

91. Although multiple flavors of architectures existed, I have provided the following exemplary figures in order to explain the architecture and operation of the more common two-motor "parallel" hybrid vehicles that were known in the art prior to September 1998.[6] (*see also* Ex. 1128 at 8).



92. The significant change between a one-motor and two-motor "parallel"

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[6] By the mid-1990's two-motor "parallel" hybrid vehicles had begun to be referred to as "series-parallel" hybrid vehicles. (Ex. 1128 at 8).

hybrid vehicle is the inclusion of a second motor/generator (illustrated as MG2).[7]

(1) “Switching” Two-Motor “Parallel” Hybrid Vehicles

93. As illustrated in paragraph 91 above, the two-motor “parallel” hybrid vehicle on the left has been classified as a “switching” system because it incorporated a clutch mechanism to selectively connect/disconnect the engine and MG2 to the road wheels.

94. As illustrated in paragraph 91 above, the two-motor “parallel” hybrid vehicle on the right has been classified as a “power split” system because it incorporated a planetary gear mechanism.

95. It was also known prior to September 1998 that the second “motor/generator” (i.e., MG2) could operate as: (1) a starter motor, (2) a secondary motor for propulsion, or (3) a generator. (Ex. 1128 at 11).

96. For “switching” two-motor systems it was known that a “clutch” was commonly included to controllably connect and/or disconnect the engine from the road wheels while the traction motor was generally coupled directly to the road wheels. (Ex. 1128 at 8).

97. It was also known that the engine would be decoupled during

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[7] While the prior art sometimes referenced MG2 simply as a “generator” it was known that these generators could operate as both a motor and generator.

operation in urban (city) driving where the load or torque required to propel the vehicle was low. (Ex. 1128 at 8).

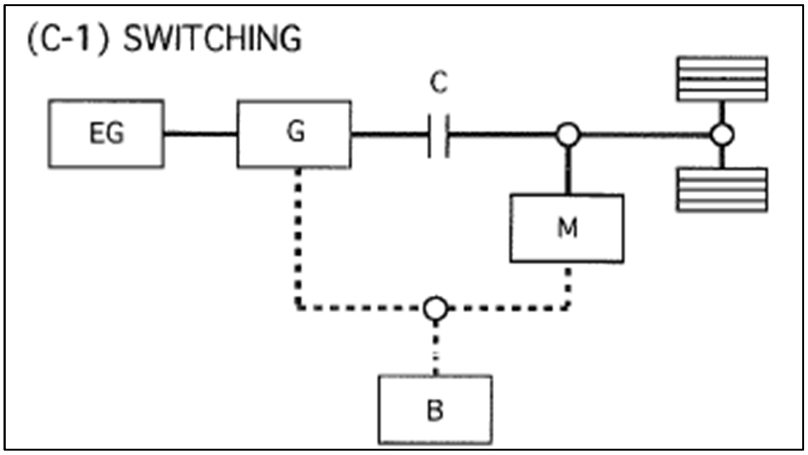
98. With the engine decoupled from the road wheels, the "switching" system could operate like a "series" hybrid vehicle with the engine powering the generator to recharge the battery when needed. (Ex. 1128 at 8).

99. At higher loads, the engine could be reconnected to the road wheels and the "switching" system could use the engine and motor to provide the torque required to propel the vehicle. (Ex. 1128 at 8).

100. For instance, a 1996 SAE publication discloses the following known benefits of a switching "parallel" hybrid vehicle.

> (C- 1) SWITCHING SYSTEM - Application and release of the clutch switches between the series and parallel systems. For driving as by the series system, the clutch is released, separating the engine and the generator from the driving wheels. For driving with the parallel system, the clutch is engaged, connecting the engine with the driving wheels.
>
> For example, since city driving requires low loads for driving and low emissions, the series system is selected with the clutch released. For high speed driving where the series system would not work efficiently due to higher drive loads and consequently higher engine output is required, the parallel system is selected with the clutch applied.

(Ex. 1128 at 8).



(Ex. 1128 at 8-Fig. 1)

101. The known advantage of such operation was that the engine operates inefficiently at low loads. By using the motor to propel the vehicle at low loads the engine would therefore not be operated where it is inefficient. However, at higher loads where engine operation is efficient, the engine could be reconnected to the drive wheels to propel the vehicle.

102. Also, as stated by the 1996 SAE publication, at low loads where the engine is not mechanically connected to the road wheels, the engine is used at its optimum efficiency and low emission region to power the generator to charge the battery. (Ex. 1128 at 8).

103. Such known advantages were not available with a one-motor "parallel" hybrid vehicle.

(2) “Power-Split” Two-Motor “Parallel” Hybrid Vehicles

104. “Power split” systems on the other hand, were known prior to September 1998 of being capable of operating as both a “series” ***and*** “parallel” hybrid at all times. (Ex. 1128 at 8).

105. It was also known prior to September 1998 that “power split” systems typically used a planetary gear mechanism to connect the motors and engine. (Ex. 1128 at 8).

106. “Power split” hybrids have also been known to have been developed as far back as the 1970 system developed by TRW and to have been commercially made available around 1997 by Toyota. (Ex. 1138 at 2).

107. Specifically, it is known that in 1997 Toyota commercially released the Prius “power split series-parallel” hybrid vehicle with a control strategy that determined operating modes based on the speed and load (i.e., required driving torque) of the vehicle. (Ex. 1138 at 2).

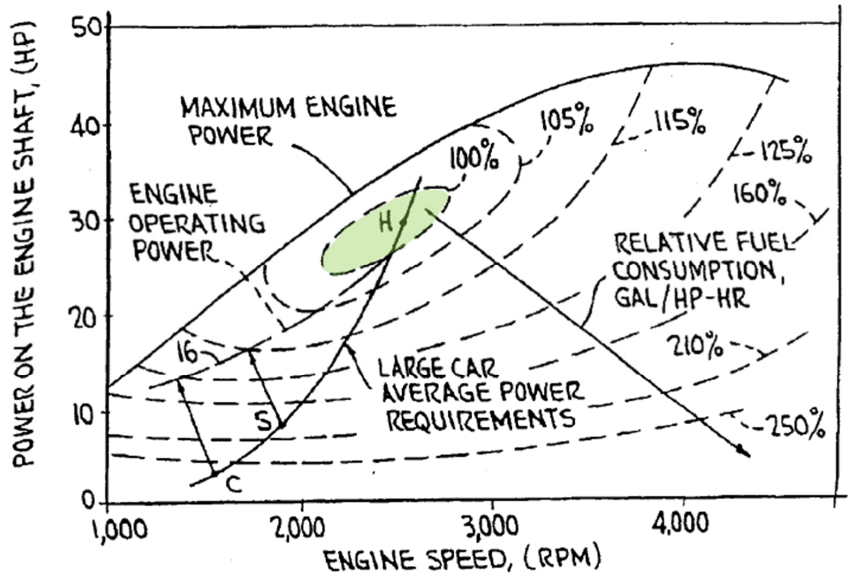
C. Hybrid Vehicle “Control Strategies”

108. It was known prior to September 1998 that engines generally operate inefficiently and have high specific fuel consumption at the low torque levels that are normally encountered at low vehicle speeds.

109. For instance, Figure 2 of the ’347 Patent illustrates that the minimum operating range of the engine does not start until 1,000 RPM. Although this figure

is not discussed in the text of the ’347 Patent, the parent ’672 Patent does describe this figure. In particular, the ’672 Patent states that “Point H” which I have highlighted in green is “the most efficient region of operation of the engine” (i.e., the engine’s “sweet spot”). (Ex. 1136 at 17:16-19, Figure 2).

FIG. 2



(Ex. 1036, Fig. 2, annotated)

110. Such knowledge was also commonly known in other prior art references. For example, a September 1988 publication illustrates an engine map showing efficiency curves for a typical gasoline engine. As shown below with annotations, the optimum engine efficiency, or “sweet spot” (highlighted in green) is the desired range of conditions in which the engine would provide torque required to propel the vehicle or charge the battery. (Ex. 1131, Figure 1)

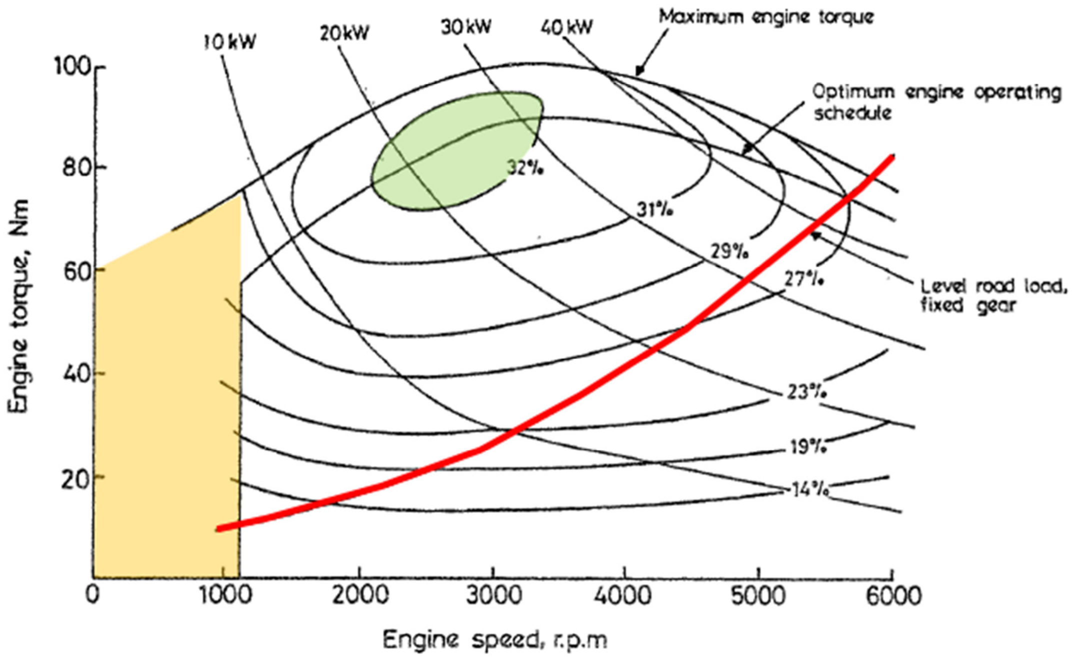


Fig 1 Road-load and engine-operating curves for an ic engine vehicle

(Ex. 1131 at 3-Fig. 1, annotated)

111. With reference to the above figure, the 1988 reference states:

Fig 1 shows a typical efficiency map for a 50 kW ic engine. Also shown on this diagram is a line corresponding to the road load seen by the engine when operating in a fixed gear. It is only at high loads that the engine operates at all efficiently. At low the operating point is well removed from the high-efficiency (low specific fuel-consumption) area. At a road load of 10 kW, the engine operates at about 3000 rev/min and is relatively inefficient. By reducing engine speed relative to the vehicle speed, through a suitable change in gear ratio, the engine operating point can be moved up, along the constant power line, towards the high-efficiency region. As the operating point moves up this constant power line it would, ultimately, reach the optimum

> engine operating line, the locus of which links the maximum engine efficiency points at each speed. (Ex. 1131 at 2).

112. It was known—as illustrated above—that engines cannot operate at low engine speeds. This is shown by the region shaded in orange above. The exemplary 50 kW discussed in this reference shows that the engine could not produce torque below an engine speed of 1000 rpm. While the speed range can vary between different engines, all engines have a minimum threshold engine speed below which the engine cannot produce torque.

113. Also shown in this figure, the line highlighted in red corresponds to "road load" at a fixed gear. It was well-known prior to September 1998 that the textbook definition of "road load" ($\mathbf{F_{RL}}$) is the sum of three external forces that act on the vehicle. These external forces are commonly referred to as the "aerodynamic drag" force (i.e., wind resistance), "rolling resistance" force, and "grade resistance" force. (Ex. 1137 at 9).

114. The "road load" definition disclosed in my textbook was also the definition that was well-known prior to September 1998. For example, a February 1997 IEEE publication confirms the definition in my textbook that "road load (F_w) consists of rolling resistance (f_{ro}), aerodynamic drag (f_l), and climbing resistance (f_{st})." (Ex. 1132 at 2; Ex. 1133 at 2).

115. Another well-known textbook used by a person of ordinary skill in the

art prior to September 1998 is the "Bosch Automotive Handbook" (4th Edition, 1996). This textbook likewise confirms that the textbook definition of "road load" forces are equal to the sum total of the "rolling resistance" force (F_{Ro}), the "aerodynamic drag" force (F_L), and the "climbing resistance" force (F_{ST}).

$$F_W = F_{Ro} + F_L + F_{ST}$$

(Ex. 1134 at 15-18).

116. Such knowledge is necessary because automotive engineers must design a powertrain that is capable of providing sufficient "tractive effort" force at the wheels to overcome these "road load" forces. For instance, as further discussed in my textbook, "tractive effort" ($\mathbf{F_{TE}}$) is the force (or torque)[8] required by the powertrain to propel the vehicle. This "tractive effort" force is almost always in response to an operator command, such as operation of the accelerator pedal, brake pedal or cruise control setting.

117. During vehicle operation, the tractive effort ($\mathbf{F_{TE}}$) is generally used to overcome the road load forces ($\mathbf{F_{RL}}$).

118. It was also known that if the tractive effort of the vehicle is greater than the road load forces ($\mathbf{F_{TE} > F_{RL}}$), the vehicle is able to accelerate. Alternatively, if the tractive effort of the vehicle is less than the road load forces

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[8] A person of ordinary skill in the art understands that Tractive Force = Torque /Radius of Tire (Ex. 1034 at 6-7).

($\mathbf{F_{TE}} < \mathbf{F_{RL}}$), the vehicle decelerates or does not move at all. It was further known that if the tractive effort is exactly equal to the road load forces ($\mathbf{F_{TE}} = \mathbf{F_{RL}}$) the vehicle will travel at a constant speed

119. It was known prior to September 1998 that when a vehicle is travelling up a hill or when the driver requests an increased demand for acceleration, road load forces may become positive. For example, when a vehicle is climbing a hill, a large amount of "tractive effort" ($\mathbf{F_{TE}}$) may be required to overcome the large "road load" ($\mathbf{F_{RL}}$) forces due to the hill gradient effect. As a result the vehicle would begin to decelerate as the vehicle climbs the hill unless the driver demands a different amount of "tractive effort" from the powertrain. If the driver does not change the requested "tractive effort", the vehicle may begin to slow down as it ascends the hill. Alternatively, if the driver further presses down the accelerator pedal, the "tractive effort" force may become greater than the "road load" force that increased due to the hill gradient effect. As stated above, if the "tractive effort" equals the "road load" force the vehicle will continue to travel at the same constant speed and no further deceleration is experienced. If the tractive effort of the vehicle is greater than the road load forces ($\mathbf{F_{TE}} > \mathbf{F_{RL}}$), the vehicle is able to accelerate up the hill.

120. Lastly, it was known prior to September 1998 that when a vehicle is travelling down a hill, road load forces may become negative. For example, when a

vehicle is climbing a hill, a large amount of "tractive effort" ($\mathbf{F_{TE}}$) may be required to overcome the large "road load" ($\mathbf{F_{RL}}$) forces due to the hill gradient effect. However, when the vehicle travels back down the hill, the previous provided uphill tractive effort would likely be much greater than the downhill road load forces. Additionally, if the hill is steep, the road load forces can act to accelerate the vehicle, even when the tractive effort is zero. As a result the vehicle would begin to accelerate down the hill unless the driver demand changes (i.e. if the driver applies the brake pedal).

121. Referring to figure below (which is the same figure shown in above in paragraph 110, with additional annotations), the line highlighted in red is the road load curve for the exemplary 50 kW engine operated in a fixed gear. At 10 kW of road load, as circled in blue, the engine is required to operate at roughly 3000 rpm, far removed from the efficient operating range that is highlighted in green. In other words, the engine would operate inefficiently at this point.

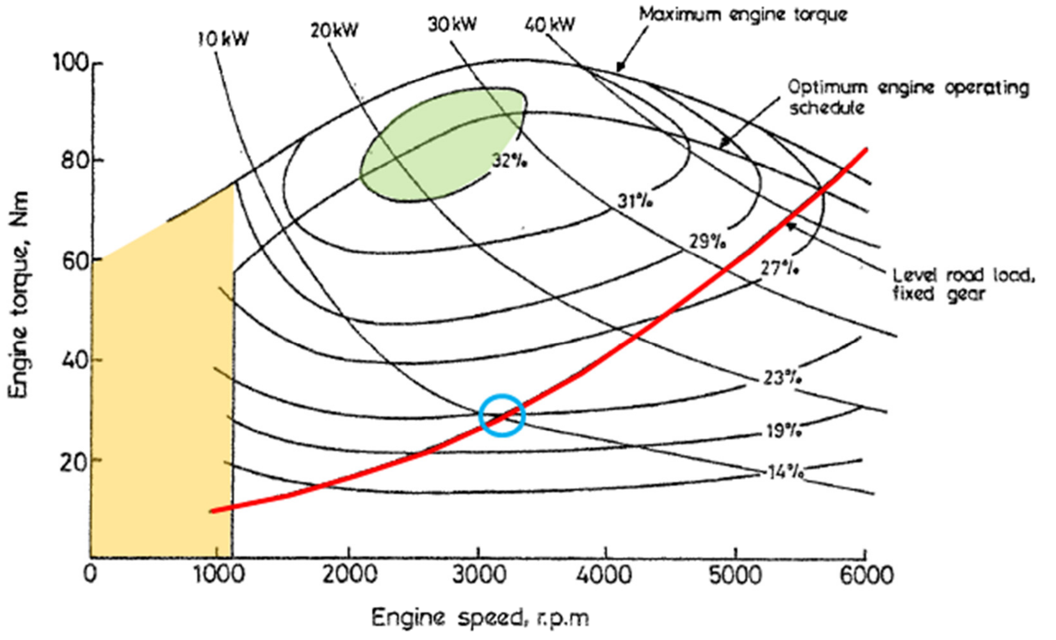


Fig 1 Road-load and engine-operating curves for an ic engine vehicle

(Ex. 1131 at 3-Fig. 1, annotated)

122. In order to operate the engine more efficiently, a conventional non-hybrid vehicle would control a transmission. As further circled in blue (below), the exemplary engine has used a transmission to shift engine operation along the 10kW constant power curve so that the engine operates more efficiently. However, changing gears in a conventional vehicle still does not shift the engine operation to the optimal range as highlighted in green.

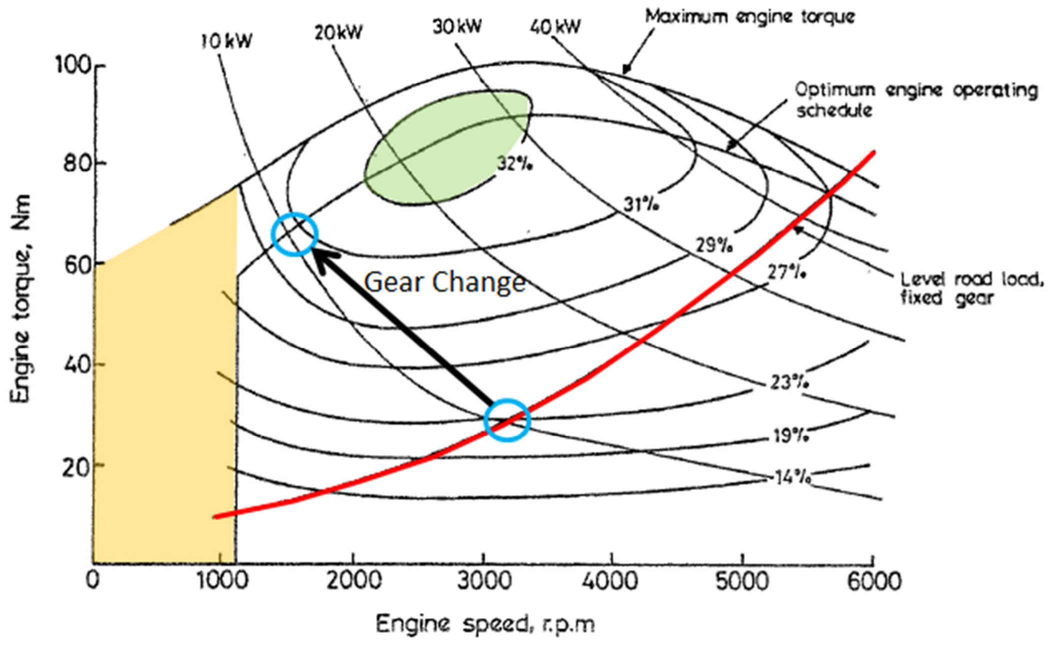


Fig 1 Road-load and engine-operating curves for an ic engine vehicle

(Ex. 1131 at 3-Fig. 1, annotated)

123. It should also be noted that either of the circles around the 10 kW of power equates to the tractive effort required to propel the vehicle in order to overcome the road load forces. However, the first operating point before the gear shift points (blue circle to right) is at a lower engine efficiency. Therefore, the transmission is used to shift gears such that the amount of tractive effort required to maintain vehicle speed is at a more efficient engine operating point which is closer to the engine's "sweet spot."

124. To further improve efficient usage of the engine, hybrid vehicles include a motor which provides an additional power source for propelling the vehicle. The addition of a motor requires a control strategy for determining when

to operate the engine, motor, or both in combination to propel the vehicle.

125. It was well known prior to September 1998 that an advantage of hybrid vehicles having a motor was to be able to control the motor to propel the vehicle at low speeds and loads so that the engine can be reserved or limited to operation in its "sweet spot."

126. Again, this known concept is noted by the '672 Patent which states that an engine "sized appropriately for highway cruising [has] substantial inefficiencies [] at lower speeds." (Ex. 1136 at 17:25-27).

127. Other prior art references again confirmed this well-known understanding of engines. For example, a 1992 SAE paper described hybrid design options and evaluations states:

> The operation of the engine in the parallel hybrid is much like that in a conventional ICE vehicle except that it will operate much less frequently at low power, because the electric driveline will provide the power at low vehicle speeds and light loads.

(Ex. 1124 at 7-8).

128. Hybrid vehicles sought to overcome such inefficient engine operation. As explained in Section IV. B. above, for hybrid vehicles, the control strategy of utilizing the engine and motor was typically accomplished using a variety of modes that included: 1) an "electric" or "motor-only" mode where the motor propels the vehicle when engine operation is inefficient (i.e., at low loads or

vehicle speeds); (2) an "engine-only" mode where the engine propels the vehicle when engine operation is efficient (i.e., higher loads or vehicle speeds); (3) a charging mode where the motor acts as a generator to provide electrical energy to recharge the battery; and (4) a "combined" or "acceleration" mode where the engine and motor are used to propel the vehicle when the demand is beyond the maximum torque capabilities of the engine. (*see e.g.*, Ex. 1123 at 3).

129. A 1995 SAE article also confirmed that one advantage of a hybrid vehicle has the ability to limit operation of the engine to its "sweet spot" or "optimum efficiency range" while still meeting the load required to propel the vehicle.

> The maximum power output of the [engine] will affect strategy design choices in a similar manner to the capacity of the battery. With a high power capability, one may design the strategy to operate more or less like a conventional car engine in a power following mode, whereas a low power capability will force the strategy to run the engine at its highest power level so that it can keep up with current demands and store extra energy for periods of high demand.

***

> The fuel efficiency of an [engine] generally varies as a function of the power level. The specific fuel consumption (SFC) of an engine is typically best at middle power levels and worst at the low and high power extremes. The [engine] operating strategy that will maximize fuel efficiency is one that runs the [engine] primarily in the range of

> powers over which the SFC is best (often termed the engine's "sweet spot").

(Ex. 1135 at 11).

130. In another example, the 1976 SAE paper emphasizes a few of the advantages of a hybrid vehicle for controlling efficient engine operation:

> It is important to understand the reasons why the average engine efficiency is improved with the hybrid configuration. The key point is that the hybrid engine is operated at more efficient operating points. This results in an improved overall engine efficiency when averaged over the drive cycle. This improvement has two sources. The first is the elimination of all fuel consumed at idle, during braking and during the low speed all-electric mode. The equivalent driving modes for the conventional [vehicle] account for 25% to 30% of the fuel consumed []. The second source of improvement is the higher load factors and wider throttle openings required by a smaller hybrid engine.

(Ex. 1123 at 12).

131. Therefore, by September 1998 it was well known that hybrid vehicles were used to improve fuel efficiency by improving engine operation. Again, this was typically accomplished using a set of operational modes that allowed the engine that to be operated at its “sweet spot.”

132. Even though the operating range of the engine was generally limited to its “sweet spot”, the motor was able to provide the tractive effort required to

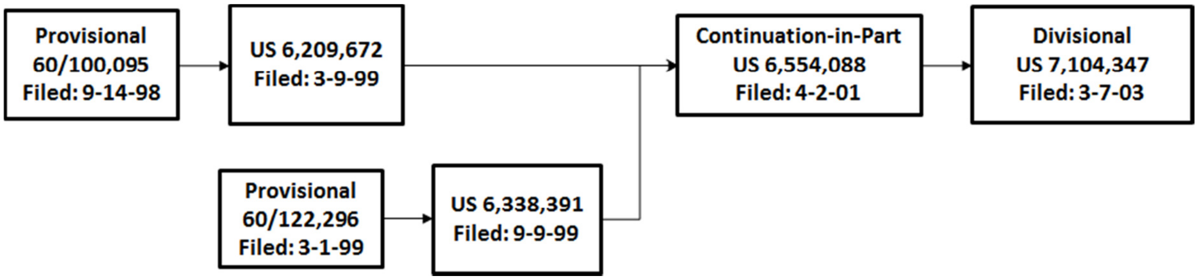
propel the vehicle alone where engine operation was not efficient (i.e. outside the "sweet spot"), or in combination with the engine at high acceleration or driver demands.

133. Control between these modes, however, is done so that the required tractive effort is provided to the road wheels using the vehicle powertrain (i.e., the motor(s) and engine) in order to order to overcome the external "road load" forces and thus propel the vehicle.

V. THE '347 PATENT

A. Effective Filing Date of the '347 Patent

134. It has been explained to me that the '347 Patent is part of an extensive chain of patent filings as illustrated below.



135. The '347 Patent is generally directed to an alleged novel hybrid vehicle architecture (which is referred to in the '347 Patent as a novel vehicle "topology") and control strategy. (Ex. 1101at 11:46-67 & 12:38-57).

136. Starting at the '347 Patent, it has been explained to me that the '347 Patent is what is referred to as a "divisional" patent application which includes a

same disclosure as the parent patent application, but claims a distinct invention different than the parent patent application. Specifically, it has been explained to me that the ’347 Patent is a divisional patent application of U.S. Patent No. 6,554,088 (“the ’088 Patent”).

137. It has also been explained to me that the ’088 Patent in turn is a “continuation-in-part” application. It has also been explained to me that a “continuation-in-part” is a patent application that includes additional disclosure or material not found in the parent patent application. Specifically, it has been explained to me that the ’088 Patent is a continuation-in-part of U.S. Patent Nos. 6,209,672 (“the ’672 Patent”) and 6,338,391 (“the ’391 Patent”).

138. It has further been explained to me that the ’672 Patent and ’391 Patents claim “priority” to Provisional Application Nos. 60/100,095 and 60/122,296.

139. It has been explained to me that a “provisional” patent application is a placeholder for a patentee for an early priority date.

140. It has further been explained to me that a provisional patent is not examined by the U.S. Patent and Trademark Office and never matures into an issued patent unless the patentee files a “non-provisional” patent application within one year of submitting the “provisional” patent application.

141. Therefore, it is my understand that the ’672 Patent claims priority to

U.S. Provisional Application No. 60/100,095 (“the ’095 Provisional”). Likewise, it is my understanding that the ‘391 Patent claims priority to U.S. Provisional Application No. 60/122,296 (“the ’296 Provisional”).

142. It has been explained to me that based on this priority chain the earliest possibly filing date in the ’347 Patent chain of patent filings is to the ’095 Provisional which was filed with the U.S. Patent Office on September 14, 1998.

B. Prosecution History of the ’347 Patent

143. I have reviewed portions of the file history associated with the ’347 Patent.

144. I understand that the ’347 Patent issued on September 12, 2006 from U.S. Patent Application No. 10/382,577, (“the ’577 Application”).

145. It is been explained to me that the ’577 Application was filed on March 3, 2003. (Ex. ’347 Patent).

146. It is been explained to me that the ’577 Application was originally filed with 16 claims. (Ex. 1102 at 107-112).

147. It is been explained to me that the Patent Owner also filed three Information Disclosures with substantive analysis and arguments that were also previously submitted during prosecution of the ’088 Patent. (Ex. 1102 at 135-169).

148. It is been explained to me that on August 11, 2003, a Preliminary Amendment was filed that cancelled claims 1-15, amended claim 16 and added

new claims 17-81. (Ex. 1102 at 176-200).

149. It is been explained to me that the new claims included independent claims 17, 57, and 74. It has been explained to me that a "preliminary amendment" may be filed before a rejection (i.e. an Office Action) is issued by the U.S. Patent and Trademark Office.

150. It is been explained to me that on May 19, 2004, the Patent Owner filed a Supplemental Preliminary Amendment amending claims 16-80 and adding new claims 81-141. (Ex. 1102 at 203-245).

151. It is been explained to me that independent claim 17 and claim 77 were amended as shown here to delete the limitation "by a clutch":

> ... said internal combustion engine being controllably coupled to said road wheels of said vehicle ~~by a clutch~~ ...

152. It is been explained to me that the Patent Owner also filed a First Supplemental Information Disclosure Statement again citing certain prior art references and providing substantive analysis regarding the prior art. (Ex. 1102 at 246-284).

153. It is been explained to me that the on December 3, 2004 a non-final office action was issued by the U.S. Patent and Trademark Office rejecting pending claims 1-142. (Ex. 1102 at 387-393).

154. It is been explained to me that the in a February 17, 2005

Amendment, the Patent Owner cancelled claims 16-81 and 123-142 and amended claims 82-122. (Ex. 1102 at 430-447).

155. It is been explained to me that in particular, the applicant amended independent claims 82 and 104 (issued independent claims 1 and 23 of the ’347 Patent) to include the following limitation:[9]

> and wherein the torque produced by said engine when operated at said setpoint (SP) is substantially less than the maximum torque output (MTO) of said engine.

(Ex. 1102 at 431-432 and 437-438)

156. It is my understanding that the above limitation was added to these claims in order to overcome the rejections based on U.S. 6,054,844 (Frank) and a non-patent publication titled “A hybrid drive based on a structure variable arrangement” to Mayrhofer.

157. It is also my understanding that the patentee argued that neither Frank nor Mayrhofer disclosed an engine that is efficiently operated when loaded “in excess of SP [setpoint], which is now defined to be ‘substantially less than the maximum torque output (MTO) of said engine.” (Ex. 1102 at 443-444 & 446).

158. It is been explained to me that with regards to the amendment

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[9] While the patentee amended other claims, these amendments were primarily directed at correcting typographical errors or to correct claim numbering.

provided, Patent Owner also made the following remarks:

> Thus claims 82 and 104 are the only remaining independent claims. These have both been amended to recite that the engine is run when it is loaded (either by the vehicle's propulsion requirement, the battery charging load, or both) in excess of a setpoint SP, which is now defined to be "substantially less than the maximum torque output (MTO) of said engine". It is respectfully submitted that this recitation clearly and patentably distinguishes over the references relied upon.

(Ex. 1102 at 443-444).

159. It is been explained to me that also attached to the Patent Owner's Amendment is a Second Supplemental Information Disclosure that provides substantive analysis of prior art references. (Ex. 1102 at 448-455).

160. It is been explained to me that on April 21, 2005 a first notice of allowance was granted allowing claims 82-122. (Ex. 1102 at 699-702).

161. It is been explained to me that on June 30, 2005 the Patent Owner paid the issue fee and publication fee. (Ex. 1102 at 708-709).

162. It is been explained to me that the Patent Owner also filed a Third Supplemental Information Disclosure citing prior art references that Toyota Motor Company had asserted in a pending District Court litigation ("Toyota Litigation"). (Ex. 1102 at 710-711).

163. It is been explained to me that on October 26, 2005, the Examiner provided a Supplemental Notice of Allowance based on a telephonic interview on

October 24, 2005. The interview authorized the Examiner to amend claim 82 (issued claim 1) as follows:

> In claim 82, line 19, after "when torque", --required to be-- has been inserted.

(Ex. 1102 at 1072-1075).

164. It is been explained to me that with the supplemental Notice of Allowance, the examiner initialed the references provided by the Patent Owner in the June 30th IDS. (Ex. 1102 at 1076-1079).

165. It is been explained to me that the on January 19, 2006 the Patent Owner filed a petition to withdraw application from issuance along with a Request for Continued Examination. (Ex. 1102 at 1084-1088).

166. It is been explained to me that along with the petition, the Patent Owner filed a Fourth Supplemental Information Disclosure statement to submit further prior art references asserted in the Toyota Litigation that was pending at that time. (Ex. 1102 at 1089-1091).

167. It is been explained to me that on March 27, 2006 the Patent Owner re-submitted the fourth Information Disclosure Statement and provided a CD-ROM to the Patent Office with all of Toyota's trial exhibits from the Toyota Litigation. (Ex. 1102 at 1093-1103).

168. It is been explained to me that on July 11, 2006 a Second

Supplemental Notice of Allowance was granted allowing claims 82-122. (Ex. 1102 at 1210-1214).

169. It is been explained to me that the ’577 Application subsequently issued as the ’347 Patent on September 12, 2006.

170. It is been explained to me that the Examiner did not provide any explanation of the reasons for allowance of the claims. (Ex. 1102 at 1211-1214).

VI. CHALLENGED CLAIMS OF THE ’347 PATENT AND PROPOSED CLAIM CONSTRUCTIONS

171. I have been asked to review claims independent claims 1 and 23.

172. I have also been asked to review dependent claims 7, 8, 18 and 21 which depend from claim 1.

173. I have further been asked to review dependent claim 37 which depends from claim 23.

174. In order to properly evaluate these claims, I understand that the terms of the claims must first be construed. For purposes of this declaration, I am applying the following claim constructions for my analysis regarding unpatentability:

a. “***road load (RL)***,” “***RL***” and “***instantaneous torque RL required to propel said vehicle***” as: “*the instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value*.”

b. "***SP***," "***Setpoint (SP)***" as: "*predetermined torque value*."

c. ***"Low-load mode I"*** as "*the mode of operation in which energy from the battery bank flows to the traction motor and torque (rotary force) flows from the traction motor to the road wheels*"

d. "***Highway Cruising mode IV***" as "*the mode of operation in which energy flows from the fuel tank into the engine and torque (rotary force) flows from the engine to the road wheels*"

e. "***Acceleration mode V***" as "*the mode of operation in which energy flows from the fuel tank to the engine and from the battery bank to at least one motor and torque (rotary force) flows from the engine and at least one motor to the road wheels*".

VII. OVERVIEW OF THE PRIOR ART

A. Prior Art Status of Bumby Project

175. The series of publications detailing Dr. Bumby's research relating to hybrid vehicles is collectively referred to as "the Bumby Project."

176. It is my understanding that each of these publications of the Bumby Project was published between 1985 and 1990.

177. It has been explained to me that each of these publications of the Bumby Project are considered prior are since they were published more than one

year before the earliest priority date of the ’347 Patent. In fact, I am aware that the Bumby Project publications were published between 8 and 13 years before the earliest priority date of the ’347 Patent.

178. The series of publications were each authored in part by J.R. Bumby, his fellow associate professors, and his doctoral students at the University of Durham located in the United Kingdom.

179. It is my opinion that these publications chronologically document the progression of a hybrid vehicle project from its inception as a software simulation tool, through the design of a control strategy for operating the hybrid vehicle, and finishing with the physical construction of a test-bed prototype of the hybrid vehicle.

180. My opinion is based on the following publications:

- “Bumby I” - Computer Modeling of the Automotive Energy Requirements for Internal Combustion Engine and Battery Electric-Powered Vehicles, J.R. Bumby at H. Clarke and I. Forster, IEE Proceedings, September 1985 (Ex. 1103)

- “Bumby II” - Optimisation and Control of a Hybrid Electric Car, J.R. Bumby and I. Forster, IEE Proceedings, November 1987 (Ex. 1104)

- “Bumby III” - A Hybrid Internal Combustion Engine/Battery Electric Passenger Car for petroleum Displacement, I. Forster and J.R. Bumby, Proceedings of the Institution of Mechanical

Engineers – Part D: Journal of Automobile Engineering, Jan 1, 1988 (Ex. 1105)

- "Bumby IV" - A Test-Bed Facility for Hybrid IC-Engine/Battery-Electric Road Vehicle drive Trains, J.R. Bumby and P.W. Masding, Trans Inst. Meas. & Cont. 1990 Vol. 10:2, April 1, 1988 (Ex. 1106)
- "Bumby V" - Bumby, J.R. et al. "Integrated Microprocessor Control of a Hybrid i.c. Engine/Battery-Electric Automotive Power Train" - Trans Inst. Meas. & Cont. 1990 Vol. 12:128, January 1, 1990 (Ex. 1107)

181. These publications all appeared in well-known British scientific journals.

182. For instance, Bumby I and II were published in the "IEE Proceedings" which is the journal for the professional society of the Institution of Electrical Engineers. It is my understanding that this society and journal is equivalent to the U.S. Institute of Electrical and Electronics Engineers (IEEE). In fact, it is my understanding that the Bumby I and II IEE Proceedings are accessible through the U.S. IEEE journal index system as these are sister societies.

183. Bumby III was included in "Part D" of The "Proceedings of the Institution of Mechanical Engineers" that is part of the "Journal of Automobile Engineering." This journal is a leading international journal focused on

advancements in the automotive industry. It is my understanding that this journal is accessible internationally using "Sage Publications." This journal is the British equivalent of the U.S. Society of Automotive Engineers journal. In fact, I am aware of this British journal due to my service as a board member on the U.S. SAE publications board.

184. The "Transactions of the Institute of Measurement and Control" is a known engineering publication that covers applications in instrumentation, systems, control theory, sensors and signal processing. It is my understanding that this journal is accessible through "Sage Publications."

185. Both students and professors alike review these scholarly journals to keep current with particular areas of research. A person working in the field of hybrid vehicles would have been motivated to research hybrid vehicle publications found in these journals, including the publications related to the University of Durham's hybrid vehicle project, to thus keep current in their field of research.

186. It is further my opinion that a person working in hybrid vehicles would have realized that the Bumby Project was based on a series of publications by the explicit overview provided within each publication. For instance, the Bumby references themselves state that the publications were part of a complete project.

> Current research work within the School of Engineering and Applied Science at Durham University is involved in developing the hybrid vehicle control algorithms described here with experimental testing being conducted on a full-scale laboratory test rig.

(Ex. 1105 at 15).

> The work at Durham University demonstrated how power should be scheduled to meet driver demand, and postulated a possible sub-optimum control scheme to achieve this. To investigate how easily such a scheme can be incorporated into the hybrid drive, a fullscale laboratory test facility has been constructed in the School of Engineering and Applied Science at Durham University.

(Ex. 1106 at 2).

187. Based on these disclosures it is my opinion that a person working in the field of hybrid vehicles would have been motivated to find the further publications regarding the research project being performed at the University of Durham.

188. Such research would have been well within the ability of a student or professor as the references themselves provide express teachings about the prior publications and work, as well as, provide full citations to these prior publications.

189. For instance, Bumby V specifically discusses and references the work disclosed in Bumby II, Bumby III, and Bumby IV.

> By correct design, such a drive arrangement not only has the potential to reduce exhaust emissions in the urban environment substantially, but also of substituting up to 70% of the petroleum fuel used by the average road user (Forster and Bumby, 1988 **[Bumby III]**; Sandberg, 1980).

(Ex. 1107 at 2).

> An optimisation study of these problems based on a computer simulation of different hybrid-vehicle power-train configurations, component ratings and control strategies is discussed in some detail in Bumby and Forster (1987) [**Bumby II**].

(Ex. 1107 at 2-3).

> A complete description of the test bed facility is given in Bumby and Masding (1988). (Masding et al., 1988). [**Bumby IV**]

(Ex. 1107 at 3).

190. Bumby IV likewise is a June 1988 publication discussing the test-bed prototype of this hybrid vehicle. (Ex. 1106 at 2-Abstract). This paper includes a section entitled "Hybrid-vehicle control hierarchy" describing the hybrid vehicle developed. (Ex. 1106 at 2-4). Bumby IV specifically discusses and references the work disclosed in Bumby II and Bumby III.

> Given that two power are available within the vehicle drive system, there are a number of ways in which they can be combined to produce torque output at the road wheels. However, earlier work (Bumby et al,

> 1984; **Bumby and Forster, 1987 [Bumby II]**) has shown the parallel arrangement of Fig 1 to have the greatest potential for use in a hybrid car.

(Ex. 1106 at 2; emphasis added).

> From this brief discussion it is apparent that the hybrid drive can be operated in a number of ways or modes. **These possible are modes are listed in Table 1 and described in detail in Forster and Bumby (1988) [Bumby III]**.

(Ex. 1106 at 3; emphasis added).

191. Bumby III is a January 1988 publication that "examines the potential of the hybrid electric vehicle" discussed in prior Bumby Project. Specifically, the "Introduction" section of Bumby III discusses and references Bumby I and Bumby II.

> The range limitations of the pure electric vehicle can be overcome by using a hybrid i.c. engine/electric drive which incorporates both an i.c. engine and an electric traction system. Although such a vehicle can be designed to meet a number of end objectives, **it has been argued (3) [Bumby II]** that a vehicle which seeks to remove the range limitation of the electric vehicle while substituting a substantial amount of petroleum fuel by electrical energy is the vehicle most worth pursuing.

(Ex. 1105 at 2; emphasis added).

> In order to optimize the control and component rating of the hybrid drivetrain, the performance and energy consumption of the vehicle over standard driving cycles is assessed using the road vehicle simulation program Janus (8) [Bumby I]. Janus is a flexible road vehicle simulation program capable of predicting the energy use and performance of vehicles with a variety of powertrain configurations and has been used previously to study the performance of advanced i.c. engine vehicles (9) and hybrid electric vehicles (3) [Bumby II].

(Ex. 1105 at 3).

192. Lastly, Bumby II discloses the design of a "control algorithm" for determining the power-split between the motor and engine of a hybrid vehicle (i.e., when the motor should operate and when the engine should operate). Bumby II states that this "control algorithm" (i.e., control strategy) was developed using a software simulation tool called "Janus" as documented by Bumby I.

> To implement the optimization process, the hybrid vehicle is simulated over a defined driving cycle using the Janus road vehicle simulation program (15) [Bumby I].

(Ex. 1104 at 4).

193. It is therefore my opinion that it would have been quite simple for a person of ordinary skill in the art to gather all the documentation relating to the hybrid vehicle project performed by the University of Durham.

194. It is also my opinion that a person of ordinary skill in the art working

in the automotive field, and particularly on hybrid vehicles, would have been motivated to acquire and read the full context of the University of Durham's hybrid vehicle project in order to keep current on advancements in this field. Such a person of ordinary skill would have further been able to fully comprehend each of these publications as each relate to the design and associated control strategy of a hybrid vehicle.

B. Overview of the Bumby Project

a. Bumby I

195. I understand that "Computer modelling of the automotive energy requirements for internal combustion engine and battery electric-powered vehicles" by J.R. Bumby et al. published in September 1985 in IEE Proceedings, Vol. 132, Pt. A. (hereinafter "Bumby I"). It has been explained to me that Bumby I is considered prior art since it was published more than one year before the earliest priority date the '347 Patent.

196. Bumby I introduces a simulating system (named "Janus") used for evaluating the power train of either a conventional or hybrid vehicle.

> In the paper the road vehicle simulation package Janus, developed in the Engineering Department at Durham University, is described. Janus is a flexible simulation package that allows internal combustion engine vehicles, electric vehicles and hybrid vehicles to be simulated, and their performance and energy consumption evaluated over standard driving cycles. The simulation techniques used in these

> programs are described and the simulation program shown to produce results comparable with experimental data.

(Ex. 1103 at 1).

197. The Janus simulator software modeling of different vehicle configurations by varying each part of the vehicle's drivetrain (i.e., the transmission, engine and motors). For example, in Janus simulator, a user could build a hybrid vehicle having an architecture with an engine and two smaller capacity motors. Or build a different hybrid vehicle with an engine and one larger capacity motor.

198. Once the assembled in the Janus simulator, the vehicle design could be driven on a simulated drive cycle to evaluate both the component and vehicle "performance and energy efficiency." (Ex. 1103 at 2).

199. As part of the vehicle evaluation, the Janus simulator calculates the "vehicle dynamics" which are described as follows:

> To provide the necessary propulsion power, any vehicle drive train must be able to **provide sufficient tractive effort at the road wheels to overcome aerodynamic drag, rolling resistance and hill gradient effects**, while still providing the necessary vehicle acceleration. Consequently, at any particular velocity and acceleration, the net tractive effort required at the road wheels can be expressed as the algebraic sum of these components, i.e.
>
> $$T_E = T_d + T_r + T_g + T_a N \quad (eqn.\ 1)$$

(Ex. 1103 at 2; emphasis added).

200. These ‘vehicle dynamics’ that are accounted for in the Janus simulator disclosed by Bumby I are identifying the textbook values of “tractive effort” force and “road load” force that I have more fully explain in paragraphs 113-120 above. It is my opinion that Bumby I correctly states the well-known meaning of both terms.

201. First, Bumby I correctly recognizes that “tractive effort” is the force required at the road wheels to propel the vehicle. This “tractive effort” is correctly identified by Bumby I as the force required to overcome the textbook “road load” forces that include “aerodynamic drag” (T_d), “rolling resistance” (T_r), and “hill gradient effects” (T_g).

202. The drive cycle is input into the Janus simulator as a function of velocity (i.e., speed) vs. time and then the “tractive effort at the road wheels is calculated at each time instant using eqn. 1 [above] and converted into a torque and rotational speed demand…” (Ex. 1103 at 3-4).

203. Janus simulator is then able to output the “full details of the vehicle, driving cycle and the individual drive-train components.” These details included “component efficiencies, losses [] the overall vehicle fuel economy [and the] percentage of the total cycle time spent in each area of the engine fuel map is also given” based on calculated torque and rotational speed demands (Ex. 1103 at 4).

204. Bumby I discloses that the "fuel map information is invaluable, particularly when detailed studies on the effect of the vehicle component sizing and control on fuel efficiencies are being undertaken." (Ex. 1103 at 4).

205. Based on the component and vehicle data gathered over a drive cycle performed on the Janus simulator, if a user determined the vehicle design did not provide the efficiency and desired fuel economy, "modifications [could] be made to the individual power-train components and/or the vehicle parameters."

206. Therefore, the Janus simulator disclosed by Bumby I allows a user to investigate and evaluate the efficiency and performance of different configurations of hybrid electric vehicles. (Ex. 1103 at 12).

b. Bumby II

207. I understand that "Optimisation and control of a hybrid electric car" by J.R. Bumby et al. published in November 1987 in IEE Proceedings, Vol. 134, Pt. D. (hereinafter "Bumby II"). It has been explained to me that Bumby II is considered prior art since it was published more than one year before the earliest priority date the '347 Patent.

208. Bumby II expands upon the analysis accomplished in Bumby I and further evaluates the fuel economy and efficient power distribution in hybrid vehicles.

209. Specifically, Bumby II discloses that two control strategies were

developed using the Janus simulation software. The first control strategy was an "energy saving" strategy that looked at the best way to lower the overall fuel and battery usage by a vehicle. The second strategy was focused on using the motor and battery as the primary propulsion source (e.g., electrical energy) as opposed to using the IC engine (e.g., petroleum fuel).

> The paper examines the potential of hybrid electric vehicles and, in particular, a hybrid electric passenger car. **Two operating objectives are identified, one for energy saving and the other for substituting petroleum fuel by electrical energy**. **The way in which the power train control and component rating can be optimised to meet these particular operating objectives is discussed**. In the final part of the paper the performance of the optimised hybrid vehicles are compared with both IC engine and electric vehicles and the petroleum substitution design is shown to warrant further development.

(Ex.1104 at 373; emphasis added).

210. Bumby II also utilizes the same Janus simulator from Bumby I to evaluate performances of hybrid vehicles in order to define "a control algorithm that can be used in a vehicle suitable for the European car market." (Ex. 1104 at 2)

211. Bumby II further recognized that hybrid vehicles are more complex than conventional vehicles as there are more than one propulsion source. In other words, in a conventional vehicle only an IC engine is used. Hybrid vehicles include both an engine and motor. How the torque output to the wheels from these two

sources is provided depends on the control strategy. As I explained above in ¶¶ 108-133, control strategies for hybrid vehicles with two power sources had been extensively evaluated prior to September 1998. Indeed, Bumby II confirms that control of these two power sources is fundamental to the performance of the vehicle. Further Bumby II recognizes that control of these two power sources must be done in order to further reduce unwanted emissions by restricting the engine to its most efficient operating region. **This goal was nearly universal to all hybrid vehicle strategy designs**.

> **When two or more power sources are used in a vehicle power train, the way in which they are controlled is fundamental to the performance of the vehicle.** However, the main objective of the control may be to **maximise the accelerative performance of the vehicle, minimise exhaust emissions or to minimise energy use**. An alternative objective, and the subject of this paper, is to examine ways in which the dependence of the vehicle on petroleum-based fuels can be reduced. This objective can be achieved either by improving the overall energy consumption of the vehicle, or by transferring some of the energy demand to the electrical system.

(Ex. 1104 at 3; emphasis added).

212. Bumby analyzed this control optimization for the “parallel” hybrid vehicle which Bumby II determined would “offer the most potential” for being a commercially viable solution. (Ex. 1104 at 2). Parallel hybrid electric architecture,

as shown in Fig. 2, below, were also well known as I discussed above in paragraph 70-107.

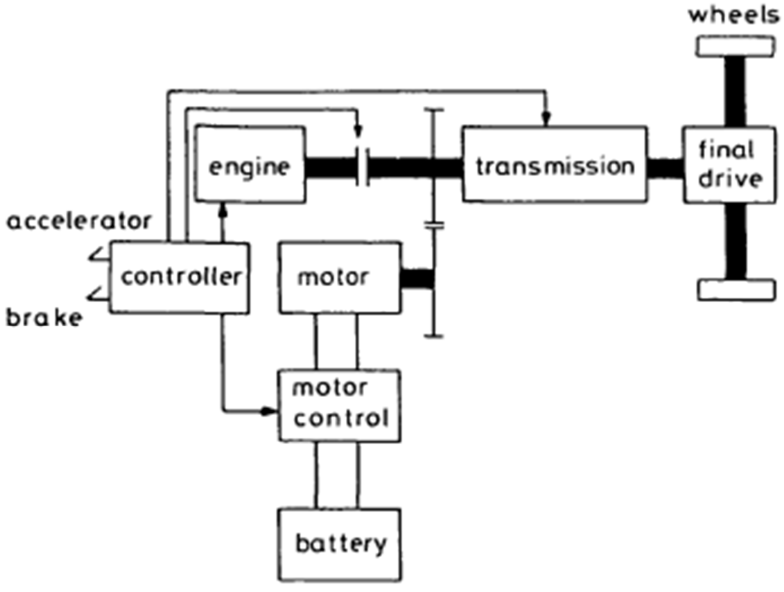


Fig. 2 *Parallel hybrid electric vehicle drive train*

213. Using the Janus simulator, Bumby II developed a first control strategy that was referred to as the "optimal control policy." By calculating the net energy required at each second, this control strategy maximized engine efficiency:

> **The optimal control policy maximises engine efficiency by moving each operating point as close to the maximum efficiency region as the available transmission ratios will allow.** Thus there is a tendency to use low gear ratios (high gears) as much as possible when the IC engine is selected as the power source. **The use of the electric drive** is also shown in Fig. 7 and, during this cycle, **is used only for regenerating braking and initial movement of the vehicle**. Torque

> transfers to the IC engine when the engine speed and load is sufficiently high to give acceptable efficiency.

(Ex. 1104 at 5-6; emphasis added).

214. Bumby II disclosed that this control strategy sought to restrict engine operation to its most efficient point of operation. The control strategy also decoupled (via a clutch mechanism) and turned off the engine when it was outside of its most efficient operating region.

> These results suggest that the IC engine can be regarded as the principle power source, **<u>when the aim of the optimal control is to maintain the efficiency of this component as high as possible. This is achieved by allowing operation only in the most efficient part of the engine fuel map and by switching off and decoupling the engine when not in operation.</u>** In addition, a proportion of the accelerative energy is recovered by regenerating into the battery.

(Ex. 1104 at 6; emphasis added).

215. Bumby II acknowledged, however, that the optimal control policy had drawbacks. Specifically, Bumby II recognized that in the mid-1980's the computing power was not capable of implementing the computationally intense "optimal control strategy." As disclosed, this strategy required such intensive computational processing because of the intensive searching that was required to find the most optimal engine operating point.

> Further consideration of the optimal policy described earlier points to a number of factors which **limit its practical application**. First, the implementation of **the optimal algorithm requires substantial computation time because of the direct search technique used. As a result, it cannot be implemented in real time**. Other optimisation techniques have been explored, but the highly non-linear nature of the loss variations make these difficult to use reliably. **Secondly, some of the operating conditions imposed on the system are unacceptable, for example the number of gear changes being made.** However, a suboptimal policy that overcomes these problems can be developed, the effect of which is described in Section 5.

(Ex. 1104 at 6; emphasis added).

216. As a result, Bumby II disclosed and developed a second control strategy that was "shown to produce similar results to the optimal policy" but was not as computationally intense. Because the second control strategy was not as computationally intense, Bumby also recognized that it was capable of being implemented on a real-world hybrid vehicle. (Ex. 1104 at 15).

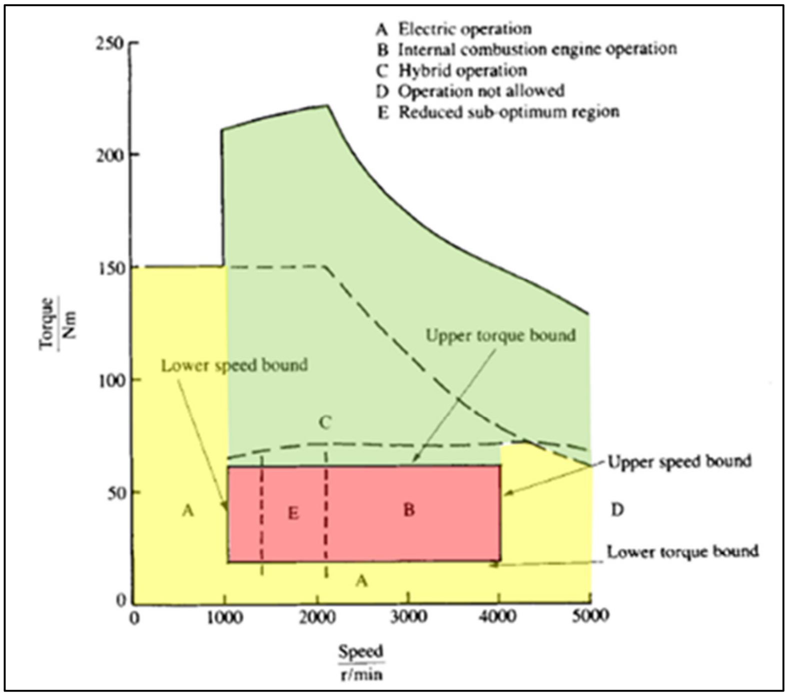
217. Bumby II disclosed that this second control strategy (referred to as the "suboptimal control policy") was computationally less intense, but still restricted engine operation to its "high-efficiency region." (Ex. 1104 at 10-13).

> Consequently, a suboptimal control policy can be defined, which defines an engine operating box as shown in Fig. 16. This box region is defined by an upper and lower torque bound and an upper and

> lower speed bound, the values of which are dependent on the particular hybrid philosophy. **Within this box, engine-only operation is favoured while**, when the operating point is outside this box, the selected mode of operation depends on the actual torque and speed values. Below the lower torque bound and the lower speed bound, all-electric operation is favoured. **This eliminates inefficient use of the engine**.

(Ex. 1104 at 11; emphasis added).

218. As illustrated below, Bumby's "suboptimal control" simplified the control strategy by defining "regions" where: (A) motor only operation (highlighted in yellow); (B) engine operation (highlighted in red); and (C) combined engine and motor operation (highlighted in green). (Ex. 1104 at 11).



(Ex. 1105 at 8-Fig. 8, annotated)

219. As illustrated, Bumby used four operating “bounds” that were used to restrict engine operation. Specifically, Bumby included a lower and upper speed bound and lower and upper torque bound that were used to restrict the engine into the “region B/E” shaded in red. Outside of this “box” either the motor alone was operated. Region “E” is a secondary area of engine operation that is used based on the state of charge (SOC) of the battery. Specifically, as the SOC falls below a speed value threshold, engine operation in region “E” is permitted. As the SOC increased above the threshold, engine operation was restricted back to region “B” (red). (Ex. 1104 at 11).

220. Bumby II confirmed that by restricting engine operation to a defined region bound by torque and speed thresholds, the desired goal of eliminating “inefficient use of the engine” and was still achieved and this control strategy was capable of being implemented on a microprocessor/controller in a vehicle.

c. Bumby III

221. I understand that “A Hybrid Internal Combustion Engine/Battery Electric Passenger Car for Petroleum Displacement” by I. Forster and J.R. Bumby published in January 1998 in Proceedings of the Institution of Mechanical Engineers, Vol. 202 No. D1 (hereinafter “Bumby III”). It has been explained to me that Bumby III is considered prior art since it was published more than one year before the earliest priority date the ‘347 Patent.

222. Bumby III even further evaluates the fuel economy and power distribution of hybrid vehicles. The Abstract of Bumby III states:

> This paper examines the potential of the hybrid electric vehicle in substituting petroleum fuel by broad-based electrical energy. In particular a hybrid car is considered. The way in which the powertrain can be controlled and the effect component ratings have on achieving the petroleum substitution objective are described. It is shown that a hybrid vehicle can be designed that can achieve a petroleum substitution of between 20 and 70 per cent of the equivalent internal combustion engine vehicle, be capable of entering environmentally sensitive areas and yet be capable of a range at high and intermediate speeds that is limited only by the size of its fuel tank.

(Ex.1105 at 2 - Abstract).

223. Bumby III also utilizes the Janus software that is explained in Bumby I and II:

> In order to optimize the control and component rating of the hybrid drivetrain, the performance and energy consumption of the vehicle over standard driving cycles is assessed using the road vehicle simulation program Janus.

(Ex.1105 at 3).

224. Bumby III further evaluates the "practical implementation" of in a parallel hybrid vehicle. (Ex. 1105 at 3).

d. Bumby IV

225. I understand that “A Test-Bed Facility for Hybrid IC Engine-Battery Electric Road Vehicle Drive Trains” by J.R. Bumby and P.W. Masding published in April 1988 in Transactions of the Institute of Measurement and Control, Vol. 10 No. 2 (hereinafter “Bumby IV”). It has been explained to me that Bumby IV is considered prior art since it was published more than one year before the earliest priority date the ‘347 Patent.

226. Bumby IV discloses that:

> **<u>This paper describes the design and development of a testbed facility for hybrid internal-combustion-engine/battery-electric vehicle power trains.</u>** The control hierarchy within the microprocessor control systems is discussed, and the influence this has on the software design is described. The instrumentation and computer software systems necessary for both data acquisition and drive train control are described. It is shown that drive train control over an urban cycle can be successfully achieved using a modified proportional-plus-integral controller.

(Ex. 1106 at 2-Abstract; emphasis added).

227. Bumby IV discloses that the Bumby Project including Bumby I-III achieved a hybrid vehicle control strategy:

> The work at Durham University demonstrated how power should be scheduled to meet driver demand, and postulated a possible sub-optimum control scheme to achieve this.

228. Specifically, Bumby IV implements the “suboptimal control” strategy and components disclosed in Bumby II and III (¶¶ 217-218 above) on a physical vehicle drive-train.

229. Bumby IV further discloses physical componentry (i.e., engine, motor, microprocessor controller, etc.) and configuration (i.e., layout) that was used to test the control strategy.

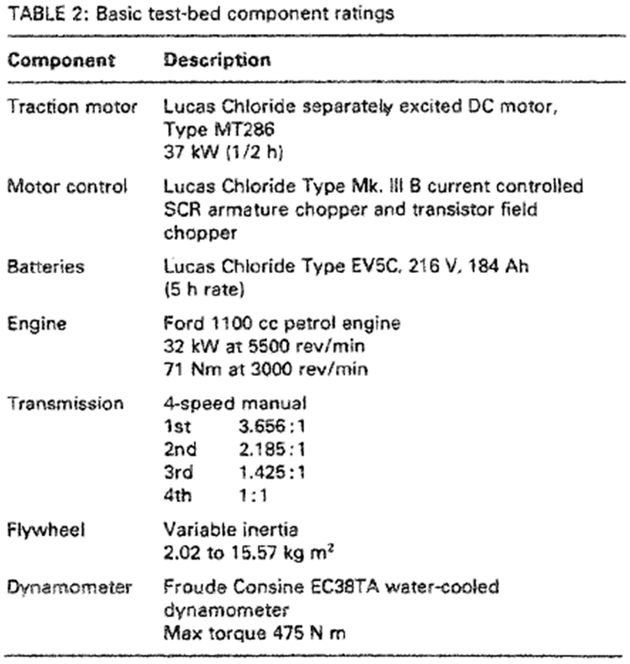


TABLE 2: Basic test-bed component ratings

Component	Description
Traction motor	Lucas Chloride separately excited DC motor, Type MT286 37 kW (1/2 h)
Motor control	Lucas Chloride Type Mk. III B current controlled SCR armature chopper and transistor field chopper
Batteries	Lucas Chloride Type EV5C, 216 V, 184 Ah (5 h rate)
Engine	Ford 1100 cc petrol engine 32 kW at 5500 rev/min 71 Nm at 3000 rev/min
Transmission	4-speed manual 1st 3.656 : 1 2nd 2.185 : 1 3rd 1.425 : 1 4th 1 : 1
Flywheel	Variable inertia 2.02 to 15.57 kg m^2
Dynamometer	Froude Consine EC38TA water-cooled dynamometer Max torque 475 N m

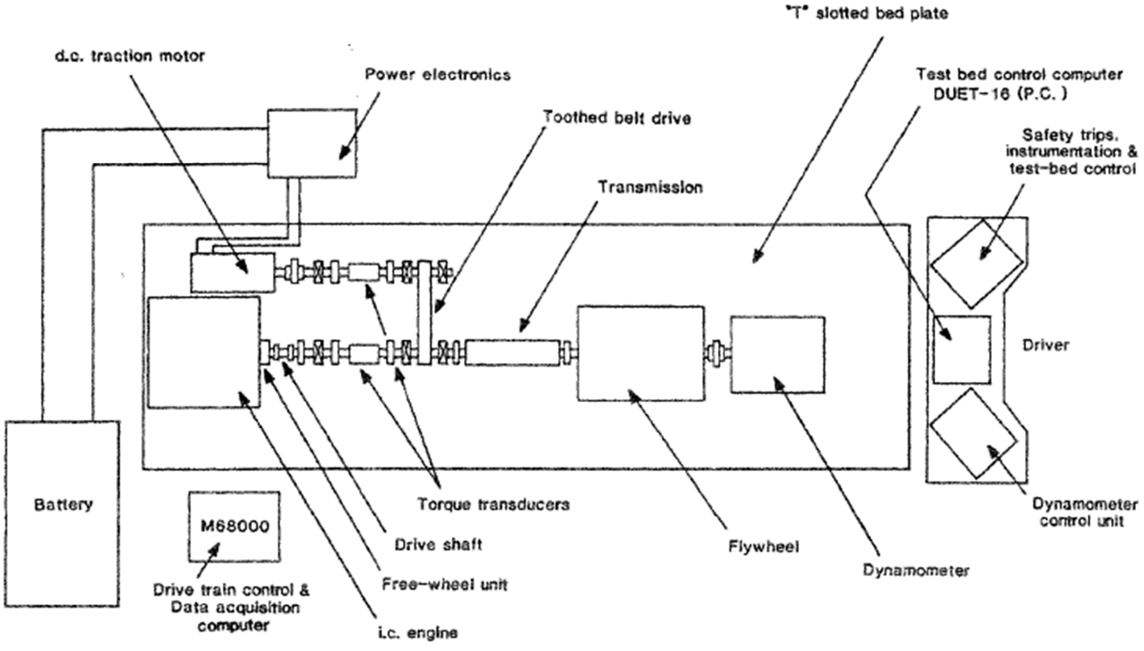


Fig 4 Test-bed layout

230. Bumby IV discusses a test-bed that was constructed to test the control policy disclosed in Bumby II and III on a physical vehicle drive-train that can be tested over specified drive cycles to evaluate overall performance and efficiency:

> The layout of the laboratory test facility representing the hybrid drive arrangement of Fig 1 is shown in Fig 4. The mechanical arrangement divides into two parts: first, that which emulates the road load and the vehicle inertia; and second, the hybrid drive system itself.

(Ex. 1106 at 4).

e. Bumby V

231. I understand that "Integrated microprocessor control of a hybrid i.c. engine/battery-electric automotive power train" by P.W. Masding and J.R. Bumby published in January 1990 in Transactions of the Institute of Measurement and

Control, Vol. 10 No. 2 (hereinafter “Bumby V”). It has been explained to me that Bumby V is considered prior art since it was published more than one year before the earliest priority date the ‘347 Patent.

232. Bumby V disclosed the further progression of the hybrid vehicle work at the University of Durham. Specifically, Bumby V focused on refining the microprocessor control algorithm that was used to determine the torque split between the engine and motor. As I discussed in ¶ 211 above, control of these two power sources was important to the overall goals of adequate acceleration and lowered emissions. Thus, Bumby V describes in detail how the torque split between these two power sources was handled. Bumby V also describes how the engine was started and brought inline so that it could provide the required torque to provide the torque required to propel the vehicle.

> **This paper describes the development of a fully integrated microprocessor control system for a hybrid i.c. engine/battery-electric automotive power train.** Torque control systems for the internal-combustion engine and the electric-traction motor are designed using digital transfer functions and indirect methods of torque measurement.

(Ex. 1107 at 2-Abstract; emphasis added).

233. Based on the prior hybrid vehicle work, Bumby V focused on the “the additional component control problems relating to engine and motor torque control

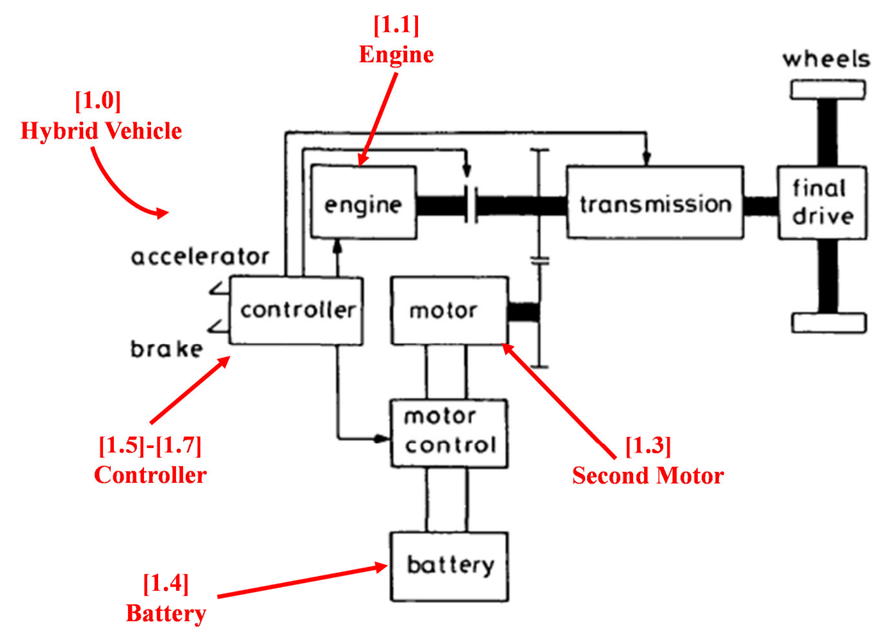
and smooth engine starting." (Ex. 1107 at 3).

VIII. ANALYSIS OF THE CLAIMS

A. Claim 1

234. I understand that claim 1 is directed to a hybrid vehicle. I understand that claim 1 includes elements that recite the structure of the hybrid vehicle. It is my opinion that these structural elements are disclosed by the Bumby Project, as generally annotated by Fig. 2 of Bumby II, reproduced below.

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

… ***[1.0] A hybrid vehicle, comprising:***

235. The Bumby Project discloses the design and development of a **parallel hybrid vehicle**, as shown in Fig. 2 above. For instance, Bumby II discloses an "optimization and control of a hybrid electric car." (Ex. 1104 at 1; *see also* Ex. 1105 at 1, Ex. 1106 at 1, Ex. 1107 at 1).

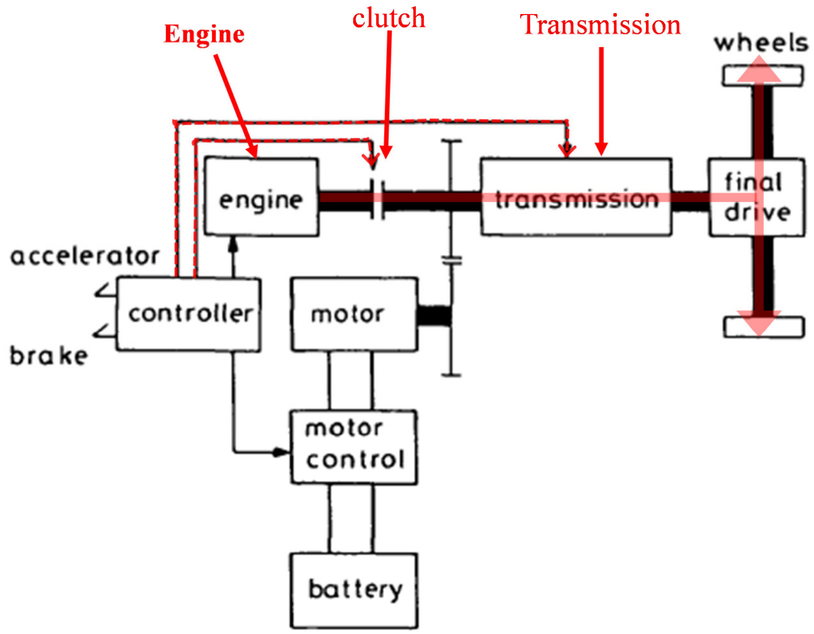
236. Each of the papers in the Bumby Project discloses the simulation, development, testing or construction of **<u>a hybrid vehicle</u>**. (*see e.g.,* Ex. 1104 at 1).

237. Therefore, it is my opinion that the Bumby Project discloses "*a hybrid vehicle*."

… [1.1] an internal combustion engine controllably coupled to road wheels of said vehicle;

238. As shown in Fig. 2 from Bumby II, annotated below, the Bumby Project discloses that the engine is connected to the road wheels via a selectable engagement clutch and a transmission. The clutch may be controllably engaged by the controller to enable torque flow to the wheels. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

239. The Bumby Project discloses that the powertrain of the hybrid vehicle includes a small engine: "The drive system incorporates both a Ford 1100 cc petrol engine and a Lucas Chloride DC traction motor." (Ex. 1106 at 4).

240. As is clearly illustrated above, that a clutch is used to couple the engine to the drive wheels. As is further illustrated, the controller includes a control signal that is used to control operation of the clutch. The engine is therefore "*controllably coupled*" to the road wheels using the clutch.

241. The Bumby Project discloses that the clutch couples the engine to the wheels when the load is high and the engine operates efficiently:

> the **ic engine is connected through a 'one-way clutch' or 'freewheel'**...The consequence of the 'free-wheel' in the ic-engine connection also means that the electric traction system can move the vehicle from rest, and the ic engine need only be started and synchronised with the drive shaft when load demand is high. It is at **such low-speed low load situations** that the ic engine is inefficient compared with the electric traction system.

(Ex. 1106 at 3, emphasis added).

242. As I explain further with respect to limitation [1.7], the Bumby Project examines whether sufficient vehicle speed and loading exist in order for the engine to be used a source of propulsion power or charging power. If the controller determines that the engine is required and is within its efficient operating range,

the controller will connect the engine to the drive wheels. This is accomplished using a one-way clutch that allows the engine to be connected/disconnected. Specifically, the one-way clutch couples the engine to the driveshaft when the engine is controlled by the controller at a predetermined speed so that the engine output shaft matches the driveshaft speed (i.e., the speed of the vehicle). When these two shaft speeds are essentially equal, the clutch engages and connects the engine to the drive wheels. This is a commonly known clutch mechanism system that is used in automotive settings to reduce the shock experienced when the engine is coupled to the driveshaft. Precise control of when the engine is coupled reduces the noise, vibration and harshness of the vehicle operation.

243. The Bumby Project further discloses disconnecting the engine using the one-way clutch whenever the engine is not needed:

> **Whenever the hybrid vehicle is operating in an all-electric mode or is stationary, the i.c.-engine will be uncoupled from the drive train by means of the one-way clutch.** Since in either of these situations the engine is not required to provide torque, the most obvious strategy is to shut it down entirely in order to conserve petroleum fuel. Adopting this strategy means that the next time the engine is required it must be started and synchronised with the moving, and possibly accelerating, drive train, before it can replace or augment the torque supplied by the electric traction system. Consequently, a starting system is required which has fast response and no tendency to overshoot the prevailing drive-train speed, thus

> avoiding a shock torque in the drive shaft as the one-way clutch is engaged.

(Ex. 1107 at 5)

244. Therefore, it is my opinion that the Bumby Project discloses "*an internal combustion engine controllably coupled to road wheels of said vehicle*."

… [1.2] a first electric motor connected to said engine nd [sic] operable to start the engine responsive to a control signal;

245. It was generally known to a person of ordinary skill in the art in September 1998 to have a starter motor that is used to start the engine.

246. For example, starter motors have been included on vehicles since 1912 when Charles Kettering patented a "self-starter" motor that was first incorporated in General Motor's 1912 Cadillac vehicles. Kettering's "self-starter" design eliminated the need for the driver to "crank" the engine. Further, an October 1996 4th edition of the Bosch Automotive Handbook identifies that electric starter motors were generally known for starting a vehicle. A person of ordinary skill in the art understands the Bosch Automotive Handbook is a common reference book in the automotive industry. (Ex. 1134 at 23). As such, electric starter motors were well known to a person of ordinary skill in the art and could easily be incorporated to start any engine, including hybrid vehicle engines. It was also generally known

247. The Bumby Project confirms my understanding that starter motors were known and used well-prior to September 1998. Indeed, the Bumby Project states that a starter motor is controlled by a microprocessor (i.e., M68000 microprocessor) controller. Based on this disclosure, it is obvious that the controller is used to send a control signal that most likely starts the starter motor and also couples the starter motor to the engine. Once coupled the starter motor would crank (i.e., start) the engine.

> To improve power-train efficiency when the engine is not in use it is shut down. Thus, when power from the ic engine is demanded by the vehicle **controller, the M68000 system must activate the ignition and start the engine**. **This is done using the conventional starter motor**.

(Ex. 1106 at 7; emphasis added).

248. The Bumby Project in fact details the sophisticated microprocessor control strategy that is used to quickly start the engine with the disclosed starter motor.

> **an engine-starting procedure** has been developed which can bring the engine on-line and actively producing power in 1 s **using the conventional electric starter motor**. When combined with a fully automated transmission system, the result is a flexible drive-train controller which can carry out sophisticated strategies for optimum use of energy.

(Ex. 1107 at 5)

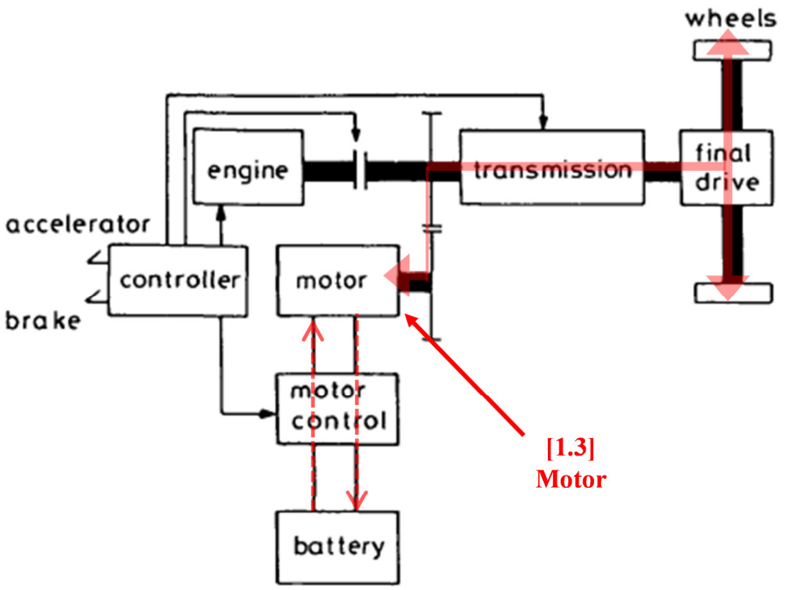
249. In other words, the Bumby Project confirms a "*first electric motor*" that is used as a starter motor to start the engine "*responsive to a control signal*" received from the microprocessor controller.

250. Therefore, it is my opinion that the Bumby Project discloses: "a first electric motor connected to the engine and operable to start the engine responsive to a control signal."

> … ***[1.3] a second electric motor connected to road wheels of said vehicle, and operable as a motor, to apply torque to said wheels to propel said vehicle, and as a generator, for accepting torque from at least said wheels for generating current;***

251. As shown in Fig. 2 from Bumby II, annotated below, the Bumby Project discloses a second electric motor that provides torque to vehicle wheels via the transmission. Based on Fig. 2, the Bumby Project also discloses that the second motor is further operates to accept torque from the engine and provide power to recharge the battery. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



[1.3]
Motor

(Ex. 1104 at 1-Fig. 2, annotated)

252. In describing the electric motor, the Bumby Project discloses that the "*second electric motor*" applies torque to the wheels as well as accepts torque when operating as a generator:

> [T]he **electric traction motor is connected permanently to the drive shaft,** while the ic engine is connected through a 'one-way clutch' or 'freewheel'. **Such a connection allows the traction motor to drive the road wheels** when the engine is stationary, but the electric motor must turn with the road wheels regardless of the drive source. This arrangement guarantees that **regenerative braking into the battery is immediately available when required**. Thus, during braking, the ic-engine speed would reduce rapidly, owing to compression braking in the engine) and the vehicle controller would then allow **vehicle kinetic energy to be returned to the battery via**

> **the electric traction system**. Such use of regenerative braking substantially increases the overall drive-train efficiency.

(Ex. 1106 at 3; emphasis added) (*See also* Ex. 1104 at 1-Fig. 2; Ex. 1105 at 3-Fig. 1).

253. The Bumby Project further emphasizes that the "*second electric motor*" is capable of applying torque to the wheels.

> In this parallel arrangement both the **electric traction motor** and he i.c. engine are **capable of driving the road wheels directly, and independently**, through a common transmission.

(Ex. 1106 at 2-3; emphasis added).

254. Specifically, the Bumby Project discloses that the electric motor is used to apply torque at to start the vehicle from rest and at low loads (i.e., low torque).

> The consequence of the 'free-wheel' in the ic-engine connection also means that **the electric traction system can move the vehicle from rest**, and the ic engine need only be started and synchronised with the drive shaft when load demand is high. It is at such **low-speed low-load situations** that the i c engine is inefficient compared with the **electric traction system**.

(Ex. 1106 at 3; emphasis added).

255. As shown in Table 2, reproduced below and annotated, the Bumby Project discloses several modes of operation, such as Electric mode, Primary

electric mode, and Hybrid mode, highlighted in green, where the traction motor provides for propulsion power, either alone or together with the engine. These modes confirm that the Bumby Project teaches a "*second electric motor*" that is capable of applying torque to the wheels. (Ex. 1105 at 5) (*See also* Ex. 1106 at 3-Table 1).

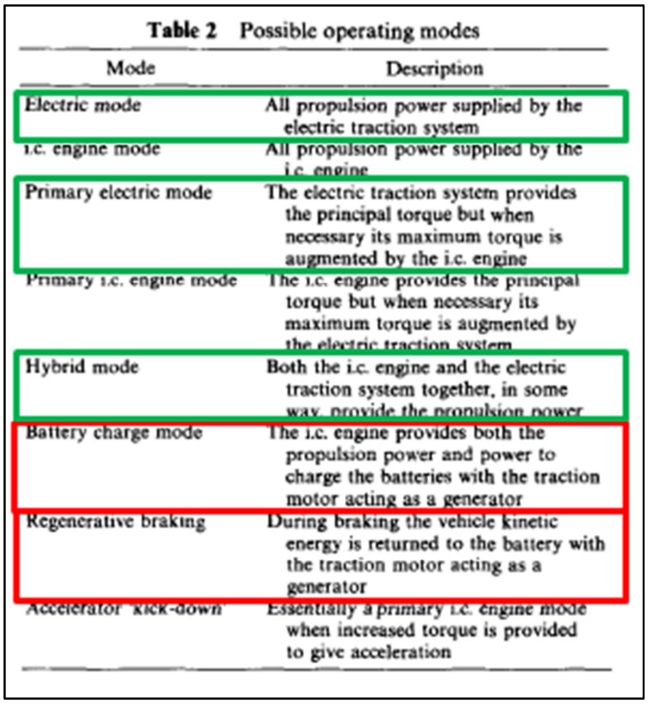


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

256. Table 2 above also discloses a Regenerative braking mode and Battery charge mode, highlighted in red, where the traction motor acts as a generator to accept torque from the wheels to generate current. (Ex. 1105 at 5) (*See also* Ex. 1106 at 3-Table 1; Ex. 1107 at 4-Fig. 1).

257. Specifically, the Bumby Project discloses that during braking when negative torque required for propulsion of the vehicle may be experienced, the

kinetic energy of the vehicle is re-captured using the motor as a regenerative brake mechanism (i.e., operate as a generator) and the electrical current is then returned to the battery.

> [D]uring braking, the ic-engine speed would reduce rapidly … and the vehicle controller would then allow **vehicle kinetic energy to be returned to the battery via the electrical traction system**. Such use of regenerative braking substantially increases the overall drive-train efficiency.

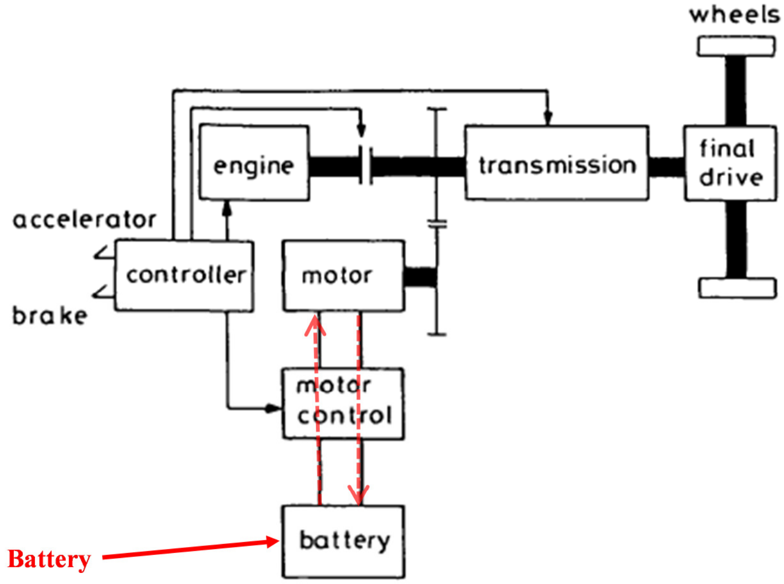
(Ex. 1106 at 3; emphasis added).

258. Therefore, it is my opinion that the Bumby Project discloses "*a second electric motor connected to road wheels of said vehicle, and operable as a motor, to apply torque to said wheels to propel said vehicle, and as a generator, for accepting torque from at least said wheels for generating current*."

… [1.4] a battery, for providing current to said motors and accepting charging current from at least said second motor; and

259. As shown in Fig. 2 from Bumby II, annotated below, the Bumby Project discloses a battery connected to the motor via the "motor controller" that operates to allow current power to be provided to the motor. The motor controller also operates to accept current from the motor for charging the battery. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

260. As shown in Table 2, reproduced below and annotated, the Bumby Project discloses several modes of operation, highlighted in green, where the battery supplies current to the "*second electric motor*." For example, Table 2 discloses an "Electric mode" where "All propulsion power supplied by the electric traction system."(Ex. 1105 at 5)(*See also* Ex. 1106 at 3-Table 1).

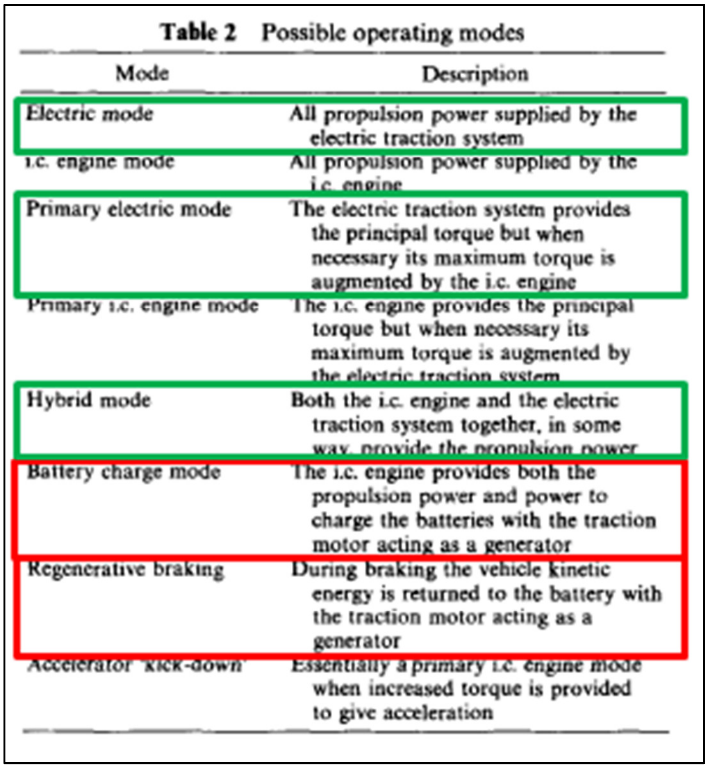


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

261. Table 2 further provides several modes, highlighted in red, where the battery accepts current from the "*second electric motor*." For example, in "Battery charge mode - The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator" or "Regenerative braking - During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator." (Ex. 1105 at 5)(*See also* Ex. 1106 at 3-Table 1).

262. The Bumby Project also states that the battery is charged by the "*second electric motor*" during regenerative braking.

> [T]he energy drained from the battery during motoring is replaced by energy recovered during regenerative braking.

(Ex. 1104 at 5).

263. To the extent that the Bumby Project does not expressly disclose that a "*first electric motor*" that receives current from the battery, it would have been well known and obvious to a person of ordinary skill in the art to provide current the disclosed "*first electric motor*" (i.e., starter motor) when operated to start the engine. It was well known in the art that the battery must be connected to power the starter motor when engine starting is required. (Ex. 1134 at 23).

264. Indeed, in describing the engine starting sequence using the starting motor, the Bumby Project discloses that during a failed engine start sequence the "starter motor is disengaged, to allow battery recovery." (Ex. 1107 at 6). This disclosure confirms that the "*first electric motor*" (i.e., starter motor) receives current from the battery in order to operate and start the engine.

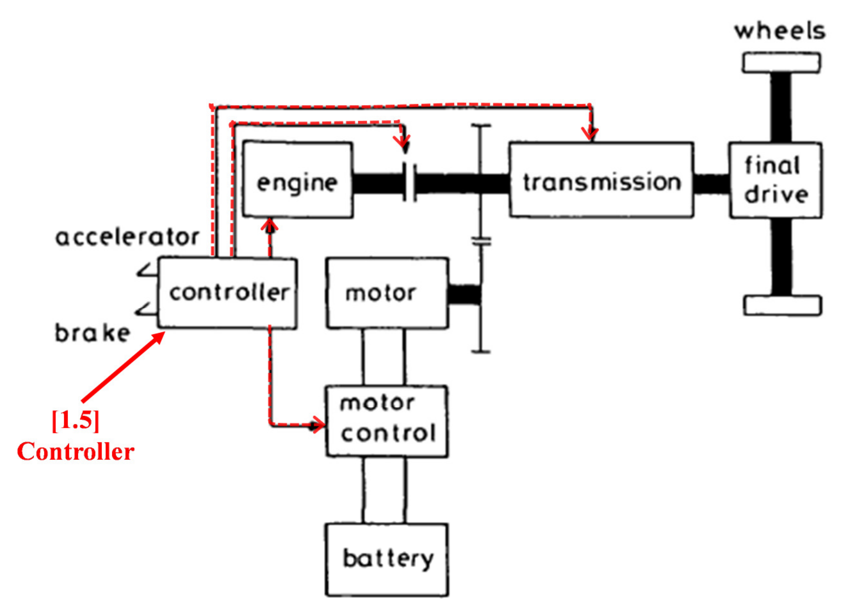
265. Therefore, it is my opinion that the Bumby Project discloses "*a battery for providing current to the motors and accepting charging current from at least the second motor.*"

> … ***[1.5] a controller for controlling the flow of electrical and mechanical power between said engine, first and second motors, and wheels,***

266. As shown in Fig. 2 from Bumby II, annotated below, the Bumby Project discloses a controller is programmed to manage the allocation of electrical

and mechanical power between the motor, engine, battery for supplying torque to propel the vehicle to the wheels. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

267. The Bumby Project discloses the necessity of the controller to apportion power between multiple propulsion sources that include the engine and motor:

> With the presence of two on-board power sources, optimum scheduling of the drive is best looked after by a microprocessor controller.

(Ex. 1106 at 2).

268. The Bumby Project confirms the importance of a controller for controlling the flow of electrical and mechanical power from the mechanical and

electrical systems.

> The M68000 **<u>microprocessor system is the heart of the drivetrain control system</u>** and has two main tasks to perform. First, it must implement the hybrid-vehicle control strategy which means **<u>controlling the electric traction system, ic engine and transmission in the most efficient way to meet driver demand</u>**. Second, during a test, it must act as a data logger.

(Ex. 1106 at 4).

269. As discussed above in limitation [1.2], the controller further controls the electrical and mechanical energy provided by the "*first electric motor*" when used to start the engine.

270. The Bumby Project also discloses that the controller determines between the operating modes illustrated below, so that the appropriate electrical and mechanical power can be provided by the combination of the engine, "*first electric motor*" (i.e. to start the engine), and the "*second electric motor*" to and from the wheels.

> In addition, depending on the driving situation, battery state of charge, etc, the vehicle **<u>controller must be capable of deciding which mode of operation</u>** listed in Table 1 is most appropriate.

(Ex. 1106 at 3-Table 1). (*See also* Ex. 1105 at 5-Table 2; Ex. 1107 at 4-Table 1).

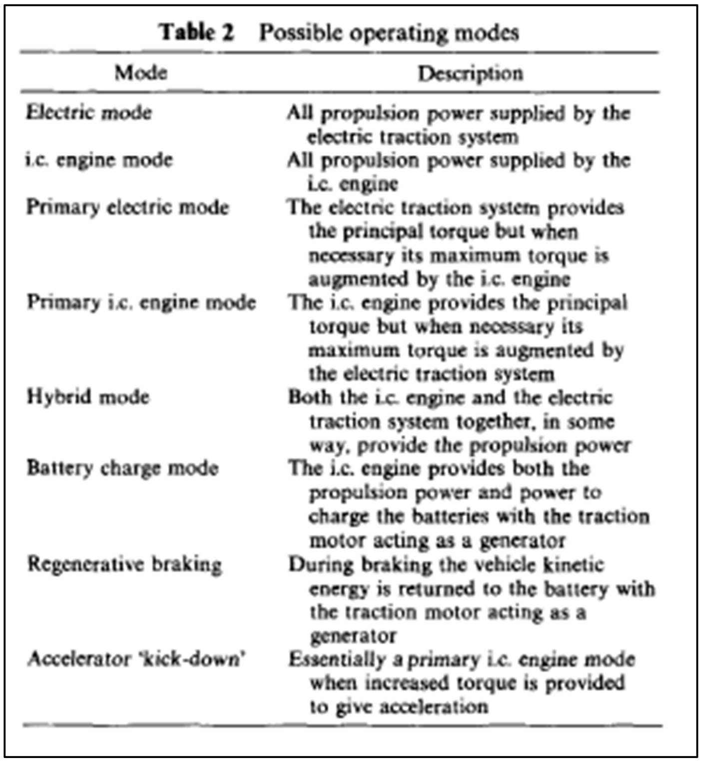


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

271. The Bumby Project also discloses that the controller controls loading between the engine, motors:

> In order to meet either of these objectives the control system must be able accurately to schedule total vehicle loading between the engine and motor and control the transmission.

(Ex. 1107 at 19).

272. Therefore, it is my opinion that the Bumby Project, whether the publications are looked at alone or in combination, discloses, "*a controller for controlling the flow of electrical and mechanical power between the engine, the motors, and the wheels.*"

… [1.6] wherein said controller starts and operates said engine when

> ***torque require to be produced by said engine to propel the vehicle and/or to drive either one or both said electric motor(s) to charge said battery is at least equal to a setpoint (SP) above which said engine torque is efficiently produced, and***

273. It is my understanding that the term “setpoint (SP)” or the abbreviation “SP” as used in claim 1 is proposed to mean a “predetermined torque value.”

274. Further, it is my understanding that “A <u>and/or</u> B” in the claim is meant to be interpreted to mean “Element A,” “Element B” or “Element A and Element B.”

275. As this is applied to this limitation of claim 1, it is my understanding that limitation[1.6] of claim 1 includes the following elements:

> **Element A** - *controller starts and operates said engine when torque require to be produced by said engine <u>to propel the vehicle</u> … is at least equal to a predetermined torque value above which said engine torque is efficiently produced.*
>
> AND/OR
>
> **Element B** - *controller starts and operates said engine when torque require to be produced by said engine … <u>to drive either one or both said electric motor(s) to charge said battery,</u> is at least equal to a predetermined torque*

value above which said engine torque is efficiently produced.

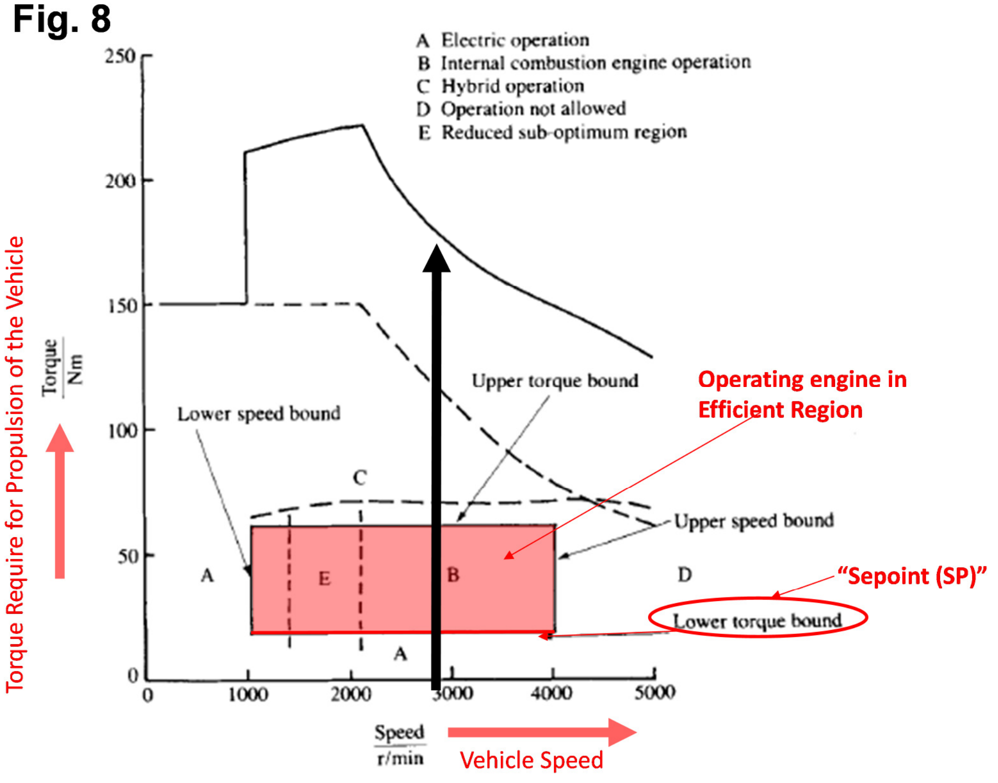
276. First, as explained above in limitation [1.2], the Bumby Project discloses that a conventional starter motor is used to start the engine.

> **<u>To improve power-train efficiency</u>** when the engine is not in use it is shut down. Thus, **<u>when power from the ic engine is demanded by the vehicle controller, the M68000 system must activate the ignition and start the engine</u>**. This is done using the conventional starter motor. To accommodate this control requirement, a microprocessor-controlled starting system is connected in parallel with the operator's main control panel.

(Ex. 1106 at 7).

277. Next, the Bumby Project identifies an engine "*setpoint,*" or predetermined torque value, as a "lower torque bound" as shown the Fig. 8 from Bumby III, reproduced below. (Ex. 1105 at 8; *see also* Ex. 1104, Fig. 16 at 11).

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

278. The Bumby Project discloses that the engine is started using the "*first electric motor*" and then engaged to the drivetrain when the vehicle speed (i.e., above the "lower speed bound" and below the "upper speed bound") and instantaneous torque required for propulsion of the vehicle (i.e., "lower torque bound" and "upper torque bound) are within the engine's maximum efficiency region that I have highlighted in red. Specifically, the Bumby control strategy states that the control strategy:

> **<u>[R]estricts the operation of the i.c. engine to the high-efficiency region</u>**. This algorithm accepts demand power as its control variable and, by sensing road speed, transforms this power to a torque at the

> output of the transmission. Demand power, as far as the simulation is concerned, is simply transmission output power, but in reality would be driver-demand power, expressed as a function of accelerator pedal position. Knowing the fixed transmission ratios available, a set of torque and speed values at the torque split point can be defined, the number of which will correspond to the number of discrete gear ratios available.
>
> By defining an **operating region or 'box' around the i.c. engine maximum efficiency region as shown in Fig. 8** then a region of acceptable engine performance is defined. **The control algorithm always seeks to place the i.c. engine operating point within the 'box'** using the available transmission ratios.

(Ex. 1105 at 7; *see also* Ex. 1104 at 10-11).

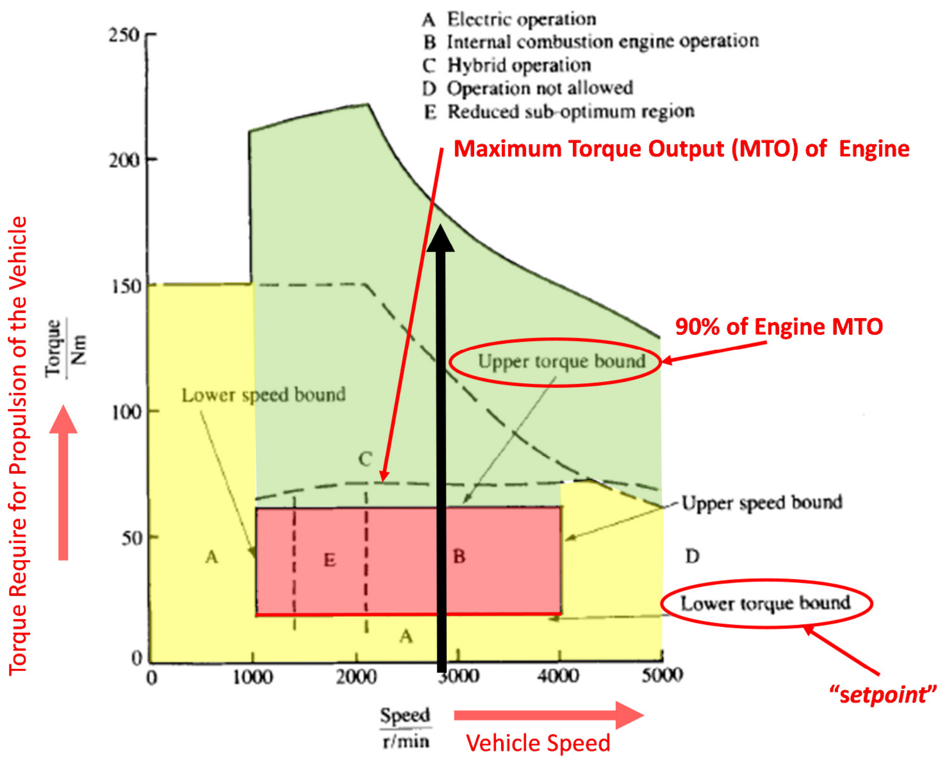
279. The Bumby Project discloses that limiting engine operation to this defined region, highlighted in red, improves efficiency by eliminating "inefficient use of the engine." (Ex. 1104 at 11).

280. The "lower torque bound" is one setpoint that is used by the Bumby Project to ensure that the engine only operates when engine torque is efficiently produced. As I discussed above, Bumby also uses an "upper torque bound" as well as a "lower speed bound" and "upper speed bound." By setting all four of these speed and torque thresholds, the Bumby Project is able to restrict engine operation to its most efficient operating region. The "lower torque bound" does meet the proposed construction of "predetermined torque value." As I further explain with

reference to limitation [7.0], the “lower torque bound” is also approximately 30% of the engine’s maximum torque output (i.e., MTO).

281. Further, the Bumby Project fully discloses a control strategy for controlling a hybrid vehicle. This control strategy is illustrated below in Fig. 8, further annotated below. (Ex. 1105 at 8; *see also* Ex. 1104, Fig. 16 at 11). As I have annotated above, the maximum torque output capabilities of the engine, the maximum torque output capabilities of the motor and the combined maximum torque output capabilities of the engine and motor are used in the control strategy. The control strategy further applies the “lower torque bound” below which engine operation is not allowed and an “upper torque bound” above which both the engine and motor are used to propel the vehicle. The control strategy includes a defined region “B/E” that illustrates operation of the engine alone. This engine operation region is the area where engine torque is most efficiently produced. By defining the engine operation region, the controller will operate the engine to provide the torque required for propulsion of the vehicle when the vehicle speed and torque are within this region.

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

282. As shown, the control strategy will also take into account the vehicle speed and vehicle torque in order to determine the mode of operation hybrid vehicle. The control strategy will also determine operation of the vehicle based solely on the instantaneous torque required for propulsion of the vehicle when the vehicle speed remains constant. For instance, as I illustrate with the black arrow above, when the vehicle speed is approximately 3000 RPM, the operational mode of the vehicle is determined solely based on the torque requirements. If the torque requirements increase (e.g., during a hill-climb) and the driver wishes to maintain the same speed of 3000 RPM, the vehicle controller will switch form motor only

mode, to engine mode, to motor + engine mode. The switch between these different modes provides the desired torque output at the wheels to meet that vehicle speed. If the vehicle didn't change modes (e.g., stayed in motor only mode) the vehicle might begin to slow down. This would be undesirable as the driver has indicated that maintaining the speed of 3000 RPM is desired.

283. The Bumby Project discloses "Element A" of claim 1 of the '347 Patent. Specifically, the Bumby Project discloses that the engine is started and operated in region "B/E" (highlighted in red) when the vehicle speed is above the lower speed bound and the torque required to propel the vehicle is above the lower predetermined value (i.e., "*setpoint SP*") that is disclosed as being the "lower torque bound."

> To implement this control, the suboptimal control algorithm converts the instantaneous power and speed requirement into a torque and speed demand, at the torque split point for each available gear ratio. **If one of this family of operating points falls within the engine operating box, then that gear and IC engine operation is selected**. This ensures maximum engine efficiency.

(Ex. 1104 at 11; emphasis added).

284. The Bumby Project also discloses "Element B" of claim 1 of the '347 Patent. The Bumby Project discloses that controller starts and operates said engine to charge said battery during either a "battery-charge mode" and a "hybrid mode."

> the i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator.

(Ex. 1106 at 3-Table 1)(*see also* Ex. 1105 at 5-Table2).

> (b) hybrid mode: used when battery state of charge is low, or when either a greater range or improved mid- to high-speed performance is required than that provided in the electric mode (used for medium length journeys).
>
> ***
>
> A default to the hybrid mode would be included. Providing the battery state of charge is above a prescribed value, then the driver preferred mode would be selected. Below the prescribed battery state of charge the energy-saving mode would be selected. If battery state of charge then falls further and reaches a lower value, then the battery charging mode would be initiated and maintained until the battery state of charge had recovered sufficiently to revert to the energy-saving mode. Electric and hybrid mode would be selected. If battery state of charge require substantial battery charge, and to provide this from the engine via the battery charge mode is not attractive.

(Ex. 1104 at 13).

285. It would have been obvious that the engine is operated to drive the generator to charge the battery during the disclosed "battery-charge mode" or "hybrid mode." It was well-known that during a battery charge mode the motor operates as a generator to provide back torque against the engine. This torque would be in addition to the torque required by the engine for propulsion of the

vehicle. Further, the torque provided by the generator (i.e., motor) and the roads would be such that the engine would be operation within its most efficient operating region "E/B." Indeed, the Bumby Project would not have included both a "hybrid mode" and "battery charge mode" if one of these two operating modes did not operate within the engine's efficient operating region. In other words, if the battery state of charge mode did not operate within the engine's most efficient region "B/E" then the "hybrid mode" most likely would. Otherwise, having two modes of operation that perform the same function would be redundant. Also, the hybrid mode is the operational mode that allows "motor only" operation. As such, the hybrid mode is indicated as operating when the state of charge is low, but not critical. As such, the hybrid mode indicates that when the state of charge requires (but does not demand) charging, the engine will operate to charge the battery when the engine is operating within region "B/E."

286. Therefore, it is my opinion that the Bumby Project discloses "*wherein said controller starts and operates said engine when torque require to be produced by said engine to propel the vehicle and/or to drive either one or both said electric motor(s) to charge said battery is at least equal to a setpoint (SP) above which said engine torque is efficiently produced.*"

> *… [1.7]* ***wherein the torque produced by said engine when operated at said setpoint (SP) is substantially less than the maximum torque***

output (MTO) of said engine.

287. As discussed above in reference to limitation [1.6] (¶¶ 281-282), the Bumby Project discloses that the engine is operated only under conditions where the engine output torque is most efficient, as shown in Fig. 8 in Region B/E, highlighted in red. Again, the "lower torque bound" would have been understood as being a lower predetermined torque value (i.e., "*setpoint*").

288. The Bumby Project discloses an upper torque bound that is 90% of the engine's maximum torque output.

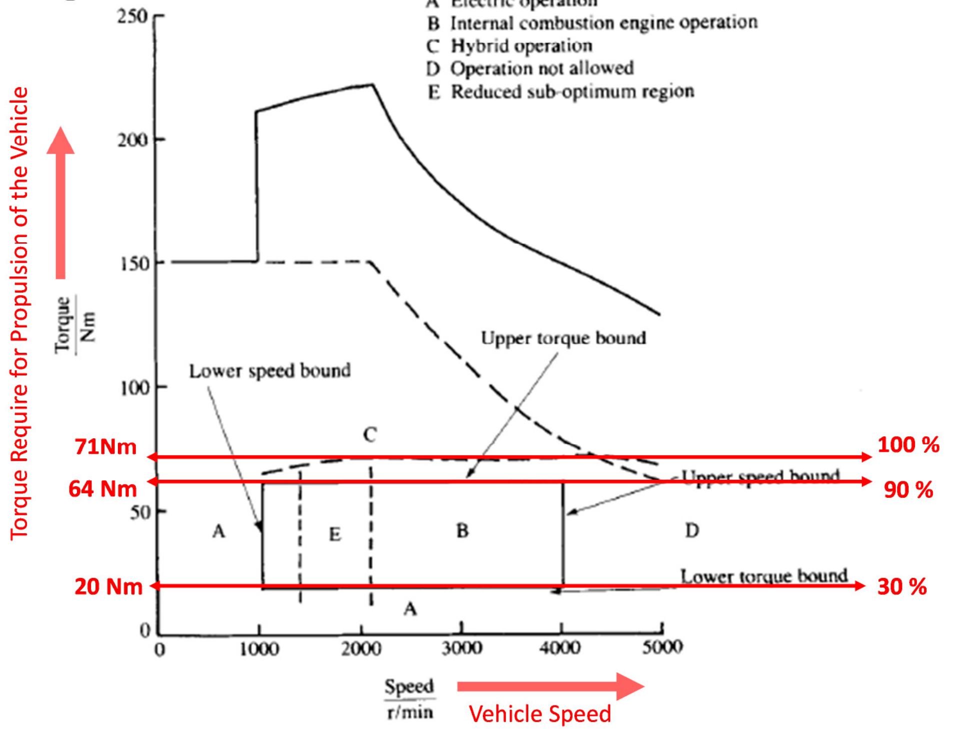
> When in this mode the i.c. engine torque is limited to about 90 per cent of full throttle output in order to maximize the i.c. engine efficiency.

(Ex. 1106 at 7)(*see also* Ex. 1105 at 7)

289. As also discussed above in [1.7], the Bumby Project states that the upper torque bound is a percentage of MTO, as illustrated below. It is evident from the figure below, the lower torque bound (i.e., "*setpoint*") is substantially less than the disclosed upper torque bound of 90% of the engine's maximum torque output.

290. The Bumby Project also discloses that the MTO of the engine is 71 Newton-meters (Nm). (Ex. 1106 at 5, Table 2). That means that the upper torque bound is approximately around 64 Nm (i.e., 90% * 71Nm = 64 Nm).

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

291. Also illustrated above, the lower torque bound is roughly 20 Nm. Based on the math, the lower torque bound is approximately 30% of the maximum torque output of the engine (20Nm/71Nm ~ 28.2%). The Bumby Project therefore discloses a predetermined torque value or "*setpoint*" that is "*expressed as percentages of the maximum torque output of the engine when normally-aspirated*."

292. The lower predetermined torque value of 30% is substantially less than the maximum torque output of the engine. Stated differently, the 20Nm lower torque bound is substantially less than the 71Nm maximum torque output of the

engine.

293. Therefore, it is my opinion that the Bumby Project discloses "*the torque produced by said engine when operated at said setpoint (SP) is substantially less than the maximum torque output (MTO) of said engine*."

B. Claim 7

294. Claim 7 depends from claim 1 which I understand means claim 7 requires all of the limitations of claim 1 in addition to the additional limitations required by limitation [7.0] – [7.3], below.

> … ***[7.0] The vehicle of claim 1, wherein said vehicle is operated in a plurality of operating modes responsive to the value for the road load (RL) and said setpoint SP, both expressed as percentages of the maximum torque output of the engine when normally-aspirated (MTO), and said operating modes include:***

295. It is my understanding that the term "*setpoint SP*" is proposed to mean a "predetermined torque value."

296. I understand that the term "*road load (RL)*" is proposed to mean "the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value."

297. It is my understanding that claim element [7.0] should be interpreted as "*wherein said vehicle is operated in a plurality of operating modes responsive*

to the value for the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value, and said predetermined torque value, both expressed as percentages of the maximum torque output of the engine when normally-aspirated (MTO)."

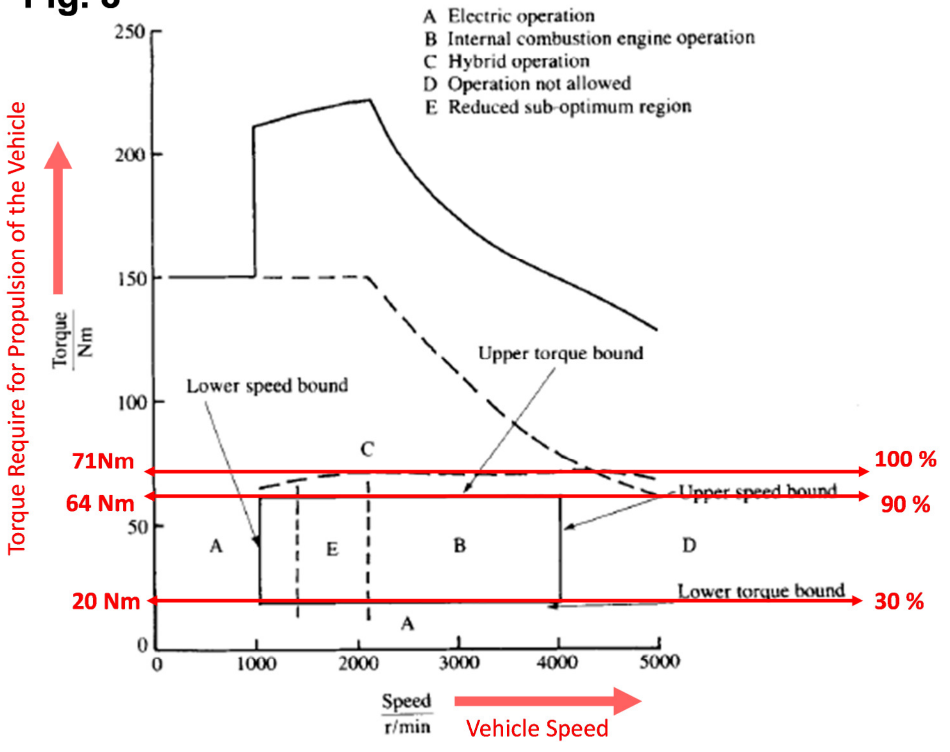
298. As discussed above in reference to limitation [1.6] (¶¶ 277-282), the Bumby Project discloses that the engine is operated only under conditions where the "*torque produced by the engine is efficiently produced.*" Again, this is shown by Fig. 8 in Region B/E, highlighted in red below. Again, the lower torque bound would be understood as the lower predetermined torque value or recited "setpoint".

299. As also discussed above in [1.7] (¶ 288), the Bumby Project states that the upper torque bound is a percentage of MTO, as illustrated below. In fact, the Bumby Project identifies this upper torque bound as being 90% of the engine's maximum torque output when normally aspirated.

300. Again, the Bumby Project also discloses that the MTO of the engine is 71 Newton-meters (Nm). (Ex. 1106 at 5, Table 2). That means that the upper torque bound is approximately around 64 Nm (i.e., 90% * 71Nm = 64 Nm). Also illustrated below, the lower torque bound is roughly 20 Nm. Based on the math, the lower torque bound is approximately 30% of the maximum torque output of the engine (20Nm/71Nm ~ 28.2%). The Bumby Project therefore discloses a predetermined torque value or "setpoint" that is "*expressed as percentages of the*

maximum torque output of the engine when normally-aspirated."

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

301. The Bumby Project also discloses that "road load" or "torque required for propulsion of the vehicle" is expressed as a percentage of the engine's maximum torque output. For example, the Bumby Project discloses "Load factor = load torque expressed as a percentage of engine maximum torque." (Ex. 1105 at 13-14; Table 3 and Table 5) (*see also* Ex. 1104 at 12-Table 3A). "Load torque" as used within the Bumby Project would be understood as describing the "torque required for propulsion of the vehicle."

302. The Bumby Project discloses "hybrid-vehicle control modes" (Ex.

1105 at 5-Table 2). (*See also* Ex. 1106 at 3-Table 1; Ex. 1107 at 4-Table 1).

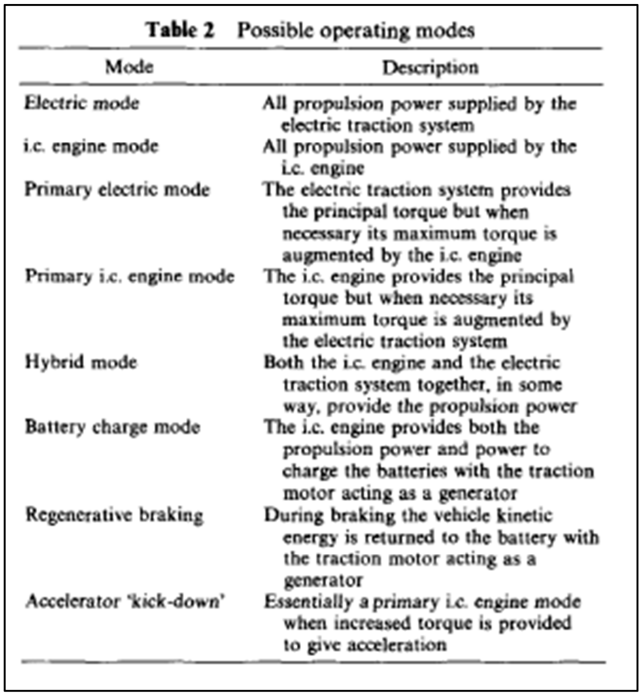


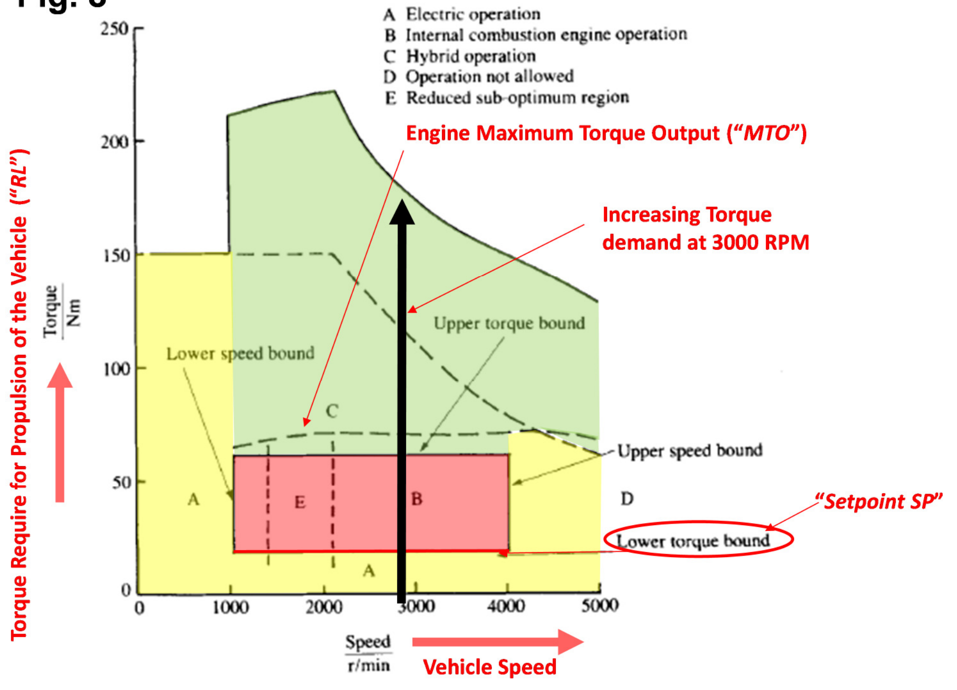
Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

303. Further, as illustrated below in Fig. 8, the Bumby Project further discloses operating the hybrid vehicle, "responsive to the value for the [instantaneous torque required for propulsion of the vehicle] and said setpoint SP." The vertical black arrow illustrates the increasing torque required for propulsion of the vehicle (i.e., "*road load (RL)*") at a constant vehicle speed (e.g. 3000 RPM in this example) As I explained in ¶¶ 281-282 at this constant speed of 3000 RPM, mode operational decisions are based on the torque required for propulsion of the vehicle. For instance, if the vehicle begins to ascend a hill and the driver wishes to maintain the current vehicle speed, the controller may be required to shift from motor only mode to engine mode or to engine+motor mode to maintain that speed. The torque requirements might increase for instance due to the slope (i.e., how

steep) of the hill climb. A moderate slope might not require a change and the torque value would be below the "lower torque bound" thereby allowing continued operation of the vehicle by the motor. However, a more severe slope might greatly increase the torque requirements of the vehicle and require both the motor and engine output combined in order to maintain the current speed. (Ex. 1105 at 8; *see also* Ex. 1104 at Fig. 16 at 11).

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

304. Assuming the speed remains constant, as the "instantaneous torque required for propulsion the vehicle" increases, the vehicle controller will change the mode of operation, as shown in Fig. 8 above.

305. For example, at torque requirements below the "lower torque bound," (i.e. "*setpoint SP*") the engine operation is inefficient and the electric motor is used to propel the vehicle, in region A, highlighted in yellow. (Ex. 1106 at 3; Ex. 1105 at 7-8; Ex. 1104 at 10-11).

306. As the "instantaneous torque required for propulsion of the vehicle" increases and exceeds past the "lower torque bound," the engine is started so that the engine is used in the efficient region B, highlighted in red. (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 7-8; Ex. 1104 at 10-11). Lastly, as the "instantaneous torque required to propel the vehicle" increases past the upper torque bound, the vehicle operates in a "hybrid mode" where the engine and motor are both operated to propel the vehicle in region C, highlighted in green (Ex. 1105 at 7-8; Ex. 1104 at 10-11)

307. Such operational mode changes would occur based on the conditions experienced during driving, such as acceleration or hill climbing. In fact, Bumby itself recognizes that operational mode changes could occur during both acceleration and hill climbing. These mode changes could result in the torque required for propulsion of the vehicle being either negative or positive in value.

> When necessary, the engine torque can be augmented by the motor for rapid acceleration or hill climbing. Typically, the **recognizes both uphill and downhill driving conditions**. Typically, the motor will be

> used to provide extra power if the engine output would otherwise exceed 90% of maximum, since this leads to inefficiency.

(Ex. 1107 at 4, emphasis added).

308. For example, the Bumby Project discloses the torque required to propel the vehicle may be positive based on an operator command for acceleration, or negative based on an operator command for deceleration by pressing the brake pedal.

> **These algorithms interact directly with both the driver commands through brake- and accelerator-pedal movement**, and communicate their requirements to the units responsible for the control of the drive-line components themselves.

(Ex. 1106 at 3, emphasis added).

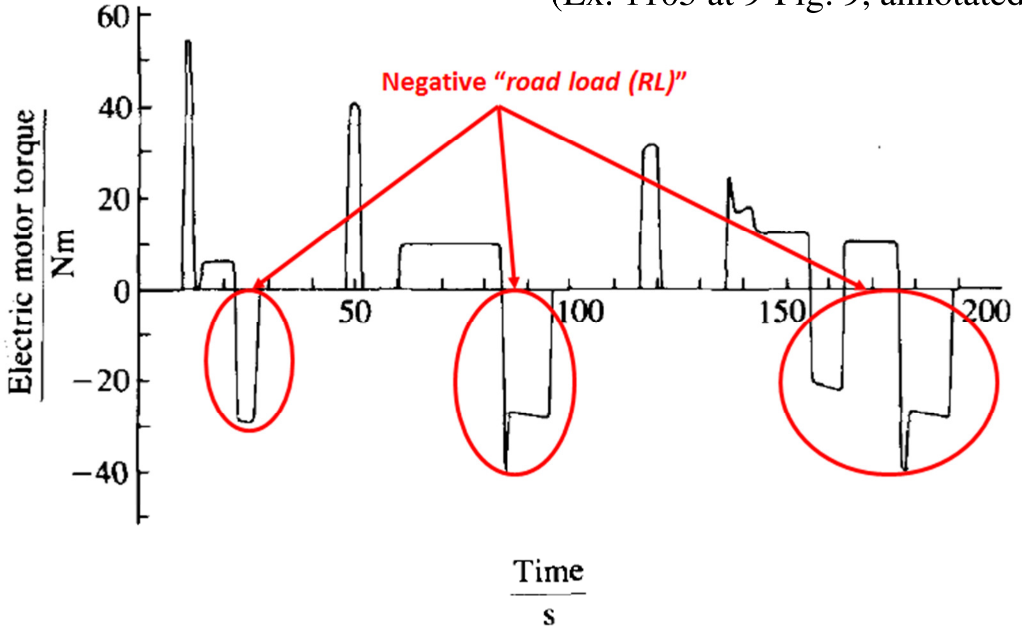
309. When the vehicle is going up the hill, or when the driver requests the vehicle accelerate, it is understood that the torque required for propulsion of the vehicle may be positive. As anyone who has ever driven a vehicle would have experienced, when the vehicle ascends the hill, if the driver does nothing, the weight of the vehicle will cause the vehicle to decelerate due to gravity. This is a commonly known and experienced phenomenon. Therefore, the torque required for propulsion of the vehicle is positive when the vehicle is traveling up a hill. Therefore, the driver needs to press the accelerator pedal to either maintain the same speed or to accelerate up the hill. Likewise, anyone who has ever wanted to

pass a vehicle understands that in order for the vehicle to accelerate, the driver must further press the accelerator pedal to accelerate past the other vehicle. Such acceleration also requires positive torque to propel the vehicle

310. Conversely, when the vehicle is going down a hill the torque required to propel the vehicle could be negative (i.e., traveling down a steep hill). As anyone who has ever driven a vehicle would have experienced, when the vehicle descends down a hill, if the driver does nothing, the weight of the vehicle will cause the vehicle to accelerate due to gravity. This is a commonly known and experienced phenomenon. Therefore, the torque required for propulsion of the vehicle may decrease or possibly become negative when the vehicle. Therefore, the driver needs to press the brake pedal to keep from accelerating.

311. Furthermore, it was understood that the torque required for propulsion of the vehicle could also be negative when the vehicle is charging the battery. For, example, in Fig. 9 from Bumby III, annotated below, the Bumby Project illustrates negative road as seen by the motor over the drive cycle. The Bumby Project discloses using this negative road load as kinetic energy during the "Regenerative braking mode" to charge the battery with the "*second electric motor*" acting as a generator.

(Ex. 1105 at 9-Fig. 9, annotated)



(c) Electric motor torque

312. Furthermore, the Bumby Project discloses that the above control strategy determines the "instantaneous torque required for propulsion of the vehicle" in order to overcome external forces that act on the vehicle:

> To implement this optimization process over an urban driving cycle such as the ECE-15 (Fig. 3) or the J227a-D (Fig. 4) **the torque required at the road wheels to overcome both vehicle drag and rolling resistance, and to provide any vehicle acceleration**, is determined at discrete (typically one second) intervals.

(Ex. 1105 at 5, emphasis added).

313. As I discussed above in paragraphs 113-121 above, these disclosed external forces accounted for by the Bumby Project, which the vehicle powertrain must overcome, are the calculated textbook definition of "road load" forces.

314. The Bumby Project further confirms that the control strategy accounts for road load forces when determining the vehicle requirements for speed/torque:

> At each drivetrain component full account is taken of efficiency, which may **vary with both torque and speed, so that the calculated energy consumed accounts for both the road load requirement** and the system losses.

(Ex. 1105 at 5, emphasis added).

315. Similarly, the Bumby Project states that the vehicles' propulsion system must be account for and provide sufficient "tractive effort" force at the road wheels in order to overcome these external textbook "road load" forces. In other words, the Bumby Project discloses determining the instantaneous torque required for propulsion of the vehicle.

> To provide the necessary propulsion power, any vehicle drive train must be able to **provide sufficient tractive effort at the road wheels to overcome aerodynamic drag, rolling resistance and hill gradient** effects, while still providing the necessary vehicle acceleration.

(Ex. 1104 at 2, emphasis added)

316. As I discussed in paragraphs 113-115 above, it was well-known that the sum of these external forces are the **textbook definition of "road load"** that act on the vehicle. For instance, when the vehicle is driving on a windy day, the driver may press the accelerator pedal requesting additional torque.

317. Therefore, it is my opinion that the Bumby Project discloses "*said vehicle is operated in a plurality of operating modes responsive to the value for the road load (RL) and said setpoint SP, both expressed as percentages of the maximum torque output of the engine when normally-aspirated (MTO).*"

> … ***[7.1] a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery, while RL<SP,***

318. It is my understanding that the term "*setpoint SP*" is proposed to mean a "predetermined torque value."

319. It is my understanding that the term "*road load (RL)*" is proposed to mean "the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value."

320. It is my understanding that "*low-load mode I*" is proposed as meaning "the mode of operation in which energy from the battery bank flows to the traction motor and torque (rotary force) flows from the traction motor to the road wheels."

321. Based on these proposed constructions it is my understanding that this claim limitation should be interpreted as "*the mode of operation in which energy from the battery bank flows to the traction motor and torque (rotary force) flows from the traction motor to the road wheels, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from*

said battery, while the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value, is less than the predetermined torque value."

322. As shown in Table 2, below, the Bumby Project discloses an "electric mode" where "all propulsion power is supplied by the electric traction system." (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 11-12). Again, as I explained in ¶ 84 above, using both the motor during lower torque requirements were engine operation is inefficient was known and disclosed by a 1976 hybrid vehicle designed and tested by Ford Motor Company.

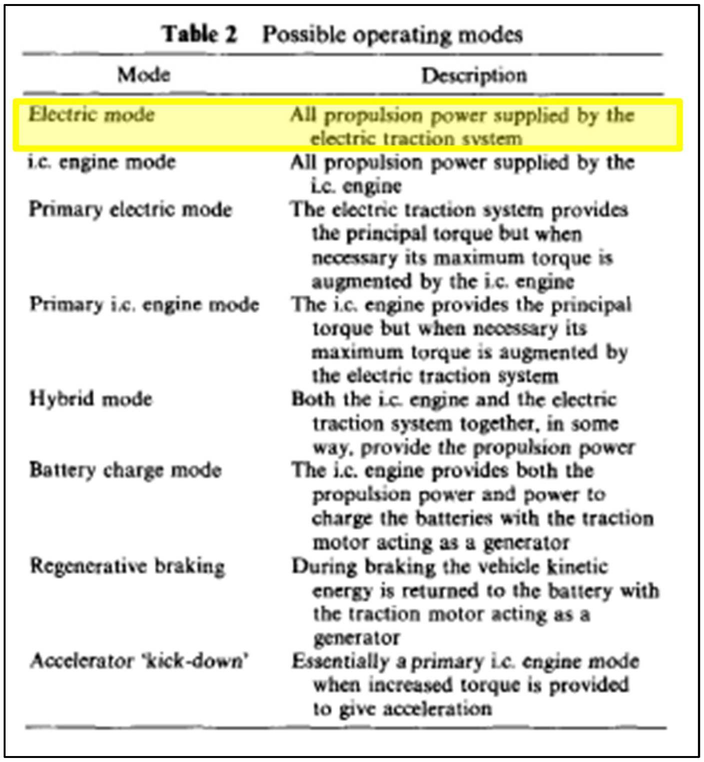


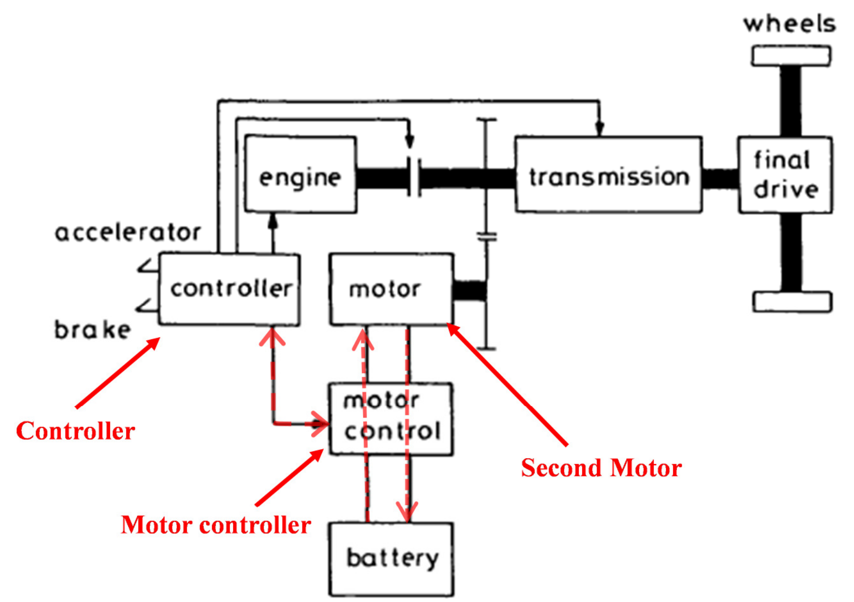
Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

323. As discussed above in [1.5] (¶¶267-270), a "motor control," is connected to the controller and in between the battery and motor. It is obvious

from the figure alone that the “motor control” is used to control the battery to supply energy when operation of the electric motor is required in the “Electric mode.” It is also obvious that the decision to operate in “electric mode” would be provided by the main system “controller” based in response on feedback from the system and the driver’s commands.

Fig. 2

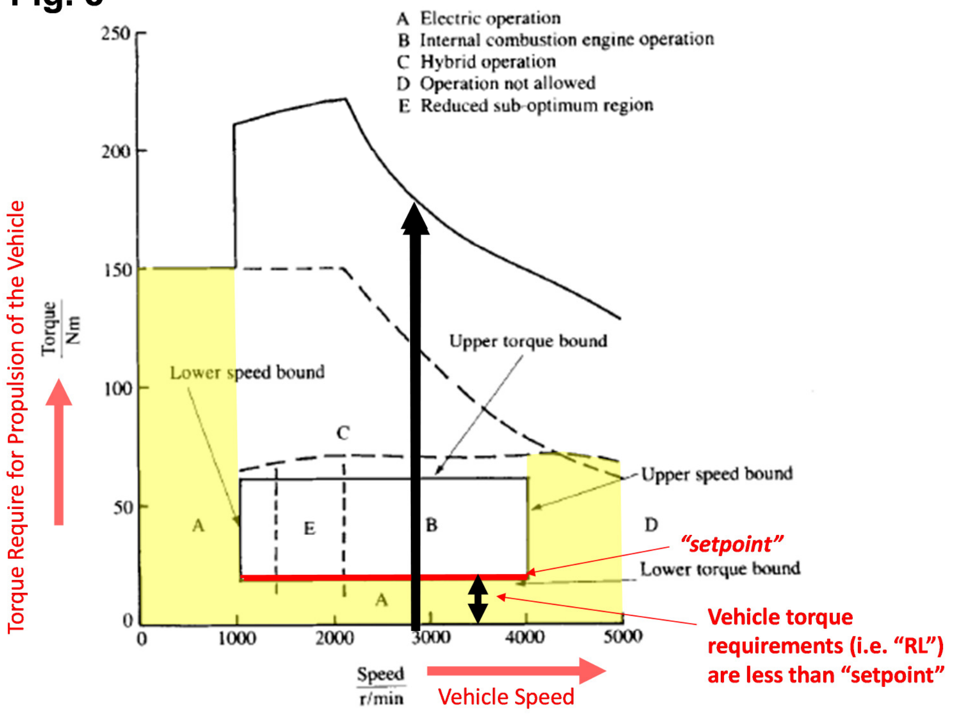


(Ex. 1104 at 1-Fig. 2, annotated)

324. Further, Fig. 8 illustrated below discloses that when the vehicle torque is below a lower speed bound and lower torque bound, the vehicle is propelled only by the traction motor in region A, highlighted in yellow, as shown below. Specifically, when the vehicle is below the lower predetermined torque value (i.e., “*setpoint*”) the torque required for propulsion of the vehicle is provided by the

motor alone. (Ex. 1105 at 8; *see also* Bumby II, Fig. 16 at 11).

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

325. In discussing the figure above, the Bumby Project further confirms that only the electric motor is operated in region A:

> This box region is defined by an upper and lower torque bound and an upper and lower speed bound, the values of which are dependent on the particular hybrid philosophy. Within this box, engine-only operation is favoured while, when the operating point is outside this box, the selected mode of operation depends on the actual torque and speed values. **Below the lower torque bound and the lower speed bound, all-electric operation is favoured**. This eliminates inefficient use of the engine. Above the upper torque bound, true hybrid

> operation is used with the electric motor supplying the excess torque above the maximum available from the engine.

(Ex. 1104 at 10-11, emphasis added)

326. The Bumby Project further confirms that the motor is operated when the torque required to propel the vehicle falls below of the "box" of the efficient engine operation, i.e. region B/E. Specifically, the Bumby Project discloses that the electric motor is used to apply torque in low load, low speed situations.

> By defining an operating region or 'box' around the i.c. engine maximum efficiency region as shown in Fig. 8 then a region of acceptable engine performance is defined. The control algorithm always seeks to place the i.c. engine operating point within the 'box' using the available transmission ratios. If no points occur in the By defining an operating region or 'box' around the i.c. engine maximum efficiency region as shown in Fig. 8 then a region of acceptable engine performance is defined. The control algorithm always seeks to place the i.c. engine operating point within the 'box' using the available transmission ratios. **If no points occur in the box and all points fall below or to the left of the box, then the electric mode of operation is selected**."

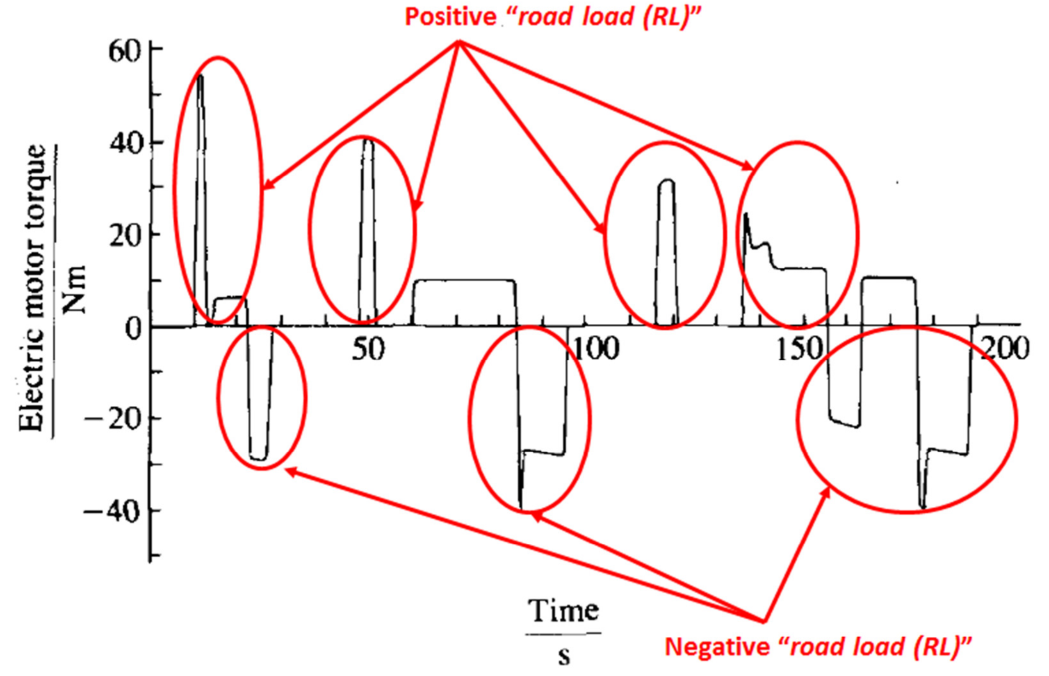
(Ex. 1105 at 7-8, emphasis added).

> The consequence of the 'free-wheel' in the ic-engine connection also means that the electric traction system can move the vehicle from rest, and the ic engine need only be started and synchronised with the drive shaft when load demand is high. It is at such **low-speed low-load**

> **<u>situations</u>** that the i c engine is inefficient compared with the electric traction system.

(Ex. 1106 at 3, emphasis added).

327. Again, as illustrated below the torque required for propulsion of the vehicle when provided by the motor may be negative (e.g., during regenerative braking or during steep downhill slopes) or positive (e.g., during hard acceleration of the vehicle or steep uphill slopes).



(c) Electric motor torque

(Ex. 1105 at 9-Fig. 9, annotated)

328. Therefore, it is my opinion that the Bumby Project discloses "*a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery, while RL<SP*."

… [7.2] a highway cruising mode IV, wherein said vehicle is propelled

by torque provided by said internal combustion engine, while SP<RL<MTO, and

329. It is my understanding that the term "*setpoint SP*" is proposed to mean a "predetermined torque value."

330. It is also my understanding that the term "*road load (RL)*" is proposed to mean "the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value."

331. It is also my understanding that the term "*highway cruising mode IV*" is proposed to mean "the mode of operation in which energy flows from the fuel tank into the engine and torque (rotary force) flows from the engine to the road wheels."

332. It is my understanding that this claim limitation should therefore be interpreted as "*the mode of operation in which energy flows from the fuel tank into the engine and torque (rotary force) flows from the engine to the road wheels, wherein said vehicle is propelled by torque provided by said internal combustion engine, while the predetermined torque value is less than the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value, and the instantaneous torque required to propel the vehicle, which may be both positive and negative in value, is less than the maximum torque output of the engine.*"

333. As discussed above in reference to limitation [1.6] (¶¶267-270) above, the Bumby Project discloses that the engine is operated only under conditions where the engine output torque is most efficient. This efficient engine operation region is shown by the control strategy illustrated in ¶ 337 Region B/E, highlighted in red. The lower torque bound is a lower predetermined torque value or "*setpoint SP*."

334. More specifically, as shown in Table 2, below the Bumby Project illustrates and discloses "i.c. engine mode" where "all propulsion power is supplied by the i.c. engine." (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 11-12). The below table also illustrates a "hybrid mode" where the power provided by the ic engine and electric traction motor are split according to the control strategy illustrated in in ¶ 337 below. Again, as I explained in ¶ 84 above, using the engine alone when the vehicle torque requirements would allow efficient operation of the engine was known and disclosed by a 1976 hybrid vehicle designed and tested by Ford Motor Company.

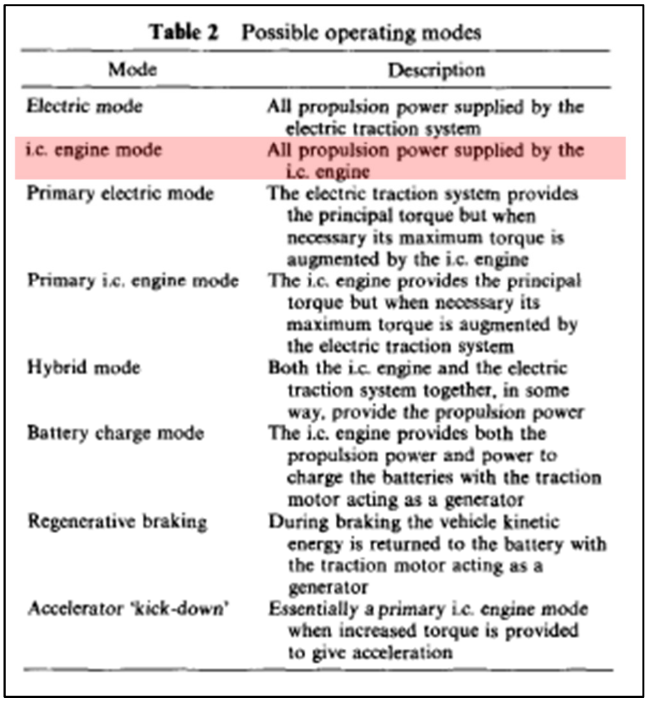


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

335. The Bumby Project further discloses that the engine is only connected to propel the road wheels when the torque required for propulsion of the vehicle is above the lower predetermined torque value where engine torque is efficiently produced:

> the ic engine is connected through a ’one-way clutch’ or ’freewheel’...The consequence of the ’free-wheel’ in the ic-engine connection also means that the electric traction system can move the vehicle from rest, and **the ic engine need only be started and synchronised with the drive shaft <u>when load demand</u> is high**. It is at such low-speed lowload situations that the ic engine is inefficient compared with the electric traction system.

(Ex. 1106 at 3; Emphasis added).

336. The Bumby Project discloses that the power split between when the

engine is activated to operate is based on the engine's maximum efficiency region "box".

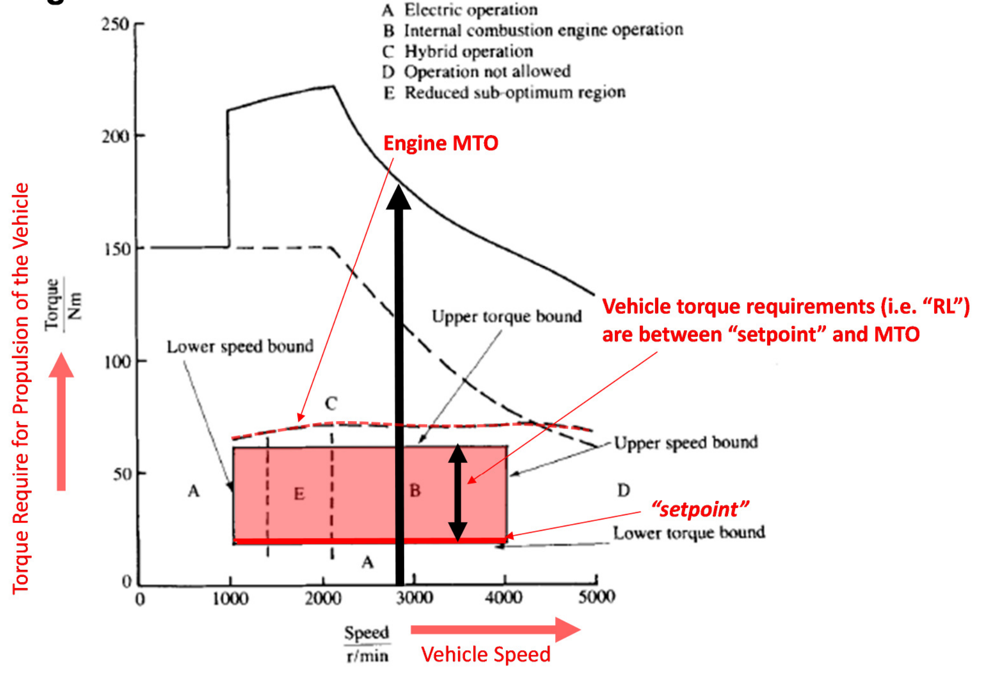
> **[The control strategy] seeks to restrict the operation of the i.c. engine to the high-efficiency region.** This algorithm accepts demand power as its control variable and, by sensing road speed, transforms this power to a torque at the output of the transmission. Demand power, as far as the simulation is concerned, is simply transmission output power, but in reality would be driver-demand power, expressed as a function of accelerator pedal position. Knowing the fixed transmission ratios available, a set of torque and speed values at the torque split point can be defined, the number of which will correspond to the number of discrete gear ratios available.
>
> **By defining an operating region or 'box' around the i.c. engine maximum efficiency region as shown in Fig. 8** then a region of acceptable engine performance is defined. The control algorithm always seeks to place the i.c. engine operating point within the 'box' using the available transmission ratios.

(Ex. 1105 at 7; Emphasis added) (*see also* Ex. 1104 at 10-11).

337. Again, as illustrated below in Fig. 8, the Bumby Project discloses operating the hybrid vehicle, "responsive to the value for the [instantaneous torque required for propulsion of the vehicle] and said setpoint SP." The vertical black arrow illustrates the increasing torque required for propulsion of the vehicle (i.e., "*road load (RL)*") at a constant vehicle speed (e.g. 3000 RPM in this example). As

I explained in ¶¶ 281-282 at this constant speed of 3000 RPM, mode operational decisions are based on the torque required for propulsion of the vehicle. For instance, if the vehicle begins to ascend a hill and the driver wishes to maintain the current vehicle speed, the controller may be required to shift from motor only mode to engine mode when the torque requirements exceed the "lower torque bound" (i.e., RL > SP). Engine only operation will also be maintained if the vehicle torque requirements do not exceed the "upper torque bound" which is 90% of the engine's maximum torque output (MTO). Alternatively, the transition to engine only mode might occur during a decreasing torque requirement (e.g., when a vehicle is descending a hill). For instance, when a vehicle is ascending a hill the torque requirements might be above the engine's MTO thereby requiring propulsion by both the engine and motor. If the vehicle then reaches the top of the hill and begins to descend the hill, the torque requirements may decrease such that operation transitions from operation in region "C" (Motor + Engine) to operation in region "B/E" (Engine only). Thus, when the torque required for propulsion of the vehicle falls in the Region "B/E," highlighted in red, the vehicle is propelled only by the engine, as shown below:

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

338. Therefore, it is my opinion that the Bumby Project discloses "*a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine, while SP<RL<MTO.*"

> *… **[7.3] an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine and by torque provided by either or both electric motor(s) in response to energy supplied from said battery, while RL>MTO.***

339. It is my understanding that the term "*setpoint SP*" is proposed to mean a "predetermined torque value."

340. It is also my understanding that the term "*road load (RL)*" is proposed

to mean “the instantaneous torque required for propulsion of the vehicle, which may be both positive and negative in value.”

341. It is also my understanding that the term “*acceleration mode V*” is proposed to mean “the mode of operation in which energy flows from the fuel tank to the engine and from the battery bank to at least one motor and torque (rotary force) flows from the engine and at least one motor to the road wheels.”

342. It is my understanding that this claim limitation should therefore be interpreted as “*the mode of operation in which energy flows from the fuel tank to the engine and from the battery bank to at least one motor and torque (rotary force) flows from the engine and at least one motor to the road wheels, wherein said vehicle is propelled by torque provided by said internal combustion engine and by torque provided by either or both electric motor(s) in response to energy supplied from said battery, while the torque required for propulsion of the vehicle, which may be positive or negative in value, is greater than the maximum torque output of the engine.*”

343. As discussed above in reference to limitation [1.6] (¶¶267-270) above, the Bumby Project discloses that the engine is operated only under conditions where the engine output torque is most efficient. This efficient engine operation region is shown by the control strategy illustrated in ¶ 337 Region B/E, highlighted in red. Again, this lower torque bound would be known as a lower predetermined

torque value or "setpoint."

344. The Bumby Project discloses that the engine and motor are used to propel the vehicle during high loads where the vehicle torque requirements cannot be provided by the engine or motor alone. The Bumby Project specifically identifies that such high loads could occur during vehicle acceleration and hill climbing. As I have explained previously, it would have been obvious that such torque requirements would eventually exist such that a combination of both power sources would be needed. Again, as I explained in ¶ 84 above, using both the engine and motor during higher torque requirements was known and disclosed by a 1976 hybrid vehicle designed and tested by Ford Motor Company.

> Primary i.c.-engine mode is used when vehicle speed and loading are both high, which gives high engine efficiency. **When necessary, the <u>engine torque can be augmented by the motor for rapid acceleration or hill climbing</u>. Typically, the motor will be used to provide extra power if the engine output would otherwise exceed 90% of maximum**, since this leads to inefficiency.

(Ex. 1107 at 4; Emphasis added) (*see also* Ex. 1105 at 11).

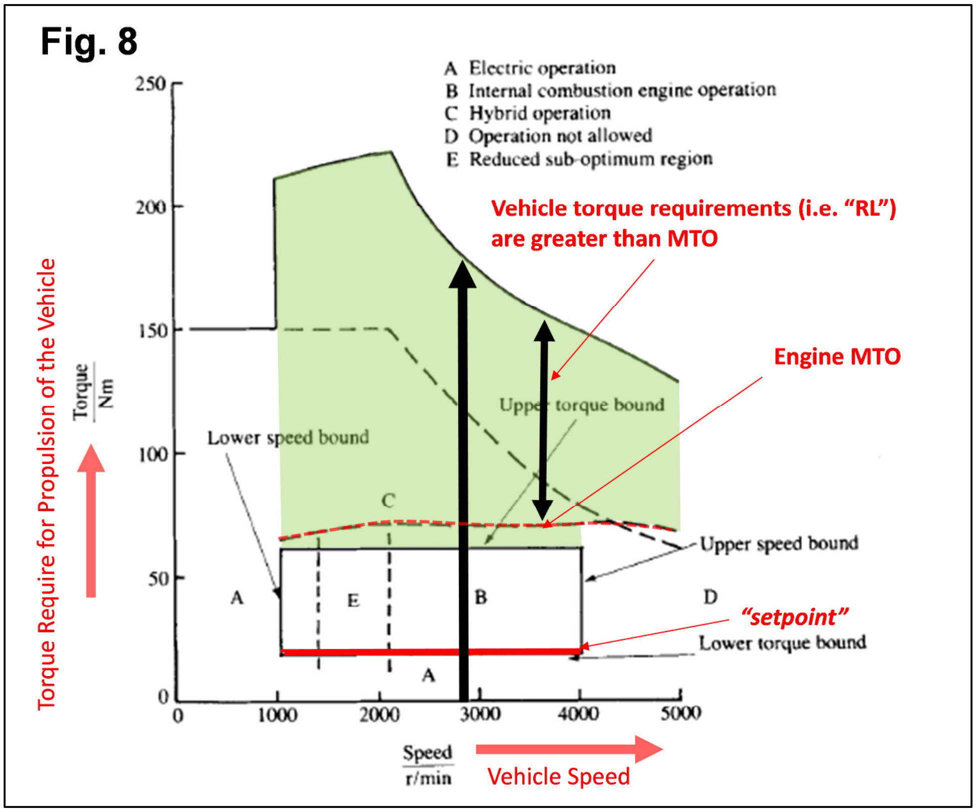
345. As discussed in paragraphs 307-313, it was known that during such operation the torque required for propulsion of the vehicle could be positive or negative.

346. As discussed above in limitation [1.5], Fig. 2 illustrates a controller

connected to the engine and "motor control." As such, the controller would control the engine and motor in a hybrid mode where both the engine and motor are employed to propel the vehicle.

347. Again, as illustrated below in Fig. 8, the Bumby Project discloses operating the hybrid vehicle, "responsive to the value for the [instantaneous torque required for propulsion of the vehicle] and said setpoint SP." The vertical black arrow illustrates the increasing torque required for propulsion of the vehicle (i.e., "*road load (RL)*") at a constant vehicle speed (e.g. 3000 RPM in this example). As I explained in ¶¶ 281-282 at this constant speed of 3000 RPM, operational mode decisions are based on the torque required for propulsion of the vehicle. For instance, if the vehicle begins to ascend a hill and the driver wishes to maintain the current vehicle speed, the controller may be required to shift from engine only mode to a motor + engine mode when the torque requirements exceed the "upper torque bound" (i.e., RL >90% MTO). Operation of both the motor and engine continues as the torque requirements exceed the maximum torque output (MTO) of the engine (i.e., RL > MTO). For instance, if the vehicle was being propelled by the engine and then begin to ascend a hill, the vehicle torque requirements might exceed the "upper torque bound." If the vehicle torque requirements further exceed due to the severity of the hill slope, the vehicle would continue to be propelled by both the engine and motor. Such a combination of motor and engine might further

be required during a hard acceleration demand from the user. Fig. 8 therefore illustrates that when the torque required for propulsion of the vehicle is higher that the engine's torque "upper torque bound," the vehicle is propelled by the both engine and traction motor in region C, highlighted in green, as shown below:

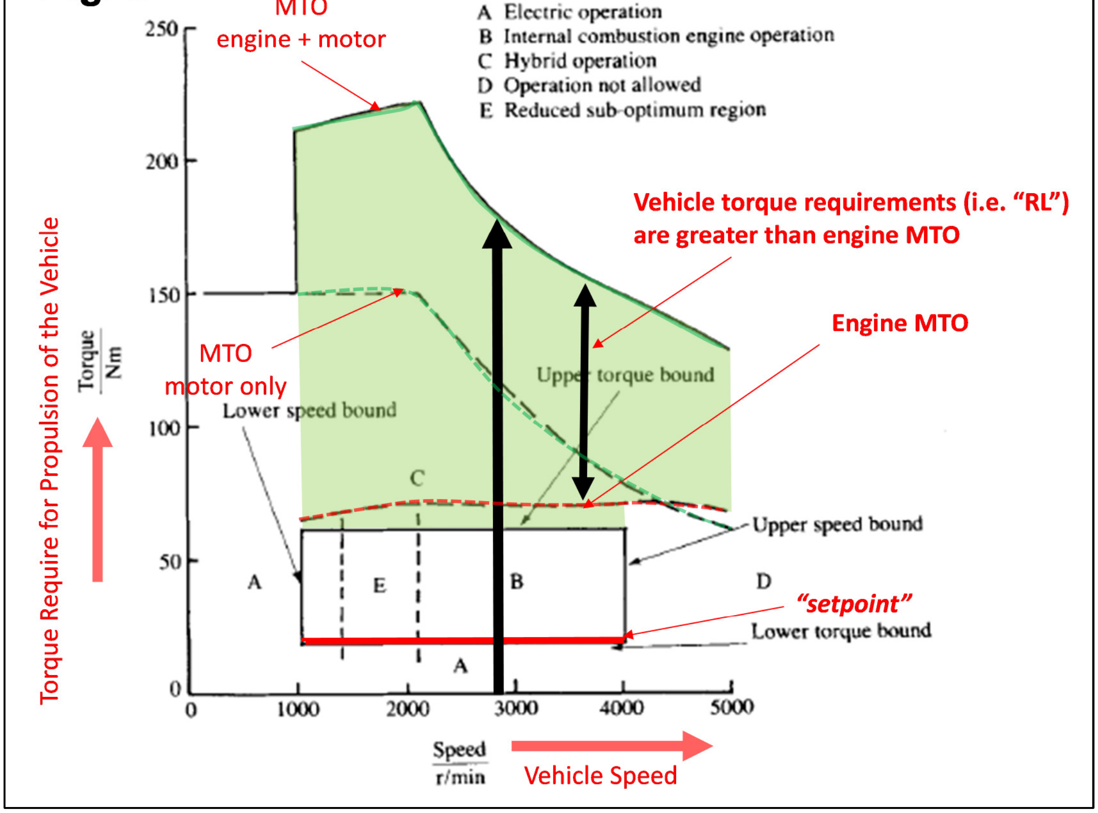


(Ex. 1105 at 8-Fig. 8, annotated)

348. It would have been well known to a person of ordinary skill in the art that adding the torque capacity of the motor allows the hybrid vehicle to meet that vehicle torque requirements that exceed the engine's maximum torque output (MTO). Fig. 8, as shown below with additional annotations, illustrates that maximum torque output curve of the motor is added to the maximum torque output

curve of the engine in order to show the maximum torque output of the vehicle using both the engine and motor for high load situation, such as accelerating or hill climbing.

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

349. Therefore, it is my opinion that the Bumby Project discloses "*an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine and by torque provided by either or both electric motor(s) in response to energy supplied from said battery, while RL>MTO*."

> … ***[8] The vehicle of claim 7, wherein the combination of said engine and said first motor is disengaged from said wheels during operation***

in mode I and engaged during operation in modes IV and V.

350. Claim 8 depends from claim 1, and further requires "wherein the combination of said engine and said first motor is disengaged from said wheels during operation in mode I and engaged during operation in modes IV and V."

351. The modes of operating including mode I, IV and V were discussed above in claim limitations [7.1]-[7.3] (¶¶ 318-349). Specifically, as I have discussed above in ¶ 324, the Bumby Project will disengage and turn off the engine during operation in "mode I" where the vehicle torque requirements are below "*setpoint SP*." In "mode I" operation the vehicle will be propelled solely by the electric motor alone. As I also discussed in ¶ 337, in "mode IV" operation the vehicle torque requirements exceed "*setpoint SP*" and the engine is started and coupled to the drive wheels using the clutch. In "mode IV" operation the engine is within its efficient operating range and is used to propel the vehicle. As I further discussed in ¶ 337 the vehicle torque requirements exceed the "upper torque bound" that is 90% of the engine's MTO. When the torque requirements transition into this region, the vehicle is propelled by both the engine and motor. This operation also will occur when the vehicle torque requirements exceed the engine's MTO (i.e., "Mode V").

352. The Bumby Project further discloses that the engine is disengaged when it is not operated:

> To further improve driveline efficiency **<u>the i.c. engine</u>** is assumed to be switched off and **<u>decoupled from the driveline when not in use</u>**.

(Ex. 1105 at 6, emphasis added).

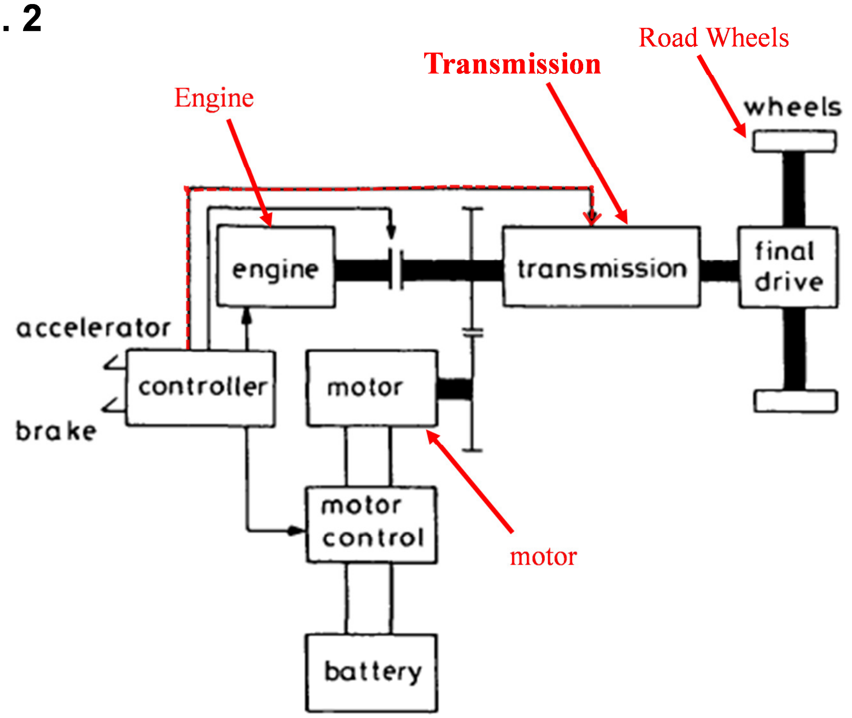
353. Therefore, it is my opinion that the Bumby Project discloses "*wherein the combination of said engine and said first motor is disengaged from said wheels during operation in mode I and engaged during operation in modes IV and V.*"

> … ***[18] The vehicle of claim 1, further comprising a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle.***

354. Claim 18 depends from claim 1, and further requires "a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle."

355. The Bumby Project illustrates and discloses a variable ratio transmission for use in the described hybrid vehicles, as shown in Fig. 2, below. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

356. As annotated in Fig. 2, above, the controller is connected to the transmission for controlling the transmission. Also, as illustrated, the transmission is positioned between the engine and the motors.

357. More specifically, the Bumby Project discloses a “four-speed” transmission, as shown in Table 1 from Bumby III, annotated below. (Ex. 1105 at 4)(*see also* Ex. 1104 at 3).

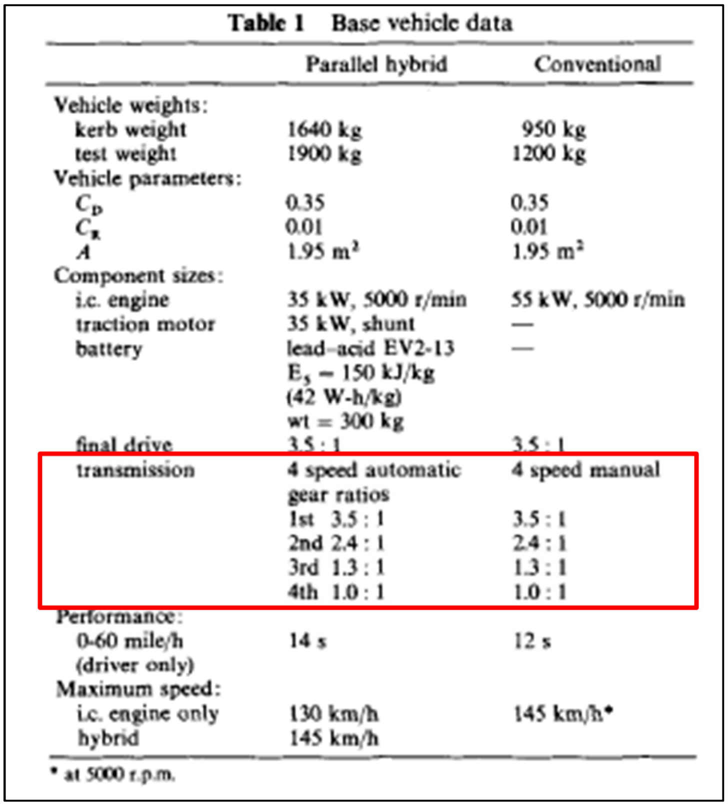


Table 1 Base vehicle data

	Parallel hybrid	Conventional
Vehicle weights:		
kerb weight	1640 kg	950 kg
test weight	1900 kg	1200 kg
Vehicle parameters:		
C_D	0.35	0.35
C_R	0.01	0.01
A	1.95 m^2	1.95 m^2
Component sizes:		
i.c. engine	35 kW, 5000 r/min	55 kW, 5000 r/min
traction motor	35 kW, shunt	—
battery	lead-acid EV2-13 E_s = 150 kJ/kg (42 W-h/kg) wt = 300 kg	—
final drive	3.5 : 1	3.5 : 1
transmission	4 speed automatic	4 speed manual
	gear ratios	
	1st 3.5 : 1	3.5 : 1
	2nd 2.4 : 1	2.4 : 1
	3rd 1.3 : 1	1.3 : 1
	4th 1.0 : 1	1.0 : 1
Performance:		
0-60 mile/h (driver only)	14 s	12 s
Maximum speed:		
i.c. engine only	130 km/h	145 km/h*
hybrid	145 km/h	

* at 5000 r.p.m.

358. The Bumby Project further describes the hybrid architecture including a transmission:

> In this parallel arrangement, both the electric traction motor and the i.c. engine are capable of driving the road wheels directly, and independently, **through a common transmission**. Such an arrangement offers the potential for maximizing the overall transmission efficiency between either prime mover and the road wheels, although, when both prime movers are operative, a compromise must be achieved. Although minor gains are possible if each power source is fed through its own, independent, transmission the efficiency benefit of such an arrangement must be carefully balanced against the added complexity, weight and cost.”

(Ex. 1105 at 2; Emphasis added).

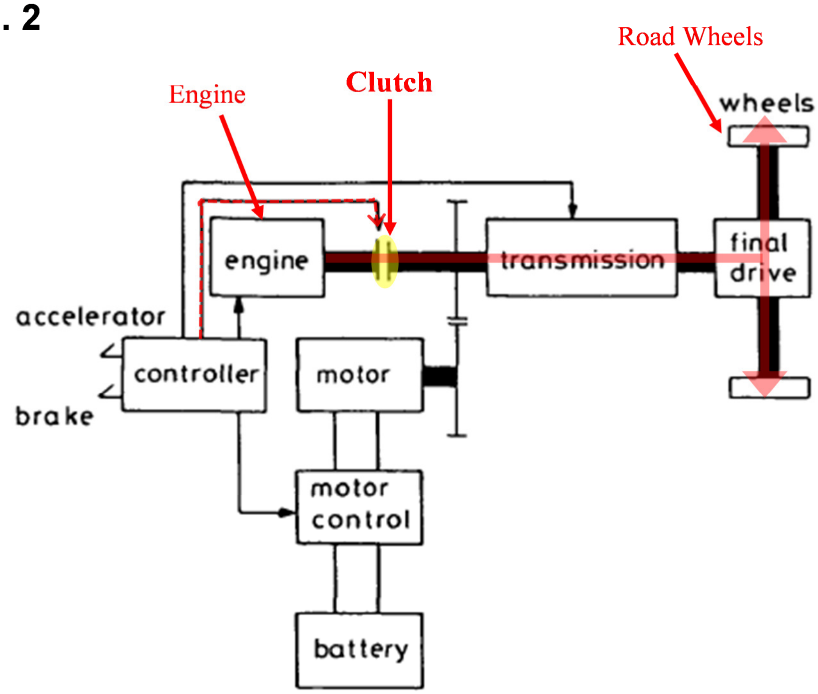
359. Therefore, it is my opinion that the Bumby Project discloses "*a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle.*"

> *… [21] The hybrid vehicle of claim 1, wherein said engine is controllably coupled to road wheels of said vehicle by a clutch.*

360. Claim 21 depends from claim 1, and further recites "wherein said engine is controllably coupled to road wheels of said vehicle by a clutch."

361. The Bumby Project illustrates the following hybrid vehicles, as shown in Fig. 2, below. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1).

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

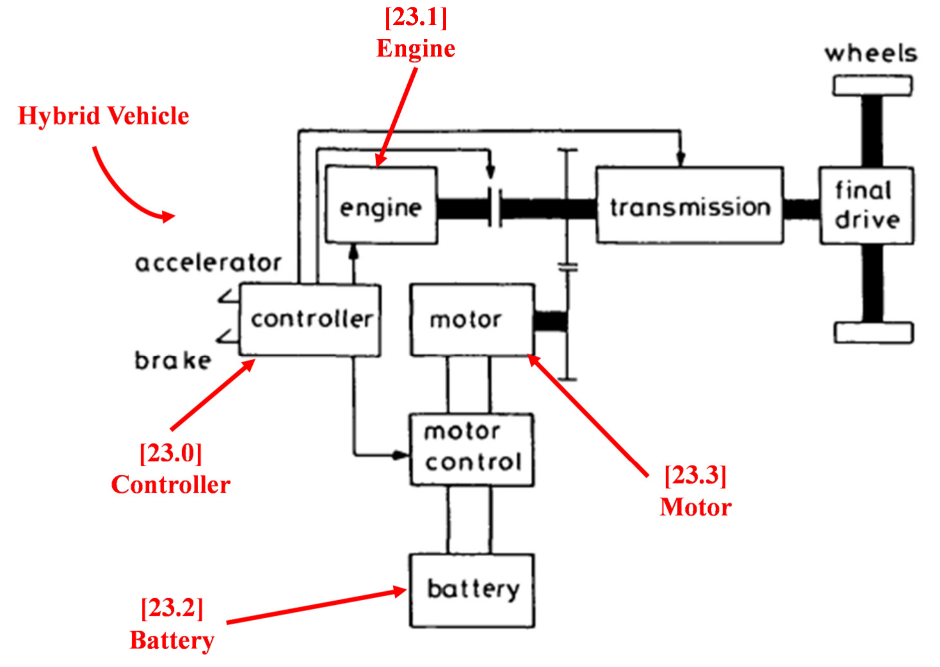
362. Therefore, it is my opinion that the Bumby Project discloses "*engine*

being controllably coupled to road wheels of said vehicle by a clutch."

C. Claim 23

363. I understand that claim 23 is a method claim that claims a method for controlling a hybrid vehicle. I understand that the preamble of claim 23 includes limitations that recite the structure of the hybrid vehicle and these limitations are largely duplicative of the limitations in claim 1, as already discussed above. In fact, many limitations of claim 23 are essentially the same limitations recited by claim 1.

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

364. For the sake of brevity, I will refer to earlier-recited paragraphs when necessary rather than repeating my statements.

… ***[23.0] A method of control of a hybrid vehicle, said vehicle***

comprising

365. The Bumby Project disclosed and evaluated several methods for the optimization and control of a hybrid vehicle. (Ex. 1107 at 2; Ex. 1106 at 2; Ex. 1105 at 2; Ex. 1104 at 1)

366. In discussing "Hybrid vehicle control" the Bumby Project states:

> **When two or more power sources are used in a vehicle power train, the way in which they are controlled is fundamental to the performance of the vehicle**. However, the main objective of the control may be to maximise the accelerative performance of the vehicle, minimise exhaust emissions or to minimise energy use. An alternative objective, and the subject of this paper, is to examine ways in which the dependence of the vehicle on petroleum-based fuels can be reduced. This objective can be achieved either by improving the overall energy consumption of the vehicle, or by transferring some of the energy demand to the electrical system.

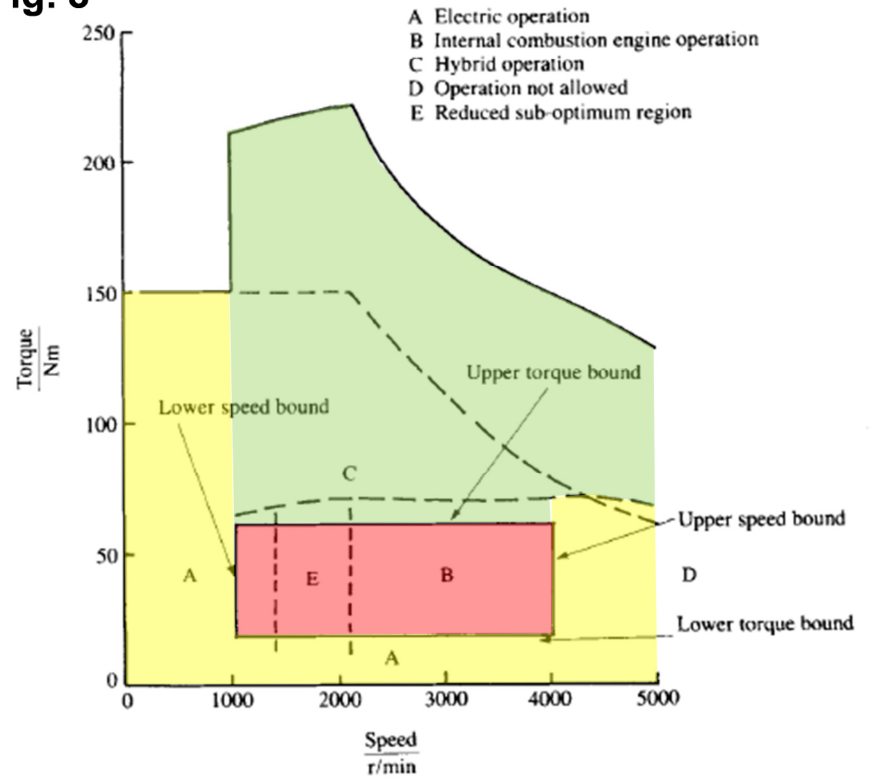
(Ex. 1104 at 3, emphasis added).

367. In particular, the Bumby Project discusses a control policy discussed and name by the Bumby Project as the "Suboptimal control." (Ex. 1104 at 10-11). This name is somewhat misleading since the simplified Bumby control strategy dramatically minimizes emissions and increases fuel efficiency while being simple enough to implement in a hybrid vehicle controller/control system. (Ex. 1104 at 10-12).

368. While the Bumby Project also discloses an “Optimal control,” this control strategy was more computationally intense because it attempted to compute the most efficient “point” of engine operation, instead of identifying “regions”, like in Fig. 8, below.

369. The Bumby Project illustrates and discloses this simplified Bumby control strategy in Fig. 8, in Bumby III, annotated below to clearly show the different operating modes, or regions, in different colors. (Ex. 1105 at 8)(*see also* Ex. 1104 at 11-Fig. 16).

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

370. Therefore, it is my opinion that the Bumby Project discloses “*a method of control of a hybrid vehicle*.”

… ***[23.1] an internal combustion engine capable of efficiently producing torque at loads between a lower level SP and a maximum torque output MTO,***

371. It is my understanding that the term “SP” is an abbreviation for “setpoint” although it is not explicitly stated as such in the claim 23. I also understand that “SP” or “setpoint” as used in claim 23 is proposed to mean a “predetermined torque value.”

372. As discussed above in claim limitation [1.1], the Bumby Project discloses an engine that is controllably coupled to the wheels.

373. As disclosed above in claim limitation [1.6], the engine is controlled for propulsion of the vehicle and operated at an efficient region above a lower torque bound, or “*setpoint*.”

374. As disclosed above in claim limitation [7.2], the engine is controlled to propel the vehicle and operate between the lower torque bound, or “setpoint” and the engine’s maximum torque output (MTO).

375. Therefore, it is my opinion that the Bumby Project discloses “*an internal combustion engine capable of efficiently producing torque at loads between a lower level SP and a maximum torque output MTO*.”

… ***[23.2] a battery, and***

376. As discussed above in claim limitation [1.4], the Bumby Project

discloses a battery.

377. Therefore, it is my opinion that the Bumby Project discloses "*a battery.*"

> … ***[23.3] one or more electric motors being capable of providing output torque responsive to supplied current, and of generating electrical current responsive to applied torque,***

378. It is my understanding that the limitation "one or more electric motors" only requires one motor.

379. As discussed above in claim limitation **[1.3],** the Bumby Project discloses a motor that operates as both a motor and generator. Specifically, as discussed above, the Bumby Project discloses the motor is responsive to current supplied from the battery to apply output torque to the wheels for propulsion of the vehicle. The Bumby Project also discloses that the motor also operates as a generator for accepting torque from the wheels for generating current.

380. As discussed above in claim limitation **[1.2]**, the Bumby Project also discloses an additional motor that is responsive to current supplied from the battery operate to provide output torque to start the engine.

381. Therefore, it is my opinion that the Bumby Project discloses "*one or more electric motors being capable of providing output torque responsive to supplied current, and of generating electrical current responsive to applied*

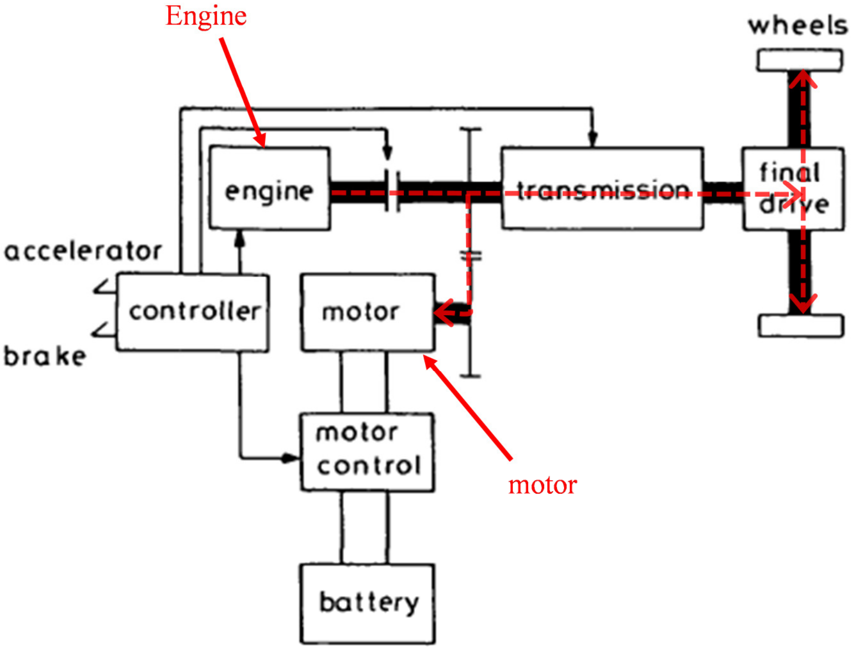
torque.”

> … ***[23.4] said engine being controllably connected to wheels of said vehicle for applying propulsive torque thereto and to said at least one motor for applying torque thereto,***

382. As discussed above in claim limitation [1.1], the Bumby Project also discloses the engine being controllably coupled to the wheels, via a clutch and transmission, to apply torque to the wheels for propulsion of the vehicle.

383. Based on Fig. 2 from Bumby II, as annotated below, the Bumby Project also illustrates and discloses that the engine is controllably connected to the motor for applying torque to the motor. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1).

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

384. Based on Fig. 2 above, it would have been understood that when the clutch is engaged, the engine may be controlled to apply torque to motor while also apply torque to the wheels.

385. The Bumby Project also discloses that the engine is controllably connected to the motor in order to apply torque to the motor when the battery state of charge is extremely low:

> Over journeys with an exceptionally large amount of acceleration or hill climbing, the battery state of charge may become very low, but this can not be allowed to continue until the batteries are completely depleted, since the vehicle would then be unable to move away from rest. To counter this problem, a negative torque may be scheduled from the motor so that **the engine both drives the wheels and charges the traction batteries**.

(Ex. 1107 at 4, emphasis added)

386. As shown in Table 2 from Bumby II, the Bumby Project also discloses that a "Battery charge mode" where the engine provides "power to charge the battery with the traction motor." (Ex. 1105 at 5)(*See also* Ex. 1106 at 3-Table 1).

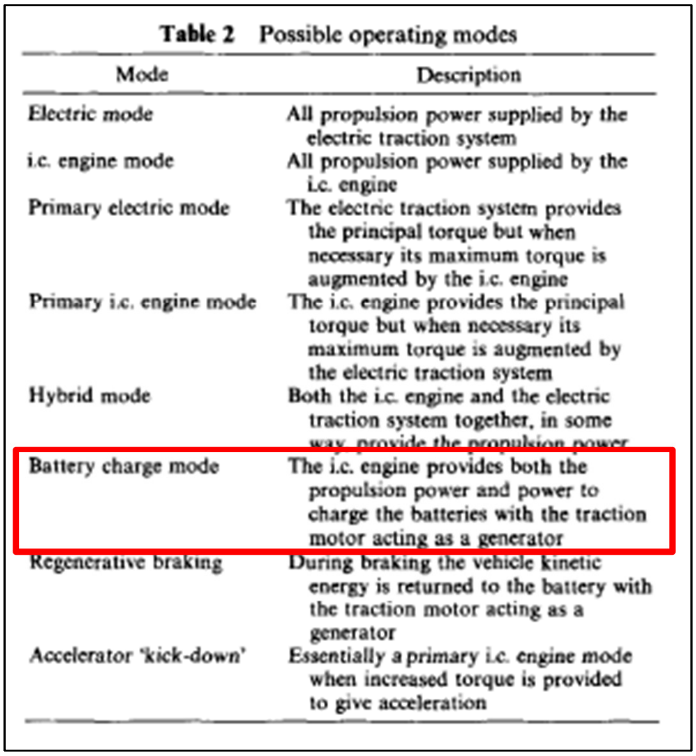


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

387. Therefore, it is my opinion that the Bumby Project discloses "*said engine being controllably connected to wheels of said vehicle for applying propulsive torque thereto and to said at least one motor for applying torque thereto*."

388. said method comprising the steps of:

> … ***[23.5] determining the instantaneous torque RL required to propel said vehicle responsive to an operator command;***

389. I understand the term "road load," or "RL," as used in the '347 Patent, is proposed to mean "the instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value."

390. I understand that the claim limitation [23.5] should be interpreted as

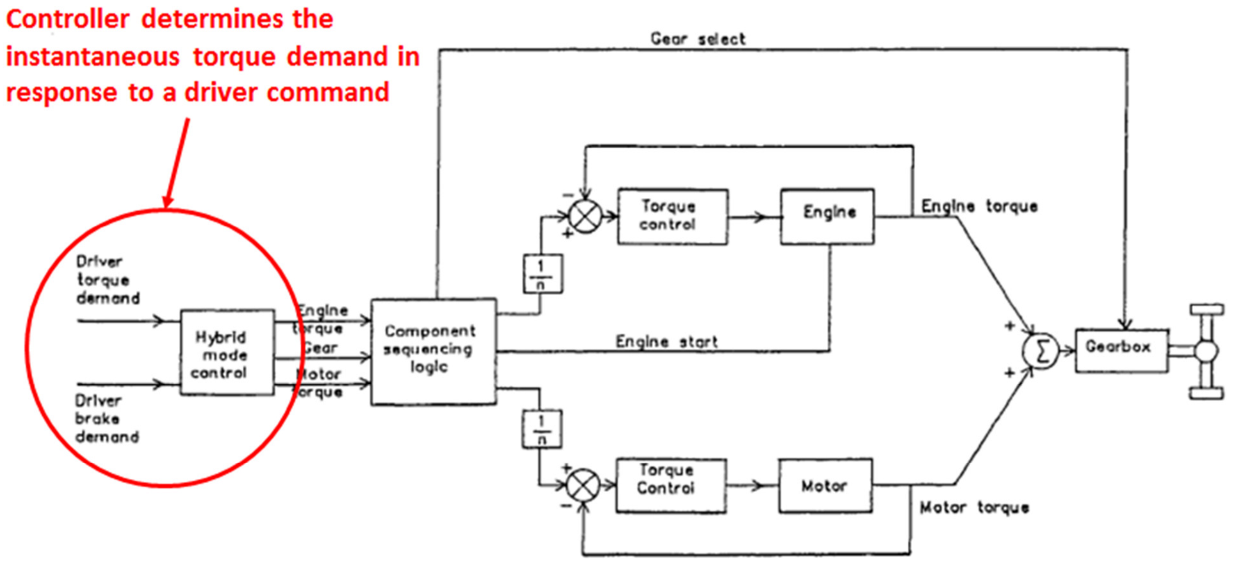
being "determining the instantaneous torque required for propulsion of the vehicle, either positive or negative, responsive to an operator command."

391. As discussed above in claim limitation [7.0], the Bumby Project discloses that the controller determines the torque required for propulsion of the vehicle and apportions the power requirements between the engine and motor:

> **With the presence of two on-board power sources, optimum scheduling of the drive is best looked after by a microprocessor controller**. This, in turn, implies the development of a 'drive-by-wire system' whereby the driver communicates his power demand via the accelerator pedal to the microprocessor controller. **The microprocessor then schedules the instantaneous outputs of the power sources**.

(Ex. 1106 at 2, emphasis added).

392. The controller controls "the electric traction system, ic engine and transmission in the most efficient way to meet driver demand" by operating in different hybrid-vehicle control modes. (Ex. 1106 at 4). The controller uses operator commands, such as accelerator/brake pedals as driver commanded input, as annotated in Fig. 16 from Bumby V, below.



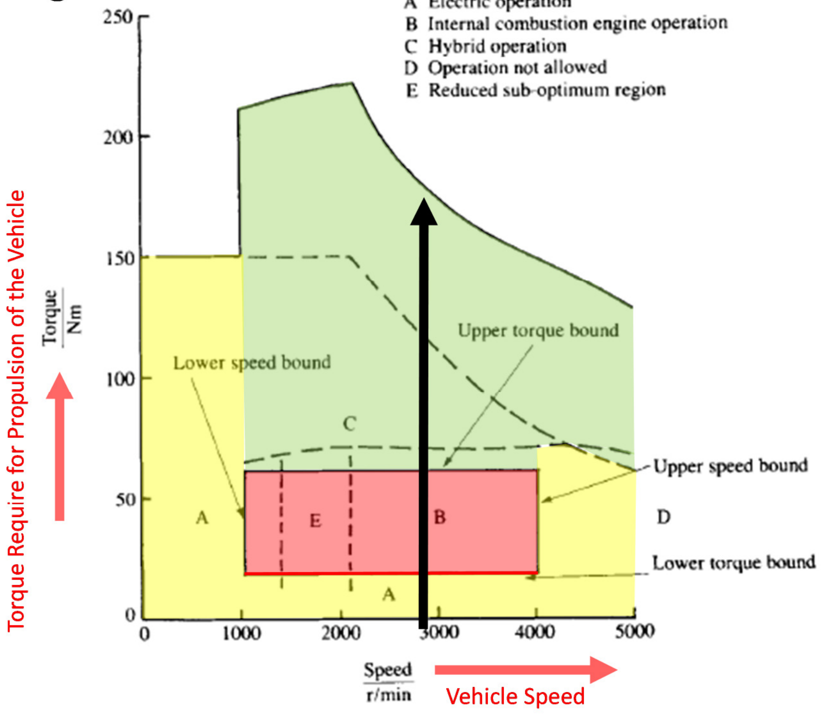
Controller determines the instantaneous torque demand in response to a driver command

Fig 16 Complete vehicle component control system

(Ex. 1107 at 13-Fig. 16, annotated)

393. The Bumby Project illustrates that various the "hybrid-vehicle control modes", that are determined based on the operator commanded torque requirements as illustrated below, in Fig. 8, below.

Fig. 8



Torque Require for Propulsion of the Vehicle

Vehicle Speed

(Ex. 1105 at 8-Fig. 8, annotated)

394. The vertical black arrow illustrates the increasing torque required for propulsion of the vehicle (i.e., "*road load (RL)*") at a constant vehicle speed (e.g. 3000 RPM in this example).

395. Assuming the speed remains constant, as the "instantaneous torque required for propulsion the vehicle" increases, the vehicle controller will change the mode of operation, as shown in Fig. 8 above.

396. For example, at torque requirements below the "lower torque bound," (i.e. "*setpoint SP*") the engine operation is inefficient and the electric motor is used to propel the vehicle, in region A, highlighted in yellow. (Ex. 1106 at 3; Ex. 1105 at 7-8; Ex. 1104 at 10-11).

397. As the "instantaneous torque required for propulsion of the vehicle" increases and exceeds past the "lower torque bound," the engine is started so that the engine is used in the efficient region B, highlighted in red. (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 7-8; Ex. 1104 at 10-11). Lastly, as the "instantaneous torque required to propel the vehicle" increases past the upper torque bound, the engine and motor are both operated to propel the vehicle in region C, highlighted in green (Ex. 1105 at 7-8; Ex. 1104 at 10-11)

398. Such operational mode changes would occur based on the conditions experienced during driving, such as acceleration or hill climbing. In fact, Bumby itself recognizes that operational mode changes could occur during both

acceleration and hill climbing. These mode changes could result in the torque required for propulsion of the vehicle being either negative or positive in value.

> When necessary, the engine torque can be augmented by the motor for rapid acceleration or hill climbing. Typically, the **recognizes both uphill and downhill driving conditions**. Typically, the motor will be used to provide extra power if the engine output would otherwise exceed 90% of maximum, since this leads to inefficiency.

(Ex. 1107 at 4, emphasis added).

399. For example, the Bumby Project discloses the torque required to propel the vehicle may be positive based on an operator command for acceleration, or negative based on an operator command for deceleration by pressing the brake pedal.

> **These algorithms interact directly with both the driver commands through brake- and accelerator-pedal movement**, and communicate their requirements to the units responsible for the control of the drive-line components themselves.

(Ex. 1106 at 3, emphasis added).

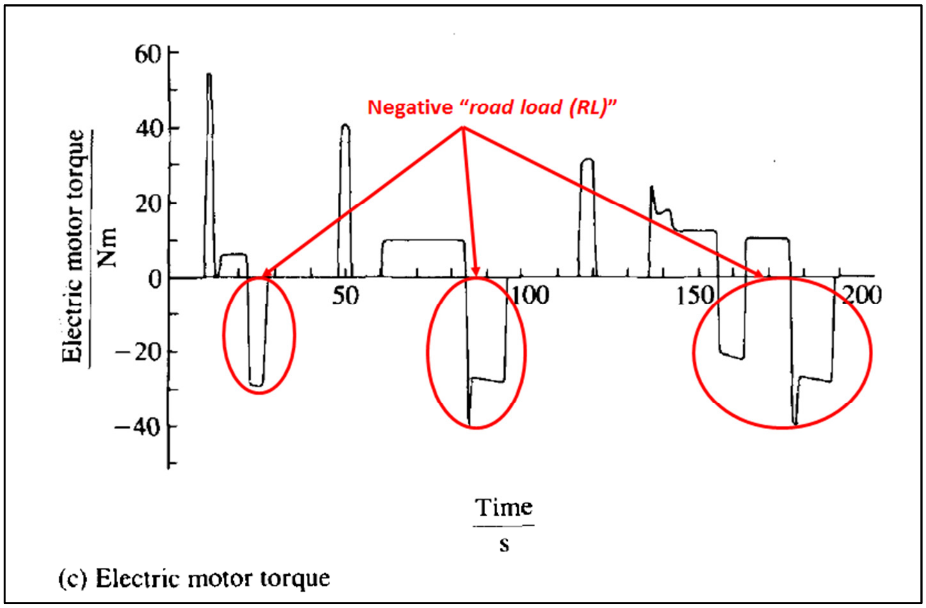
400. When the vehicle is going up the hill, or when the driver requests the vehicle accelerate, it is understood that the torque required for propulsion of the vehicle may be positive. As anyone who has ever driven a vehicle would have experienced, when the vehicle ascends the hill, if the driver does nothing, the weight of the vehicle will cause the vehicle to decelerate due to gravity. This is a

commonly known and experienced phenomenon. Therefore, the torque required for propulsion of the vehicle is positive when the vehicle is traveling up a hill. Therefore, the driver needs to press the accelerator pedal to either maintain the same speed or to accelerate up the hill. Likewise, anyone who has ever wanted to pass a vehicle understands that in order for the vehicle to accelerate, the driver must further press the accelerator pedal to accelerate past the other vehicle. Such acceleration also requires positive torque to propel the vehicle

401. Conversely, when the vehicle is going down a hill the torque required to propel the vehicle could be negative (i.e., traveling down a steep hill). As anyone who has ever driven a vehicle would have experienced, when the vehicle descends down a hill, if the driver does nothing, the weight of the vehicle will cause the vehicle to accelerate due to gravity. This is a commonly known and experienced phenomenon. Therefore, the torque required for propulsion of the vehicle may decrease or possibly become negative when the vehicle. Therefore, the driver needs to press the brake pedal to keep from accelerating.

402. Furthermore, it was understood that the torque required for propulsion of the vehicle could also be negative when the vehicle is charging the battery. For, example, in Fig. 9 from Bumby III, annotated below, the Bumby Project illustrates negative road as seen by the motor over the drive cycle. The Bumby Project discloses using this negative road load as kinetic energy during the "Regenerative

braking mode" to charge the battery with the "*second electric motor*" acting as a generator.



(Ex. 1105 at 9-Fig. 9, annotated)

403. Furthermore, the Bumby Project discloses that the above control strategy determines the "instantaneous torque required for propulsion of the vehicle" in order to overcome external forces that act on the vehicle:

> To implement this optimization process over an urban driving cycle such as the ECE-15 (Fig. 3) or the J227a-D (Fig. 4) **the torque required at the road wheels to overcome both vehicle drag and rolling resistance, and to provide any vehicle acceleration**, is determined at discrete (typically one second) intervals.

(Ex. 1105 at 5, emphasis added).

404. As I discussed above in paragraphs 113-120 above, these disclosed external forces accounted for by the Bumby Project, which the vehicle powertrain

must overcome, are the calculated textbook definition of "road load" forces.

405. The Bumby Project further confirms that the control strategy accounts for road load forces when determining the vehicle requirements for speed/torque:

> At each drivetrain component full account is taken of efficiency, which may **vary with both torque and speed, so that the calculated energy consumed accounts for both the road load requirement** and the system losses.

(Ex. 1105 at 5, emphasis added).

406. Similarly, the Bumby Project states that the vehicles' propulsion system must be account for and provide sufficient "tractive effort" force at the road wheels in order to overcome these external textbook "road load" forces. In other words, the Bumby Project discloses determining the instantaneous torque required for propulsion of the vehicle.

> To provide the necessary propulsion power, any vehicle drive train must be able to **provide sufficient tractive effort at the road wheels to overcome aerodynamic drag, rolling resistance and hill gradient** effects, while still providing the necessary vehicle acceleration.

(Ex. 1104 at 2, emphasis added)

407. As I discussed in paragraphs 307-313 above, it was well-known that the sum of these external forces are the textbook definition of "road load" that act on the vehicle. For instance, when the vehicle is driving on a windy day, the driver

may press the accelerator pedal requesting additional torque.

408. The Bumby Project therefore teaches **determining** the road loads necessary to be overcome such that the vehicle can be propelled. Moreover, the Bumby Project confirms:

> To implement this optimization process over an urban driving cycle such as the ECE-15 (Fig. 3) or the J227a-D (Fig. 4) **the torque required at the road wheels to overcome both vehicle drag and rolling resistance, and to provide any vehicle acceleration, is determined** at discrete (typically one second) intervals. Over each discrete time interval the power and speed are assumed to be constant. These values are then reflected back through the drivetrain to the on-board energy sources. At each drivetrain component full account is taken of efficiency, which may vary with both torque and speed, so that **the calculated energy consumed accounts for both the road load requirement and the system losses**.

(Ex. 1105 at 5, emphasis added).

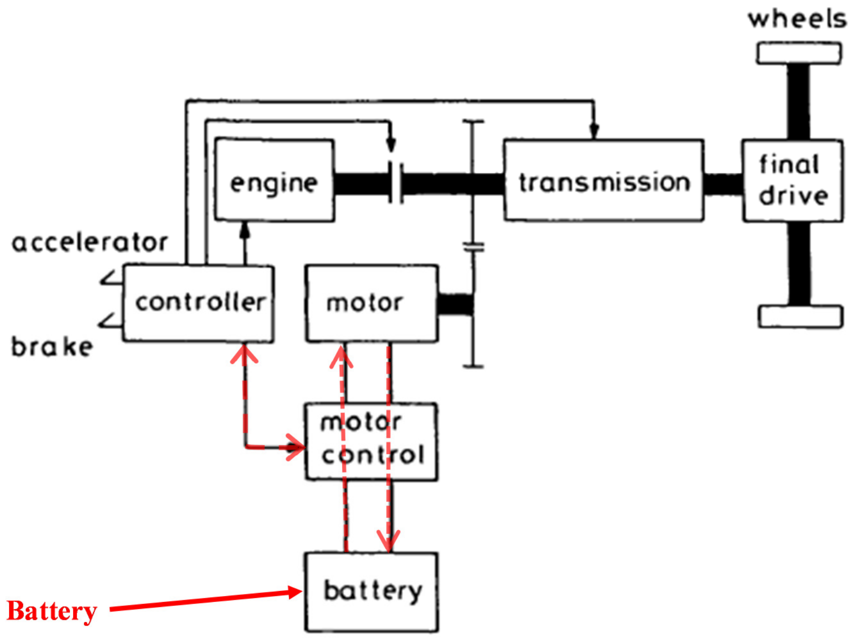
409. Therefore, it is my opinion that the Bumby Project discloses "*determining the instantaneous torque RL required to propel said vehicle responsive to an operator command.*"

… [23.6] monitoring the state of charge of said battery;

410. As discussed above in claim limitation [1.4] the Bumby Project discloses and illustrates a battery configured to provide current power to the motor

and propel and to receive current from the motor for charging, as shown in Fig. 2 from Bumby II. The Figure also discloses and illustrates that the controller monitors the state of charge of the battery. (Ex. 1104 at 1; Ex. 1105 at 1; Ex. 1106 at 1)

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

411. The Bumby Project also discloses monitoring the incremental change in the state of charge of the battery:

> Throughout the optimisation process, although E_1 is directly related to the petroleum fuel used, **E_2 is dependent on the rate at which the battery is discharged. E_2 is therefore <u>calculated</u> as the product of the incremental change in the battery state of charge** and the battery five hour energy capacity.

(Ex. 1104 at 376, emphasis added).

412. As shown in Table 2 in Bumby III, the Bumby Project also also discloses a "battery charge mode" in which the engine "provides . . . power to charge the batteries with the traction motor acting as a generator." (Ex.1105 at 5; Table 2).

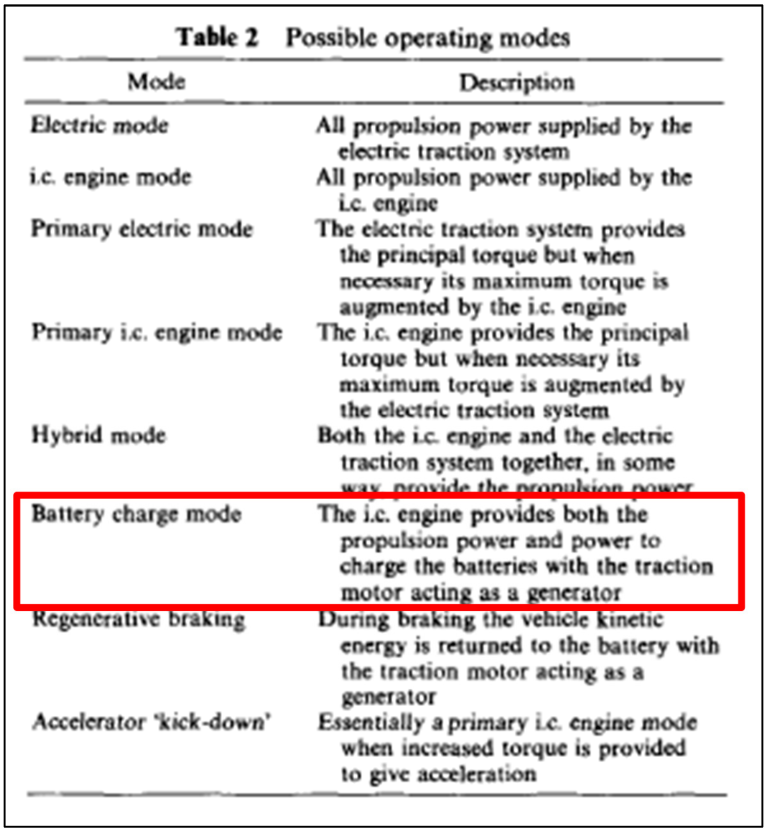


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator 'kick-down'	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

413. In further describing the "Battery Charging mode", the Bumby Project discloses that this mode is only "used at unacceptably low battery states of charge." (Ex. 1105 at 12).

414. The Bumby Project also discloses that mode selection is based on battery state of charge:

> From this brief discussion it is apparent that the hybrid drive can be operated in a number of ways or modes. These possible are m Table 1 and described in detail in -Forster and Bumby (1988). In addition, depending on the driving situation, battery state of drive can be operated in a number of ways or modes. These possible are m Table 1 and described in detail in -Forster and Bumby (1988). In addition, **depending on the driving situation, battery state of charge, etc., the vehicle controller must be capable of deciding which mode of operation** listed in Table 1 is most appropriate."

(Ex. 1106 at 3, emphasis added).

415. A person of ordinary skill in the art would understand that if the control system is making mode decisions, such as the operating the "Battery Charging mode" based on the state of charge of the battery, then the controller is monitoring the battery charge level.

416. Therefore, it is my opinion that the Bumby Project discloses "*monitoring the state of charge of the battery*."

… [23.7] employing said at least one electric motor to propel said vehicle when the torque RL required to do so is less than said lower level SP;

417. I understand the proposed construction of the term "RL" as "the instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value."

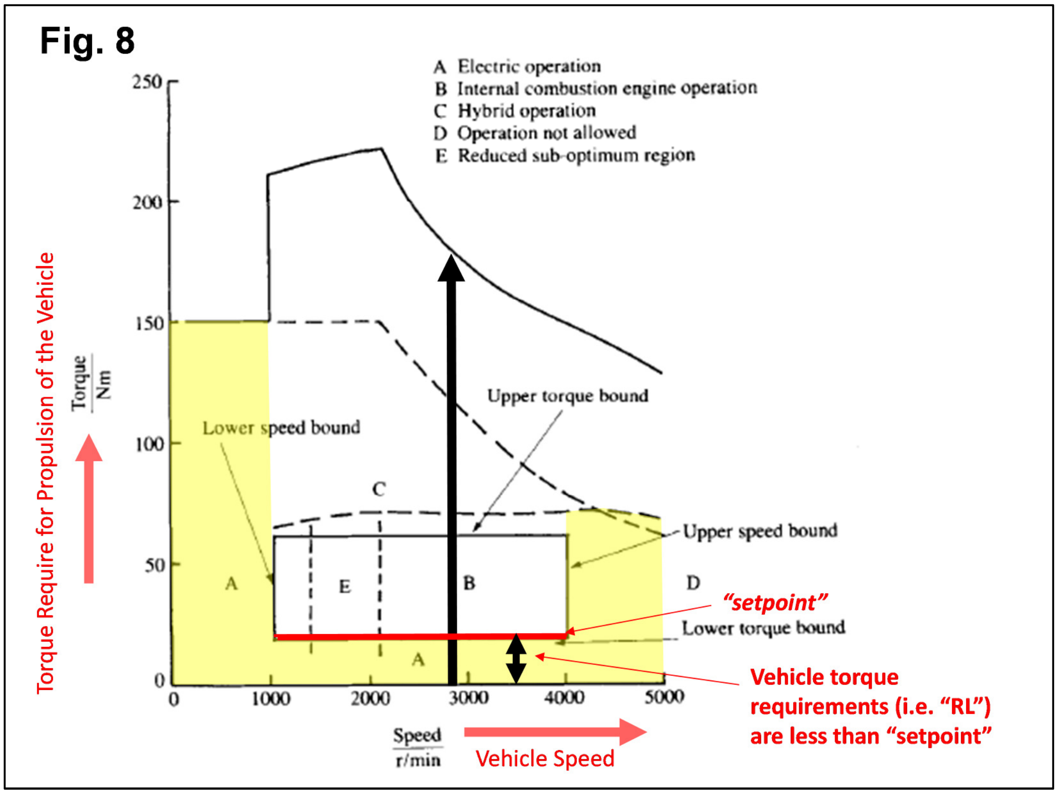
418. It is my understanding that proposed construction of “SP” as being “predetermined torque value.”

419. It is my understanding that claim limitation [23.7] should be interpreted as “employing said at least one electric motor to propel said vehicle when the torque required for propulsion of the vehicle, which may be positive or negative in value, is less than said lower level predetermined torque value.”

420. As explained in limitation [7.1], the Bumby Project discloses an “electric mode” where “all propulsion power is supplied by the electric traction system” when the torque required for propulsion of the vehicle is less than the lower torque bound. (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 11-12).

421. Further, based on Fig. 8 from Bumby III, a person of ordinary skill in the art would understand that the Bumby Project discloses that the when the load is low, the vehicle is propelled only by the traction motor in region A, highlighted in yellow, as shown below:

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

422. In discussing the figure above, the Bumby Project further confirms that only the electric motor is operated in region A:

> **<u>Below the lower torque bound and the lower speed bound, all-electric operation is favoured</u>**. This eliminates inefficient use of the engine. Above the upper torque bound, true hybrid operation is used with the electric motor supplying the excess torque above the maximum available from the engine.

(Ex. 1104 at 10-11, emphasis added)

423. Therefore, it is my opinion that the Bumby Project, whether the publications are looked at alone or in combination, discloses "*employing at least one electric motor to propel the vehicle when the torque required to do so is less*

than the lower level SP."

*… **[23.8] employing said engine to propel said vehicle when the torque RL required to do so is between said lower level SP and MTO;***

424. I understand the term "RL" or "road load" or "RL" as used in the '347 Patent, should be interpreted as "instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value."

425. Also, it is my understanding that "SP" should be interpreted to mean a "predetermine torque value."

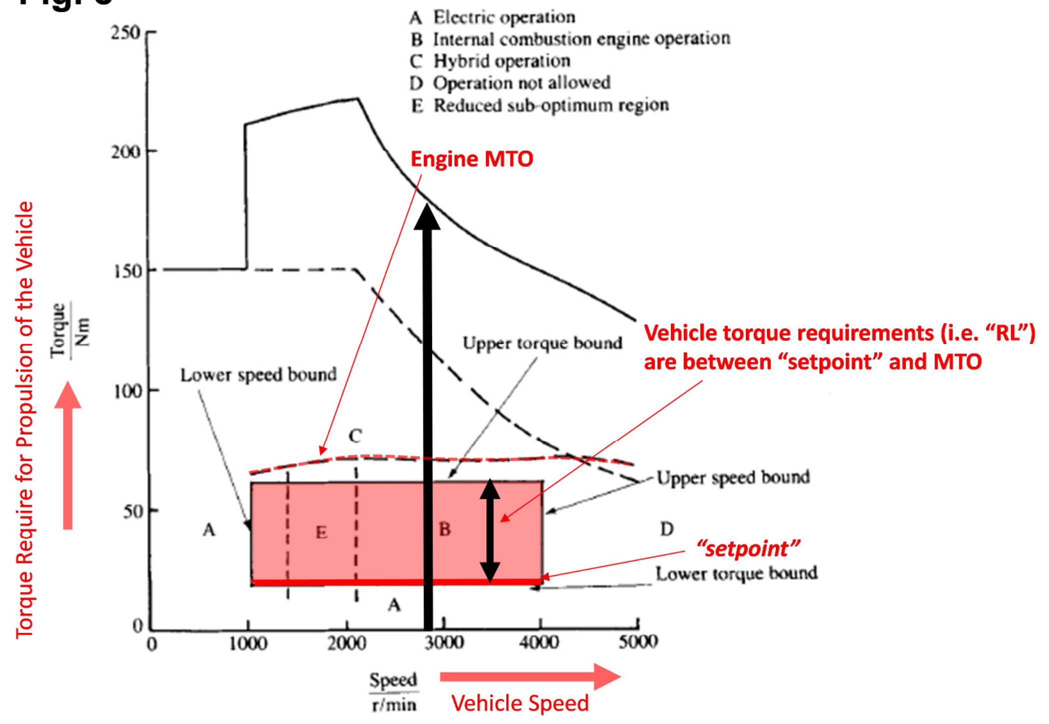
426. It is my understanding that this claim limitation should be interpreted as "employing said engine to propel said vehicle when the torque required for propulsion of the vehicle, which may be positive or negative in value, is between said lower level predetermine torque value and MTO."

427. As explained in limitation [7.2], the Bumby Project discloses an "i.c. engine mode" where "all propulsion power is supplied by the i.c. engine" when torque required for propulsion of the vehicle is greater than the lower torque bound and less than the engine's maximum torque output. (Ex. 1107 at 4; Ex. 1106 at 3; Ex. 1105 at 11-12).

428. Further, based on Fig. 8 from Bumby III, a person of ordinary skill in the art would understand that the Bumby Project discloses that the when the torque required for propulsion of the vehicle falls in Region B/E , highlighted in

red, the vehicle is propelled only by the engine, as shown below:

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

429. Therefore, it is my opinion that the Bumby Project, whether the publications are looked at alone or in combination, discloses "*employing said engine to propel said vehicle when the torque RL required to do so is between said lower level SP and MTO.*"

> ***… [23.9] employing both said at least one electric motor and said engine to propel said vehicle when the torque RL required to do so is more than MTO; and***

430. I understand the term "RL" or "road load" or "RL" as used in the '347

Patent, should be interpreted as "instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value."

431. It is my understanding that this claim limitation should be interpreted as "employing both said at least one electric motor and said engine to propel said vehicle when the torque required for propulsion of the vehicle, which may be positive or negative in value, is more than MTO."

432. As explained in limitation **[7.3],** The Bumby Project discloses that the engine and motor are used for propulsion of the vehicle during high load, such as acceleration and hill climbing:

> Primary i.c.-engine mode is used when vehicle speed and loading are both high, which gives high engine efficiency. **When necessary, the <u>engine torque can be augmented by the motor for rapid acceleration or hill climbing</u>. Typically, the motor will be used to provide extra power if the engine output would otherwise exceed 90% of maximum**, since this leads to inefficiency.

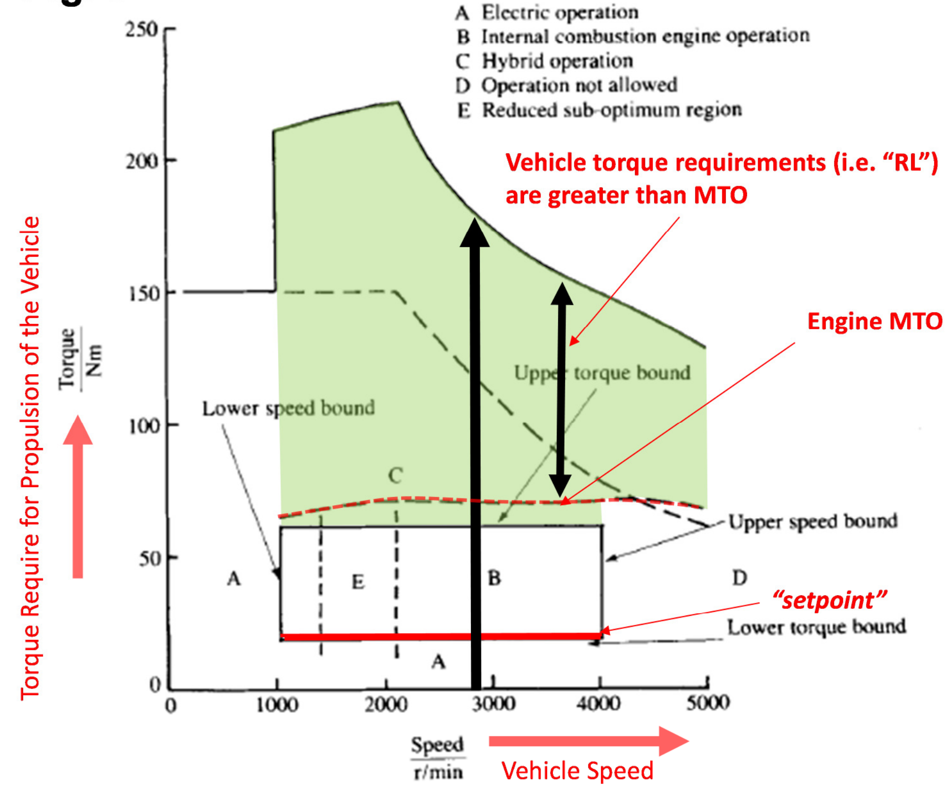
(Ex. 1107 at 4; Ex. 1105 at 11, emphasis added).

433. As discussed in paragraphs 307-313, it was known that during such operation the torque required for propulsion of the vehicle could be positive or negative.

434. Further, based on Fig. 8 from Bumby III, the Bumby Project discloses that the when the torque required for propulsion of the vehicle is higher that the

engine's upper torque bound, the vehicle is propelled by the both engine and traction motor in region C, highlighted in green, as shown below:

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

435. I would have been well known to a person of ordinary skill in the art that adding the torque capacity of the motor allows the hybrid vehicle to meet that vehicle torque requirements that exceed the engine's maximum torque output (MTO). Fig. 8, also illustrates that maximum torque curve of the motor

436. It would have been well known to a person of ordinary skill in the art that adding the torque capacity of the motor allows the hybrid vehicle to meet that vehicle torque requirements that exceed the engine's maximum torque output

(MTO). Fig. 8, as shown below with additional annotations, illustrates that maximum torque output curve of the motor is added to the maximum torque output curve of the engine in order to show the maximum torque output of the vehicle using both the engine and motor for high load situation, such as accelerating or hill climbing.

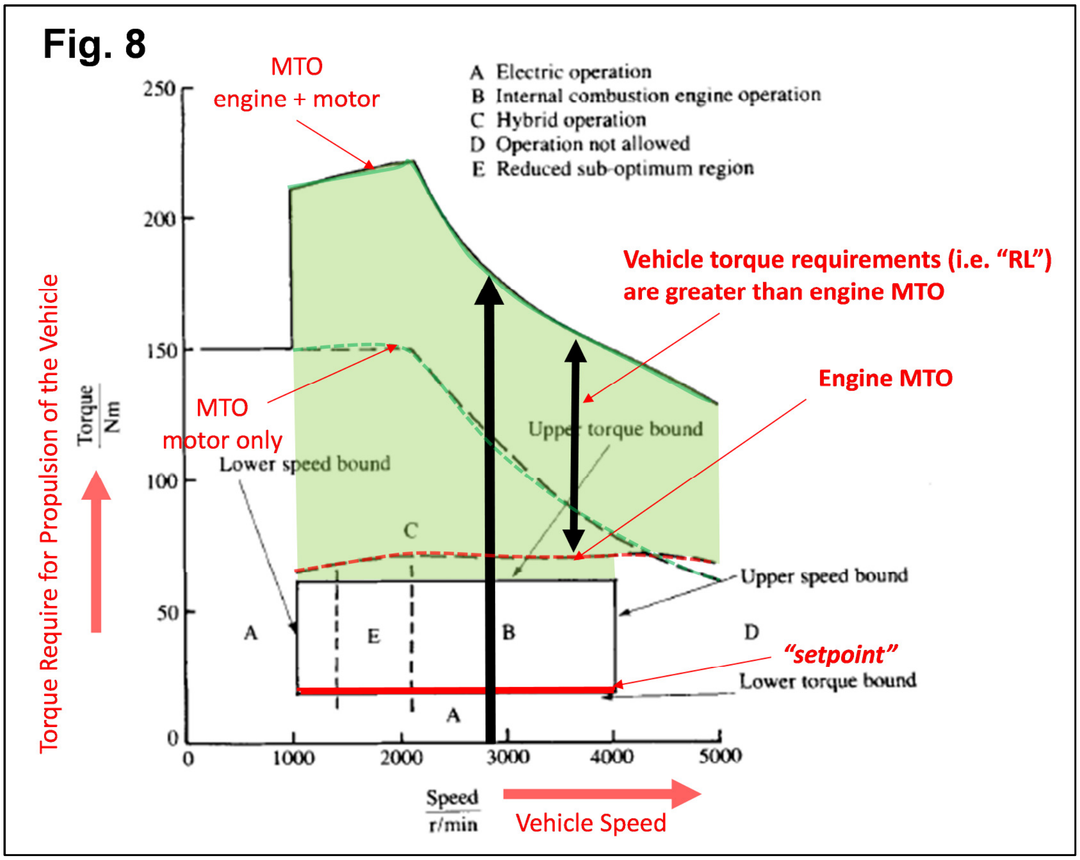


Fig. 8

(Ex. 1105 at 8-Fig. 8, annotated)

437. Therefore, it is my opinion that the Bumby Project discloses "*employing said engine to propel said vehicle when the torque RL required to do so is between said lower level SP and MTO*."

… [23.10] employing said engine to propel said vehicle when the torque

RL required to do so is less than said lower level SP and using the torque between RL and SP to drive said at least one electric motor to charge said battery when the state of charge of said battery indicates the desirability of doing so; and

438. I understand the term “road load” or “RL” as used in the ‘347 Patent, should be interpreted as “the instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value.”

439. It is my understanding that proposed construction of “SP” as being “predetermined torque value.”

440. It is my understanding that this claim limitation should be interpreted as “employing said engine to propel said vehicle when the torque required for propulsion of the vehicle, which may be positive or negative in value, is less than said lower level predetermined torque value and using the torque between the torque required for propulsion of the vehicle, which may be positive or negative in value, and the predetermined torque value to drive said at least one electric motor to charge said battery when the state of charge of said battery indicates the desirability of doing so.”

441. As disclosed above in claim limitation [1.6], the engine is controlled to operate in a in an efficient region above a lower torque bound, or “setpoint.”

442. As shown in Table 2 from Bumby II, the Bumby Project also

discloses a “Battery charge mode” where the engine provides “power to charge the battery with the traction motor.” (Ex. 1105 at 5)(*See also* Ex. 1106 at 3-Table 1).

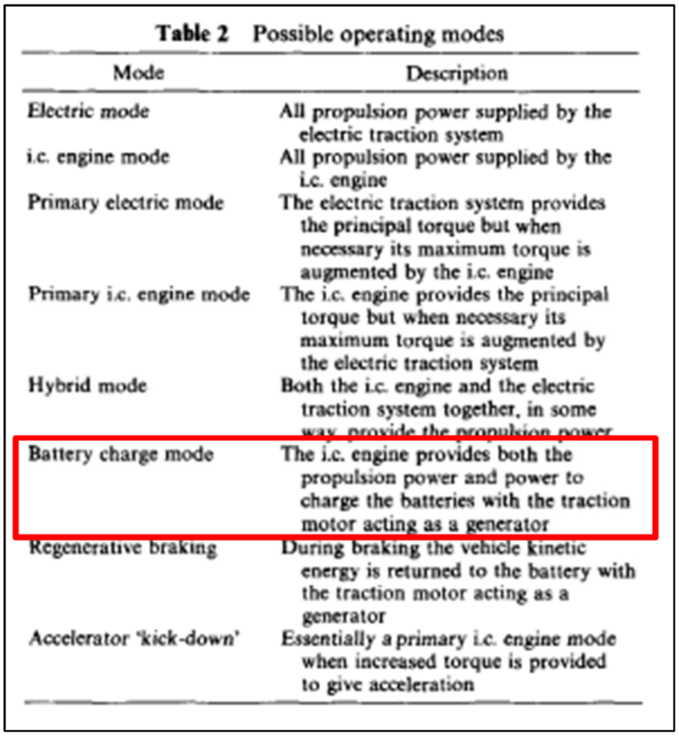


Table 2 Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric traction system
i.c. engine mode	All propulsion power supplied by the i.c. engine
Primary electric mode	The electric traction system provides the principal torque but when necessary its maximum torque is augmented by the i.c. engine
Primary i.c. engine mode	The i.c. engine provides the principal torque but when necessary its maximum torque is augmented by the electric traction system
Hybrid mode	Both the i.c. engine and the electric traction system together, in some way, provide the propulsion power
Battery charge mode	The i.c. engine provides both the propulsion power and power to charge the batteries with the traction motor acting as a generator
Regenerative braking	During braking the vehicle kinetic energy is returned to the battery with the traction motor acting as a generator
Accelerator ‘kick-down’	Essentially a primary i.c. engine mode when increased torque is provided to give acceleration

443. The Bumby Project also discloses that the engine can be operated to provide more torque than what is required for propulsion of the vehicle, and use the excess torque to charge the battery:

> Indeed, the **IC engine could supply torque in excess of the value demanded at the road wheels**, such that the **excess energy is used to charge the traction batteries**.

(Ex. 1104 at 3, emphasis added.)

444. The Bumby Project also discloses that the engine is controllably connected to the motor in order to apply torque to the motor when the battery state

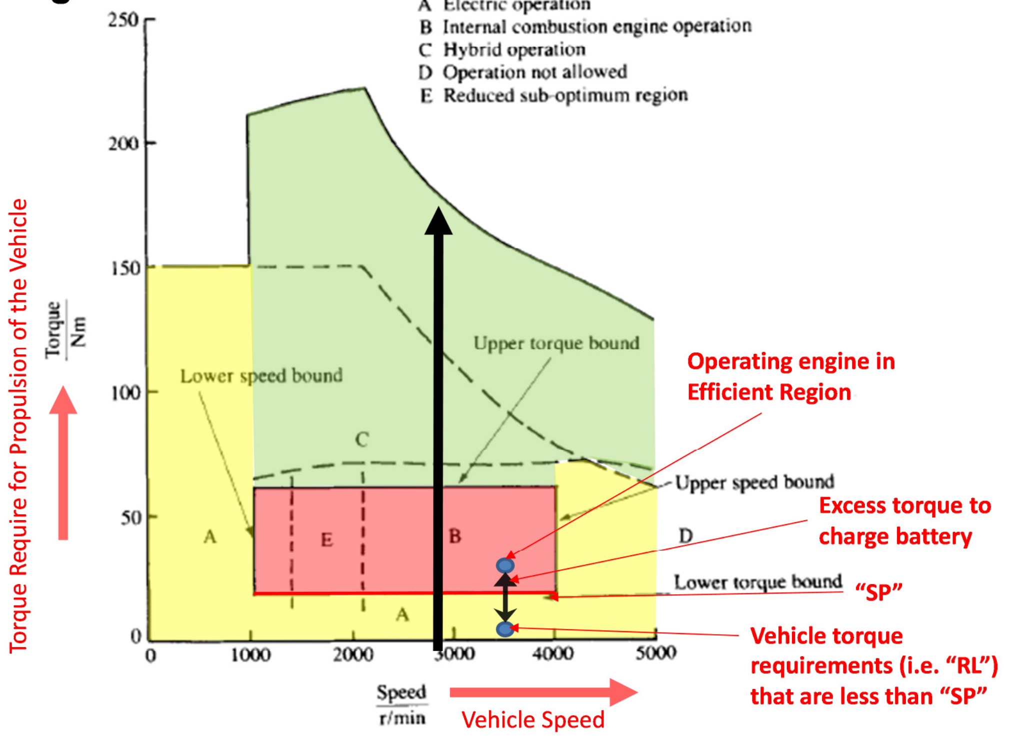
of charge is extremely low:

> Over journeys with an exceptionally large amount of acceleration or hill climbing, the battery state of charge may become very low, but this can not be allowed to continue until the batteries are completely depleted, since the vehicle would then be unable to move away from rest. To counter this problem, a negative torque may be scheduled from the motor so that **the engine both drives the wheels and charges the traction batteries**.

(Ex. 1107 at 4, emphasis added.)

445. Based on these disclosure in the Bumby Project, a person of ordinary skill in the art would understand that the engine could be operated to charge the battery when the torque required for propulsion of the vehicle was less than the lower torque bound, or "setpoint," as shown in Fig. 8, annotated below.

Fig. 8



(Ex. 1105 at 8-Fig. 8, annotated)

446. Since the Bumby Project discloses only operating the engine in the efficient region B/E, shown in Fig. 8, it would have been known that if the battery was too low to operate the motor in region A that corresponded to the low torque requirement, that the engine could be used. Based on the disclosures in the Bumby Project, it also would have been known that the engine could be operated at a higher torque level that was within the engine's efficient range, highlighted in red. Then the excess torque from the engine could be used to charge the battery.

447. While claim limitation [23.10] recites only "using the torque between RL and SP," it would have been known that the engine could be operated at or above the setpoint while still being in the engine's efficient operating region. For

the sake of illustration above, the engine is shown operating above the setpoint. Operating the engine above the setpoint would allow greater torque for charging the battery. Therefore, the Bumby Project discloses using the torque between the vehicle torque requirements ("RL") and the lower torque bound ("SP") to drive the electric motor to charge said battery.

448. The Bumby Project also discloses automatically changing to the "battery charging mode" when the battery state of charge is too low:

> The performance of a vehicle in any of these modes and the limits they impose on the operation can be defined but when to switch from one mode to another is less obvious. **However, the control must be able to automatically change modes when the battery state of charge is operating modes most appropriate for the journey**. A default to the hybrid mode would be included. Providing the battery state of charge is above a prescribed value then the driver preferred mode would be selected. **Below the prescribed battery state of charge the energy-saving mode would be selected. If battery state of charge then falls further and reaches a lower value, then the battery charging mode would be initiated and maintained until the battery state of charge had recovered sufficiently to revert to the energy-saving mode**.

(Ex.1104 at 13, emphasis added).

449. Therefore, it is my opinion that the Bumby Project discloses "*employing the engine to propel said vehicle when the torque required to do so is*

less than the lower level SP, and using the torque between RL and SP to drive the electric motor to charge said battery when the state of charge of said battery indicates the desirability of doing so."

> … ***[23.11] wherein the torque produced by said engine when operated at said setpoint (SP) is substantially less than the maximum torque output (MTO) of said engine.***

450. It is my understanding that proposed construction of "SP" as being "predetermined torque value."

451. As discussed above in claim limitation [1.7], the Bumby Project discloses that lower toque bound is substantially less than the engine's maximum torque output.

452. Therefore, it is my opinion that the Bumby Project discloses "*the torque produced by said engine when operated at said setpoint (SP) is substantially less than the maximum torque output (MTO) of said engine*."

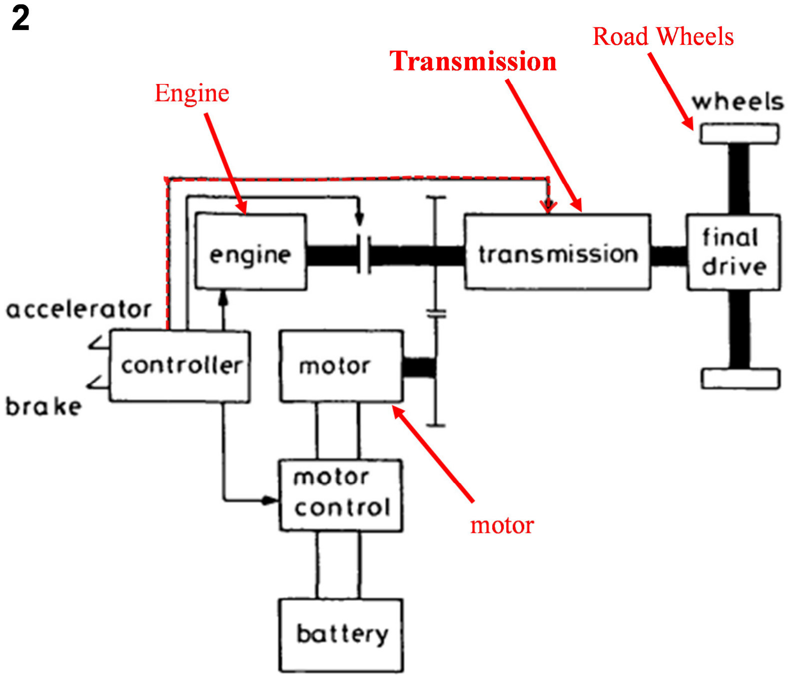
> … ***[37] The method of claim 23, wherein said hybrid vehicle further comprises a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller.***

453. Claim 37 depends from claim 23, and recites "wherein said hybrid

vehicle further comprises a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller."

454. As discussed above in Claim **[18]** The Bumby Project illustrates and discloses a variable ratio transmission, as shown in Fig. 2, below.

Fig. 2



(Ex. 1104 at 1-Fig. 2, annotated)

455. As annotated in Fig. 2, above, the controller is connected to the transmission for controlling the transmission and as such, the transmission would be responsive to a control signal from the controller.

456. Also, as illustrated, the transmission is positioned between the engine/motor and the road wheels.

457. Therefore, it is my opinion that the Bumby Project discloses "*a*

variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller."

IX. OBJECTIVE EVIDENCE OF NONOBVIOUSNESS

458. I understand that objective non-obviousness factors are to be considered in the obviousness analysis.

459. I understand that the Patentee is a non-practicing entity and will likely be unable to present on any commercial success from the sale of products.

460. I understand that other objective factors of nonobviousness include "long-felt but unmet need," "failed attempts by others," or "unexpected results." As I explained in the "State of the Art" (¶¶ 43-133) and "Analysis of the Claims" (¶¶ 234-457) above, hybrid vehicle architectures and control strategies were so well-known in the prior art that these factors do not appear to apply.

461. I understand that the patentee allegedly has obtained a bundled license to settle a string of infringement lawsuits involving Severinsky '970, the '347 Patent and certain other related patents.

462. It is my understanding that a nexus between the merits of the invention and this bundled license must be demonstrated in order to overcome a conclusion of obviousness. It is my understanding that such a nexus has not been presented.

463. Accordingly, having considered all of the relevant factors for obviousness, it is my opinion that the claims challenged are unpatentable.

X. CONCLUSION

464. In my opinion, all the elements of the challenged claim limitations are disclosed by the references discussed above and that the claims are unpatentable in view of these prior art references.

465. I reserve the right to supplement my opinions to address any information obtained, or positions taken, based on any new information that comes to light throughout this proceeding.

I declare under the penalty of perjury that the foregoing is true and accurate to the best of my ability.

Executed on: April 4, 2014

Gregory W. Davis, Ph.D., P.E.