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. 7,237,634 to Severinsky *et al.*

IPR Case No.: IPR2015-00800

DECLARATION OF DR. GREGORY W. 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 80, 91, 92, 95, 96, 99, 100, 102, 106, 114, 125, 126, 129, 132, 133, 135, 161, 172, 215, 226, 230, 233 AND 234 OF U.S. PATENT NO. 7,237,634)

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EXHIBIT LIST

Exhibit No.	Description	Date	Identifier
1901	U.S. Patent No. 7,237,634	July 3, 2007	'634 Patent
1902	7,237,634 File History (certified)	n/a	'634 Patent File History
1903	Declaration of Gregory Davis		Davis Dec.
1904	Ford Letter to Paice	Sept. 2014	
1905	"Computer modelling of the automotive energy requirements for internal combustion engine and battery electric-powered vehicles," IEE PROCEEDINGS, Vol. 132	Sept. 1985	Bumby I
1906	"Optimisation and control of a hybrid electric car," IEE PROCEEDINGS, Vol. 134	Nov. 1987	Bumby II
1907	"A hybrid internal combustion engine/battery electric passenger car for petroleum displacement," Proc Inst Mech Engrs Vol 202	1988	Bumby III
1908	"A test-bed facility for hybrid i c-engine/battery-electric road vehicle drive trains," Trans Inst MC Vol 10	Apr.-June 1988	Bumby IV
1909	"Integrated microprocessor control of a hybrid i.c. engine/battery-electric automotive power train," Trans Inst MC Vol 12	1990	Bumby V
1910	Masding Thesis – "Some drive train control problems in hybrid i.c engine/battery electric vehicles"	Nov. 1989	Masding Thesis
1911	US Patent 7,104,347	Sept. 12, 2006	'347 Patent
1912	Toyota Litigations	2005	Toyota Litigation
1913	Hyundai Litigation	2013-2014	Hyundai Litigation
1914	PTAB Decisions & Preliminary Response in 2014-00571		

Exhibit No.	Description	Date	Identifier
1915	Excerpt of USPN 7,104,347 File History	n/a	'347 File History
1916	Innovations in Design: 1993 Ford Hybrid Electric Vehicle Challenge	Feb. 1994	
1917	1996 & 1997 Future Car Challenge	Feb. 1997 & Feb. 1998	
1918	Introduction to Automotive Powertrain (Davis)		Davis Textbook
1919	US Application 60-100095	Filed Sept. 11, 1998	'095 Provisional
1920	History of Hybrid Electric Vehicle (Wakefield-1998)	1998	Wakefield
1921	SAE 760121 (Unnewehr-1976)	Feb. 1, 1976	Unnewehr
1922	SAE 920447 (Burke-1992)	Feb. 1, 1992	Burke 1992
1923	Vehicle Tester for HEV (Duoba-1997)	Aug. 1, 1997	Duoba 1997
1924	DOE Report to Congress (1994)	April 1995	1994 Report to Congress
1925	SAE SP-1331 (1998)	Feb. 1998	SAE SP-1331
1926	SAE SP-1156 (1996)	Feb. 1996	SAE SP-1156
1927	Microprocessor Design for HEV (Bumby-1988)	Sept. 1, 1988	Bumby/Masding 1988
1928	DOE HEV Assessment (1979)	Sept. 30, 1979	HEV Assessment 1979
1929	EPA HEV Final Study (1971)	June 1, 1971	EPA HEV Final Study
1930	WO 9323263A1 (Field)	Nov. 25, 1998	9323263
1931	Toyota Prius (Yamaguchi-1998)	Jan. 1998	Toyota Prius Yamaguchi 1998
1932	US Patent 6,209,672	April 3, 2001	'672 Patent
1933	Propulsion System for Design for EV (Ehsani-1996)	June 5, 1996	IEEE Ehsani 1996
1934	Propulsion System Design for HEV (Ehsani-1997)	Feb. 1997	IEEE Ehsani 1997
1935	Bosch Automotive Handbook (1996)	Oct. 1996	Bosch Handbook
1936	SAE SP-1089 (Anderson-1995)	Feb. 1995	SAE SP-1089

Exhibit No.	Description	Date	Identifier
1937	Critical Issues in Quantifying HEV Emissions (An 1998)	Aug. 11, 1998	An 1998
1938	Gregory Davis Resume		
1939	Gregory Davis Data		
1940	US Patent 5,789,882	Aug. 4, 1998	Ibaraki ’882
1941	US Patent 5,343,970	Sept. 6, 1994	Severinsky ‘970
1942	Paice Complaint	Feb. 25, 2014	
1943	U.S. Patent 6,116,363	April 21, 1998	Frank

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. 7,237,634 ("the '634 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. Each of the exhibits listed are true and accurate copies. The Exhibit list also includes true and accurate citations for each exhibit I have reviewed including a weblink, library of congress number or other markings denoting authenticity where applicable.

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 to me, 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 1938.

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. Further, I am a licensed "Professional Engineer" in the state of Michigan.

8. As shown in my curriculum vitae, most of my career has been in the field of automotive engineering, including 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 continued my education at 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. Some of the hybrid electric vehicle work that I worked on at the U.S. Naval Academy was published in a bound 1994 SAE special publication. I have attached as Exhibit 1916 a true and accurate copy of the 1994 paper that was

submitted on behalf of my team for this competition. (Ex. 1916 [1993 Hybrid Challenge].)

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 Motors Company, and Chrysler Corporation.

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

24. Attached as Exhibit 1917 is a true and accurate copy of the competition papers that were submitted for the 1996 and 1997 competitions for which I served as the faculty advisor. (Ex. 1917 [1996 & 1997 Future Car Challenge].)

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. For one of my classes on automotive powertrains, I and a fellow professor (Craig

Hoff) co-authored a textbook titled "Introduction to Automotive Powertrains." A true and accurate copy of excerpts from this textbook is attached as Exhibit 1918. The full version of this textbook is around 400 pages long and is used in my course to give engineering students an introductory understanding of the fundamentals of automotive engines, automotive transmissions, and how to select those components to provide the optimum compromise between acceleration performance, gradeability performance and fuel economy performance. (Ex. 1918 [Davis Textbook] at 2.) Further, this textbook is based on mine and Professor Hoff's personal collection of class notes that we had been using to teach such fundamental automotive principles as far back as the mid-1990's.

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, the development of electric vehicles, and other extensive modifications and development of vehicular powertrains.

34. I also serve as faculty advisor to the Society of Automotive Engineers International (SAE) of the local Student Branch and for the "SAE Clean Snowmobile Challenge," and "SAE Aero Design" collegiate design competitions. At the national level, 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 or governmental entities.

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 '634 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 account 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 ’634 Patent, those patents cited in the ’634 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. 1919.) 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. It is my opinion that 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. My opinion is supported by a true and accurate copy of excerpts from the 1998 textbook titled the "History of the Electric

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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".)

Automobile" authored by Ernest Wakefield. (Ex. 1920 [Wakefield] at 11.)[2]

44. For instance, Wakefield describes a functioning hybrid vehicle that was designed and built by Justus Entz in May 1897. (Ex. 1920 [Wakefield] at 11-13.)

45. My opinion is also supported by hybrid vehicle patents that I am aware extend as far back as 1909 for U.S. Patent No. 913,846 to Pieper that was granted for a "Mixed Drive Auto Vehicle."

46. As is explained by Wakefield, the hybrid vehicle disclosed by the Pieper patent was likewise assembled as a functioning hybrid vehicle that was publically used. (Ex. 1920 [Wakefield] at 13-14.)

47. As is explained by Wakefield, well-known hybrid vehicles were built and publically used by Baker and Woods in 1917. (Ex. 1920 [Wakefield] at 21-23.)

48. Based on my experience and knowledge a known goal of using hybrid vehicles is the possibility of operating the engine at its "optimum efficiency." For instance, a 1976 SAE paper states:

> 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**

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[2] Ex. 1920 [Wakefield] is stated as being copyrighted in 1998 and available from the Society of Automotive Engineers (SAE.) (Ex. 1920 [Wakefield] at 2.)

> **acceleration capability, audible noise reduction, operation of an engine or turbine at optimum efficiency, reduction of noxious emissions, and improved fuel economy**.

(Ex. 1921 [Unnewehr] at 1, emphasis added.)[3]

49. It is my understanding that based on events in the 1970's, 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. 1922 [Burke 1992] at 3[4]; Ex. 1923 [Duoba 1997] at 3.)[5]

50. It is also my understanding that 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

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[3] Ex. 1921 [Unnewehr] is a true and accurate copy of an SAE paper titled "Hybrid Vehicle for Fuel Economy" that was published by L.E. Unnewehr et al. that I understand was published on February 1, 1976.

[4] Ex. 1922 [Burke 1992] is a true and accurate copy of a SAE paper titled "Hybrid/Electric Vehicle Design Options and Evaluations" authored by Andrew Burke that I understand was published on February 1, 1992.

[5] Ex. 1923 [Duoba 1997] is a true and accurate copy of a paper titled "Challenges for the Vehicle Tester in Characterizing Hybrid Electric Vehicles" authored by Michael Duoba that I understand was published by the U.S. DOE on August 1, 1997.

technologies." (Ex. 1924 [1994 Report to Congress] at 4.)[6]

51. As a result of this law, it is my understanding that hybrid and electric vehicles were being developed by automotive corporations. (Ex. 1924 [1994 Report to Congress] at 4.)

52. It is my understanding that during the 1980's and 1990's, Ford Motor Company and Toyota Motor Company were involved in the design and development of both hybrid and electric vehicles. (*See e.g.,* Ex. 1921 [Unnewehr] at 1; Ex. 1925 [SAE SP-1331][7] at 4-5.)

53. It is further my understanding that collegiate competitions intensified hybrid vehicle research during the 1990's starting with the 1993 Ford Hybrid Electric Vehicle Challenge. As indicated by Ex. 1916 [1993 Hybrid Challenge] I personally participated in the 1993 Ford Hybrid Electric Vehicle Challenge. (Ex. 1916 [1993 Hybrid Challenge] at 6.) By 1994 these competitions had grown to include teams from over 30 universities representing more than 800 students. (Ex. 1924 [1994 Report to

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[6] Ex. 1924 [1994 Report to Congress] is a true and accurate copy of the "Electric and Hybrid Vehicles Program – 18th Annual Report to Congress for Fiscal Year 1994" that I understand was published by the U.S. Department of Energy in April 1995.

[7] Ex. 1925 [SAE SP-1331] is a true and accurate copy of excerpts from a SAE special publication that I understand was published in February 1998. (Ex. 1925 [SAE SP-1331] at 2.)

Congress] 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" and the 1994-1995 competitions. (Ex. 1916 [1993 Hybrid Challenge] 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 electric vehicle competitions. (Ex. 1917 [1996 & 1977 Futurecar] at 6, 23.)

56. Based upon the level of research and development prior to 1998, it is my opinion that various hybrid vehicle "architectures" were well-known. (*See e.g.*, Ex. 1926 [SAE SP-1156] at 4, 7-8.)[8] As I explain in more detail below, hybrid vehicle "architectures" included: (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 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 below, these varying hybrid vehicle architectures differed in

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[8] Ex. 1926 [SAE SP-1156] is a true and accurate copy of an SAE special publication titled "Strategies in Electric and Hybrid Vehicle Designs" that I understand was published in February 1996.

how the powertrain (*i.e.*, the engines and motors) was arranged and connected to the wheels. It is my opinion that the various architectures were implemented to achieve many of the goals I mentioned above in ¶48, including operating the engine at its peak efficiency. (*See e.g.*, Ex. 1921 [Unnewehr] at 1; Ex. 1926 [SAE SP-1156] at 4, 7.)

58. It is my opinion that computer based microprocessor controllers were implemented to refine the control the engine, motor(s), transmission, and clutching mechanisms of the hybrid vehicle. For instance, my opinion is supported by a September 1988 paper which states:

> Automating the operation of a vehicle transmission allows the control of the engine and transmission system to be integrated, giving substantial benefits in terms of vehicle performance, energy efficiency and driveability. Although such a statement is applicable to internal combustion {ic} engine vehicles, electric vehicles and hybrid-electric vehicles the details relating to how the engine/transmission should be controlled are quite different. The main thrust of this paper is to consider the automation and control of a discrete ratio, synchromesh transmission for use in an electric or a hybrid-electric vehicle. As a hybrid-electric vehicle includes both an electric traction motor and an ic engine in its drive system it is relevant to outline briefly the benefits to be gained by automating the transmission system in both an ic engine and an electric vehicle.

(Ex. 1927 [Bumby 1988] at 2.)[9]

59. It is also my understanding that control strategies for hybrid vehicles varied based on the architecture being employed but the primary goal typically remained focused on operating the engine within its "sweet spot" or "optimum efficiency range." (*See e.g.,* Ex. 1921 [Unnewehr] at 1; Ex. 1925 [SAE SP-1331] at 4.)

60. It is my opinion that 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. 1923 [Duoba 1997] at 3.)

A. "Series" Hybrid Vehicle

61. It is my opinion that a person of ordinary skill in the art understood certain design and operational advantages were possible with "series" hybrid vehicle architectures. My opinion is supported by Ex. 1928 [HEV Assessment 1979] which is a true and accurate copy of a September 1979 publication titled "Hybrid Vehicle Potential Assessment" authored by K.O. Leschly and a 1996 SAE publication. (Ex.

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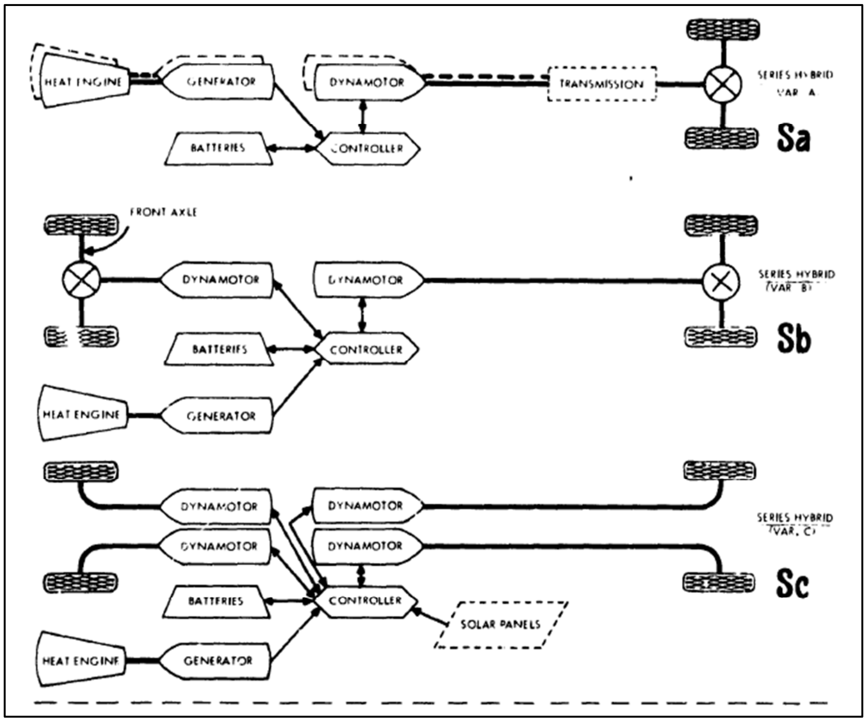
[9] Ex. 1927 [Bumby 1988] is a true and accurate copy of a September 1988 journal article titled "A microprocessor controlled gearbox for use in electric and hybrid electric vehicles." that is stated as being published in the journal of Transactions of the Institute of Measurement and Control and available through Sage publications at http://tim.sagepub.com/content/10/4/177.

1928 [HEV Assessment 1979][10]; Ex. 1926 [SAE SP-1156].)

62. As illustrated by the 1979 publication, is my opinion that a person having ordinary skill understood that "series" hybrid vehicles could be designed in various arrangements that could include one or more electric motors.[11] (Ex. 1928 [HEV Assessment 1979] at 17.)



Ex. 1928 [HEV Assessment 1979] at 17, Fig. 7

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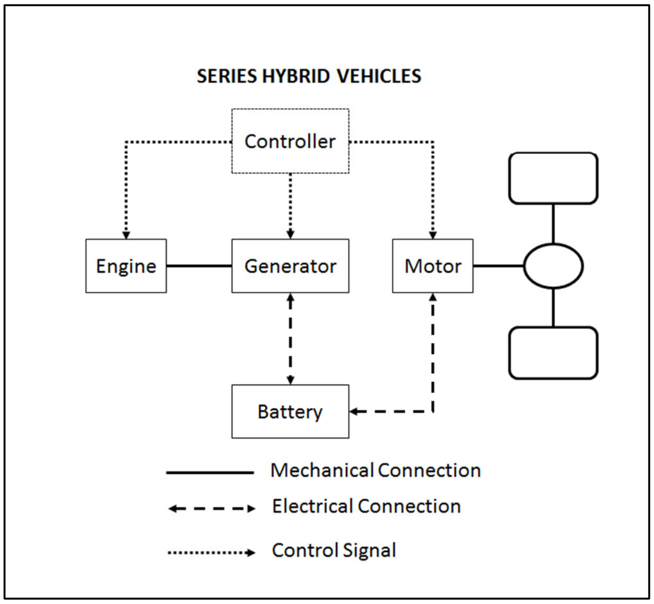
[10] Ex. 1928 [HEV Assessment 1979] is a true and accurate copy of a U.S. Department of Energy's OSTI paper that was published on Sept. 30, 1979.

[11] 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.

63. Although multiple configurations were known, I have provided the following exemplary figure that is based on my understanding, experience and knowledge to explain the general architecture and operation of a "series" hybrid vehicle.



64. As I illustrated, the traction motor is connected to the road wheels for a "series" hybrid vehicle as discussed in Ex. 1922 [Burke 1992] at page 6, and Ex. 1926 [SAE SP-1156] at pages 7-8.

65. In other words, it is my opinion that the **motor alone** provides the torque required to propel the vehicle. (Ex. 1922 [Burke 1992] at 6; Ex. 1926 [SAE SP-1156] at 15.)

66. The engine in a series hybrid, on the other hand, is **not mechanically connected** to the wheels and the engine is therefore controlled independently of driving conditions. (Ex. 1922 [Burke 1992] at 6; Ex. 1926 [SAE SP-1156] at 7-8.)

67. It is my opinion that the engine does not provide any of the torque required to propel the vehicle; rather, the engine powers the generator independent of road conditions to produce electrical energy that is stored in the battery and/or used by the motor.

68. It is my opinion that for a series hybrid, the "primary function of the engine/ generator is to extend the range of the electric vehicle beyond that possible on batteries alone." (Ex. 1922 [Burke 1992] at 6.) It is also my opinion that 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. It is my understanding that electrical sources were less common than gas stations and the time required to fully charge the battery could be longer than most drivers would be willing to wait.

69. It is my understanding that by having the engine controlled independently of the torque and speed requirements of the vehicle, "series operation has the advantage of allowing the engine to operate at a constant speed in the vicinity of its optimum (in terms of efficiency and emissions) operating point." (Ex. 1926 [SAE SP-1156] at 4.) However, during conditions of low battery state of charge, the engine could be operated outside its "sweet spot." Such efficient operation was performed for the sole purposes of operating the generator illustrated by the figure in ¶63. (Ex. 1922 [Burke 1992] at 6-7; Ex. 1926 [SAE SP-1156] at 7.)

B. "Parallel" Hybrid Vehicle

70. It is my opinion that a person of ordinary skill in the art understood certain design and operational advantages were possible with "parallel" hybrid vehicle architectures. (*See e.g.,* Ex. 1922 [Burke 1992] at 7-8; Ex. 1926 [SAE SP-1156] at 7-8.)

71. As is illustrated by the 1979 DOE paper, it is my opinion that a person having ordinary skill understood that "parallel" hybrid vehicles could be designed in various arrangements that could include one or more electric motors.[12] (Ex. 1928 [HEV Assessment 1979] at 18.)

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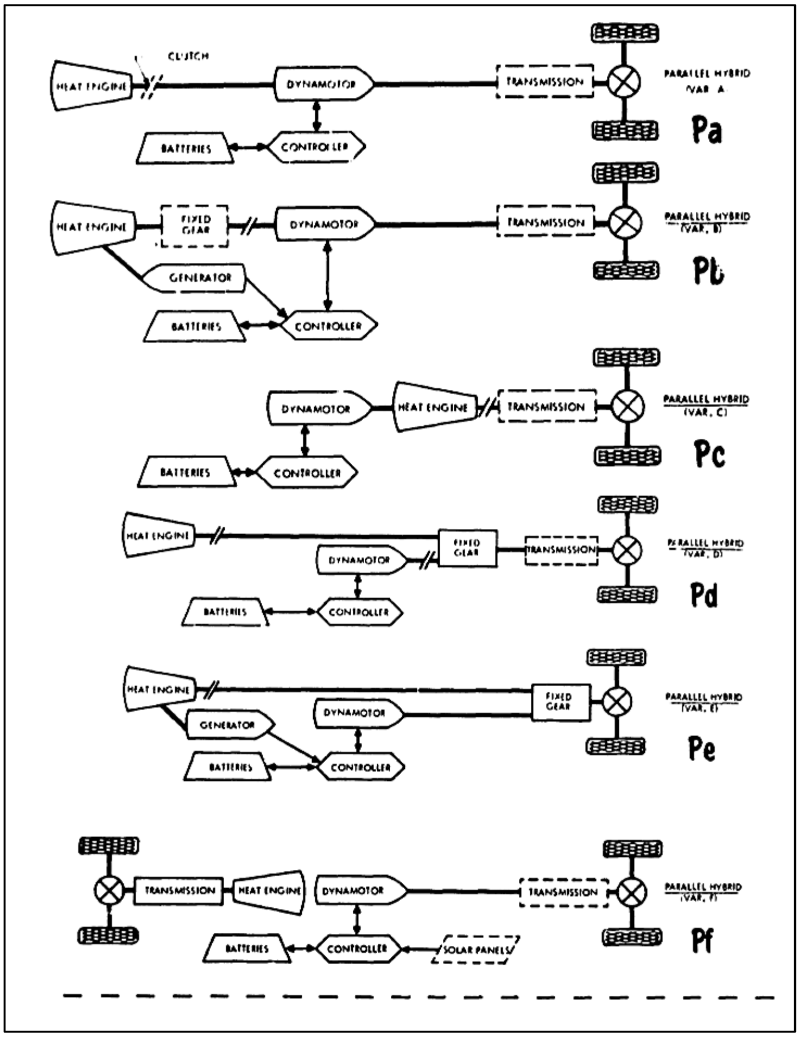
[12] The term "dynamotor" was commonly used to describe an electric motor that was capable of operating both as (1) a motor for propulsion; and (2) as a generator that converts mechanical torque into electrical energy that is stored in the battery.



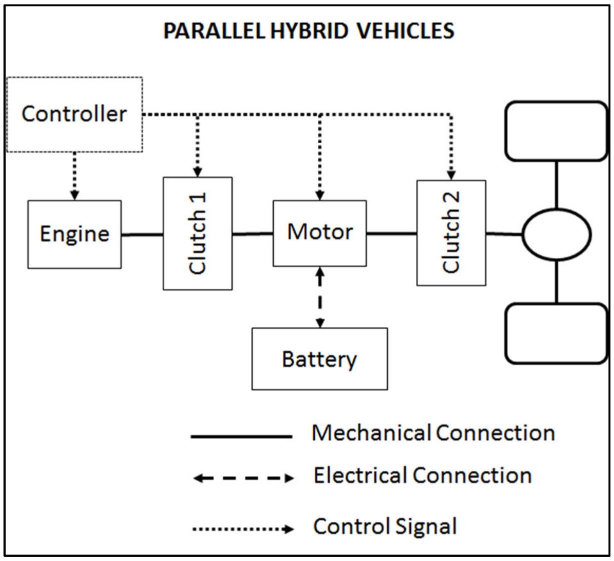
Ex. 1928 [HEV Assessment 1979] at 18, Fig.7

72. As illustrated above, it was known that 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. 1928 [HEV Assessment 1979] at 18.)[13]

1. One-Motor "Parallel" Hybrid Vehicle

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



74. As illustrated, "parallel" hybrid vehicles typically included one or more "clutches" that were controlled by a microprocessor (*i.e.*, controller.)[14] These clutches

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[13] 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."

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

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. 1922 [Burke 1992] at 5.)

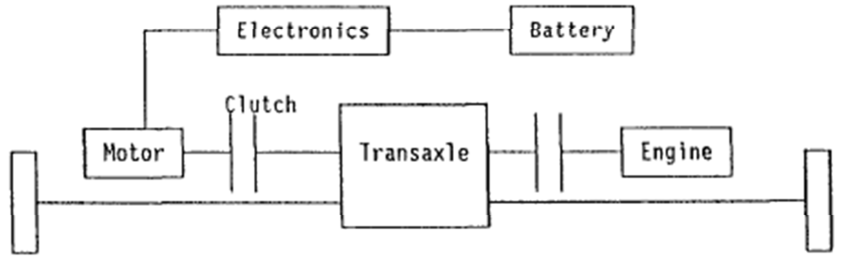

Figure 5. Parallel hybrid driveline schematics.

Ex. 1922 [Burke 1992] at 25, Fig. 5

76. With reference back to my exemplary figure illustrated in ¶73, "parallel" hybrid vehicles engage the motor and/or engine by operating one or more clutches. For example, the controller could engage "clutch 1" and "clutch 2" which would connect the engine to the road wheels.

77. Alternatively, the controller could disengage "clutch 1" and engage

"clutch 2" which would connect the motor to the road wheels. Either or both "clutch 1" and "clutch 2" could be engaged in order to connect either the motor or both the engine and the motor 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) becomes 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 is also my opinion based on my knowledge and experience that, the engine in a "parallel" hybrid vehicle could be downsized and controlled to run only at speed and load ranges where engine operation was most efficient (*e.g.*, steady state or highway cruising.)

81. It is also my opinion based on my knowledge and experience that, the traction motor in a "parallel" hybrid vehicle could 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 explained 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. 1921 [Unnewehr] at 17.)

83. In other words, it is my opinion that 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. 1922 [Burke 1992] 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. 1921 [Unnewehr] 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.

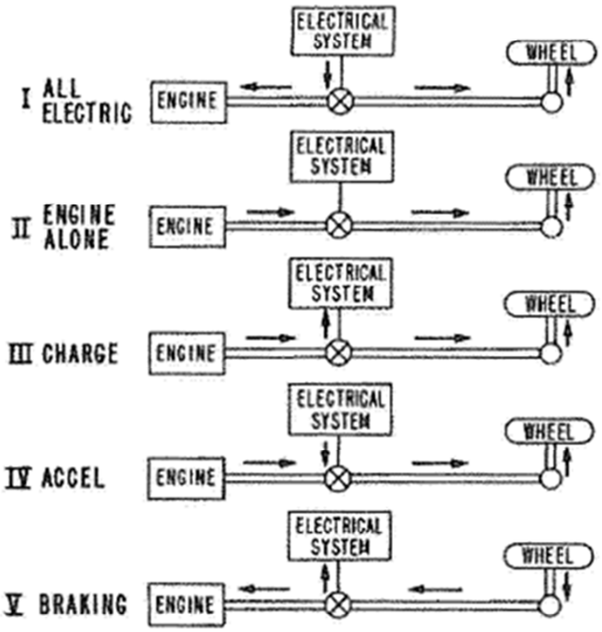

Fig.2 -Five hybrid modes of operation

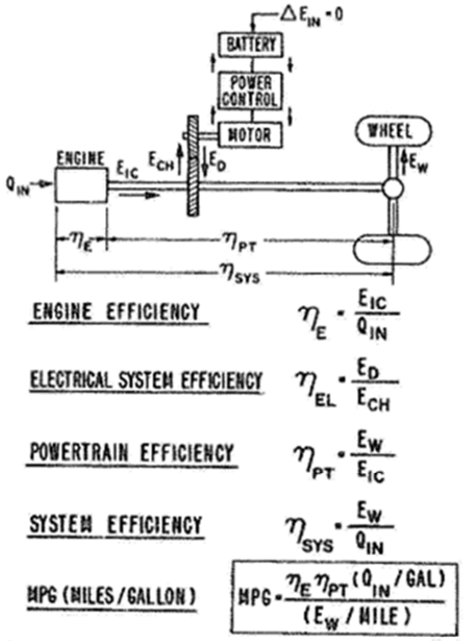

Fig.4 -Average fuel economy for a hybrid vehicle in terms of system efficiencies and energies

(Ex. 1921 [Unnewehr] at 3-4, Fig. 2 & 4)

85. This disclosure supports my understanding 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. 1921 [Unnewehr] at 17.) In other words, the engine could be operated at "higher load factors" which provides "increased efficiencies." (Ex. 1921 [Unnewehr] at 4.)

86. It is also my opinion that it was known by 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. 1921 [Unnewehr] at 17.)

2. Two-Motor "Series-Parallel" Hybrid Vehicle

87. As was illustrated in ¶ 72 above, two-motor "parallel" hybrid vehicles

were also well known. (Ex. 1928 [HEV Assessment 1979] at 18; Ex. 1926 [SAE SP-1156] at 8.)

88. I have provided below an illustration from a true and accurate copy of a 1971 Department of Energy report that describes one well-known two motor "parallel" hybrid vehicle configuration. (Ex. 1929 [EPA HEV Final Study 1971] at 20.)[15]

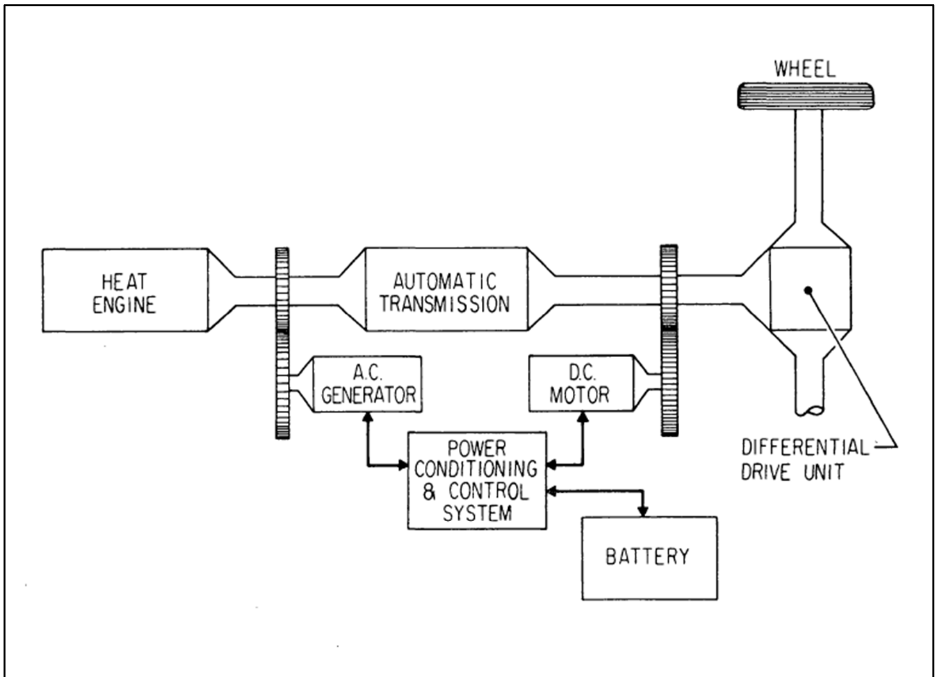

Figure 10- 7. Selected Baseline Parallel Configuration Concept

Ex. 1929 [EPA HEV Final Study] at 381, Fig. 10-7

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[15] Ex. 1929 [EPA HEV Final Study 1971] is true and accurate copy of a 1971 U.S. Environmental Protection Agency ("EPA") publication titled "Final Report Hybrid Heat Engine / Electric Systems Volume l: Sections l through 13 Study." (Ex. 1929 [EPA HEV Final Study 1971] at 1.)

89. It is my opinion that 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. 1929 [EPA HEV Final Study 1971] at 380.)

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. By the mid-1990's two-motor "parallel" hybrid vehicles had begun to be referred to as "**series-parallel" hybrid** vehicles. (Ex. 1926 [SAE SP-1156] at 8.) In September 1998, it was well known that "series-parallel" hybrid architectures combined the functionality of both "series" and "parallel" systems to achieve the advantages of both systems while overcoming the problems of either system when used individually. For instance a true and accurate copy of a 1993 PCT international patent application states:

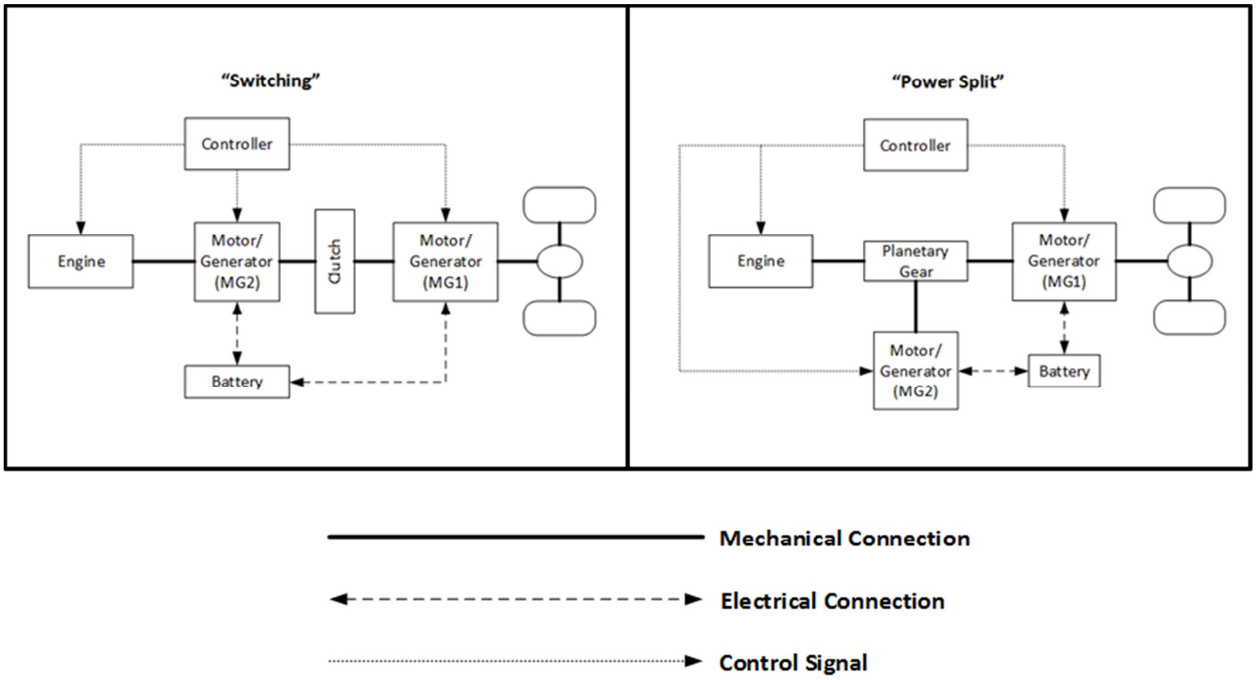
> Prior hybrid propulsion systems were typically capable of operating in one or more of the following modes (but none were capable of operating in a choice of all of them): (1) a series hybrid, which is plugged in for recharge, and which uses the engine as a "range extender" when the electrical storage mechanism are depleted, and/or (2) a series hybrid which runs the engine in order to recharge its own electrical storage mechanism, typically via a generator/alternator, and/or (3) a parallel hybrid, which is plugged in for recharge, and which uses the engine and/ or the electric motor either separately or in unison,

> depending upon conditions, circumstances, and the process controller, in order to directly power the vehicle, and/or (4) a parallel hybrid similar to the one described in (3), directly above, but which recharges its own electrical storage system via the engine and, typically, a generator/alternator (see U.S. Patent No. 5,081,365.) Each of these modes has its benefits and drawbacks, depending on circumstances, thus the industry is involved in debate over which system is the most promising.
>
> **<u>The purpose of the series-parallel functionality is to overcome problems inherent to either concept when employed individually.</u>** The advantages are increased range in the urban driving mode and a secondary method of range extension in highway mode without significantly increasing the bulk or cost of the base parallel system. In addition, the control of the operation of the drive motor is more versatile and efficient.

(Ex. 1930 [9323263], 7, line 8-29, emphasis added.)

92. Although multiple flavors of series-parallel architectures existed, I have provided the following non-limiting exemplary figures based on my understanding, experience and knowledge in order to explain the architecture and operation of the more common two-motor "series-parallel" hybrid vehicles that were known in the art prior to September 1998. (*See e.g.,* Ex. 1926 [SAE SP-1156] at 8.) Based on my understanding, experience and knowledge, one of the more significant changes between a one-motor and two-motor "parallel" hybrid vehicle is the inclusion of a

second motor/generator (illustrated as MG2.)[16]



a. "Switching" Two-Motor "Series-Parallel" Hybrid Vehicles

93. As illustrated in ¶92 above, the two-motor "series-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 ¶92 above, the two-motor "series-parallel" hybrid

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[16] 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. Again, historically such a component was referred to as a "dynamotor."

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. 1926 [SAE SP-1156] 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. 1926 [SAE SP-1156] at 8.)

97. It was also known that the engine would be decoupled during operation in urban (city) driving where the load or torque required to propel the vehicle was low. (Ex. 1926 [SAE SP-1156] at 8.)

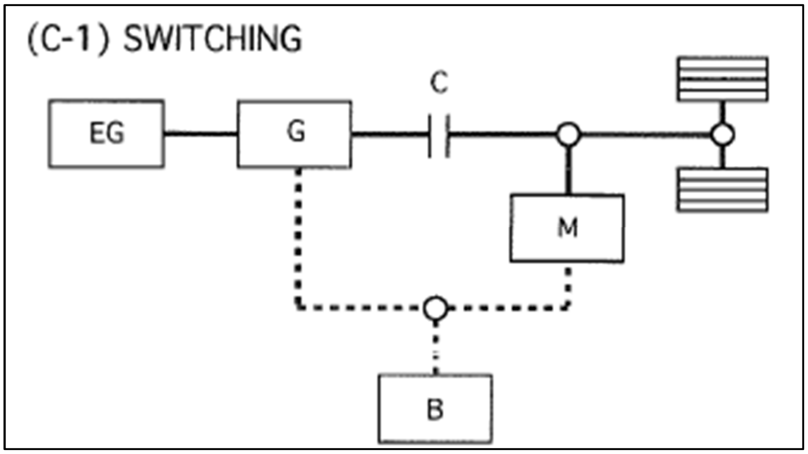
98. With the engine decoupled from the road wheels, the "switching" system could operate like a "series" hybrid vehicle with the engine powering the generator to recharge the battery when needed. (Ex. 1926 [SAE SP-1156] at 8.)

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. 1926 [SAE SP-1156] at 8.)

100. For instance, a 1996 SAE publication discloses the following known benefits of a switching "series-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. 1926 [SAE SP-1156] at 8.)



Ex. 1926 [SAE SP-1156] at 8, Fig. 1

101. Based on my understanding, experience and knowledge, one known advantage of the operation described in paragraph 100 is that the engine operates inefficiently at low loads so during such conditions (*e.g.*, city driving) the vehicle operates as a series vehicle with the electric motor propelling the vehicle. However, at higher loads where engine operation is efficient, the engine could be reconnected *via*

the clutch and used to propel the vehicle. (Ex. 1926 [SAE SP-1156] at 8, 15.)

102. Also, 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. 1926 [SAE SP-1156] at 8.)

103. Based on my understanding, experience and knowledge, one-motor "parallel" hybrid vehicles were not able to operate in a series mode due to the absence of the second motor/generator.

b. "Power-Split" Two-Motor "Series-Parallel" Hybrid Vehicles

104. "Power split" systems on the other hand, were known as being capable of operating as both a "series" ***and*** "parallel" hybrid at all times. (Ex. 1926 [SAE SP-1156] 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. 1926 [SAE SP-1156] at 8.)

106. It is my understanding that "power split" hybrids were developed as far back as 1970 by TRW and were commercially made available around 1997 by Toyota. My opinion is supported by a true and accurate copy of a July 1998 Automotive Engineering International article titled "Toyota Prius" that describes the original Toyota Prius platform. (Ex. 1931 [Toyota Prius Yamaguchi 1998] at 2.)

107. It was known that in 1997 Toyota commercially released the Prius

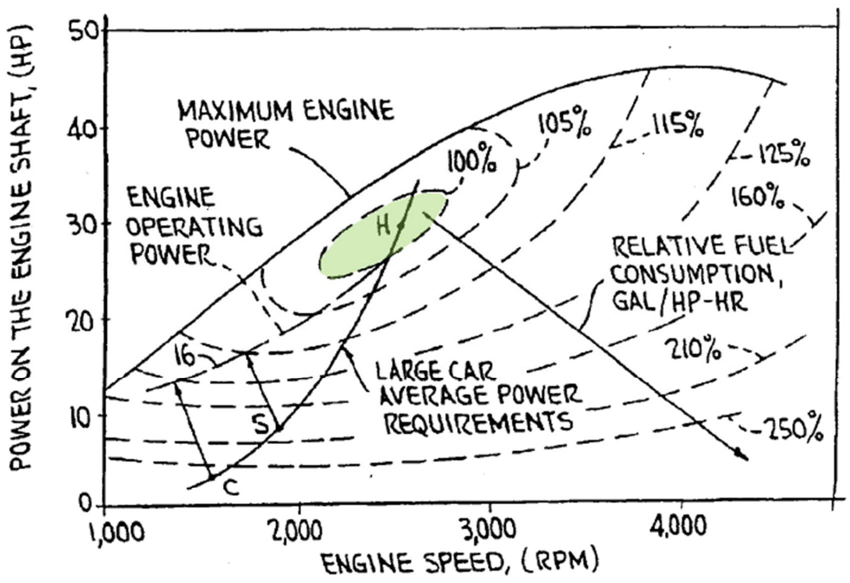
"power split series-parallel" hybrid vehicle with a control strategy that determined operating modes based on the speed and load (*i.e.*, required driving torque) of the vehicle. (Ex. 1931 [Toyota Prius Yamaguchi 1998] at 2.)

C. Hybrid Vehicle "Control Strategies"

108. It is also my opinion that a person having ordinary skill in the art understood 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 '634 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 100% region which I have highlighted in green is "the most efficient region of operation of the engine" (*i.e.*, the engine's "sweet spot".) (Ex. 1932 ['672 Patent] at 17:16-19, Figure 2.)

FIG. 2



Ex. 1932 ['672 Patent] at Fig. 2 (annotated)

110. A September 1988 publication also illustrates an engine map showing efficiency curves for a typical gasoline engine. Based on my experience and knowledge, and 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. 1927 [Bumby 1998] at Figure 1.)

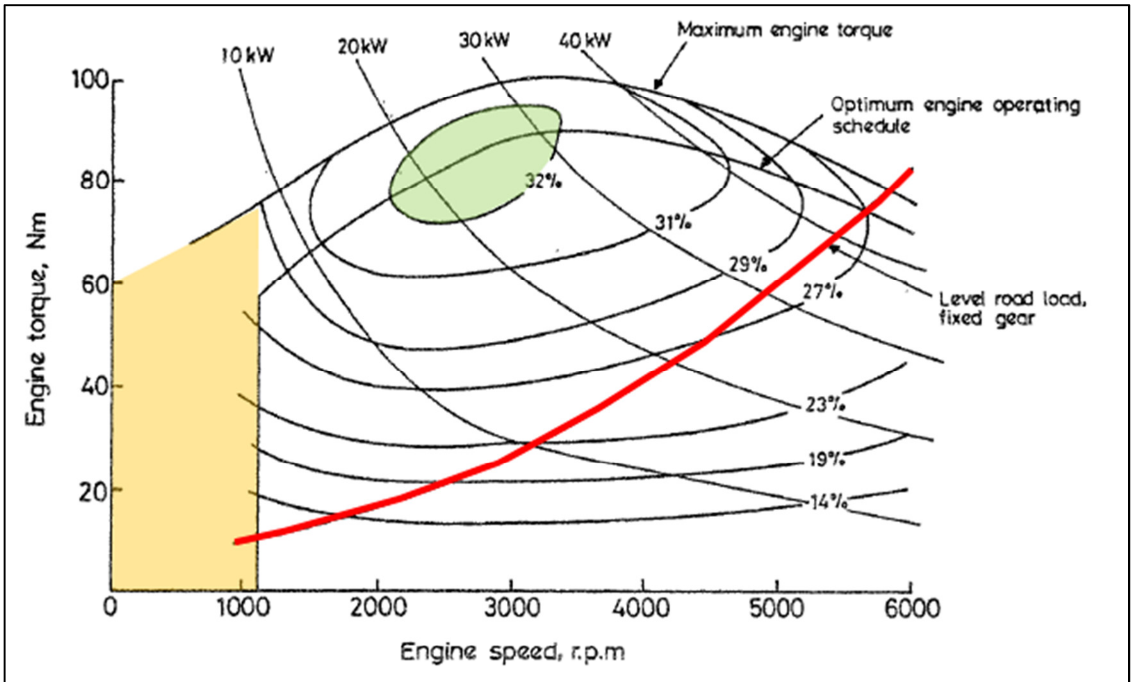


Fig 1 Road-load and engine-operating curves for an ic engine vehicle

Ex. 1927 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. 1927 [Bumby 1998] at 2.)

112. It is also my opinion that a person having ordinary skill understood that engines typically 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 is my opinion that 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. 1918 [Davis Textbook] at 9.)

114. For instance 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 supports 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. 1933 [IEEE Ehsani 1996] at 2[17]; *see also* Ex. 1934 [IEEE Ehsani 1997] at 2[18].)

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[17] It is my understanding that Ex. 1933 [IEEE Ehsani 1996] is a true and accurate copy of a 1996 Institute of Electrical and Electronics Engineers (IEEE) publication

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 supports my understanding 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. 1935 [1996 Bosch Handbook] at 15-18[19].)

116. It is my opinion that such knowledge is necessary because automotive engineers must design a powertrain that is capable of providing sufficient "tractive

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titled "Propulsion system design of electric vehicles" authored by Mehrdad Ehsani et al.

[18] Ex. 1934 [IEEE Ehsani 1997] is a true and accurate copy of a 1997 IEEE publication entitled "Propulsion system design of electric and hybrid vehicles" authored by Mehrdad Ehsani et al.

[19] Ex. 1935 [1996 Bosch Handbook] is a true and accurate copy of excerpts from the 1996 Bosch Automotive Handbook that is published by the SAE. Ex. 1935 [1996 Bosch Handbook] is my personal copy that I have maintained without modifications throughout the years. Ex. 1935 [1996 Bosch Handbook] is identified as being published and copyrighted by Robert Bosch GmbH in 1996. (Ex. 1935 [1996 Bosch Handbook] at 2.)

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)[20] 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. Based on my experience and knowledge, during vehicle operation, the tractive effort ($\mathbf{F_{TE}}$) is generally used to overcome the road load forces ($\mathbf{F_{RL}}$) experienced by the vehicle.

118. Based on my experience and knowledge, 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. Alternatively, if the tractive effort of the vehicle is less than the road load forces ($\mathbf{F_{TE}} < \mathbf{F_{RL}}$), 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. Based on my experience and knowledge, when a vehicle is travelling up a hill or when the driver requests an increased demand for acceleration, tractive 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

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[20] A person of ordinary skill in the art understands that Tractive Force = Torque /Radius of Tire (Ex. 1935 [Bosch Handbook] at 6-7.)

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. Further based on my experience and knowledge, 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 provided by the powertrain 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 the figure below (which is the same figure shown in above

in ¶ 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.

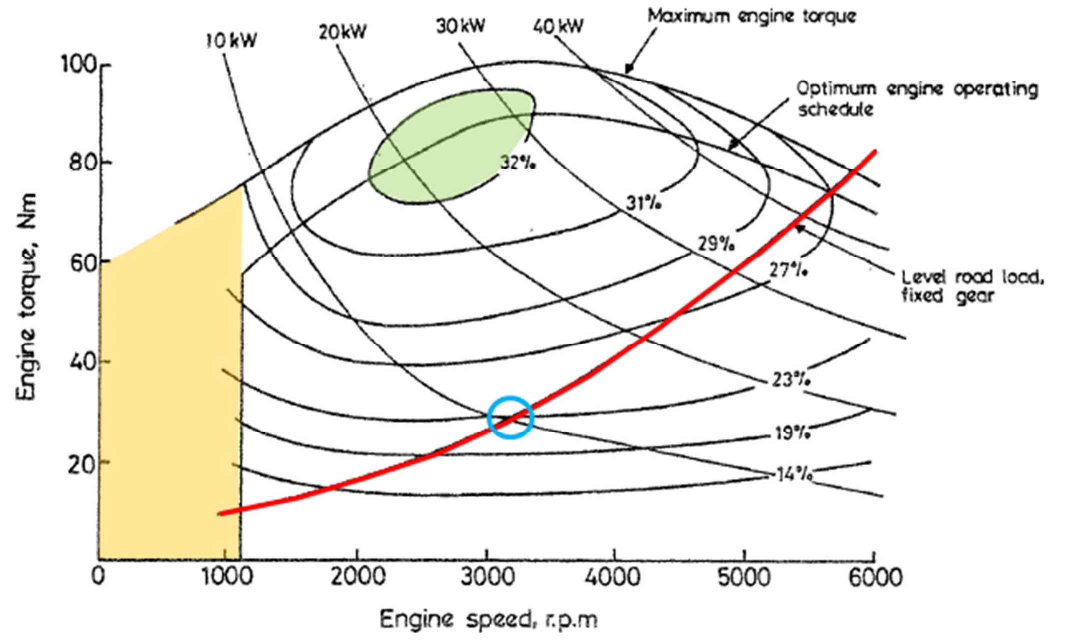

Fig 1 Road-load and engine-operating curves for an ic engine vehicle

Ex. 1927 [1988 Bumby] 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.

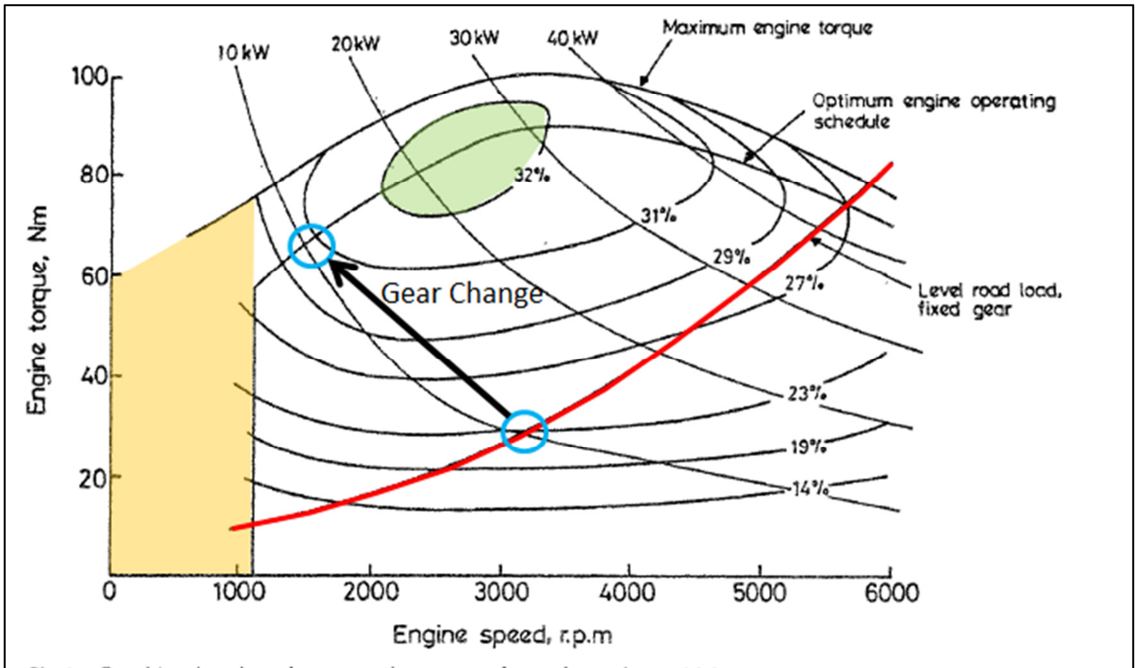

Fig 1 Road-load and engine-operating curves for an ic engine vehicle

Ex. 1927 [1988 Bumby] 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 transmission gear shift (blue circle to right) is provided 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 provided at a more efficient engine operating point, which is closer to the engine's "sweet spot."

124. Based on my experience and knowledge, efficient usage of the engine may further be improved if a hybrid vehicle includes a motor which can be used to provide 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. Based on my experience and knowledge, 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. 1932 ['672 Patent] at 17:25-27.)

127. Other prior art references again support this well-known understanding of engines.

> 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. 1922 [Burke 1992] at 7-8.)

128. Hybrid vehicles sought to overcome such inefficient engine operation. As explained in Section 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 and vehicle speeds); (2) an "engine-only" mode where the engine propels the vehicle when engine operation is

efficient (*i.e.*, higher loads and 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. 1921 [Unnewehr] at 3.)

129. A 1995 SAE article also supports my understanding that one advantage of a hybrid vehicle is the ability to limit operation of the engine to its "sweet spot" or "optimum efficiency range" while still meeting the load required for propelling 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. 1936 [SAE SP-1089] at 11.)[21]

130. In another example, a 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. **<u>The key point is that the hybrid engine is operated at more efficient operating points</u>**. This results in 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. 1921 [Unnewehr] at 12, emphasis added.)

131. More specifically, based on my understanding, experience and knowledge, hybrid vehicles could be operated using a well-known "load-following charge-sustaining" control strategy. This control strategy limited operation of the engine to a defined efficient operating range using a predetermined lower and upper value threshold value. For instance, an August 1998 SAE article describing this "load-

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[21] Exhibit 1936 [SAE SP-1089] is a true and accurate copy of excerpts from the 1995 SAE Special Publication (SP) entitled "Design Innovations in Electric and Hybrid Electric Vehicles."

following charge-sustaining" control strategy that may restrict operation of the engine within a "lower motive power" and "higher motive power" value (highlighted in red below.) (Ex. 1937 [An 1998] at 10.)[22] This control strategy operated so that: (1) the electric motor propelled the vehicle when the amount of power required to propel the vehicle was below the "lower motive power" value (highlighted in red below); (2) the engine alone propelled the vehicle when the amount of power required to propel the vehicle was between the "lower motive power" and "upper motive power" threshold values; and (3) the motor and engine are used together when the amount of power required to propel the vehicle was above the "higher motive power" value (highlighted in green below.) As is described in the paper, this control strategy ensured that the engine was only used in a specified area where engine operation is most efficient. (Ex. 1937 [An 1998] at 10.)

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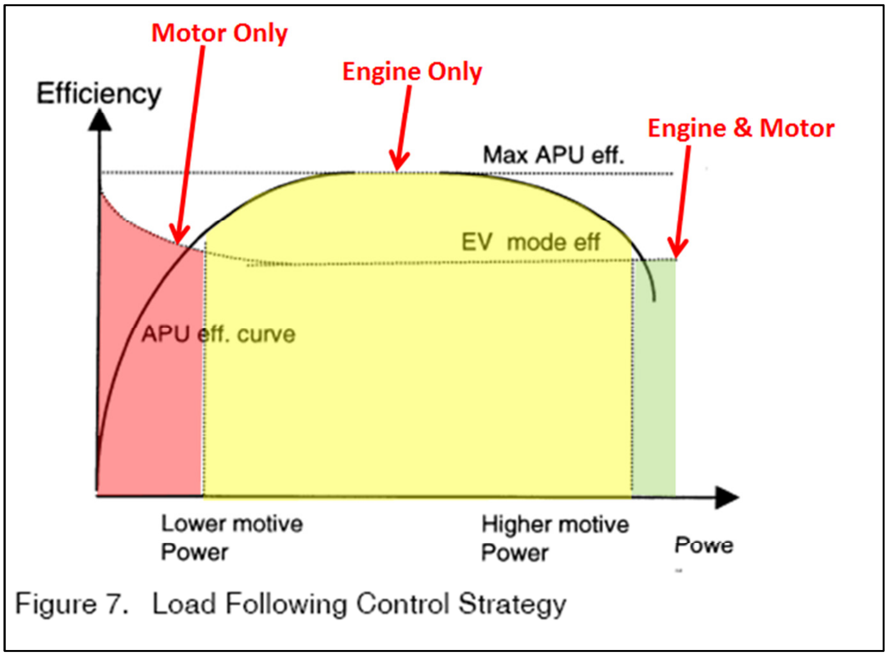
[22] Ex. 1937 [An 1998] is a true and accurate copy of a 1998 SAE paper titled "Critical Issues in Quantifying Hybrid Electric Vehicle Emissions and Fuel Consumption" authored by Feng An and Matthew Barth.



Ex. 1937 [An 1998] at 10, Fig. 7 (annotated)

132. Based on my experience and knowledge hybrid vehicles were used to improve fuel efficiency by improving engine operation. Again, it is my understanding that this was typically accomplished using a set of operational modes that allowed the engine that to be operated at or near its "sweet spot" or efficient operating range.

133. Also based on my experience and knowledge, the electric motor could either (1) provide the tractive effort required to propel the vehicle alone when engine operation was not efficient (*i.e.* outside the "sweet spot"), or (2) in combination with the engine at high acceleration or driver demands.

134. Lastly, based on my experience and knowledge, control between these modes 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. CHALLENGED CLAIMS OF THE '634 PATENT AND PROPOSED CLAIM CONSTRUCTIONS

I have been asked to review independent claims 80, 91, 92, 95, 96, 99, 100, 102, 106, 114, 125, 126, 129, 132, 133, 161, 172, 215, 226, 227, 230, 233 and 234.

135. 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 have been provided with the following claim constructions for my analysis regarding unpatentability:

a. "**road load (RL)**" and "**RL**" as: "*amount of instantaneous torque required to propel the vehicle, be it positive or negative*"

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

c. **"mode I", "Low-load operation 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 operation 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 operation 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*".

VI. OVERVIEW OF THE PRIOR ART

A. Prior Art Status of Durham Project

136. It is my understanding that each of the referenced publications was part of a collaborative hybrid project occurring between 1985 and 1990 at the University of Durham ("the Durham Project".)

137. It has been explained to me that each of these publications are considered prior are since they were published more than one year before the earliest priority date of the '634 Patent. In fact, I am aware that the Durham Project publications were published between 8 and 13 years before the earliest priority date of the '634 Patent.

138. The series of publications were each authored in part by professors and doctoral students at the University of Durham located in the United Kingdom. It is my understanding that each of these publications was primarily authored by J.R. Bumby, I. Forster, and P.W. Masding.

139. 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 the physical construction of a test-bed prototype.

140. My opinion is based on the following publications:

- "**Bumby I**" - J.R. Bumby at H. Clarke and I. Forster, "Computer Modeling of the Automotive Energy Requirements for Internal

Combustion Engine and Battery Electric-Powered Vehicles", IEE Proceedings, September 1985 (Ex. 1905 [Bumby I])

- "**Bumby II**" - J.R. Bumby and I. Forster, "Optimisation and Control of a Hybrid Electric Car", IEE Proceedings, November 1987 (Ex. 1906 [Bumby II])
- "**Bumby III**"[23] - I. Forster and J.R. Bumby, "A Hybrid internal combustion engine/battery electric passenger car for petroleum displacement", Proceedings of the Institution of Mechanical Engineers – Part D: Journal of Automobile Engineering, Jan 1, 1988 (Ex. 1907 [Bumby III])
- "**Bumby IV**" - J.R. Bumby and P.W. Masding, "A test-bed facility for hybrid ic-engine/battery-electric road vehicle drive trains," Trans Inst. Meas. & Cont. 1990 Vol. 10:2, April 1, 1988 (Ex. 1908 [Bumby IV])
- "**Bumby V**" - P.W. Masding and J.R. Bumby, "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. 1909 [Bumby V])
- "**Masding Thesis**" – Masding, Philip Wilson "Some Drive Train

---

[23] Although Professor Bumby is not the first named author on each paper, for ease of reference I use this to reference each paper upon which he appears as a co-author.

Control Problems in Hybrid IC Engine/Battery Electric Vehicles", Durham University, November 2, 1989. (Ex. 1910 [Masding Thesis])

141. I understand Bumby I-V as being a series of publications that were published in well-known British scientific journals.

142. 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.

143. 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.

144. Bumby IV and V were included in the "Transactions of the Institute of Measurement and Control" that 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."

145. 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.

146. I also understand the Masding Thesis as being a doctoral thesis submitted for the Degree of Doctor of Philosophy by Philip Wilson Masding. (Ex. 1910 [Masding Thesis] at 4.) It is my understanding that a declaration has been provided from the University of Durham attesting that the Masding Thesis was publicly indexed and searchable from their library since approximately November 2, 1989. (Ex. 1910 [Masding Thesis] at 2.)

147. It is my opinion that students and professors would review scholarly doctoral thesis works within their particular field. A person working in the field of hybrid vehicles would have been motivated to research hybrid vehicle including thesis dissertations to thus keep current in their field of research.

B. Overview of the Durham Project Publications

1. Bumby I

148. 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 '634 Patent.

149. 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. 1905 [Bumby I] at 1.)

150. 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 with an engine and two smaller capacity motors. Or build a different hybrid vehicle with an engine and one larger capacity motor.

151. Once 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. 1905 [Bumby I] at 2.)

152. 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.
>
> $T_E = T_d + T_r + T_g + T_a N$ (eqn. 1)

(Ex. 1905 [Bumby I] at 2; emphasis added.)

153. 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 113-119 above. It is my opinion that Bumby I correctly states the well-known meaning of both terms.

154. 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.)

155. 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. 1905 [Bumby I] at 3-4.)

156. 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. 1905 [Bumby I] at 4.)

157. 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. 1905 [Bumby I] at 4.)

158. 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." (Ex. 1905 [Bumby I] at 4.)

159. 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. 1905 [Bumby I] at 12.)

2. Bumby II

160. 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 "634 Patent.

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

162. 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. 1906 [Bumby III] at 1; emphasis added.)

163. 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. 1906 [Bumby II] at 2)

164. 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. 1906 [Bumby II] at 3; emphasis added.)

165. 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. 1906 [Bumby II] at 2.) Parallel hybrid electric architecture, as shown in Fig. 2, below, were also well known as I discussed above in paragraphs 70-107.

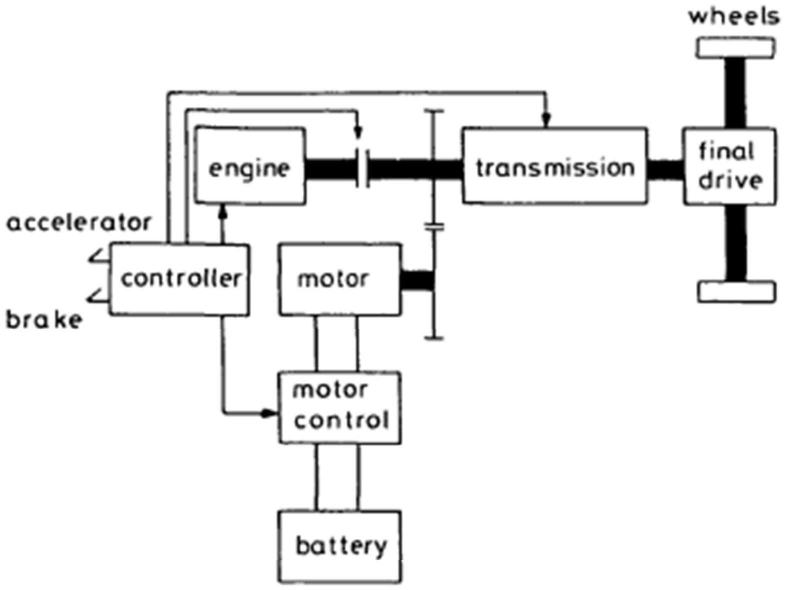


Fig. 2 *Parallel hybrid electric vehicle drive train*

166. 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. 1906 [Bumby II] at 5-6; emphasis added.)

167. 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, **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**. In addition, a proportion of the accelerative energy is recovered by regenerating into the battery.

(Ex. 1906 [Bumby II] at 6; emphasis added.)

168. 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. 1906 [Bumby II] at 7; emphasis added.)

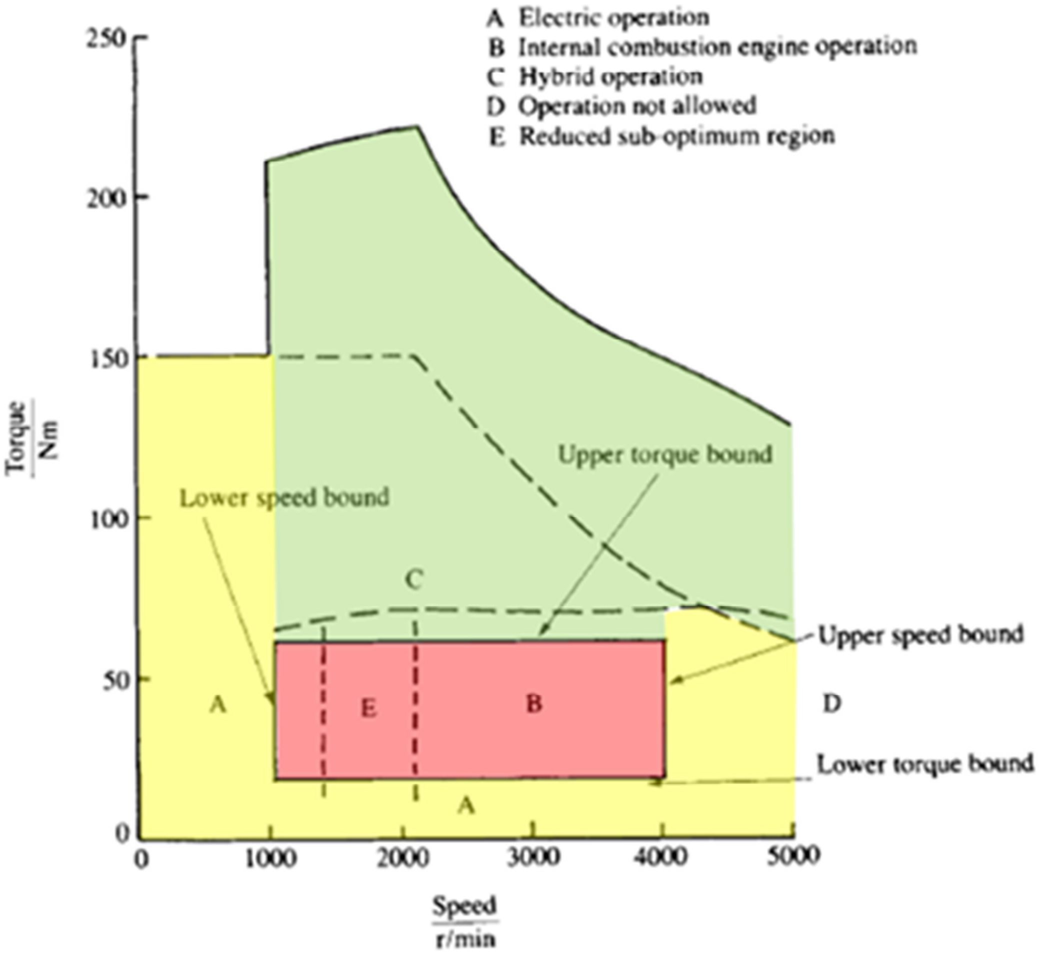
169. As a result, Bumby II disclosed and developed a second control strategy that was "shown to produce similar results to the optimal policy" but was not as computationally intense. Because the second control strategy was not as computationally intense, Bumby also recognized that it was capable of being implemented on a real-world hybrid vehicle. (Ex. 1906 [Bumby II] at 15.)

170. Bumby II disclosed that this second control strategy (referred to as the "suboptimal control policy" and referred to herein as "the Durham strategy") was computationally less intense, but still restricted engine operation to its "high-efficiency region." (Ex. 1906 [Bumby II] at 10-11.)

> 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. 1906 [Bumby II] at 11; emphasis added.)

171. As illustrated below, the Durham strategy 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. 1906 [Bumby II] at 11.)



172. 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. 1906 [Bumby II] at 11.)

173. 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.

3. Bumby III

174. 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 "634 Patent.

175. 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. 1907 [Bumby III] at 2 - Abstract.)

176. 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. 1907 [Bumby III] at 3.)

177. Bumby III further evaluates the "practical implementation" of in a parallel hybrid vehicle. (Ex. 1907 [Bumby III] at 3.)

4. Bumby IV

178. 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 "634 Patent.

179. Bumby IV discloses that:

> **This paper describes the design and development of a testbed facility for hybrid internal-combustion-engine/battery-electric vehicle power trains.** 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. 1908 [Bumby IV] at 2-Abstract; emphasis added.)

180. Bumby IV discloses that the Durham 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.

181. Specifically, Bumby IV implements the "suboptimal control" Durham strategy and components disclosed in Bumby II and III (¶¶ 170-171 above) on a physical vehicle drive-train.

182. 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.

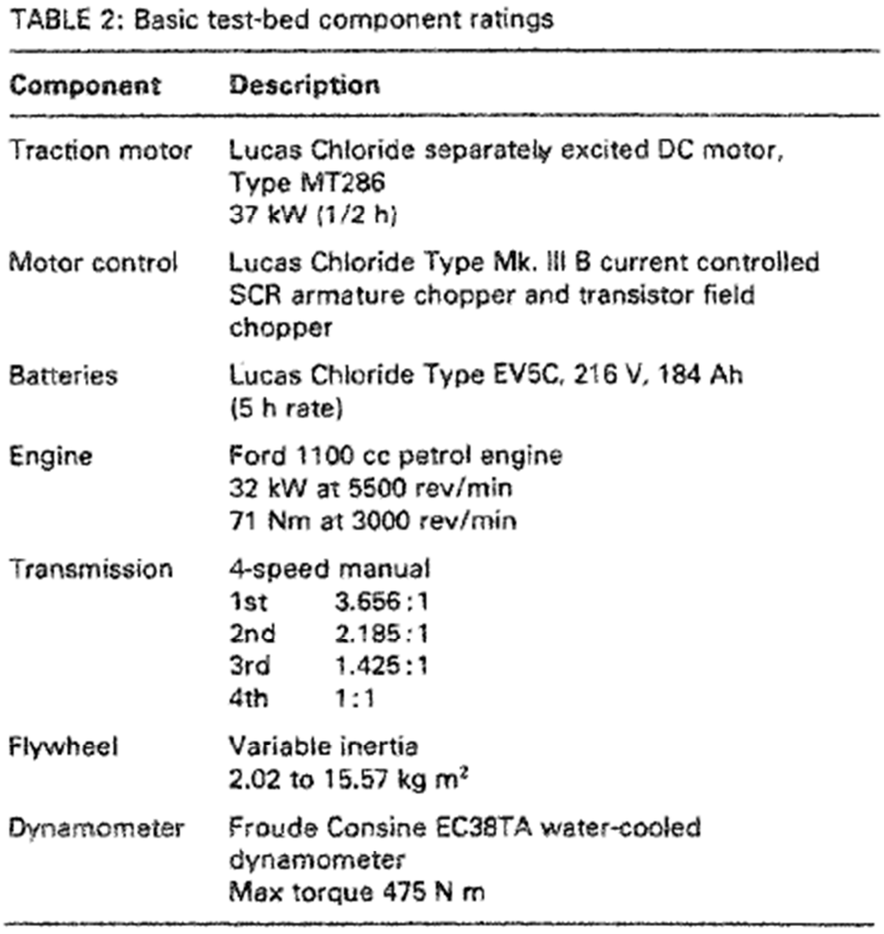


TABLE 2: Basic test-bed component ratings

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

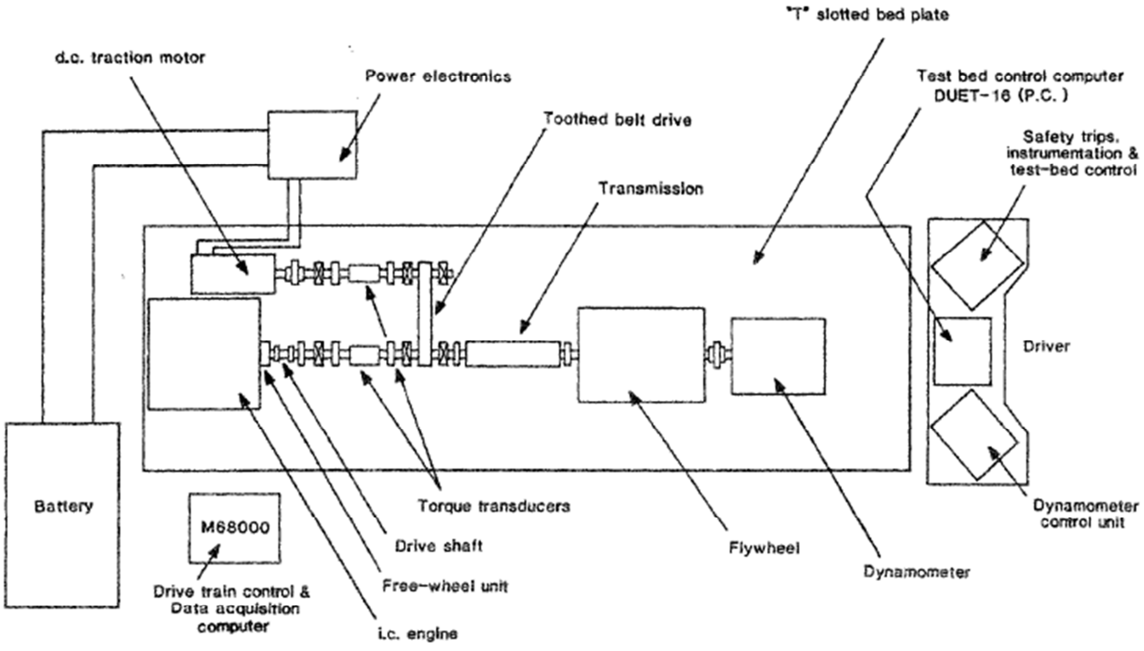


Fig 4 Test-bed layout

183. 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. 1908 [Bumby IV] at 4.)

5. Bumby V

184. 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 "634 Patent.

185. 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.

> **<u>This paper describes the development of a fully integrated microprocessor control system for a hybrid i.c. engine/battery-electric automotive power train</u>**. 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. 1909 [Bumby V] at 2-Abstract; emphasis added.)

186. 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. 1909 [Bumby V] at 3.)

6. The Masding Thesis

187. I understand that "Some drive train control problems in hybrid i.c. engine/battery electric vehicles" is a doctoral thesis publication that was authored by Philip Wilson Masding. (hereinafter "Masding Thesis".)

188. It is my understanding that the thesis paper was presented by Peter Masding for his Doctoral Degree in Philosophy. It is my understanding that a declaration has been provided from Durham University stating that the Masding Thesis was indexed and publically available at the University's Library in November 1988. (Ex. 1910 [Masding Thesis] at 2.)

189. It has been explained to me that Masding Thesis is considered prior art

since it was published more than one year before the earliest priority date the '634 Patent.

190. It is my opinion that the Masding Thesis builds upon the teachings of the Bumby publications (Bumby I-V), even expressly referencing the work discussed in each Bumby publications.

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C. Motivation to Combine

218. It is further my opinion that a person working in hybrid vehicles would have realized that the Durham Project was based on a series of publications by the explicit overview provided within each publication. For instance, the Durham references themselves state that the publications were part of a complete work. Many citations are provided between each of the Bumby publications as well as the later-produced Masding Thesis.

219. For example, under the section titled "The Context of the Present Work," the Masding Thesis provides a general overview of the Durham project that included a summary of work accomplished and published as the five Bumby publications (*i.e.*, Bumby I – V).

220. For instance, the Masding Thesis first summarizes the work accomplished and published by Bumby I:

> Having brought this survey of hybrid vehicle technology up to date with the discussion of the latest Volkswagen results, the relevance of the

> present work and the computer studies which lead up to it, can now be established. Computer studies of hybrid vehicles have been carried out at the University of Durham using a general purpose road vehicle simulation package called Janus [Bumby et al, 1985] **[Bumby I].** This program, developed over a number of years in the School of Engineering and Applied Science, is capable of predicting the energy use of a variety of power train configurations.

(Ex. 1910 [Masding Thesis] at 38.)

221. The Masding Thesis then explains the Janus computer simulation programs developed and explained by Bumby I. The Masding Thesis then explains that Bumby II carried out the Janus computer simulations to investigate the economics of hybrids:

> Once the simulated cycle is complete the user has at his disposal of breakdown of energy requirements on an individual component basis. Using a method similar to this Janus has been used to thoroughly investigate the economic potential of parallel i.e. engine/electric hybrids. [Bumby and Forster, 1987] **[Bumby II]**.

(Ex. 1910 [Masding Thesis] at 39.)

222. After explaining benefits of an energy source as a substitution for petroleum, the Masding Thesis explains the work of Bumby III illustrates the complexity of precisely figuring how much petroleum might be saved in a hybrid:

> This petroleum substitution potential is also sensitive to the conventional vehicle technology used for comparison, although to a lesser extent than overall energy saving. Placing a precise figure on the

> percentage of petroleum which might be saved by the hybrid is complicated by the vehicle use pattern [Forster and Bumby, 1998] **[Bumby III]**… By assuming equal use of engine and motor at 90 km/h Bumby and Forster [Forster and Bumby, 1988] **[Bumby III]** calculated that a parallel hybrid could save 50% of petrol when compared with an advanced conventional vehicle featuring an efficient continuously variable transmission (CVT). Clearly such a vehicle represents a much more formidable target performance than vehicles considered in American studies.

(Ex. Masding Thesis at 39-40.)

223. One of ordinary skill in the art, given the Masding Thesis, would have therefore looked to the Bumby Publications to learn about the software and testing systems accomplished to improve a vehicle's efficiency and reduce the usage of petroleum fuel.

224. 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.

225. Once of ordinary skill in the art would have therefore been motivated to look to the Bumby publications to find additional information about the current state of research regarding hybrid vehicles.

226. Once reading the Bumby publications referenced in the Masding Thesis,

one of ordinary skill in the art would have been motivated to read and review all five Bumby publications (Bumby I-V) as these publications reference one another and each builds upon the teachings of its predecessor Bumby publication, as described below.

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236. It is further my opinion that a person working in hybrid vehicles would have realized that the Durham 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. 1907 [Bumby III] 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. 1908 [Bumby IV] at 2.)

237. 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.

238. 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.

239. 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. 1909 [Bumby V] 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. 1909 [Bumby V]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. 1909 [Bumby V] at 3.)

240. Bumby IV likewise is a June 1988 publication discussing the test-bed prototype of this hybrid vehicle. (Ex. 1908 [Bumby IV] at 2-Abstract.) This paper includes a section entitled "Hybrid-vehicle control hierarchy" describing the hybrid vehicle developed. (Ex. 1908 [Bumby IV] 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. 1908 [Bumby IV] 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. 1908 [Bumby IV] at 3; emphasis added.)

241. Bumby III is a January 1988 publication that "examines the potential of the hybrid electric vehicle" discussed in prior Bumby publications. 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. 1907 [Bumby III] 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. 1907 [Bumby III] at 3.)

242. 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. 1906 [Bumby II] at 4.)

243. 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.

244. 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.

VII. ANALYSIS OF THE CLAIMS

A. GROUND 1: Claims 80, 91, 92, 95, 96, 98, 100, 106, 114, 125, 126, 129, 133, 135, and 139

245. It is my opinion that claims 80, 91, 92, 95, 96, 98, 100, 106, 114, 125, 126, 129, 133, 135, and 139 are obvious in view of Bumby I-V, the Masding Thesis, Frank '363 and the general knowledge that a person having ordinary skill in the art.

1. Independent Claim 80

… *[80.0] A method for controlling a hybrid vehicle, comprising:*

246. The Durham Project discloses the "development of a microprocessor based control system for a parallel hybrid petrol/electric vehicle." (Ex. 1910 [Masding Thesis] at 9.)

247. The Durham Project specifically disclosed and evaluated several methods for the optimization and control of a hybrid vehicle. (Ex. 1907 [Bumby III] at 2; Ex. 1906 [Bumby II] at 2; Ex. 1905 [Bumby I] at 1.)

248. In particular, the Durham Project discusses a control policy that was called the "Suboptimal control algorithm." (Ex. 1906 [Bumby II] at 10-11). This name is somewhat misleading since the "sub-optimal" control strategy still dramatically minimizes emissions and increases fuel efficiency while being simple enough to implement in a hybrid vehicle controller/control system. (Ex. 1906 [Bumby II] at 10-12). To avoid confusion, I refer to this hybrid control as the "Durham strategy."

249. While the Durham 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.

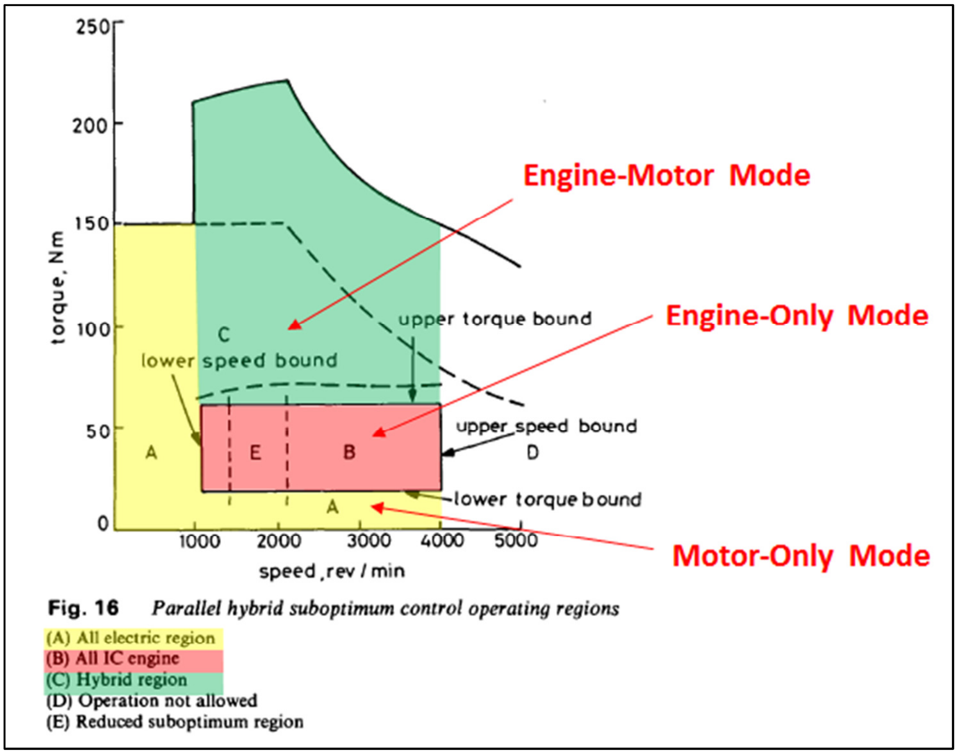
250. The Durham Project illustrates and discloses the simplified "Durham strategy" in Fig. 8, in Bumby III, annotated below to clearly show the different operating modes, or regions, in different colors. (Ex. 1906 [Bumby II] Fig. 16 at 8) (*see also* Ex. 1907 [Bumby III] at 8-Fig. 16.)

251. The Durham strategy was a region based strategy that determined how to control the electric motor and engine based on the "**actual torque and speed values**." As annotated below, the Durham Project defined three separate operating regions based on the actual torque and speed values. First, when the vehicle's torque and speed values are within the boxed region, the engine propels the vehicle (*i.e.* **engine-only mode**). Below the torque and speed bound thresholds, the motor alone was used to propel the vehicle. (*i.e.*, **motor-only mode**). Above, the upper torque bound threshold both the motor and engine are used to propel the vehicle (*i.e.*, **engine-motor mode**).

> 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. [**Engine-only mode**] 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. [**Motor-only mode**] Below the lower torque bound and the lower speed bound, all-electric operation is favoured. This eliminates inefficient use of the engine. [**Engine-Motor mode**] 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. 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.

(Ex. 1906 [Bumby II] at 10-11; *see also* Ex. 1907 [Bumby III] at 7-8.)



Ex. 1906 [Bumby II] at 11, Fig. 16

252. The other publications as part of the Durham Project further confirm that the Durham Project pertained to the development of a control strategy for a parallel hybrid vehicle. (Ex. 1907 [Bumby III] at 1, Ex. 1908 [Bumby IV] at 1, Ex. 1909 [Bumby V] at 1.)

253. Therefore, it is my opinion that the Durham Project discloses *a method for controlling a hybrid vehicle.*

*… **[80.1] determining instantaneous road load (RL) required to propel the hybrid vehicle responsive to an operator command;***

254. The Durham Project discloses a sub-optimal control strategy that makes operational mode decisions based on "actual torque and speed values." (Ex. 1906 [Bumby II] at 11. This "actual torque" value is the *road load (RL) required to propel the vehicle.*

255. For instance, the Durham Project discloses a sub-optimal control strategy that uses the actual torque requirements (*road load*) in order to select the proper operational mode for the vehicle. (Ex. 1906 [Bumby II] at 10-11; Ex. 1907 [Bumby III] at 7-8.)

256. As annotated below, an engine-only mode is selected when the required torque (*road load*) and speed values are within a "box region. . . defined by an upper and lower torque bound and an upper and lower speed bound[.]" (Ex. 1906 [Bumby II] at 10.) A motor-only mode (shaded in yellow) is selected when the required torque (*road load*) and speed values are "[b]elow the lower torque bound and the lower speed bound[.]" (Ex. 1906 [Bumby II] at 11.) Lastly, a combined engine-motor mode (shaded in green) is selected when the required torque (*road load*)and speed values are "[a]bove the upper torque bound." (Ex. 1906 [Bumby II] at 11.)

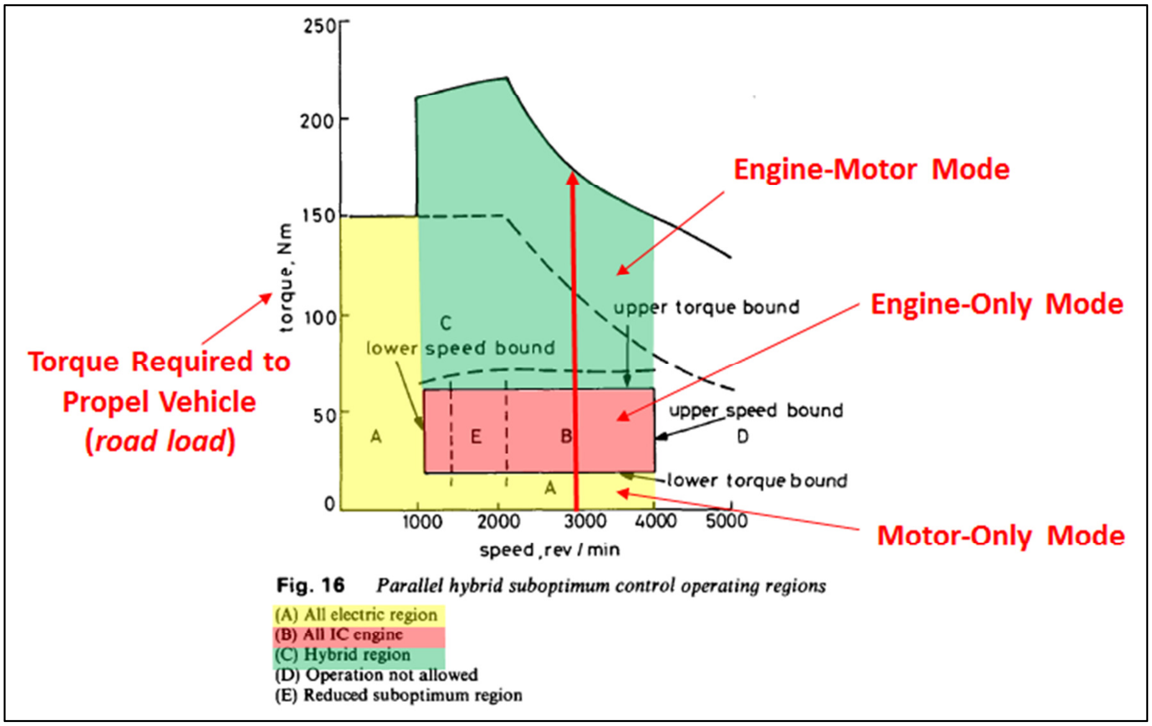


Fig. 16 *Parallel hybrid suboptimum control operating regions*

Ex. 1906 [Bumby II] at 11, Fig. 16

257. For instance, when the vehicle is travelling at a steady speed in a fixed gear and the engine speed is approximately 3000 RPM (as indicated by the red arrow above), the operational mode of the vehicle is determined solely based on the instantaneous torque requirements or *road load*. If the torque requirements increase (*e.g.*, during a hill-climb) and the driver wishes to maintain the same speed, the vehicle controller will switch form motor-only mode, to engine-only mode, or to engine-motor mode. The switch between these different modes allows the vehicle to provide the desired torque and speed output at the wheels as requested by the driver. If the vehicle doesn'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 requested the vehicle maintain the speed.

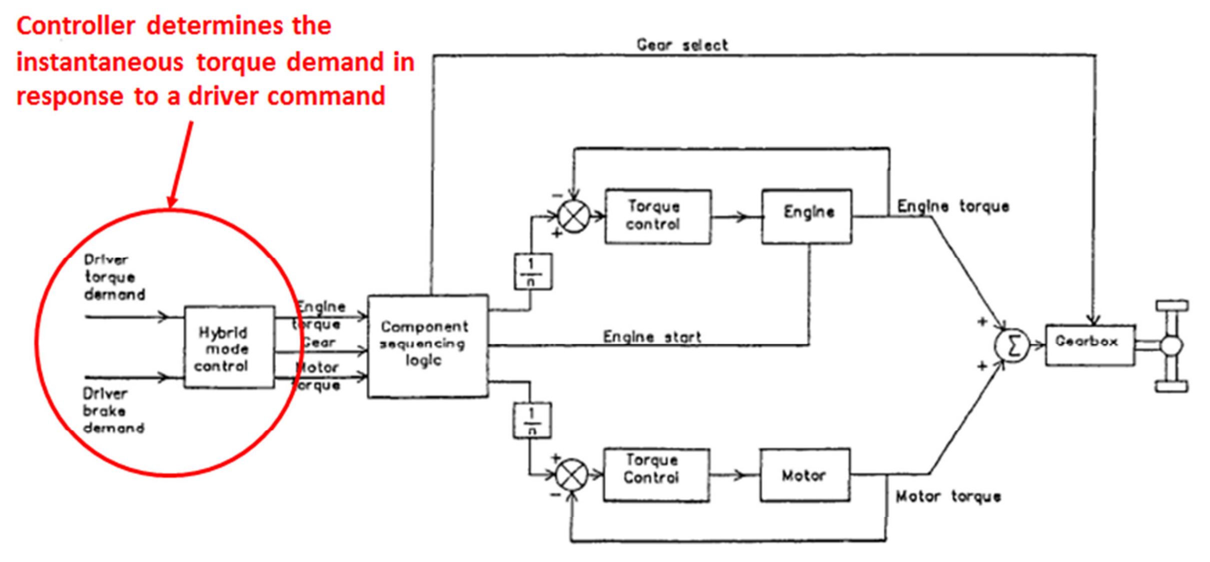
258. In fact, the Durham Project itself recognizes that operational mode changes could occur during both acceleration and hill climbing. These mode changes occur based on determining the torque required to propel the vehicle.

> When necessary, the **engine torque can be augmented by the motor for rapid acceleration or hill climbing**.

(Ex. 1909 [Bumby V] at 4, emphasis added.)

259. The above disclosure confirms that the Durham Project makes operational mode changes based on the torque requirements or *road load*. For instance, when a vehicle is climbing a hill, or when the driver requests the vehicle accelerate, it is understood that the torque required to propel the vehicle may be positive. 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. Therefore, the driver needs to press the accelerator pedal further to maintain the same speed or to accelerate up the hill. Likewise, in order for the vehicle to accelerate under load, the driver must further press down on the accelerator pedal to accelerate past the other vehicle. Such acceleration also requires positive torque to propel the vehicle.

260. Further, the Durham Project discloses that the propulsive torque is responsive to the operator's command *via* operation of the accelerator pedal, as illustrated in below.



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

Fig 16 Complete vehicle component control system

Ex. 1909 [Bumby V] at Fig. 16

> In normal driving conditions the **driver controls the overall torque demand by pressing the accelerator or brake pedal** so that the vehicle speed responds in the way that he wants. **In the hybrid vehicle this torque demand is intercepted by the hybrid-mode control unit as illustrated by the block diagram of Fig 16**. Incorporated in the hybrid-mode controller is some overall strategy which decides how to split the total driver demand between the engine and motor and also what transmission ratio to use. How it does this will ultimately determine the relative use made by the vehicle of petrol and electricity as well as the efficiency of the engine and motor. After the hybrid-mode controller has made these two decisions, it is left to the individual component controllers to carry out its instructions. Between these systems and the mode controller lies the component sequencing control necessary to achieve a logical order of events. Fig 16 Complete vehicle component control system.

(Ex. 1909 [Bumby V] at 13-14, emphasis added.)

261. In other words, the Durham Project discloses that the "sub-optimal" control algorithm determines the torque required to propel the vehicle *responsive to an operator command* through operation of the accelerator pedal.

262. It is therefore my opinion that the Durham Project discloses *determining instantaneous road load (RL) required to propel the hybrid vehicle responsive to an operator command.*

… ***[80.2] monitoring the RL over time;***

263. The Durham Project discloses monitoring the driving conditions experienced by the vehicle (*e.g.*, speed and torque) in order to determine the correct operating mode.

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

(Ex. 1908 [Bumby IV] at 3, emphasis added).

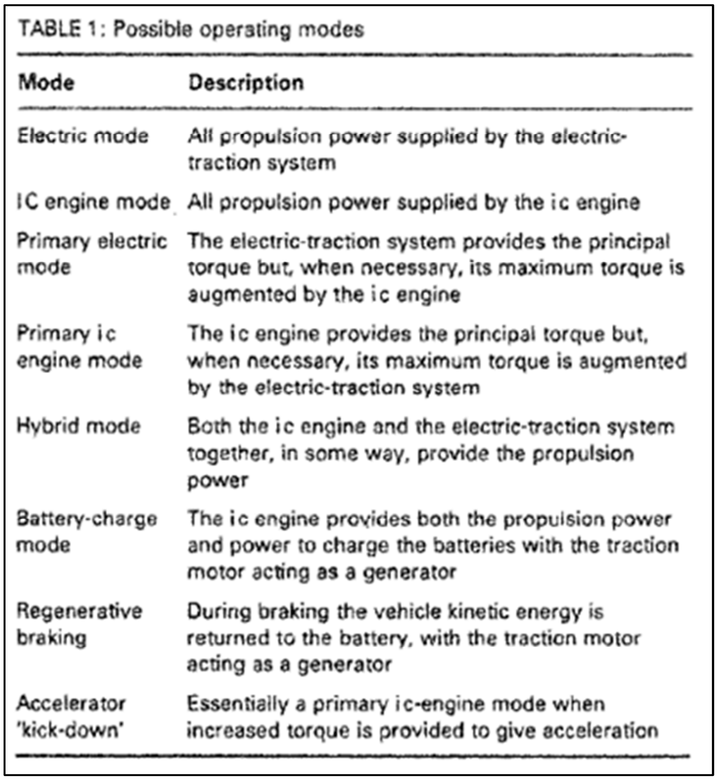


TABLE 1: Possible operating modes

Mode	Description
Electric mode	All propulsion power supplied by the electric-traction system
IC 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

Ex. 1908 [Bumby IV] at 3, Table 1

264. Specifically, the Durham Project discloses a controller based system that monitors the driver's input signals and then makes an appropriate mode selection using the "sub-optimal" control strategy.

> The job of the sub-optimal controller can be seen as that of selecting one of the possible operating modes that are available with a parallel hybrid drive train. All of the operating modes are described in Table 1.1. With maximum petroleum substitution as the goal each mode tends to be suited to a particular type of vehicle operation.
>
> ***
>
> **<u>The inputs to the mode controller are the driver's demand signals represented by the position of the accelerator and brake pedals</u>**. . . . Combining all these considerations produces the vehicle control

> hierarchy illustrated by figure 1.6. At the top of the hierarchy is the driver who makes inputs to the system in two ways. Firstly his unique knowledge of intended destination allows him to select one of the three possible journey types. Secondly he communicates his power demand through use of the brake and accelerator. Journey type has a large influence on which operating strategy is best for the vehicle and hence which operating modes should be used. Restricting the use of some of these modes however are the battery charge constraints which seek to keep the battery SOC above 20% at all times. **After processing through these constraints it is then up to the mode controller, which embodies the sub-optimal strategy to operate the vehicle in the best way to meet the power demands coming from the driver**.

(Ex. 1910 [Masding Thesis] at 43.)

265. As the instantaneous torque requirements (i.e., *road load*) change over time, the sub-optimal control must likewise monitor and update the vehicle's operational mode. For instance, the vehicle may be operating on a flat road where the required torque (*road load*) at a given speed in a fixed gear is below the "lower torque bound." (Ex. 1906 [Bumby II] at 11.) In such a situation, the sub-optimal controller would place the vehicle in motor-only mode where the vehicle is propelled using the electric motor alone. (Ex. 1906 [Bumby II] at 11.) However, if the actual torque requirements (*road load*) requirements began to increase (*e.g.*, due to hill-climb) the sub-optimal controller may transition to operation in the engine-only mode or engine-motor mode.

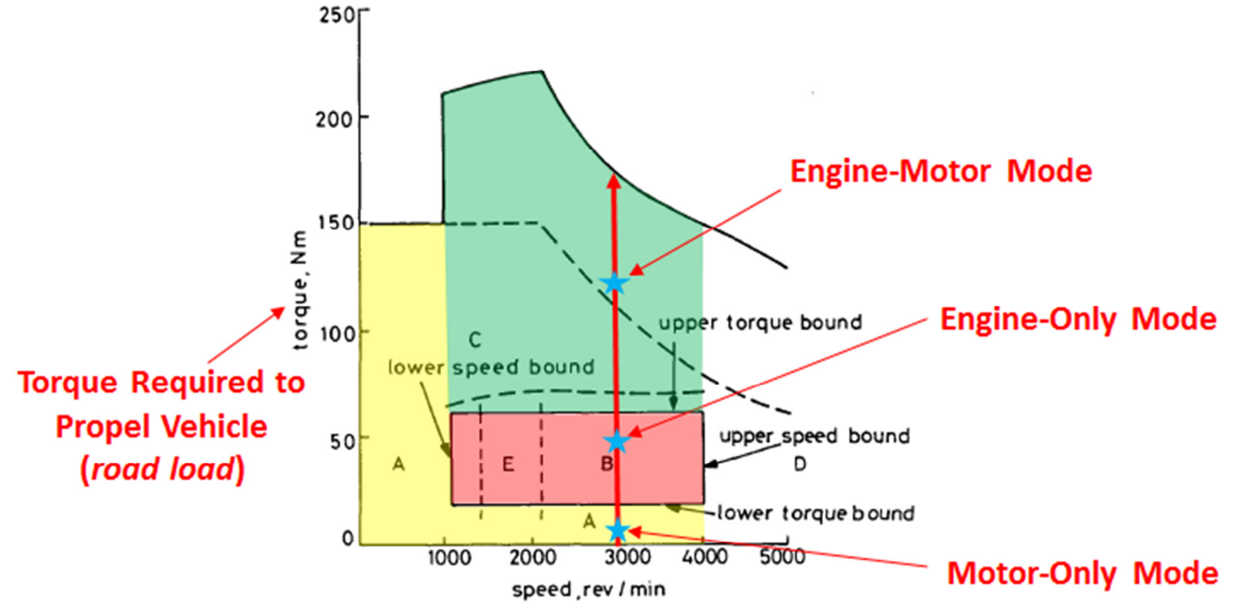


Fig. 16 *Parallel hybrid suboptimum control operating regions*

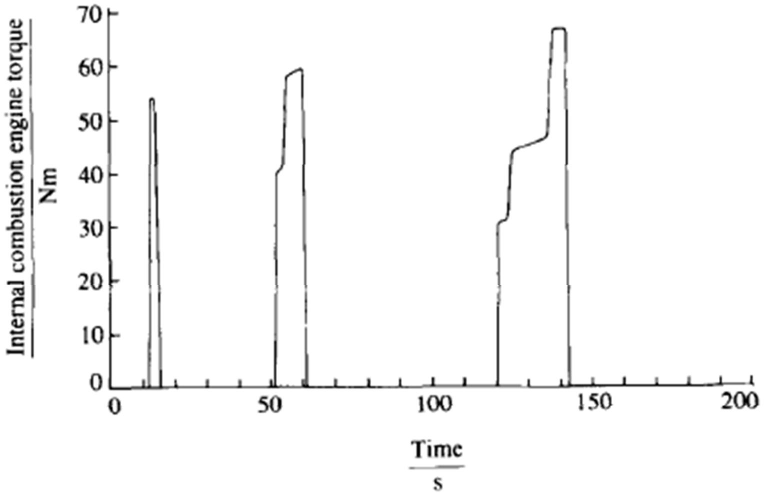
🟨 (A) All electric region
🟥 (B) All IC engine
🟩 (C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at 11, Fig. 16

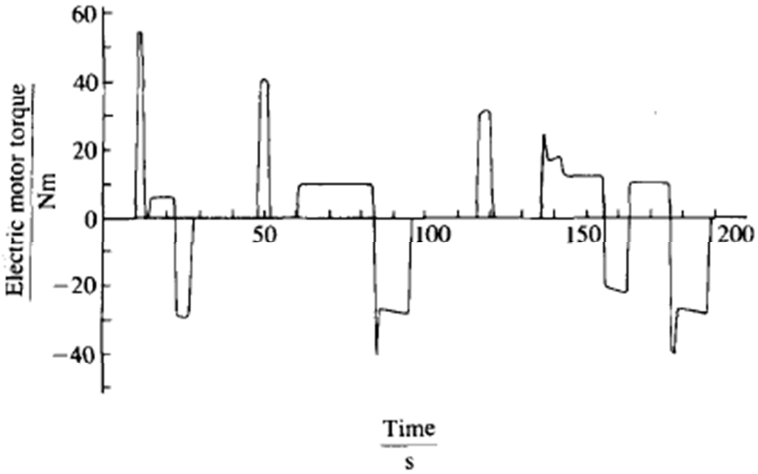
266. Furthermore, the Durham Project discloses operating the sub-optimal control strategy over a specified drive cycle. As shown below, the control strategy will monitor the required drive requirements and will vary operation of the engine and motor using the sub-optimal control strategy.

> The **result of applying such a control algorithm to the hybrid drive designed** for petroleum substitution **is shown in Fig. 9 where** the i.c. engine fuel usage map and **variation in the i.c. engine and traction motor torque and speed over the cycle are shown**.

(Ex. 1907 [Bumby III] at 8, emphasis added.)



(b) Internal combustion engine torque



(c) Electric motor torque

Fig. 9 Results of applying the sub-optimum control algorithm over the ECE-15 urban cycle

Ex. 1907 [Bumby III] at 9

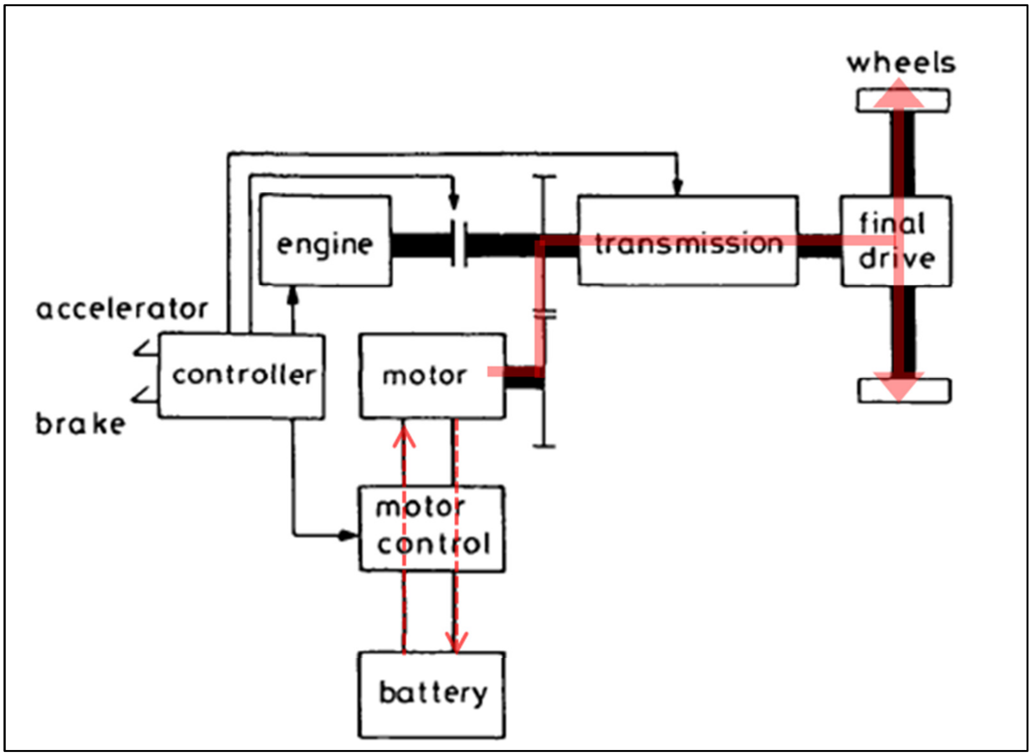
267. As shown above, when the sub-optimal control of the vehicle (Fig. 9) is operated over a drive cycle, the engine torque and motor torque varies over time. For example, the engine is on and producing drive torque between approximately 10-15 seconds, 50-60 seconds, and 120-140 seconds. These times correspond to the sub-

optimal control strategy commanding an engine-only mode or a motor-engine mode of operation. When the engine is off during the drive cycle, the motor torque continues to produce drive torque at various times. These times correspond to the sub-optimal control strategy commanding a motor-only mode of operation. The changes in operational modes correspond to the changes in instantaneous torque required to propel the vehicle (i.e., "road load") during the drive cycle. It is therefore my opinion that operation over this drive cycle illustrates monitoring the torque required to propel the vehicle over time.

268. It is therefore my opinion that the Durham Project discloses *monitoring the* RL *over time.*

> … ***[80.3] operating at least one electric motor to propel the hybrid vehicle when the RL required to do so is less than a setpoint (SP);***

269. As annotated below, the Durham Project discloses a hybrid vehicle having an electric motor that provides torque to vehicle wheels *via* a transmission. (Ex. 1906 [Bumby II] at 1; Ex. 1907 [Bumby III] at 1, 3; Ex. 1908 [Bumby IV] at 1, 3; Ex. 1910 [Masding Thesis] at 49.) The electric motor is disclosed as being operable to drive or *propel the hybrid vehicle.*



Ex. 1906 [Bumby II] at Fig. 2

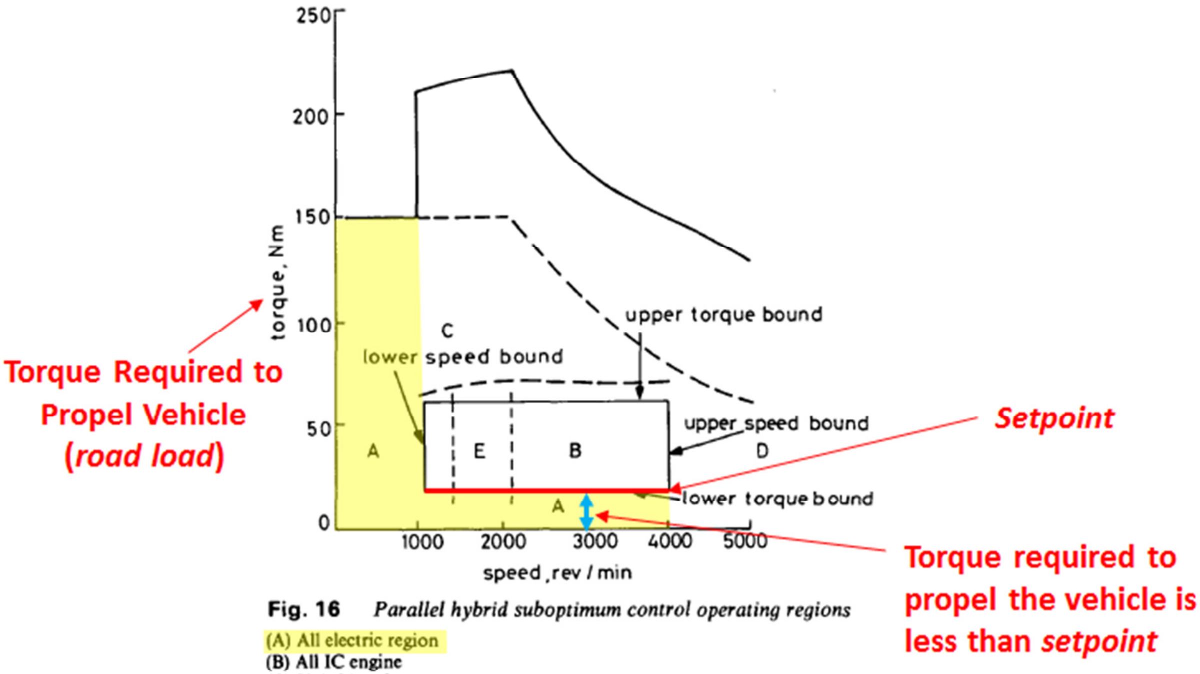
> [T]he **<u>electric traction motor is connected permanently to the drive shaft,</u>** while the ic engine is connected through a 'one-way clutch' or 'freewheel'. Such a connection **<u>allows the traction motor to drive the road wheels</u>** when the engine is stationary, but the electric motor must 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.

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

(Ex. 1907 [Bumby III] at 2-3; emphasis added.)

270. Again, "the selected mode of operation depends on the **<u>actual torque</u>** and speed values." (Ex. 1906 [Bumby II] at 11, emphasis added.) When the actual torque or *road load* is "[b]elow the lower torque bound and the lower speed bound, all-electric operation is favoured." (Ex. 1906 [Bumby II] at 11; *see* Ex. 1907 [Bumby III] at 7-8.)

271. It is my opinion that the "lower torque bound" is the *setpoint*. Thus, when the required torque (*road load*) is below the "lower torque bound" (*setpoint*) the sub-optimal controller operates the electric motor to propel the vehicle (*i.e.*, motor-only mode). This is illustrated by "Region A" which I have highlighted in yellow.



Torque Required to Propel Vehicle (*road load*)

Setpoint

Torque required to propel the vehicle is less than *setpoint*

Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at 11, 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. 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. 1906 [Bumby II] at 10-11, emphasis added.)

> 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

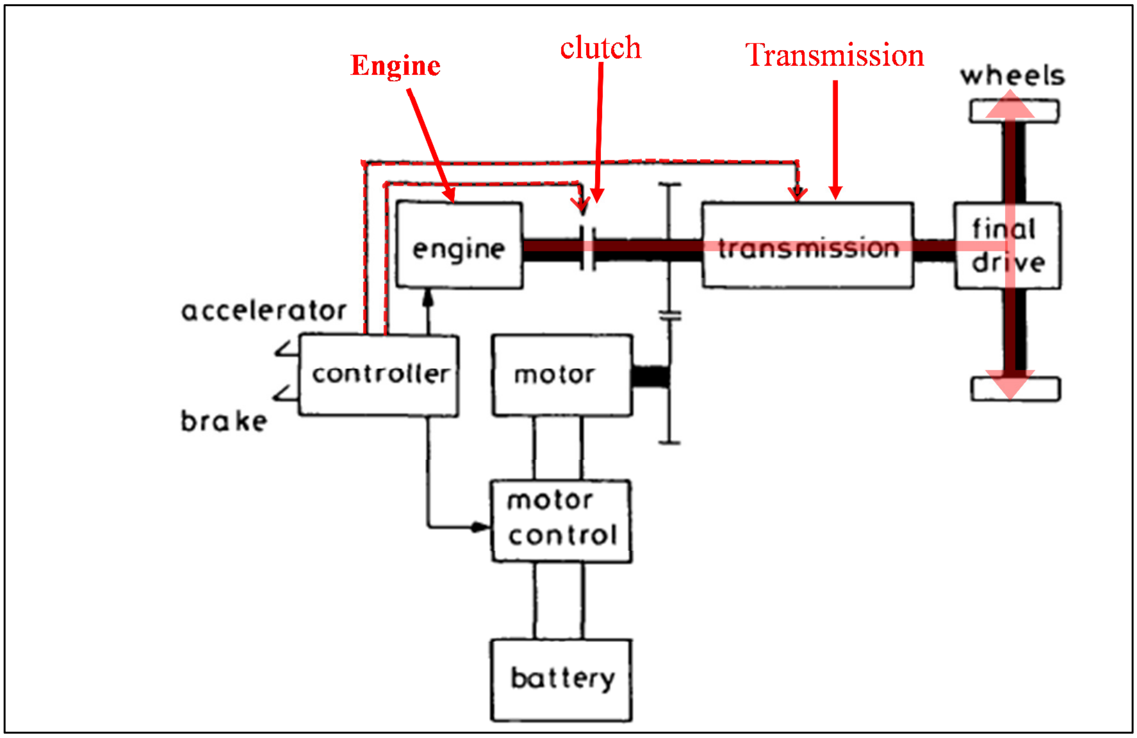
> performance is defined. The control algorithm always seeks to place the i.c. engine operating point within the 'box' using the available transmission ratios. <u>**If no points occur in the box and all points fall below or to the left of the box, then the electric mode of operation is selected**</u>."

(Ex. 1907 [Bumby III] at 7-8, emphasis added.)

272. Therefore, it is my opinion that the Durham Project discloses *operating at least one electric motor to propel the hybrid vehicle when the RL required to do so is less than a setpoint (SP)*.

> … ***[80.4] operating an internal combustion engine of the hybrid vehicle to propel the hybrid vehicle when the RL required to do so is between the SP and a maximum torque output (MTO) of the engine,***

273. As annotated below, the Durham Project discloses an engine that can be connected to the road wheels and used to propel the vehicle *via* a clutch and transmission. The clutch is operated to couple the engine to the drive wheels. (Ex. 1906 [Bumby II] at 1; Ex. 1907 [Bumby III] at 1; Ex. 1908 [Bumby IV] at 1)



Ex. 1906 [Bumby II] at 1, Fig. 1 (annotated)

274. Again, "the selected mode of operation depends on the **actual torque** and speed values." (Ex. 1906 [Bumby II] at 11, emphasis added.) When the actual speed and torque (*road load*) values are within the "upper and lower torque bound and. . . upper and lower speed bound. . . engine-only operation is favoured. . ." (Ex. 1906 [Bumby II] at 10-11; *see also* Ex. 1907 [Bumby III] at 7-8.)

275. For instance, at a given vehicle speed, in a fixed gear, the engine-only mode is selected when the torque required to propel the vehicle (*road load*) is between *setpoint* ("lower torque bound") and the "upper torque bound." The upper torque bound is disclosed as being 90% of the engine's MTO. (Ex. 1907 [Bumby III] at 8, Fig. 8; Ex. 1906 [Bumby II] at 10-11.) The upper torque bound and engine's MTO is illustrated in the sub-optimal control strategy as I have indicated below. Since 90%

MTO is the upper bound, the Durham Project discloses operating the engine **between** *setpoint* and MTO.

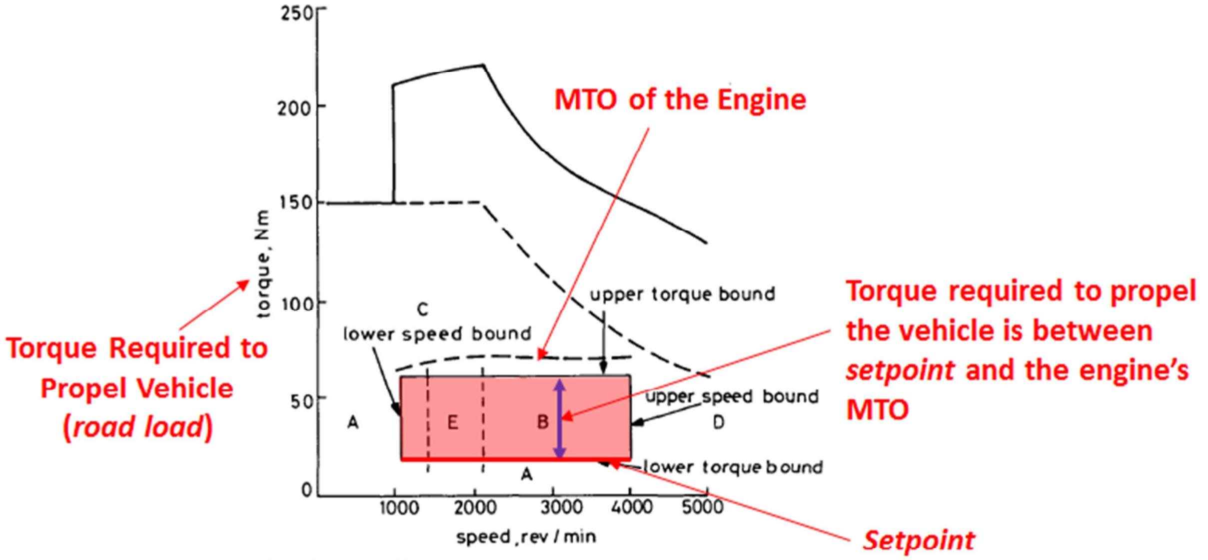


Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at 11, Fig. 16

276. The Durham Project further discloses and illustrates the engine's MTO as the "engine full throttle torque," as shown below in Fig. 3. A person of ordinary skill in the art would understand that the engine's maximum torque output (MTO) curve and "engine full throttle torque" curve are equivalent at each engine speed. Therefore, the engine-only mode disclosed by the Durham Project is *between setpoint and MTO*.

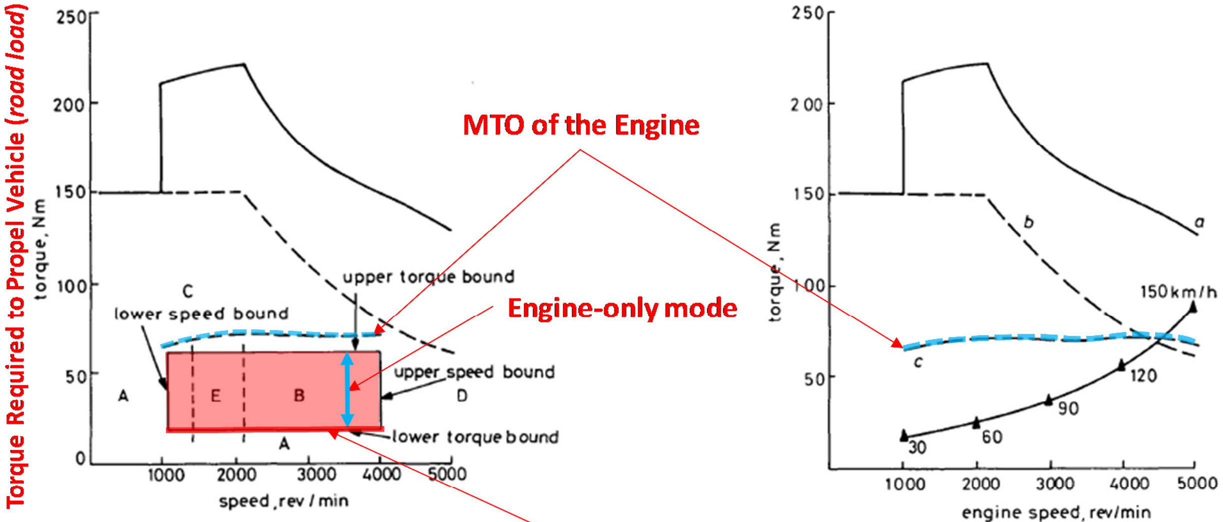


Fig. 16 *Parallel hybrid suboptimum control operating regions*
(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Fig. 3 *Base hybrid electric performance curves*
a Combined maximum torque line
b Traction motor torque
c Engine full throttle torque
▲ constant speed road load

Ex. 1906 [Bumby II] at 2 and 11, Fig. 3 and 16 (annotated)

277. It is therefore my opinion that the Durham Project discloses *operating an internal combustion engine of the hybrid vehicle to propel the hybrid vehicle when the RL required to do so is between the SP and a maximum torque output (MTO) of the engine.*

> … ***[80.5] wherein the engine is operable to efficiently produce torque above the SP, and***

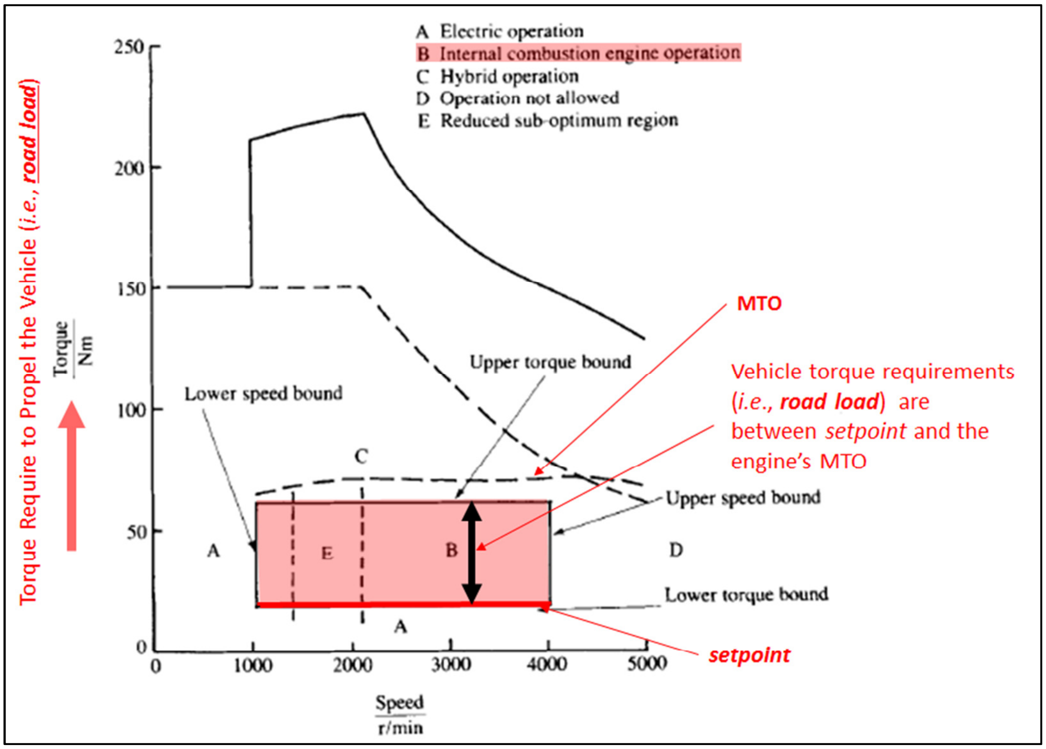
278. The Durham Project discloses that the sub-optimal controller seeks to operate the engine only within its "high-efficiency region." This region is disclosed as being both speed bound and torque bound.

> **<u>To develop a control algorithm that can be implemented on an actual vehicle a sub-optimal control algorithm is postulated that seeks to restricts the operation of the i.c. engine to the high-</u>**

> **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.
>
> 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. 1907 [Bumby III] at 7; *see also* Ex. 1906 [Bumby II] at 10-11.)

279. Thus, when the vehicle is operating at a given speed in a fixed gear and the torque requirements (*road load*) are above the "lower torque bound" (*setpoint*) the vehicle is operated in engine-only mode. Operating the engine within this boxed region (which is above *setpoint*) eliminates "inefficient use of the engine." (Ex. 1906 [Bumby II] at 11; Ex. 1907 [Bumby III] at 8.)



Ex. 1907 [Bumby III] at 8, Fig. 8

280. It is therefore my understanding that the Durham Project discloses *wherein the engine is operable to efficiently produce torque above the SP.*

… ***[80.6] wherein the SP is substantially less than the MTO;***

281. As discussed above in reference to limitation [80.4] and [80.5] above, the Durham Project discloses that the engine is operated only under conditions where the engine output torque is most efficient. Again, the "lower torque bound" would have been understood as being a lower predetermined torque value (*i.e.*, "*setpoint*".)

282. As also discussed above in reference to limitation [80.4] and [80.5] above, the Durham Project discloses an "upper torque bound" that is 90% of the engine's maximum torque output (MTO).

> 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. 1907 [Bumby III] at 7.)

283. The Durham Project also discloses that the maximum torque output (MTO) of the engine is 71 Newton-meters (Nm.) (Ex. 1908 [Bumby IV] at 5, Table 2.) As I explain in ¶ 276, the below graph shows a dotted line that is engine's MTO curve. That means that the upper torque bound is approximately 64 Nm (i.e., 90% * 71Nm = 64 Nm.)

284. It is evident from the annotated Fig. 8 of Bumby III (below) that the lower torque bound (i.e., "*setpoint*") is *substantially less* than the engine's maximum torque output.

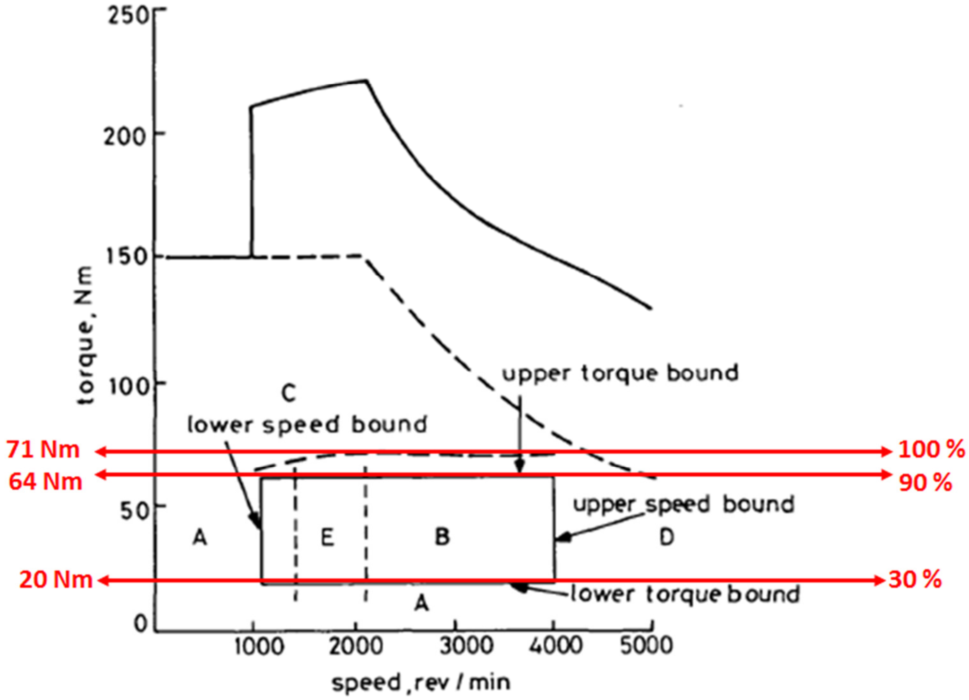


Fig. 16 *Parallel hybrid suboptimum control operating regions*

Ex. 1906 [Bumby II] at 11, Fig. 16 (annotated)

285. Also illustrated above, the lower torque bound (i.e. "setpoint") 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%.)

286. The lower torque bound (*i.e.* "setpoint") of 30% MTO 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.

287. Therefore, it is my opinion that the Durham Project discloses *wherein the predetermined torque value is substantially less than the MTO.*

> … ***[80.7] wherein said operating the internal combustion engine to propel the hybrid vehicle is performed when: the RL>the SP for at least a predetermined time; or the RL>a second setpoint (SP2), wherein the SP2 is a larger percentage of the MTO than the SP; and***

288. It is my understanding that an "OR" within the claim is meant to be interpreted to mean "Element A" or "Element B" as follows:

- **Element A** - operating the internal combustion engine to propel the hybrid vehicle is performed when: the instantaneous torque required for propulsion of the vehicle, which may be positive or negative in value is greater than the SP predetermined torque value for at least a predetermined time;

OR

- **Element B** - operating the internal combustion engine to propel the hybrid vehicle is performed when...the instantaneous torque required for propulsion of the vehicle is greater than a second setpoint (SP2), wherein the SP2 is a larger percentage of the MTO than the predetermined torque value.

289. Both Elements of limitation [80.7] relate to a well-known "hysteresis" control that was known and employed to control rapid on/off switching of a controlled device. The hysteresis prevents unnecessary engine stops and restarts. In fact, these limitations are also disclosed as "hysteresis" by the '634 Patent.

> By monitoring the road load over time, and comparing it to different setpoints accordingly, much of this undesirable repetitive sequence of engine starting and shut-off can be eliminated. It might be preferable to commence mode IV operation upon the occurrence of differing conditions; for example, mode IV might be entered from mode I only after the road load exceeded a first, lower setpoint SP for **an extended period of time,** so that the engine would be run for extended low-speed cruising, but to start the engine immediately if the road load **exceeded a higher setpoint SP2**, e.g. 50% of MTO, as during acceleration to highway speed. Similarly, the engine might preferably be shut down only if the road load was less than a minimum setpoint for mode IV operation for **an extended period of time**. Thus providing **"hysteresis"** in the mode-switching determination would limit repetitive engine starts in certain types of driving. These limits could be further

> adjusted as the driving pattern became clear, i.e., as discerned by the microprocessor.

('634 Patent, Ex. 1901 at 41:30-47, emphasis added.)

290. The Durham Project also recognized the known problems with excessive starting and stopping of the engine. As such, the Durham Project aimed to avoid rapid starting and stopping of the engine due to the potential damage that could occur to the engine and starter motor, as well preventing user drivability concerns due to vibration and shock.

> A second important consideration affecting whether or not the engine should be started concerns **avoiding too many start up operations**. **Failure to restrict the amount of engine starts would lead to excessive wear on the starter motor**, and might damage the engine itself. As a result the sequencing logic includes two safeguards designed to stop this eventuality from occurring. **Firstly the engine is allowed to idle for five seconds at zero torque before being shut down**.

(Ex. 1910 [Masding Thesis] at 209.)

> Consequently **a starting system** is needed that 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. 1910 [Masding Thesis] at 151.)

291. To prevent undesirable cycling of the engine and drivability concerns, the Durham Project recognized that hysteresis control would have been helpful during mode switching in hybrid vehicles.

> **Smooth switching between modes and gears is achieved by defining a hysteresis band** around each threshold speed. As a result an arbitrary gear change speed of 20 km/h will result in an upshift at 21.9 km/h but no change down again until 18.1 km/h. This is vital to gear changing in particular because the speed inevitably falls during the gear change. A slightly smaller band of ±0.95 km/h is defined for mode transitions in recognition of the fact that speed changes are less severe in this case.

(Ex. 1910 [Masding Thesis] at 211.)

292. Hysteresis control strategies were widely known prior to 1998, particularly in the automotive field. For instance, hysteresis delays are frequently employed in automatic transmissions in order to prevent excessive shifting between gears. The Durham Project itself discloses such well-known hysteresis controls for transmission systems. Specifically, the Durham Project recognizes using hysteresis bands and time-based hysteresis to reduce undesirable shifts.

> In work at Ford [Kuzak et al, 1987] transmission output speed and throttle position were used as indicators of engine efficiency and thus a shift strategy was based on them. Several steps were needed to reduce numbers of shifts from those produced with fully optimal control, the simplest defined **hysteresis bands** on the throttle angle/speed plane between the zones defined for each gear. Secondly a minimum time between shifts was imposed to improve driveability. Such a limitation could easily be applied to the sub-optimal mode controller, and it is encouraging to note that the Ford [Kuzak et al, 1987] result showed that

> by **<u>imposing a 5 second limit</u>** between shifts, fuel economy in city driving suffered by only 3% but shift frequency was reduced by 50%.

(Ex. 1910 [Masding Thesis] at 244, emphasis added.)

293. To the extent that it is not obvious based on the teaching of the Durham Project alone to use *a predetermined time* delay or a *second setpoint* (control band) to solve the problem of engine cycling during mode switching, Frank provides further teaching about using hysteresis setpoints and time-delay between mode switching.

294. Frank "pertains generally to hybrid powered vehicles employing both electric motors and auxiliary power units. . . ." (Ex. 1943 ['363 Frank] at 1:15-17.) Figure 1 of Frank is reproduced below, illustrating an exemplary parallel hybrid vehicle having an IC engine 14 and an electric motor 12, both capable of propelling the vehicle either individually or together. As Frank states:

> By way of example, and not of limitation, the invention provides for operating the hybrid powertrain in a zero emissions vehicle (ZEV) mode and in an HEV mode. In the ZEV mode, the EM provides all driving power while the ICE is uncoupled and turned off. In the HEV mode, operation of the EM and ICE is coordinated for maximum range and efficiency. (Ex. 1943 ['363 Frank] at 2:25-31.)

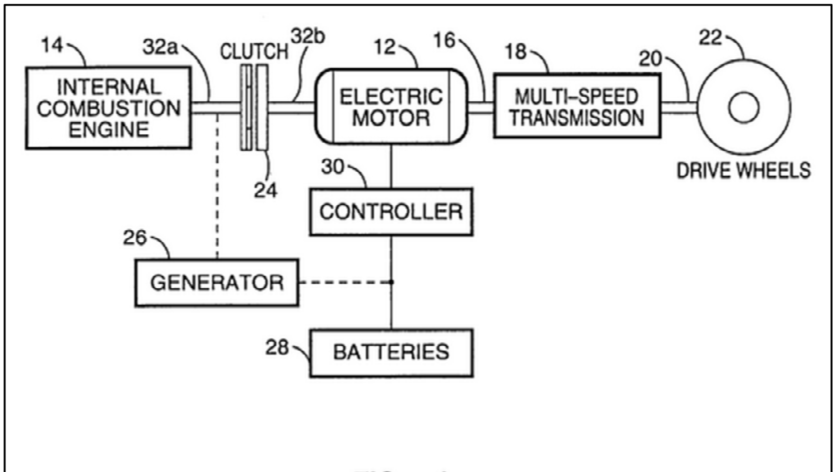


FIG. – 1

Ex. 1943 ['363 Frank] at Fig. 1

295. The control strategy disclosed by Frank monitors the vehicle speed and depth of discharge. Based on these sensed values, Frank transitions between: (1) an electric-motor mode (highlighted in red) where the electric motor is used to drive the vehicle; (2) an engine mode (highlighted in green) where the only the IC engine is used to drive the vehicle; and (3) an engine-motor mode (highlighted in blue) where the electric motor and IC engine are used to drive the vehicle. (Ex. 1943 ['363 Frank] at 7:63-8:37.)

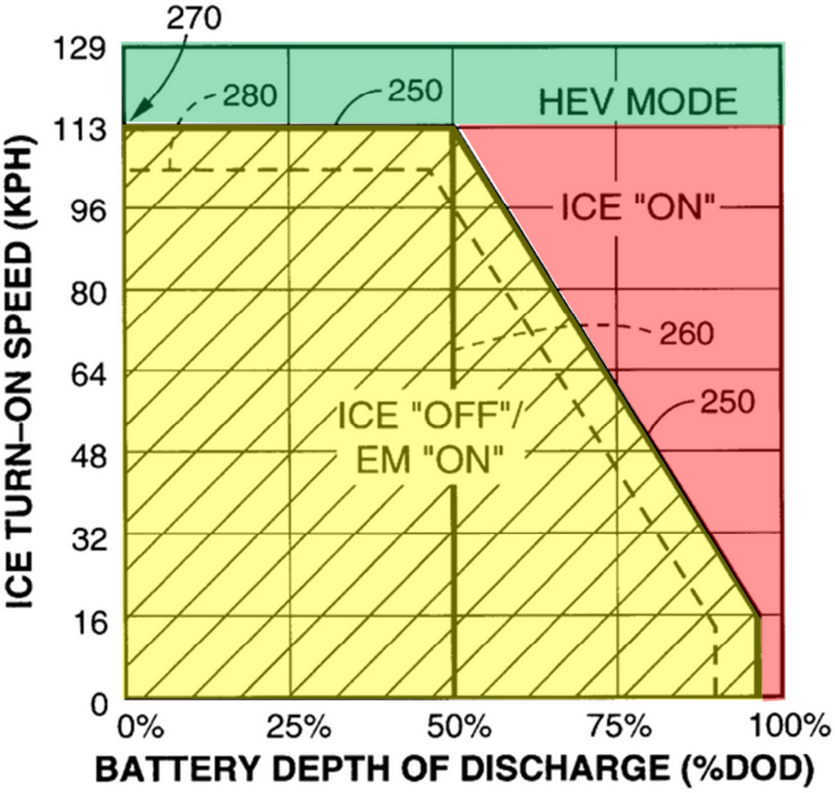


FIG. – 4

Ex. 1943 ['363 Frank] at Fig. 4 (annotated)

296. With respect to Frank's control strategy, Fig. 4 further shows an "on threshold curve" (bold line labeled as "250") and an "off threshold curve" (dashed line labeled as "280").

> Referring also to FIG. 4, the control parameters used for coordinating the operation of the EM 12 and the ICE 14 in step 150 of FIG. 3 are graphically shown. The area below the "on" threshold curve is where the vehicle operates in a ZEV mode, with the EM 12 turned on and the ICE 14 decoupled and turned off. The area above the "on" threshold curve is where the vehicle operates in a HEV mode with the ICE 14 coupled and turned on, and with the EM 12 being used only for accelerating, climbing hills and regenerative braking.

(Ex. 1943 ['363 Frank] at 7:63-8:5, emphasis added.)

297. Although Frank determines whether to operate the IC engine based on speed and depth of discharge (rather than torque and speed like the Durham Project), Frank describes the problem of "frequent cycling" of the engine shared by all parallel hybrid vehicles including the vehicle disclosed by the Durham Project. Further, Frank's disclosure of different on/off setpoints applies to any control system, regardless of the variable feature that is serving as the on/off setpoint. Further, Frank discloses that another solution to the problem of "frequent cycling" is to simply add a time delay between switching.

> As an alternative to separate "on" and "off" thresholds, a single threshold could be used in combination with **a time delay between the "on" and "off" modes to prevent frequent cycling**.

(Ex. 1943 ['363 Frank] at 8:32-37, emphasis added.)

298. In this disclosure, Frank explains that "frequent cycling" is preventable by including a time delay when vehicle conditions exceed the threshold in which the hybrid vehicle switches from motor mode to engine mode. In other words, Frank discloses setting a predetermined time for which the vehicle conditions must be conducive to operating in the engine mode before switching the drive source from the motor to the engine. Again, this time delay solution to frequent on/off cycling would apply to any system with on/off control.

299. A person having ordinary skill in the art would have understood that

there is a reason to combine the teaching of Frank with the Durham Project. Both Frank and the Durham Project disclose parallel hybrid vehicles. As I have further illustrated below, both Frank and the Durham Project use base-control strategies where an electric motor and IC engine are used to drive the vehicle in various operating modes.

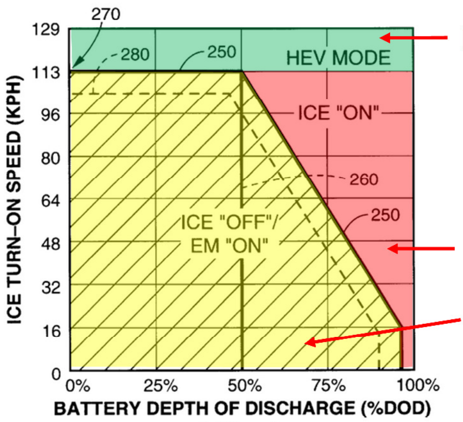


FIG. – 4

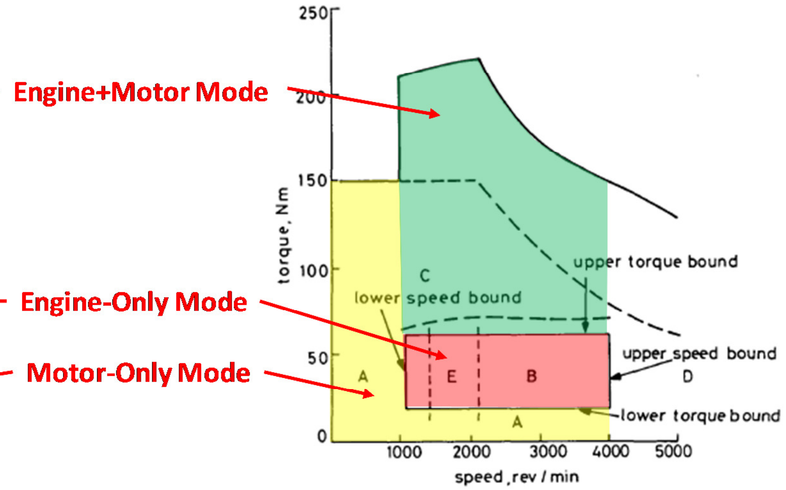


Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1943 ['363 Frank] at Fig. 4 **Ex. 1904 [Bumby II] Fig. 16 (annotated)**

300. As also discussed above, both systems utilize control strategies with threshold values ("On/Off" of Frank and the "lower torque bound" of the Durham Project) at which point their disclosed hybrid systems switch from motor-only mode to engine-only mode. For these reasons, the engines in both systems would be at risk of frequent cycling when conditions vary close to the setpoint. Further, the risk of frequent cycling arises regardless of the whether the setpoint is torque-based or speed based. And hysteresis techniques can help solve the frequent cycling problem

regardless of nature of the setpoint.

301. It is my opinion that the Durham Project contemplates hysteresis techniques in transmission (i.e. a time-based delay and "hysteresis bands" having two setpoints.) The Durham Project also discusses hysteresis techniques to solve the known problems associated with mode changes in a hybrid vehicle (i.e. between motor and engine modes).

302. Therefore, it is my opinion that a person of ordinary skill in the art would have been obvious to use the well-known hysteresis techniques disclosed by Frank to improve the similar hybrid system and base-control strategy in the Durham Project in the same way. Indeed, by adding a "time delay" along the "lower torque bound" of the Durham Project (shown in Fig. 16, above), like the time delay taught by Frank, would prevent the known problem of "undesirable or excessive cycling" of the engine in the Durham Project. (Ex. 1943 ['363 Frank] at 8:32-37.)

303. It is my opinion that a person of ordinary skill in the art would have been able to implement Frank's time-delay hysteresis technique with the base-hybrid control strategy disclosed by the Durham Project. Frank's time-delay would have been an algorithm that could be implemented much the same as the hysteresis "5 second limit between shifts" already disclosed by the Durham Project. (Ex. 1910 [Masding Thesis] at 244.) Implementing this hysteresis control technique would have been well within the skill of a person of ordinary skill in the art.

304. Thus, the Durham Project in view of Frank discloses *operating the internal*

combustion engine to propel the hybrid vehicle is performed when: the RL>the SP for at least a predetermined time; or the RL>a second setpoint (SP2), wherein the SP2 is a larger percentage of the MTO than the SP.

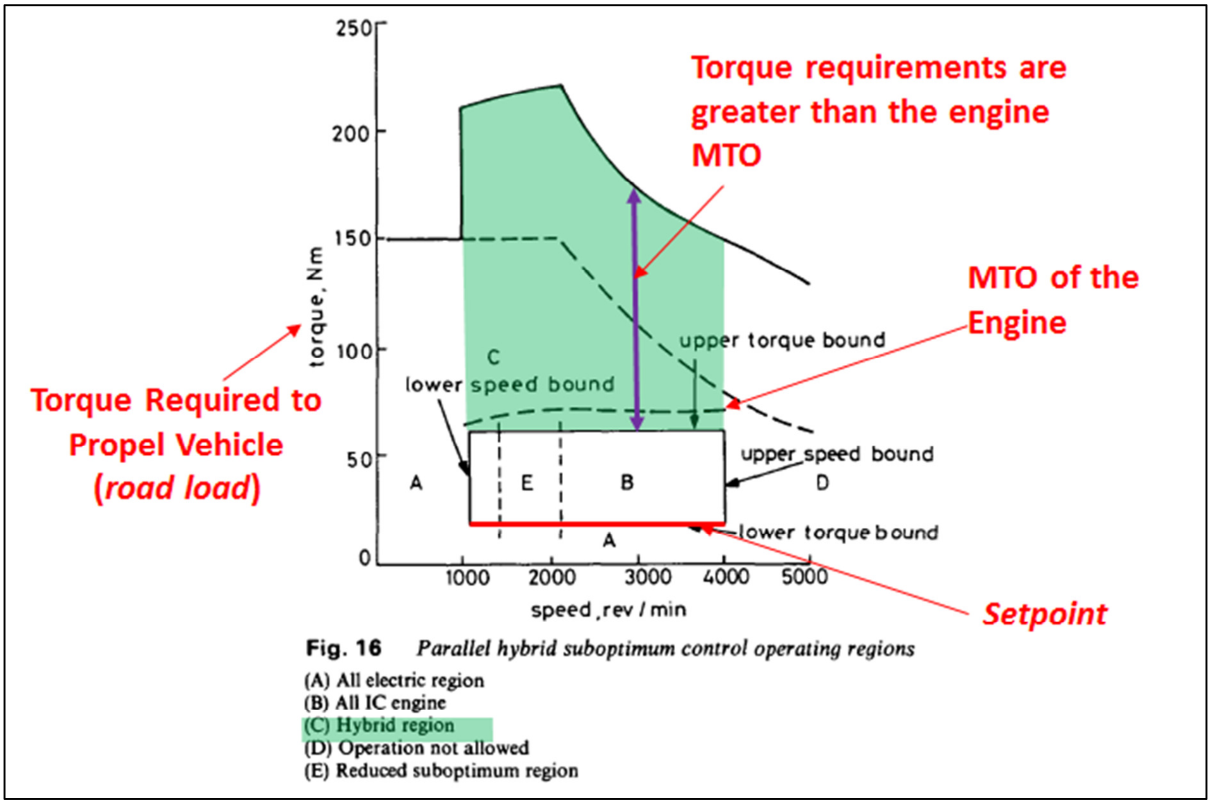
… ***[80.8] operating both the at least one electric motor and the engine to propel the hybrid vehicle when the torque RL required to do so is more than the MTO.***

305. Once again, the Durham Project discloses determining operational modes of the vehicle based on the actual torque and speed of the vehicle: "Within this [engine operation] 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." (Ex. 1906 [Bumby II] at 11.) The Durham Project also discloses that an engine-motor mode is executed when the torque requirements (*road load*) are above the "upper torque bound." (Ex. 1906 [Bumby II] at 11; Ex. 1907 [Bumby III] at 11.) The Durham Project discloses that during such high torque requirements, the motor provides supplemental torque above 90% MTO of the engine. Unless the driver requests full torque output from the vehicle, the motor will provide the supplemental torque in order to allow the engine to remain within its "high-efficiency region" (*i.e.* < 90%MTO). Indeed, the Durham Project recognizes these high torque situations as occurring during 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 **engine torque can be augmented by the motor for rapid acceleration or hill climbing**. 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. 1909 [Bumby V] at 4, emphasis added; *see also* Ex. 1907 [Bumby III] at 11).

306. As I highlight in green below, when the torque requirements exceed the "upper torque bound" (*i.e.*, 90% engine MTO), the vehicle is driven in the engine-motor mode. (Ex. 1906 [Bumby II] at 10-11; Ex. 1907 [Bumby III] at 7-8). As I have also annotated below, this engine-motor mode continues beyond the engine's MTO. "Above the upper torque bound, true hybrid operation [region "C"] is used with the electric motor supplying the excess torque above the maximum available from the engine." (Ex. 1906 [Bumby II] at 10-11.) In other words, when the torque requirements (*road load*) exceed the engine's MTO, the motor continues to provide supplemental drive torque to meet the driver's demand.



Ex. [Bumby 11] at 11, 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. **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. 1906 [Bumby II] at 10-11, emphasis added.)

307. As stated above, the engine and motor are both operated to propel the

vehicle the torque required to propel the vehicle is "above he maximum available from the engine." (Ex. 1906 [Bumby II] at 10-11.) 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 increase the vehicle's total torque capabilities beyond that of the engine alone. This is shown above, and would be understood as being needed during high load operations, such as accelerating or hill climbing.

308. Therefore, it is my opinion that the Durham Project discloses *operating both the at least one electric motor and the engine to propel the hybrid vehicle when the torque* RL *required to do so is more than the MTO.*

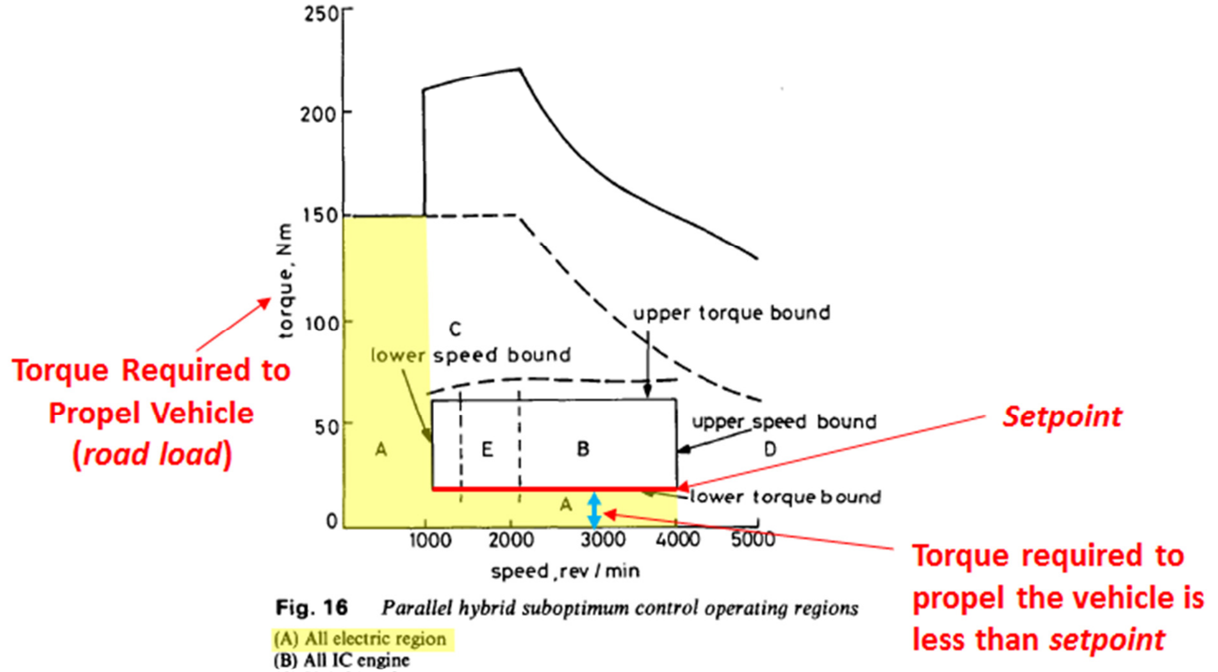
2. Dependent Claim 91

… ***[91.] The method of claim 80, further comprising: turning off the engine when the torque required to propel the vehicle is less than the SP.***

309. The Durham Project discloses an "electric mode" where "all propulsion power is supplied by the electric traction system." (Ex. 1909 [Bumby V] at 4; Ex. 1908 [Bumby IV] at 3; Ex. 1907 [Bumby III] at 11-12.)

310. The sub-optimal control strategy will also operate the vehicle in a motor-only mode (*i.e.*, "Electric operation") when the speed and torque requirements are outside the engine's "high-efficiency region." (Ex. 1907 [Bumby III] at 7; Ex. 1906 [Bumby II] at 10-11.) In other words, motor-only mode occurs when the actual

torque and speed "lower speed bound" or "lower torque bound." (Ex. 1907 [Bumby III] at 7; Ex. 1906 [Bumby II] at 10-11.) In Fig. 16, below, I have annotated in yellow the motor-only mode of operation (*i.e.* "All electric region"). When the torque requirements for propelling the vehicle (*i.e. road load*) are below the "lower torque bound," or *setpoint*, the vehicle is propelled by the motor alone. (Bumby II, Fig. 16 at 11; *see also* Ex. 1907 [Bumby III] at 8.) As, illustrated, the Durham Project also discloses operation in motor-only mode below a lower speed threshold when the speed is less than approximately 1000 rev/min.



Torque Required to Propel Vehicle (*road load*)

Setpoint

Torque required to propel the vehicle is less than *setpoint*

Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at 11, Fig. 16 (annotated)

311. If the vehicle is operating in the motor-only mode (highlighted in yellow, above), the engine is de-clutched from the drivetrain and shut-down. It was known

that leaving the IC engine idling for long periods of time during the motor-only mode would be undesirable from both an emissions and fuel consumption standpoint. Otherwise, the engine would be running without providing any benefit – *i.e.,* propelling the vehicle or generating electricity – while consuming unnecessary fuel and emitting unnecessary exhaust. Indeed, the Durham Project recognizes wasted fuel and increased emissions as the reason for shutting down the engine during motor-only mode operation.

> To improve power-train efficiency **when the engine is not in use it is shut down**.

(Ex. 1908 [Bumby IV] at 7.)

> 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**.

(Ex. 1909 [Bumby V] at 5.)

> **Whenever the hybrid vehicle is operating in all electric mode** or is stationary, the i.c. engine can 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**.

(Ex. 1910 [Masding Thesis] at 151, 165.)(*see* also Ex. 1909 [Bumby V] at 5.)

312. Therefore, the Durham Project would have turned off the engine when

the torque required to propel the vehicle was less than the lower torque bound during motor-only mode, and the engine is not in use.

313. Therefore, the Durham Project therefore discloses *turning off the engine when the torque required to propel the vehicle is less than the SP.*

3. Dependent Claim 92

… ***[92.] The method of claim 80, further comprising: turning off the engine when the torque required to propel the vehicle <u>and/or</u> charge the battery is less than the SP.***

314. I understand that use of the "and/or" in this limitation indicates that only one of the alternatives needs to be met for this claim limitation to be satisfied. Accordingly, I understand claim 92 is met by the Durham Project if either of the below elements are disclosed:

Element A - *turning off the engine when the torque required to propel the vehicle . . . is less than the SP.*

Element B - *turning off the engine when the torque required to . . . charge the battery is less than the SP.*

315. I understand that Element A is substantially similar to the limitations of claim 91 and therefore, **please refer to my analysis for claim [91]**.

4. Dependent Claim 95

… ***[95.] The method of claim 80, wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle and said operating both the at least one electric motor and the engine to propel the hybrid vehicle, each comprises: if the engine is not already running, starting the engine.***

316. The Durham Project discloses starting the engine when it is required:

> To improve power-train efficiency when the engine is not in use it is shut down. Thus, **when power from the i.c. engine is demanded by the vehicle controller, the M68000 system must activate the ignition and <u>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. 1906 [Bumby IV] at 7, emphasis added.)

317. The Durham Project discloses a hybrid vehicle that de-couples and shuts down the engine when the vehicle is being driven using the electric motor. When the engine is again required to propel the vehicle a starting sequence is initiated that (1) starts the engine; (2) synchronizes the engine with the drivetrain; and (3) connects the engine to the drive train using a clutch.

> Whenever the hybrid vehicle is operating in all electric mode or is stationary, the i.e. engine can 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. **<u>Adopting this strategy means that the next time the engine is needed it must be started and synchronized with the moving, and possibly accelerating drive train, before it can replace or augment the torque supplied by the electric traction system</u>**. Consequently a starting system is needed that 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. Design of such a control system uses the transfer function relating throttle position to speed identified in chapter 4.

(Ex. 1910 [Masding Thesis] at 151, *see* also 78, 152-153.)

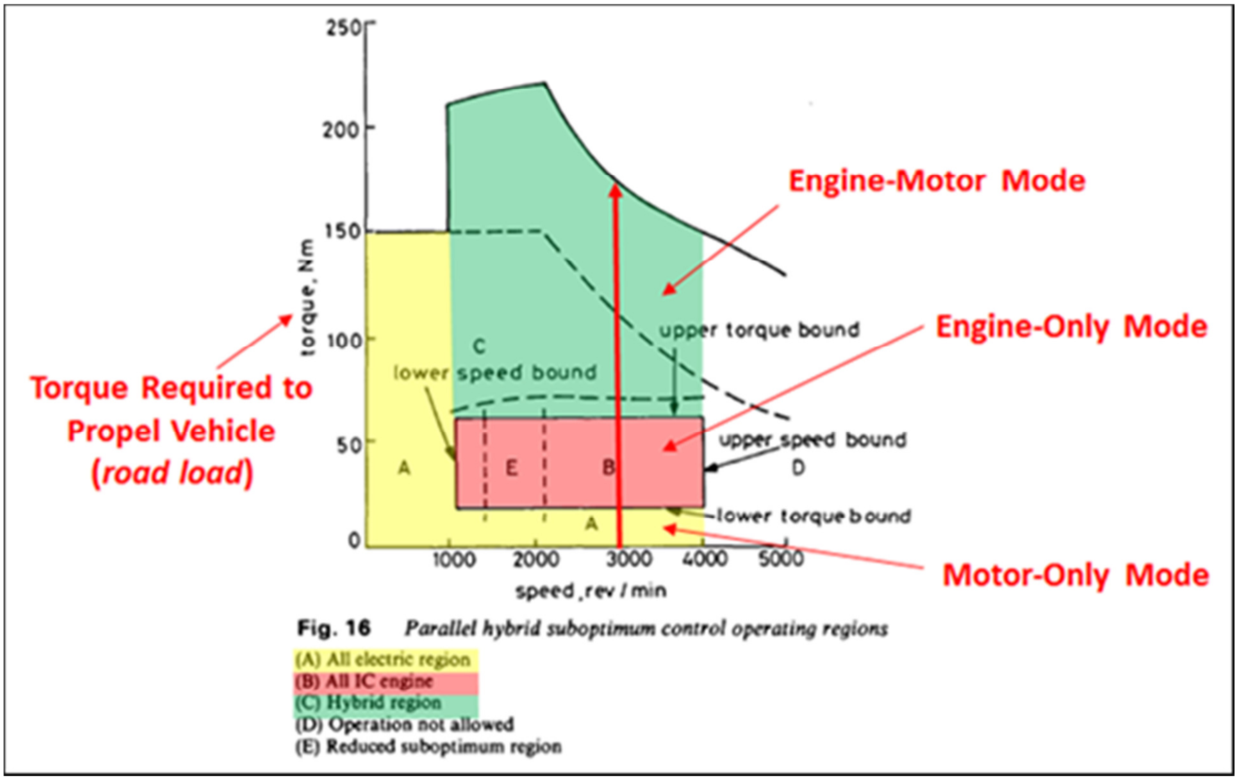
> **<u>an engine-starting procedure</u>** has been developed which can bring the engine on-line and actively producing power in 1 s using the conventional electric starter motor. When combined with a fully automated transmission system, the result is a flexible drive-train controller which can carry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

(Ex. 1909 [Bumby V] at 5.)

318. As discussed in claim **80**, the Durham project discloses that the vehicle is controlled using a sub-optimal control strategy that determines whether the vehicle should be operated in: (1) a motor-only mode (*i.e.*, "electric operation"); (2) engine-

only mode (*i..e*, "Internal combustion engine operation"); or (3) engine-motor mode (*i.e.*, "Hybrid operation"). (Ex. 1906 [Bumby II] at 11-12; Ex. 1907 [Bumby III] at 7-8; Ex. 1910 [Masding Thesis] at 43-44.) As discussed in **[80.4]** or [**80.8],** the engine is operated either alone, or with the electric motor to propel the vehicle.

319. As I have shaded in red below, the engine-only mode is selected when the speed and torque requirements are within the engine's "high-efficiency region." (Ex. 1907 [Bumby III] at 7.) Also shaded in green below, the engine-motor mode is selected when the torque requirements exceed 90% of the engine's MTO (the upper torque bound). (Ex. 1906 [Bumby II] at 11-12; Ex. 1907 [Bumby III] at 7-8; Ex. 1910 [Masding Thesis] at 43-44.)



Ex. 1906 [Bumby II] at 11, Fig. 16

320. If the Durham Project determines that operation of the vehicle is within one of these two operating regions, an engine starting and synchronization procedure is employed. Once the engine speed is synchronized within 45 RPM of the drivetrain, the clutch is engaged and the vehicle is then propelled using the engine.

> When required the warm engine will fire in typically 250 ms using the conventional electric starter motor, but there is a further delay whilst the engine accelerates up to the drive train speed. Inertia starting used in the HTV-1 project [Trummel and Burke, 1983] allowed the engine to be completely coupled into the drive train in 300 ms but the cost was the need for an additional clutch between the engine and the engine flywheel. A time analysis of the starting process on the rig is shown in figure 5.14. In this experiment the motor was initially accelerating under load, as illustrated by the motor speed and torque traces. At time t=0.45 however, the computer receives the start command, immediately it turns on the ignition and engages the starter motor. At the same time the throttle is opened 9° and the computer then waits for the engine to fire. This is adjudged to happen when the engine speed passes 490 r.p.m. Above this speed the starter motor is turned off and the speed control algorithm is entered to run the engine up to the drive train speed. Synchronisation is deemed complete when the engine speed is within 45 r.p.m. of the drive train speed which in this case is achieved within 0.7 seconds of the original command to start. At this stage torque control is transferred to the engine which continues to accelerate the load.

(Ex. 1910 [Masding Thesis] at 152-153; Ex. 1909 [Bumby V] at 5-6.)

321. It is therefore my opinion that the Durham Project fully discloses

operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle and said operating both the at least one electric motor and the engine to propel the hybrid vehicle, each comprises: if the engine is not already running, starting the engine.

5. Dependent Claim 96

… ***[96.0] The method of claim 80, further comprising:***

monitoring the RL over time;

322. I understand that this limitation is substantially similar to the limitations of claim [80.2] and therefore, please r**efer to my analysis with respect to limitation [80.2]** above.

… ***[96.1] wherein said operating the at least one electric motor to propel the hybrid vehicle is performed when the RL<the SP for at least a predetermined amount of time.***

323. As discussed above in limitation [**80.7**] the Durham Project I combination with Frank discloses a hysteresis time-delay for *a predetermined amount of time* when transitioning from the motor-only mode to engine-mode operation.

324. For the reasons discussed in claim [80.7], it is my opinion that it would have been obvious to a person having ordinary skill in the art to delay operating the hybrid vehicle described in Durham Project in the motor-only mode *for at least a predetermined time* even after the torque falls below the "lower torque bound." By instituting a time delay before switching from the engine-only mode to the motor-only

mode, the hybrid system would prevent, or at least substantially reduce, any unnecessary toggling between these modes at times when the torque required to propel the vehicle is hovering on or near a point along the "lower torque bound." This would reduce the threat of erratic starting and stopping of the motor and engine, preventing inefficient starting, and avoidable wear of the motor, engine and clutch mechanism. For instance, the amount of fuel consumed during engine restarts typically exceeds the amount of fuel that would be consumed from simply running the engine at idle for a short period of time prior to shut-down. By delaying the engine shut-down and idling the engine momentarily, the controller could ensure that the torque required to propel the vehicle is not hovering below and above the *setpoint*. This would in turn ensure that the driving conditions intend for a transition between operating modes. Also frequent connecting/disconnection of the engine and motor *via* the clutch would lead to noise, vibration and harshness issues due to the shock the system would experience. This would be unacceptable from both a drivability as well as performance standpoint. For instance, the vehicle would likely lurch forwards and backwards as the clutch mechanism attempts to connect the engine shaft to the drive shaft at a high frequency.

325. For all the reasons discussed for claim [80.7], a person of ordinary skill in the art would have recognized the inherit problems with such a high frequency of switching between operational modes of hybrid vehicles that correspond to the vehicle drive torque fluctuating above and below the transition point between the

operational modes. It would have therefore been obvious to a person having ordinary skill in the art to continue operating the engine to propel the vehicle in the engine-only mode until the vehicle drive torque (*i.e., RL*) has been less than the predetermined torque value (*i.e., SP*) *for at least a second length of time*. It would have also been known by a person having ordinary skill that such frequent starting and stopping of the engine would lead to increased exhaust emissions and reduced fuel efficiency. Additionally, it would have been known that connecting and disconnecting the clutch at a high frequency could also lead to potential damage to not only the clutch mechanism, but also to the engine, motor and transmission.

326. Similar to claim limitation [80.7], to the extent this functionality is not obvious based on the teaching of the Durham Project alone, Frank further supports my opinion that it would have been obvious to a person of ordinary skill in the art to include a delay for a *predetermined amount of time* when transitioning between drive modes. For the reasons discussed below, it would have been obvious to a person having ordinary skill in the art to combine the teaching of Frank with the Durham Project.

327. As described for claim limitation [80.7], Frank pertains to hybrid powered vehicles, describes the problems of frequent on/off engine cycling, and discloses hysteresis solutions based on either (1) different setpoints or (2) time delay.

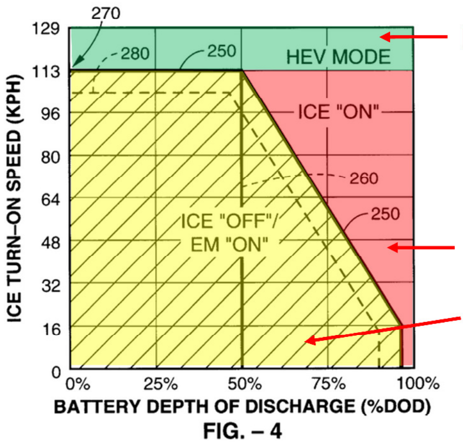
328. Regarding time delays, Frank describes time delays between both "on" and "off" modes:

> As an alternative to separate "on" and "off" thresholds, a single threshold could be used in combination with **a time delay between the "on" and "off" modes to prevent frequent cycling**.

(Ex. 1943 ['363 Frank] at 8:32-37, emphasis added.)

329. Again, Frank explains that "frequent cycling" is preventable by including a time delay when vehicle conditions exceed the threshold in which the hybrid vehicle switches from engine-only mode to motor-only mode. In other words, Frank discloses setting a predetermined time for which the vehicle conditions must be conducive to operating in the motor-only mode before switching the drive source from the engine to the motor.

330. A person having ordinary skill in the art would have understood that there is a reason to combine the teachings of Frank with the Durham Project. Both Frank and the Durham Project disclose parallel hybrid vehicles. As I have further illustrated below, both Frank and the Durham Project employ control strategies where an electric motor and IC engine are used to drive the vehicle in various operating modes.



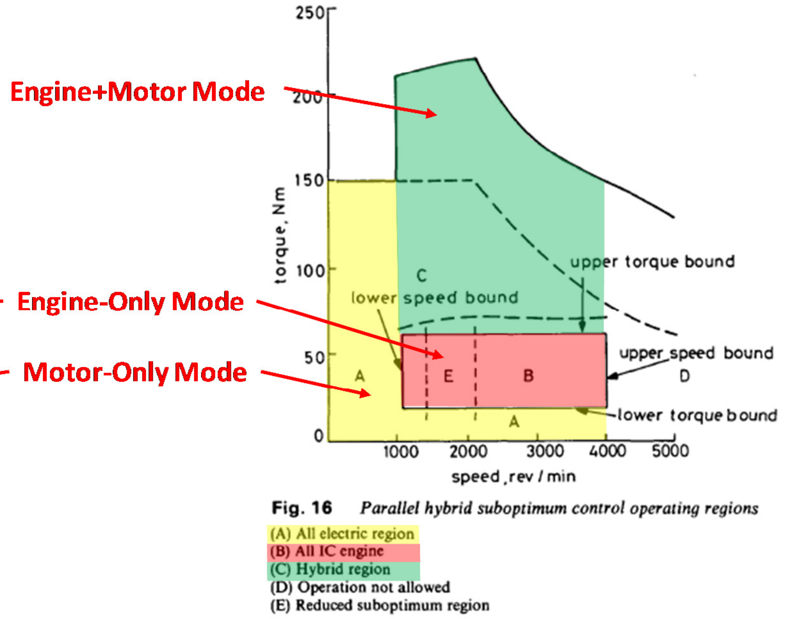


Fig. 16 *Parallel hybrid suboptimum control operating regions*

Ex. 1943 ['363 Frank] at Fig. 4 **Ex. 1906[Bumby II] Fig. 16 (annotated)**

331. As also discussed above, both systems utilize control strategies with threshold values ("On/Off" of Frank and "lower torque bound" of the Durham Project) at which point their disclosed hybrid systems switch from engine drive mode to motor drive mode. For these reasons, the engines in both systems would be at risk of frequent cycling. Thus, there would be a reason to add the teachings in Frank to prevent frequent cycling in the hybrid vehicle disclosed in the Durham Project. Indeed, by adding a "time delay" along the "lower toque bound" in Fig. 16 of the Durham Project, like the time delay taught by Frank, the Durham Project would prevent the known problem of "undesirable or excessive cycling" of the engine. (Ex. 1943 ['363 Frank] at 8:32-37, emphasis added.)

332. <intentionally left blank>

333. As I discussed in claim 95, the engine is not coupled to the drive wheels

until a proper starting and synchronization process has been completed. The disclosed synchronization process may require several seconds to complete. Again, it would be obvious to include such a synchronization process prior coupling the engine to the driveline so that any potential noise, shock and vibration to the system may be avoided. In order to ensure this synchronization process is completed, the Durham Project implements a time-based hysteresis delay before transitioning from motor-only mode to engine-only mode. (Ex. 1910 [Masding Thesis] at 209; Ex. 1909 [Bumby V] at 15.)

334. Similarly, the Durham Project discloses a hysteresis time delay that is used during the transition back from engine-only mode to motor-only mode. The Durham Project discloses that this converse hysteresis time-delay is employed to: (1) protect the engine from to many false starts and stops; and (2) reduce excessive wear on the starter motor and engine.

> A second important consideration affecting whether or not the engine should be **started concerns avoiding too many start up operations**. Failure to restrict the amount of engine starts would lead to excessive wear on the starter motor and might damage the engine itself. As a result the sequencing logic includes two safeguards designed to stop this eventuality from occur[r]ing. **Firstly, the engine is allowed to idle for five seconds at zero torque before being shut down**. This five second figure is based on the estimated fuel penalty associated with the starting procedure as discussed by Volkswagen [Schmidt, 1981].

(Ex. 1910 [Masding Thesis] at 209, emphasis added.)

335. It would have again been obvious for a hybrid vehicle to employ such a hysteresis base time-delay when transitioning from engine-only mode to motor-only mode, as disclosed by the Durham Project. For example, such a time-based delay may be required when the torque requirements (*road load*) are toggling around the "lower torque bound" threshold (*setpoint*). If the torque requirements (*road load*) were to fall just slightly below the *setpoint* the vehicle controller would: (1) de-clutch and shut-down the engine, and (2) begin propelling the vehicle using the electric motor alone.

336. However, if the torque requirements (*road load*) were to quickly move back up above *setpoint*, the vehicle controller would be required to: (1) start the engine, (2) synchronize the engine speed with the drive train, and (3) connect the engine to the drivetrain *via* the clutch.

337. It would have been obvious that such operation would be both undesirable from both a performance and durability standpoint. First, as stated in the quote above, there is a "fuel penalty" associated with engine re-starts. This penalty would be a result of the amount of fuel that is required to re-start the engine after only a momentary dip below the *setpoint*. The Durham Project therefore recognizes that fuel can be conserved by eliminating or at least substantially reducing the unnecessary engine restarts that could occur during transient dips below *setpoint*.

338. Second, the Durham Project recognizes that rapid restarts might also lead to excessive wear and/or damage to the starter motor and engine. Having two power sources requires a person having ordinary skill consider how to properly switch

between propulsion by the engine to propulsion by the electric motor. The Durham Project not only acknowledges the problems associated with such a transition but also incorporates a hysteresis time-delay to ensure that unnecessary false-starts are eliminated when the torque requirements (*road load*) is toggling around *setpoint.*

339. The Durham Project therefore discloses a hysteresis time-based delay that will ensure the engine remains running. This time delay will ensure that full transition to motor-only mode does not occur until the torque requirements (*road load*) are less than *setpoint* (*i.e.*, *road load* < *SP*) **<u>for at least five seconds</u>**.

340. Therefore, *operating the at least one electric motor to propel the hybrid vehicle is performed when the RL<the SP for at least a predetermined amount of time* would be obvious in view of the Durham Project either alone or combined with Frank.

6. Dependent Claim 99

… ***[99.0] The method of claim 80, wherein the hybrid vehicle is operated in a plurality of operating modes corresponding to values for the RL and the SP;***

341. As discussed above with regard to claims **[80.1]-[80.8]**, the Durham Project discloses that the "**<u>selected mode of operation</u>** depends on the actual torque and speed values." (Ex. 1906 [Bumby II] at 11, emphasis added.)

342. Again, as discussed above in reference to limitation **[80.0]-[80.8]** above, the Durham Project discloses a torque *setpoint (SP)* for determining the operation

mode of the engine. Again, this "lower torque bound" would be understood as the lower predetermined torque value, or "*setpoint*".

343. Further, discussed in claim **[80.1]** the Durham Project further discloses that the modes of operation also correspond to the torque required to propel the vehicle, or *road load (RL)*. As I explained for claim limitation **[80.1]-[80.8]**, the modes of operation based on *road load*, where at constant speed of 3000 RPM, mode operational decisions are based on the torque required to propel the vehicle. (Ex. 1907 [Bumby III] at 8; *see also* Ex. 1906 [Bumby II] at Fig. 16 at 11.)

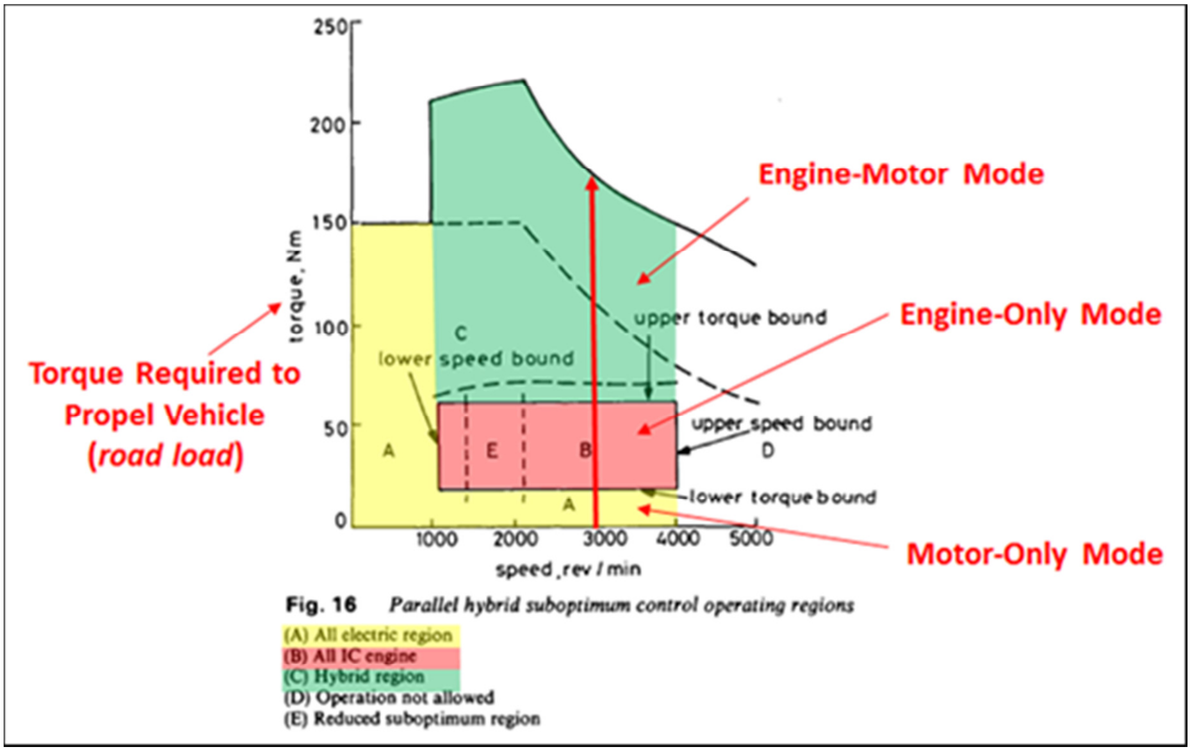


Fig. 16 *Parallel hybrid suboptimum control operating regions*

Ex. 1906 [Bumby II] at Fig. 16 (annotated)

344. Assuming the speed and gear remain constant, as the "instantaneous torque required for propulsion the vehicle" increases, the vehicle controller will change the mode of operation.

345. It is therefore my opinion that the Durham Project discloses wherein the hybrid vehicle is *operated in a plurality of operating modes corresponding to values corresponding to values for the* RL *and the SP.*

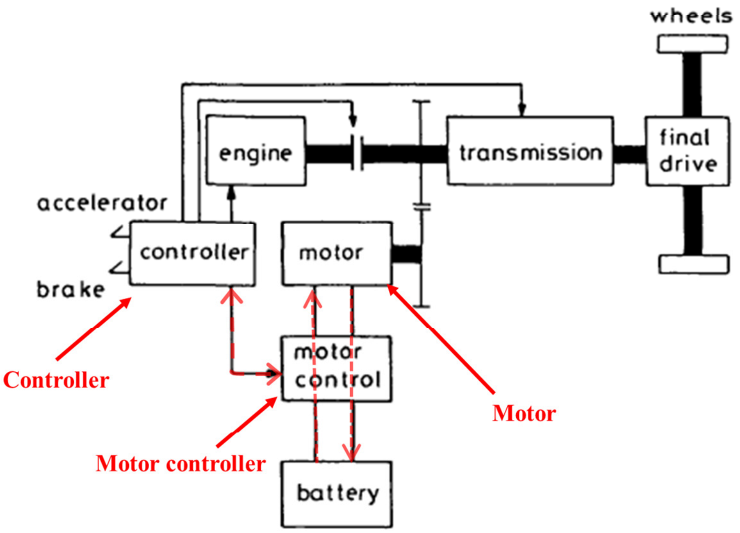
> … ***[99.1] wherein said operating the at least one electric motor to drive the hybrid vehicle composes a low-load operation mode I;***

346. 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."

347. As discussed in **[80.3],** the Durham Project discloses an "electric mode" where "all propulsion power is supplied by the electric traction system." (Ex. 1909 [Bumby V] at 4; Ex. 1908 [Bumby IV] at 3; Ex. 1907 [Bumby III] at 11-12.)

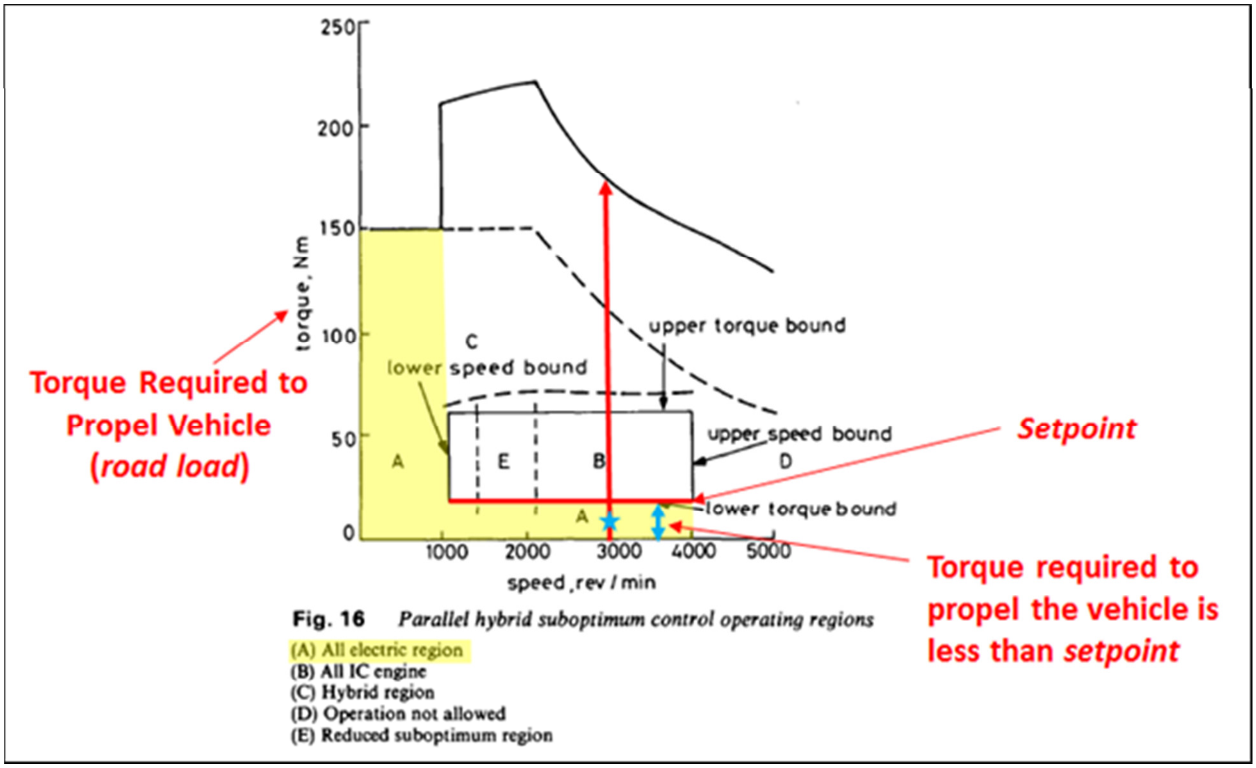
348. Further, the Durham Project discloses *energy from the battery bank flows to the traction motor*. A "motor control," is connected to the controller and in between the battery and motor, as shown in Fig. 2 of Bumby II, below. It is obvious from the figure alone that the "motor control" is used to 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 to the driver's commands from the accelerator or brake pedals.

Fig. 2



Ex. 1906 [Bumby II] at Fig. 2 (annotated)

349. Further, Fig. 8, as discussed above in **[80.3]** illustrates 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, below. Specifically, when the *road load* is below the lower predetermined torque value (i.e., "*setpoint*") the torque required to propel the vehicle is provided by the motor alone. (Ex. 1907 [Bumby III] at 8; *see also* Bumby II, Fig. 16 at 11.)



Torque Required to Propel Vehicle (*road load*)

Setpoint

Torque required to propel the vehicle is less than *setpoint*

Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at Fig. 16 (annotated)

350. In discussing the figure above, the Durham 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. 1906 [Bumby II] at 10-11, emphasis added.)

351. Therefore, it is my opinion that the Durham Project discloses *wherein said operating the at least one electric motor to drive the hybrid vehicle composes a low-load operation mode I.*

… ***[99.2] wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle composes a high-way cruising operation mode IV; and***

352. It is 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."

353. As discussed above in **[80.4]**, the Durham Project illustrates and discloses "i.c. engine mode" where "all propulsion power is supplied by the i.c. engine." (Ex. 1909 [Bumby V] at 4; Ex. 1908 [Bumby IV] at 3; Ex. 1907 [Bumby III] at 11-12.)

354. As further discussed in **[80.4]**, the Durham Project discloses that the when the actual torque and speed required to propel the vehicle falls in Region B/E, highlighted in red, the vehicle is propelled only by the engine:

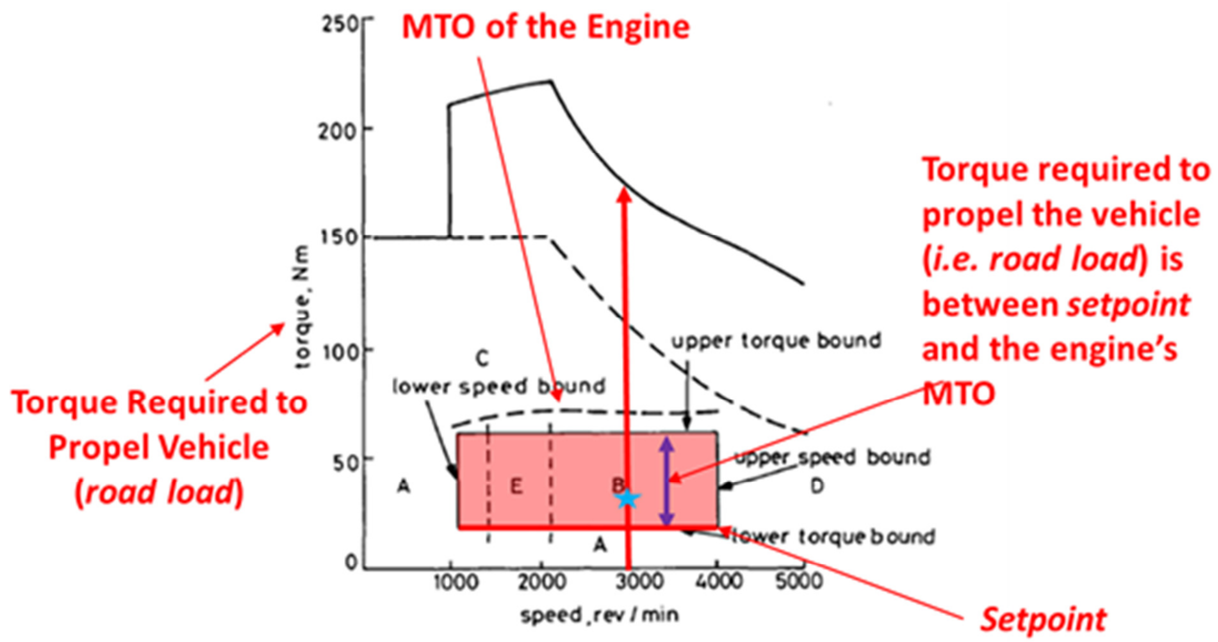


Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at Fig. 16 (annotated)

355. Further, it would be obvious to a person of ordinary skill in the art that for operation of the engine, *energy flows from the fuel tank into the engine*. Indeed, the Durham Project confirms that the fuel is provided from a "fuel tank" for operation of the engine:

> In this type of operation the petroleum substitution hybrid electric vehicle may achieve a degree of substitution ranging from 20-70 percent of the equivalent i.c. engine vehicle, be capable of entering environmentally sensitive areas and yet be capable of a range at high and intermediate speeds limited only by the size of its **fuel tank**.

(Ex. [Bumby III at 15, emphasis added.)

356. Therefore, it is my opinion that the Durham Project discloses *wherein said*

operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle composes a high-way cruising operation mode IV.

> … ***[99.3] wherein said operating both the at least one electric motor and the engine to propel the hybrid vehicle composes an acceleration operation mode V.***

357. It is 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."

358. <intentionally left blank>

359. As discussed in **[80.8] t**he Durham Project also illustrates and discloses a "hybrid mode" where "both the i.c. engine and the electric traction system together, in some way, provide the propulsion power." (Ex. 1909 [Bumby V] at 4; Ex. 1908 [Bumby IV] at 3; Ex. 1907 [Bumby III] at 11.) The Durham Project illustrates this engine and motor mode when the torque required to propel 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:

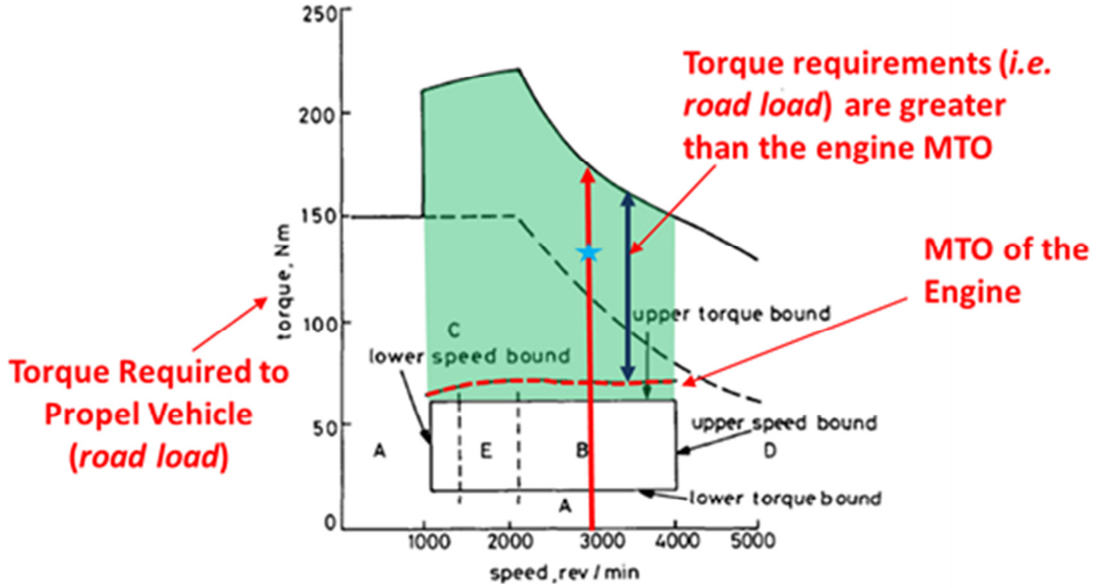


Fig. 16 *Parallel hybrid suboptimum control operating regions*

(A) All electric region
(B) All IC engine
(C) Hybrid region
(D) Operation not allowed
(E) Reduced suboptimum region

Ex. 1906 [Bumby II] at 11, Fig. 16 (annotated)

360. As discussed above in [99.1], the Durham Project discloses that energy from the battery bank is used to operate the motor. And as discussed in [99.2], the Durham Project discloses that for operation of the engine, the energy flows from the fuel tank to the engine.

361. Therefore, it is my opinion that the Durham Project discloses *wherein said operating both the at least one electric motor and the engine to propel the hybrid vehicle composes an acceleration operation mode V*.

7. Dependent Claim 100

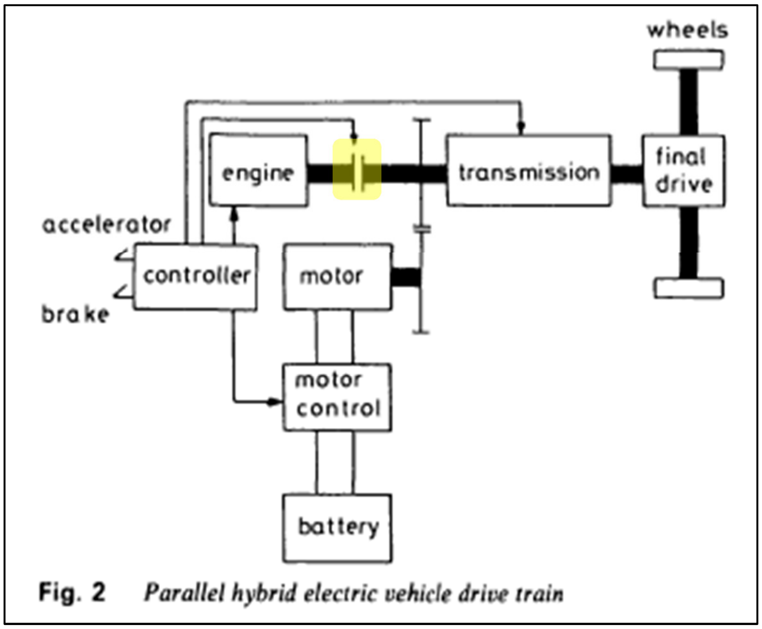
… ***[100.] The method of claim 99, wherein the engine can be operated in mode I without transmitting power to the wheels.***

362. It is my understanding that "*mode I*" 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."

363. As shown below, the Durham Project discloses a parallel hybrid vehicle having a clutch (highlighted in yellow) between the engine and drive wheels. The clutch is operated to decouple the engine from the wheels when the vehicle is operated in "all electric" mode.

> Whenever the hybrid vehicle is operating **in all electric mode** or is stationary, the **i.c. engine can be uncoupled** from the drive train by means of the one-way clutch.

(Ex. 1909 [Bumby V] at 5.)(*see also* Ex. 1910 [Masding Thesis] at 151.)



Ex. 1906 [Bumby II] at 1, Fig. 2 (annotated)

364. It is my opinion that the Durham Project decouples the engine from the wheels using the clutch. Once the engine is disconnected it no longer is *transmitting power to the wheels*. When the engine is disconnected, the vehicle is being propelled by the electric motor in (*i.e.*, *mode I*) with energy being supplied from the battery.

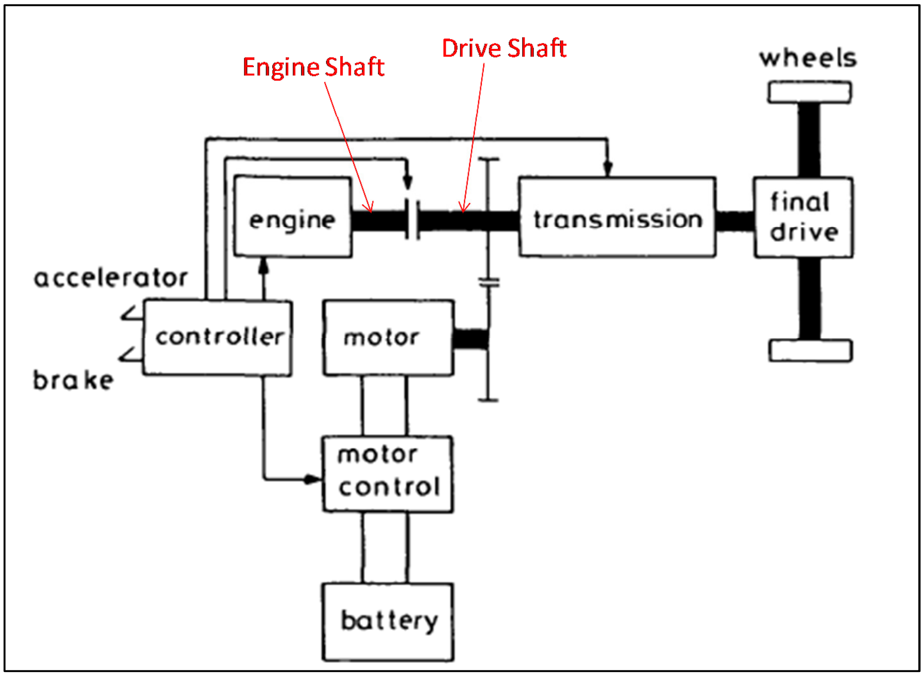
365. It is also my opinion that the Durham Project discloses **<u>operating</u>** the engine while the vehicle is still in *mode I* when the engine is started and synchronized with the drive train (*i.e.*, "Engine Speed Synchronisation" routine). As specifically, emphasized below during operation in "all electric mode" (*mode I*) the vehicle is propelled by the electric motor alone.

> 5.3.5 Engine Speed Synchronisation
>
> Whenever the hybrid vehicle is operating **<u>in all electric mode</u>** or is stationary, the **<u>i.c. engine can be uncoupled from the drive train by means of the one-way clutch</u>**. 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 needed 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 needed that 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. 1910 [Masding Thesis] at 151.)

366. As shown more clearly below, the engine shaft and drive-shaft are separated by the clutch. When the engine is needed for propulsion (*i.e.*, engine-only mode), the controller needs to: (1) start the engine; and (2) then synchronize the engine shaft speed with the drive-train shaft speed; and 3) couple the engine to the drives shaft with the clutch. During this synchronization process (2) the engine is being operated while the vehicle is still being operated in all-electric mode (*i.e. mode I*).



Ex. 1906 [Bumby II] at 1, Fig. 2

367. The Durham Project discloses that this entire engine starting and synchronization process occurs in about 0.7-1 second. Therefore, during this starting and synchronization process the vehicle is being driven by the electric motor.

> At time t=0.45s, however, the computer receives the start command: immediately it turns on the ignition and engages the starter motor. <u>At the same time the throttle is opened 9° and the computer then waits for the engine to fire. This is adjudged to happen when the engine speed passes 490 rev/min</u>. Above this speed the starter motor is turned off and the speed control algorithm is entered to run the engine up to the drive-train speed. **<u>Synchronisation is deemed complete when the engine speed is within 45 rev/min of the drive-train speed which in this case is achieved within 0.7s of the original command to start</u>**. At this stage, torque control is transferred to the engine which continues to accelerate the load. In figure 5.14 the slow rise time shown

> by engine torque is in fact false, since the trace represents the output of the highly filtered torque transducer. **Total times for starting, speed synchronisation and transfer of load are consistently about 1 second as demonstrated by figure 5.14**.

(Ex. 1909 [Bumby V] at 6; *see also* Ex. 1910 [Masding Thesis] at 153-154.)

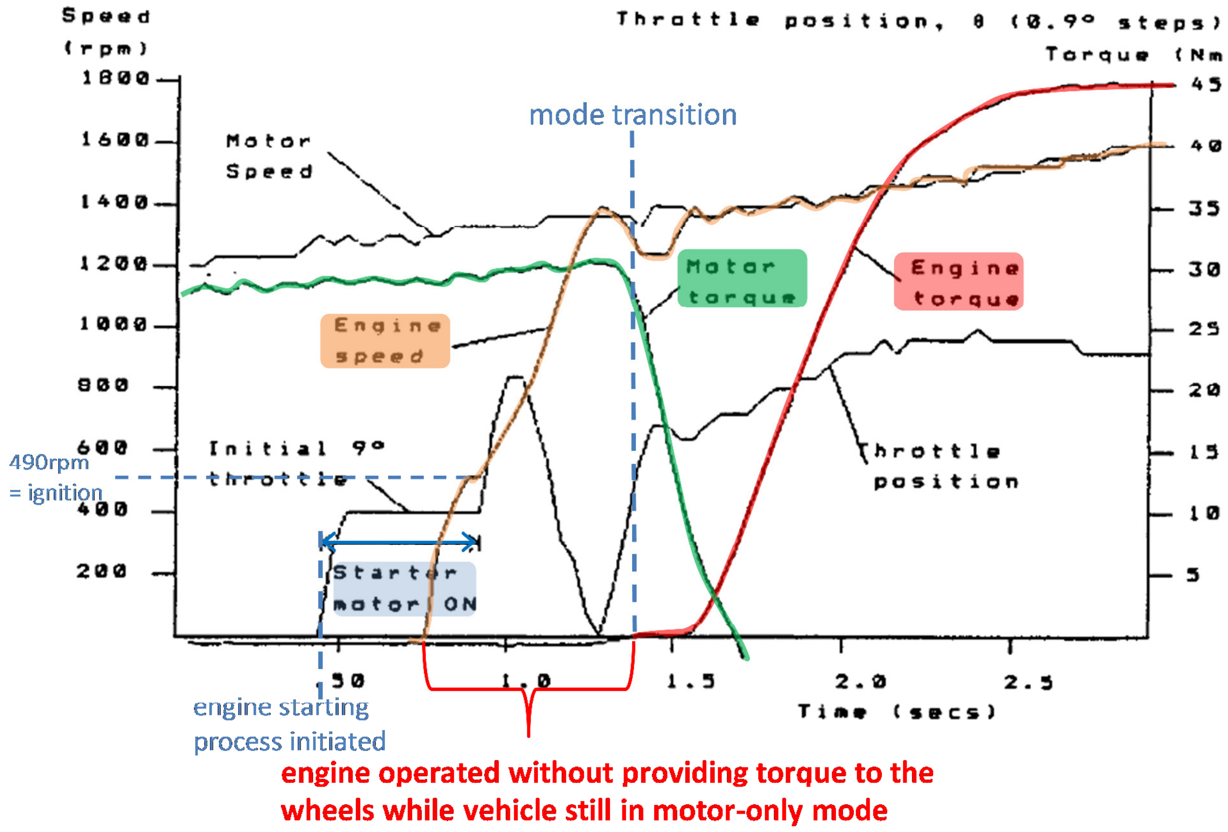


Fig. 5.14 Analysis of the Engine Starting and Load Transfer Process

Ex. 1910 [Masding Thesis] at Fig. 5.14 (annotated)

368. As shown above in Fig. 5.14, the engine is operated during the "Engine Speed Synchronisation" process. As annotated, the engine starting process is initiated when the starter motor is turned ON. As the engine speed is increased with the starter motor, ignition occurs when the engine reaches 490 rpm. Subsequently, the engine is

firing and engine speed is ramped up towards the motor speed. During this time, the vehicle is still being propelled by the motor in *mode I.* Not until the engine speed is almost equal to the motor speed can mode transition from motor-mode to engine-mode occur. At this point, the clutch is engaged and the engine torque begins to increase and the motor torque decreases. This increase in engine torque signifies when the engine has been clutched into the driveline and is being used to propel the vehicle.

369. While this "Engine Speed Synchronisation" process aims to be completed relatively quickly, nevertheless, this feature disclosed by the Durham Project illustrates that the *engine* ***<u>can</u>*** *be operated in mode I without transmitting power to the wheels.*

370. It is my opinion that the Durham Project therefore discloses *wherein the engine can be operated in mode I without transmitting power to the wheels.*

8. Dependent Claim 102

… ***[102.0] The method of claim 99, further comprising:***

receiving operator input specifying a change in required torque to be applied to wheels of the hybrid vehicle; and

371. As discussed above in **[80.1],** the Durham Project discloses *receiving operator input* for operating "the electric traction system, ic engine and transmission in the most efficient way **<u>to meet driver demand</u>**" for determining the different hybrid-vehicle control modes. (Ex. 1908 [Bumby IV] at 4; Ex. 1910 [Masding Thesis] at 43-

44.) The controller uses operator commands, such as accelerator/brake pedals as driver commanded input, as annotated below.

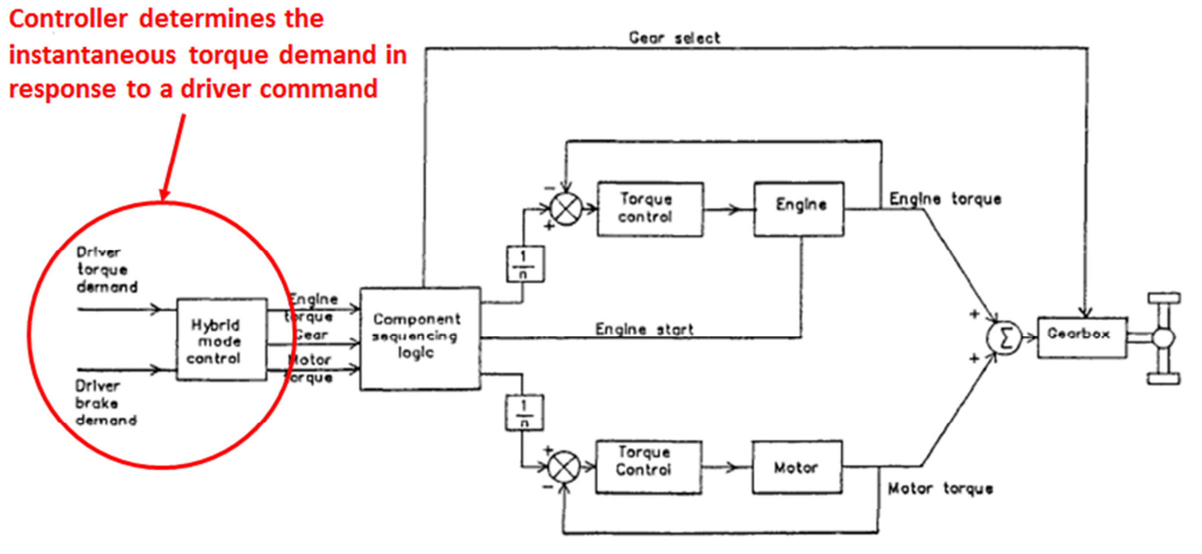

Controller determines the instantaneous torque demand in response to a driver command

Fig 16 Complete vehicle component control system

Ex. 1909 [Bumby V] at Fig. 16

372. The Durham Project further teaches that the *operator input*, such as accelerator or brake, specifies a *change in required torque.*

> The end result of the optimisation process is a mode controller which receives, as input, the **<u>driver's brake and accelerator signals</u>** and then adjusts the **<u>torque demand</u>** to the engine and motor to meet the total demand.

(Ex. 1909 [Bumby V] at 3.)

373. The Masding Thesis further confirms that the *operator input*, such as accelerator or brake, specifies a *change in required torque.*

> Primary inputs to the system come from the driver via the **<u>accelerator and brake pedals</u>** in the same way as they would in any conventional vehicle. At this point though, in contrast with the conventional system,

> the pedals are not mechanically connected directly to the engine or straight to the power electronics unit for the motor. Instead the pedal positions are fed electrically to the computer based hybrid mode controller, where they are **interpreted as torque or power demands**, either positive in the case of the accelerator, or negative in the case of the brake.

(Ex. 1910 [Masding Thesis] at 207, emphasis added.)

374. Therefore, it is my opinion that the Durham Project discloses *receiving operator input specifying a change in required torque to be applied to wheels of the hybrid vehicle.*

… ***[102.1] if the received operator input specifies a rapid increase in the required torque, changing operation from operating mode I directly to operating mode V.***

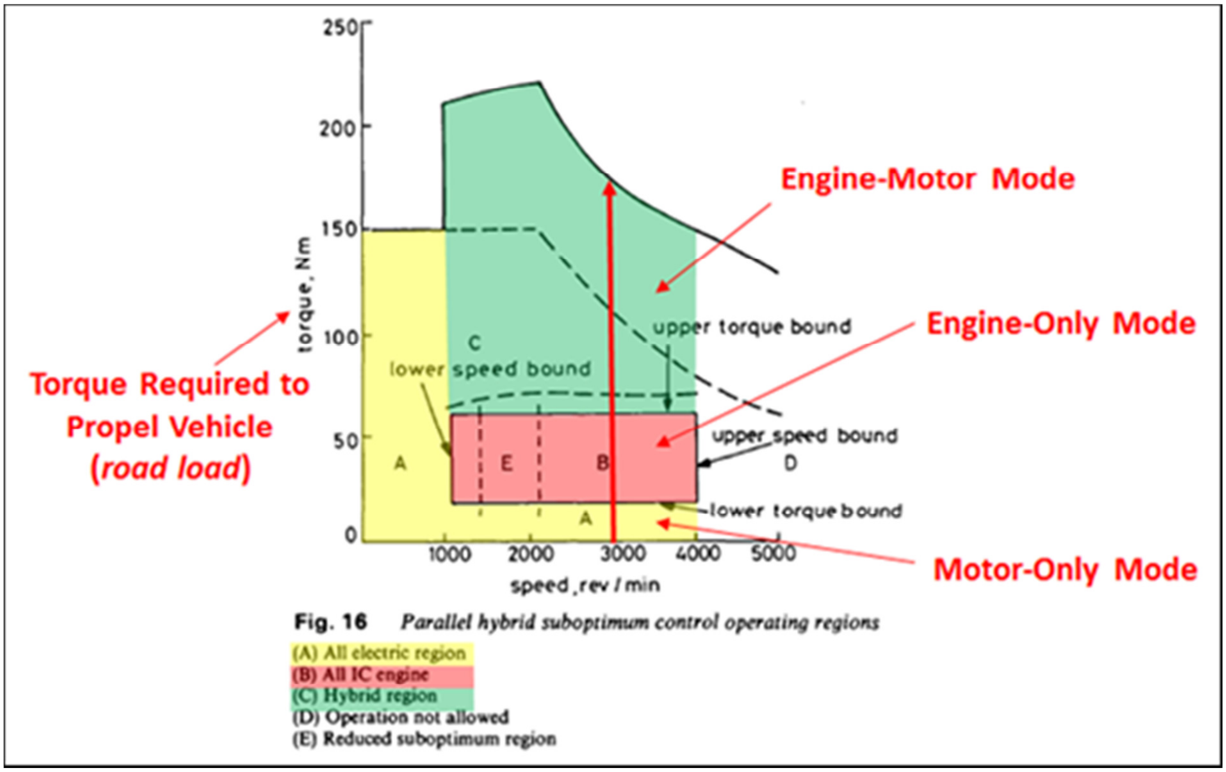
375. As discussed above at **[99.1]**, the Durham Project discloses *mode I.* And as discussed in **[99.3]**, the Durham Project discloses *mode V.*

376. In particular, the Durham Project discloses that *mode V*, where both the engine and motor provide torque to propel the vehicle, is used during "rapid acceleration." A person of ordinary skill in the art would understand that *rapid increase in required torque* would be demanded in conditions of rapid acceleration.

> When necessary, the **engine torque can be augmented by the motor** for **rapid acceleration** or hill climbing. 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. 1909 [Bumby V] at 4, emphasis added.)

377. As I have illustrated below, the Durham Project control strategy that includes: (1) a **<u>motor-only mode</u>** (*i.e.*, "A Electric operation", shaded in yellow); (2) **<u>engine-only mode</u>** (*i.e.*, "B Internal combustion engine operation", shaded in red); (3) an **<u>engine-motor mode</u>** ("C Hybrid operation", shaded in green). (Ex. 1907 [Bumby III] at 8; *see also* Ex. 1906 [Bumby II] at 11.)

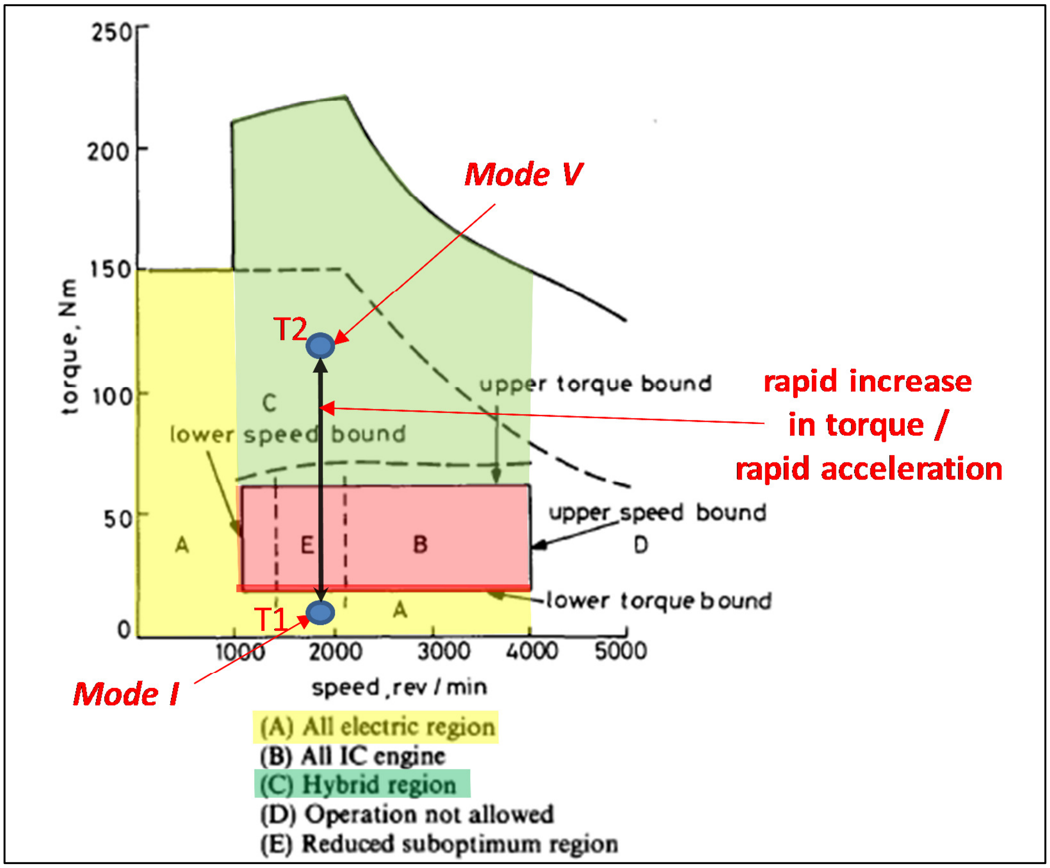


Ex. 1906 [Bumby III] at 11, Fig. 16 (annotated)

378. It would have been well known to a person of ordinary skill in the art that adding the torque capacity of the engine and motor allows the hybrid vehicle to meet that vehicle torque requirements during rapid acceleration. For example, when the torque requirements during rapid acceleration exceed the engine's maximum

torque output (MTO), it would have been obvious to a person of ordinary skill in the art to switch the mode disclosed by the Durham Project that utilizes both the engine and motor, as discussed in **[80.8]**.

379. For example, it would be obvious to a person of ordinary skill in the art that during a *rapid increase in required torque*, as I have annotated below, that the vehicle would switch directly from *mode I* to *mode V*. As I have annotated as "T1" below for instance, the torque required to propel the vehicle at constant speed in a fixed gear may be below the "lower torque bound" or *setpoint*. The vehicle would be operating in the motor-only mode where propulsion is provided by the electric motor. However, if at the same speed (again in a fixed gear) there is a rapid request for acceleration (*e.g.*, the driver presses down the accelerator pedal a large amount) a person of ordinary skill in the art would understand a rapid increase in torque would result. Due to the rapid acceleration request, the torque required to propel the vehicle would move to the point I have annotated as "T2." This shift from "T1" to "T2" would result in the operational mode shifting from a motor-only mode to an engine-motor mode of operation. A person having ordinary skill in the art would have further understood that the control logic would not force the vehicle to stop in the engine-only mode region as the controller would not be providing the actual torque that is required to propel the vehicle.



Ex. 1906 [Bumby II] at 11, Fig. 16

380. Indeed, during a *rapid increase in required torque*, a person of ordinary skill in the art would understand that the modes of operation would not need to be completed in any particular order. In fact, the Masding Thesis confirms this understanding that any mode can be transitioned directly to another mode, such as *mode I* (*i.e* "Electric mode") directly to *mode V* (*i.e* "Hybrid mode"). In fact, the Masding Thesis confirms this understanding that any mode can be transitioned directly to another mode, such as *mode I* (*i.e* "Electric mode") directly to *mode V* (*i.e* "Hybrid mode") when the torque required to propel the vehicle indicates so.

> Regardless of the final mode control used there are five fundamental operating modes which occur:

> 1. i.c. engine
> 2. Electric
> 3. Hybrid
> 4. Regenerative braking
> 5. Battery recharge
>
> **From these five possible modes there arise 20 possible types of mode transition** all of which must be achieved quickly and smoothly.

(Ex. 1910 [Masding Thesis] at 221, emphasis added.)

381. Therefore, it is my opinion that it would be obvious to a person of ordinary skill in the art that the Durham Project discloses *if the received operator input specifies a rapid increase in the required torque, changing operation from operating mode I directly to operating mode V*.

9. Dependent Claim 106

> … ***[106.] The method of claim 80, further comprising:***
>
> ***regeneratively charging a battery of the hybrid vehicle***
>
> ***when instantaneous torque output of the engine>the RL,***
>
> ***when the RL is negative, and/or when braking is***
>
> ***initiated by an operator of the hybrid vehicle.***

382. Claim 106 depends from claim 80, which I understand means that claim 106 includes each of the limitations of claim 80 as well as "regeneratively charging a battery of the hybrid vehicle when instantaneous torque output of the engine > the RL, when the RL is negative, and/or when the braking is initiated by the operated of

the hybrid vehicle."

383. Again, it is my understanding that "RL" should be interpreted as "the instantaneous torque required to propel the vehicle, which may be positive or negative in value."

384. Claim 106 should therefore be interpreted as "regeneratively charging a battery of the hybrid vehicle when [A] instantaneous torque output of the engine exceeds the instantaneous torque required to propel the vehicle, which may be both positive and negative in value, [B] the instantaneous torque required to propel the vehicle is negative, <u>and/or</u> [C] the braking is initiated by the operated of the hybrid vehicle."

385. Further, it is my understanding that "AND/OR" within the claim is meant to be interpreted to mean "Element A" or "Element B" or "Element C," as follows:

> **Element A** - regeneratively charging a battery of the hybrid vehicle when instantaneous torque output of the engine exceeds the instantaneous torque required to propel the vehicle, which may be both positive or negative in value.
>
> **<u>OR</u>**
>
> **Element B** - regeneratively charging a battery of the hybrid vehicle when. . . the instantaneous torque required to propel the vehicle, which may be both positive or negative in value, is negative.

<u>OR</u>

Element C - regeneratively charging a battery of the hybrid vehicle when. . . the braking is initiated by the operated of the hybrid vehicle.

386. It is further my understanding that the claim limitation is disclosed by the prior art if any one of the three limitations is satisfied.

387. The Durham Project discloses a mode for "Regenerative Braking, as shown in Table 2, below.

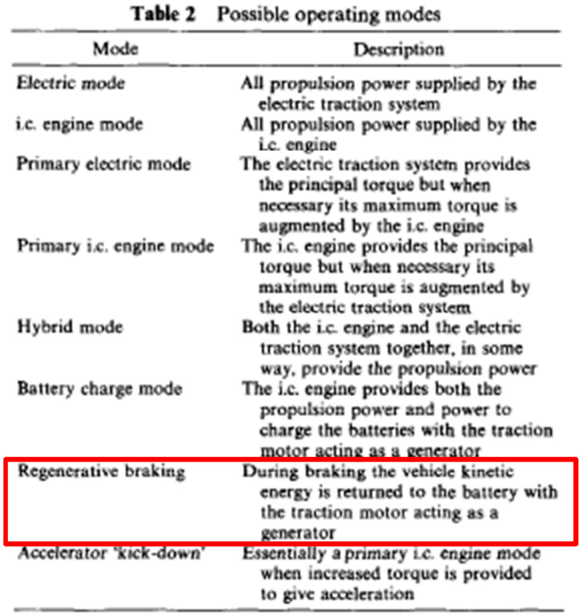


Table 2 Possible operating modes

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

(Ex. 1906 [Bumby II] at 1; Ex. 1907 [Bumby III] at 1; Ex. 1908 [Bumby IV] at 1.)

388. The Durham Project further describes that regenerative braking allows charging of the battery:

> This arrangement guarantees that **<u>regenerative braking</u>** into the battery is immediately available when required. Thus, **<u>during braking</u>**, 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. 1908 [Bumby IV] at 3; emphasis added.) (*See also* Ex. 1906 [Bumby II] at 1-Fig. 2; Ex. 1907 [Bumby III] at 3-Fig. 1.)

389. As discussed above, the Durham Project discloses Element C where the battery is regeneratively charged during braking.

390. It would also be obvious to a person of ordinary skill in the art would understand that the "Regenerative Braking" mode could be used when *road load is negative* (Element B), such when the vehicle is going down a hill and the driver demands braking to prevent accelerating from gravity. Or it would be obvious to a person of ordinary skill in the art to regeneratively charge a battery of the hybrid vehicle when output of the engine exceeds the road load (Element C).

391. The Masding Thesis confirms that the Durham Project discloses regenerative charging the battery whenever there is surplus kinetic energy using the regenerative braking operation mode: "**Regenerative Braking. Used whenever possible to recoup vehicle kinetic energy**." (Ex. 1910 [Masding Thesis] at 44, emphasis added.)

392. Therefore, it is my opinion that the Durham Project discloses regeneratively charging a battery of the hybrid vehicle when instantaneous torque

output of the engine>the RL, when the RL is negative, and/or when braking is initiated by an operator of the hybrid vehicle.

10. Independent Claim 114

393. I understand that claim 114 is directed to a method for controlling a hybrid vehicle. It is my opinion that these steps are disclosed by the Durham Project, as outlined below.

> … ***[114.0] A method for controlling a hybrid vehicle, comprising:***

394. I understand that this limitation is substantially similar to the limitations of claim [80.0] and therefore, please **refer to my analysis with respect to limitation [80.0]** above.

> … ***[114.1] determining instantaneous road load (RL) required to propel the hybrid vehicle responsive to an operator command;***

395. I understand that this limitation is substantially similar to the limitations of claim [80.1] and therefore, please **refer to my analysis with respect to limitation [80.1]** above.

> … ***[114.2] monitoring the RL over time;***

396. I understand that this limitation is substantially similar to the limitations

of claim [80.2] and therefore, please r**efer to my analysis with respect to limitation [80.2]** above.

> … ***[114.3] operating at least one electric motor to propel the hybrid vehicle when the RL required to do so is less than a setpoint (SP);***

397. I understand that this limitation is substantially similar to the limitations of claim [80.3] and therefore, please **refer to my analysis with respect to limitation [80.3]** above.

> … ***[114.4] wherein said operating the at least one electric motor to propel the hybrid vehicle is performed when the RL<the SP for at least a predetermined amount of time;***

398. I understand that this limitation is substantially similar to the limitations of claim [96.1] and therefore, **please refer to my analysis with respect to claim [96.1] above**.

> … ***[114.5] operating an internal combustion engine of the hybrid vehicle to propel the hybrid vehicle when the RL required to do so is between the SP and a maximum torque output (MTO) of the engine,***

399. I understand that this limitation is substantially similar to the limitations

of claim [80.4] and therefore, please **refer to my analysis with respect to limitation [80.4]** above.

> … ***[114.6] wherein the engine is operable to efficiently produce torque above the SP, and***

400. I understand that this limitation is substantially similar to the limitations of claim [80.5] and therefore, please **refer to my analysis with respect to limitation [80.5]** above.

> … ***[114.7] wherein the SP is substantially less than the MTO; and***

401. I understand that this limitation is substantially similar to the limitations of claim [80.6] and therefore, please **refer to my analysis with respect to limitation [80.6]** above.

> … ***[114.8] operating both the at least one electric motor and the engine to propel the hybrid vehicle when the torque RL required to do so is more than the MTO.***

402. I understand that this limitation is substantially similar to the limitations of claim [80.8] and therefore, please **refer to my analysis with respect to limitation [80.8]** above.

11. Dependent Claim 125

… ***[125.] The method of** claim 114**, further comprising:***

turning off the engine when the torque required to propel the vehicle is less than the SP.

403. I understand that this limitation is substantially similar to the limitations of claim [91] and therefore, please refer to my analysis for claim [91].

12. Dependent Claim 126

… ***[126.] The method of** claim 114**, further comprising:***

turning off the engine when the torque required to propel the vehicle and/or charge the battery is less than the SP.

404. I understand that this limitation is substantially similar to the limitations of claim [92] and therefore, please refer to my analysis for claim [92].

13. Dependent Claim 129

… ***[129.] The method of** claim 114**, wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle and said operating both the at least one electric motor and the engine to propel the hybrid vehicle, each comprises: if the engine is not already running, starting the engine***

405. I understand that this limitation is substantially similar to the limitations of claim [95] and therefore, please refer to my analysis for claim [95].

14. Dependent Claim 132

… ***[132.0] The method of** claim 114**, wherein the hybrid vehicle is operated in a plurality of operating modes corresponding to values for the RL and the SP;***

406. I understand that this limitation is substantially similar to the limitations of claim [99.0] and therefore, please **refer to my analysis for limitation [99.0]**, above.

> … ***[132.1] wherein said operating the at least one electric motor to drive the hybrid vehicle composes a low-load operation mode I;***

407. I understand that this limitation is substantially similar to the limitations of claim [99.1] and therefore, please **refer to my analysis for limitation [99.1]**, above.

> … ***[132.2] wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle composes a high-way cruising operation mode IV; and***

408. I understand that this limitation is substantially similar to the limitations of claim [99.2] and therefore, please **refer to my analysis for limitation [99.2]**, above.

> … ***[132.3] wherein said operating both the at least one electric motor and the engine to propel the hybrid vehicle composes an acceleration operation mode V.***

409. I understand that this limitation is substantially similar to the limitations of claim [99.3] and therefore, please **refer to my analysis for limitation [99.3]**, above.

15. Dependent Claim 133

… ***[133.] The method of claim 132, wherein the engine can be operated without transfer of power to wheels of the hybrid vehicle in mode I.***

410. I understand that this limitation is substantially similar to the limitations of claim [100] and therefore, **please refer to my analysis for claim [100]**.

16. Dependent Claim 135

… ***[135.0] The method of claim 132, further comprising: receiving operator input specifying a change in required torque to be applied to wheels of the hybrid vehicle; and***

411. I understand that this limitation is substantially similar to the limitations of claim [102.0] and therefore, **please refer to my analysis for claim [102.0]**.

… ***[135.1] if the received operator input specifies a rapid increase in the required torque, changing operation from operating mode I directly to operating mode V.***

412. I understand that this limitation is substantially similar to the limitations of claim [102.1] and therefore, **please refer to my analysis for claim [102.1]**.

B. Ground 2: Claims 161, 172, 215, 226, 230, 232 and 234

It is my opinion that claims 161, 172, 215, 226, 230, 232 and 234 are obvious in view of Bumby I-V, the Masding Thesis, and the general knowledge that a person having ordinary skill in the art.

1. Independent Claim 161

… ***161. A method for controlling a hybrid vehicle, comprising:***

413. I understand that this limitation is substantially similar to the limitations of claim [80.0] and therefore, **please refer to my analysis for claim [80.0]**.

… ***determining instantaneous road load (RL) required to propel the hybrid vehicle responsive to an operator command;***

414. I understand that this limitation is substantially similar to the limitations of claim [80.1] and therefore, **please refer to my analysis for claim [80.1]**.

… ***wherein the hybrid vehicle is operated in a plurality of operating modes corresponding to values for the RL and a setpoint (SP);***

415. I understand that this limitation is substantially similar to the limitations of claim [99.0] and therefore, **please refer to my analysis for claim [99.0]**.

> … ***operating at least one first electric motor to propel the hybrid vehicle when the RL required to do so is less than the SP;***

416. I understand that this limitation is substantially similar to the limitations of claim [80.3] and therefore, **please refer to my analysis for claim [80.3]**.

> … ***wherein said operating the at least one first electric motor to drive the hybrid vehicle composes a low-load operation mode I;***

417. I understand that this limitation is substantially similar to the limitations of claim [99.1] and therefore, **please refer to my analysis for claim [99.1]**.

> … ***operating an internal combustion engine of the hybrid vehicle to propel the hybrid vehicle when the RL required to do so is between the SP and a maximum torque output (MTO) of the engine,***

418. I understand that this limitation is substantially similar to the limitations of claim [80.4] and therefore, **please refer to my analysis for claim [80.4]**.

> … ***wherein the engine is operable to efficiently produce torque above the SP,***

419. I understand that this limitation is substantially similar to the limitations

of claim [80.5] and therefore, **please refer to my analysis for claim [80.5]**.

> … ***and wherein the SP is substantially less than the MTO;***

420. I understand that this limitation is substantially similar to the limitations of claim [80.6] and therefore, **please refer to my analysis for claim [80.6]**.

> … ***wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle composes a high-way cruising operation mode IV;***

421. I understand that this limitation is substantially similar to the limitations of claim [99.2] and therefore, **please refer to my analysis for claim [99.2]**.

> … ***operating both the at least one first electric motor and the engine to propel the hybrid vehicle when the torque RL required to do so is more than the MTO;***

422. I understand that this limitation is substantially similar to the limitations of claim [80.8] and therefore, **please refer to my analysis for claim [80.8]**.

> … ***wherein said operating both the at least one first electric motor and the engine to propel the hybrid vehicle composes an acceleration operation mode V;***

423. I understand that this limitation is substantially similar to the limitations of claim [99.3] and therefore, **please refer to my analysis for claim [99.3]**.

> … ***receiving operator input specifying a change in required torque to be applied to wheels of the hybrid vehicle; and***

424. I understand that this limitation is substantially similar to the limitations of claim [102.0] and therefore, **please refer to my analysis for claim [102.0]**.

> … ***if the received operator input specifies a rapid increase in the required torque, changing operation from operating mode I directly to operating mode V.***

425. I understand that this limitation is substantially similar to the limitations of claim [**102.**1] and therefore, **please refer to my analysis for claim [102.1]**.

2. Dependent Claim 172

> … ***172. The method of claim 161, wherein said engine can be operated without transmitting power to the wheels of the hybrid vehicle during operation in mode I.***

426. I understand that this limitation is substantially similar to the limitations of claim [**100.0**] and therefore, please refer to my analysis for claim [**100.0**].

3. Independent Claim 215

… ***[215.0] A method for controlling a hybrid vehicle, comprising:***

427. <Intentionally left blank>

428. I understand that this limitation is substantially similar to the limitations of claim [**80.0**] and therefore, please refer to my analysis for claim [**80.0**].

… ***[215.1] determining instantaneous road load (RL) required to propel the hybrid vehicle responsive to an operator command;***

429. I understand that this limitation is substantially similar to the limitations of claim [**80.1**] and therefore, please **refer to my analysis for claim** [**80.1**].

… ***[215.2] operating at least one electric motor to propel the hybrid vehicle when the RL required to do so is less than a setpoint (SP);***

430. I understand that this limitation is substantially similar to the limitations of claim [**80.3**] and therefore, **please refer to my analysis for claim** [**80.3**].

… ***[215.3] operating an internal combustion engine of the hybrid vehicle to propel the hybrid vehicle when the RL required to do so is between the SP and a maximum torque output (MTO) of the engine,***

431. I understand that this limitation is substantially similar to the limitations of claim [**80.4**] and therefore, please refer to my analysis for claim [**80.4**].

… ***[215.4] wherein the engine is operable to efficiently produce torque above the SP, and***

432. I understand that this limitation is substantially similar to the limitations of claim [**80.5**] and therefore, please refer to my analysis for claim [**80.5**].

… ***[215.5] wherein the SP is substantially less than the MTO; and***

433. I understand that this limitation is substantially similar to the limitations of claim [80.6] and therefore, please refer to my analysis for claim [80.6].

434. <blank>.

… ***[215.6] operating both the at least one electric motor and the engine to propel the hybrid vehicle when the torque RL required to do so is more than the MTO; and***

435. I understand that this limitation is substantially similar to the limitations

of claim [80.8] and therefore, please refer to my analysis for claim [80.8].

436. <Intentionally left blank>

… ***[215.7] regeneratively charging a battery of the hybrid vehicle when instantaneous torque output of the engine > the RL, when the RL is negative, and/or when the braking is initiated by the operated of the hybrid vehicle.***

437. I understand that this limitation is substantially similar to the limitations of claim [106] and therefore, please **refer to my analysis for claim [106].**

4. Dependent Claim 226

… ***[226.] The method of claim 215, further comprising: turning off the engine when the torque required to propel the vehicle is less than the SP.***

438. I understand that this limitation is substantially similar to the limitations of claim [91] and therefore, **please refer to my analysis for claim [91].**

5. Dependent Claim 230

… ***[230.] The method of claim 215, wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle and said operating both the at least one electric motor and the engine to propel the hybrid vehicle, each comprises: if the engine is not already running, starting the engine.***

439. I understand that this limitation is substantially similar to the limitations of claim [95] and therefore, **please refer to my analysis for claim [95].**

6. Dependent Claim 233

… ***[233.0 The method of claim 215, wherein the hybrid vehicle is operated in a plurality of operating modes corresponding to values for the RL and the SP;***

440. I understand that this limitation is substantially similar to the limitations of claim [99.0] and therefore, please **refer to my analysis for limitation [99.0]**, above.

> … ***[233.1] wherein said operating the at least one electric motor to drive the hybrid vehicle composes a low-load operation mode I;***

441. I understand that this limitation is substantially similar to the limitations of claim [99.1] and therefore, please **refer to my analysis for limitation [99.1]**, above.

> … ***[233.2] wherein said operating the internal combustion engine of the hybrid vehicle to propel the hybrid vehicle composes a high-way cruising operation mode IV; and***

442. I understand that this limitation is substantially similar to the limitations of claim [99.2] and therefore, please **refer to my analysis for limitation [99.2]**, above.

> … ***[233.3] wherein said operating both the at least one electric motor and the engine to propel the hybrid vehicle composes an acceleration operation mode V.***

443. I understand that this limitation is substantially similar to the limitations of claim [99.3] and therefore, please **refer to my analysis for limitation [99.3]**, above.

7. Dependent Claim 234

… ***[234.] The method of claim 215, wherein the engine can be operated without transfer of power to the wheels of the hybrid vehicle during operation in mode I.***

444. I understand that this limitation is substantially similar to the limitations of claim [100] and therefore, please **refer to my analysis for claim [100]**.

VIII. TORQUE-BASED CONTROL WAS WELL-KNOWN

445. As discussed above, the Durham Project and Bumby Publication discloses a torque-based hybrid control strategy that includes mode control using *road load* and an engine torque *setpoint*. Additional prior art references, described below, also disclose these torque-based control strategies. It is my opinion that these strategies were well known in the prior art.

A. Ibaraki ’882

446. I understand U.S. Patent No. 5,789,882 to Ibaraki et al. (“Ibaraki ’882”), was filed on July 22, 1996 and issued on August 4, 1998, and is therefore prior art to the claims of the ’634 Patent. Exhibit 1940 is a true and accurate copy of Ibaraki ’882.

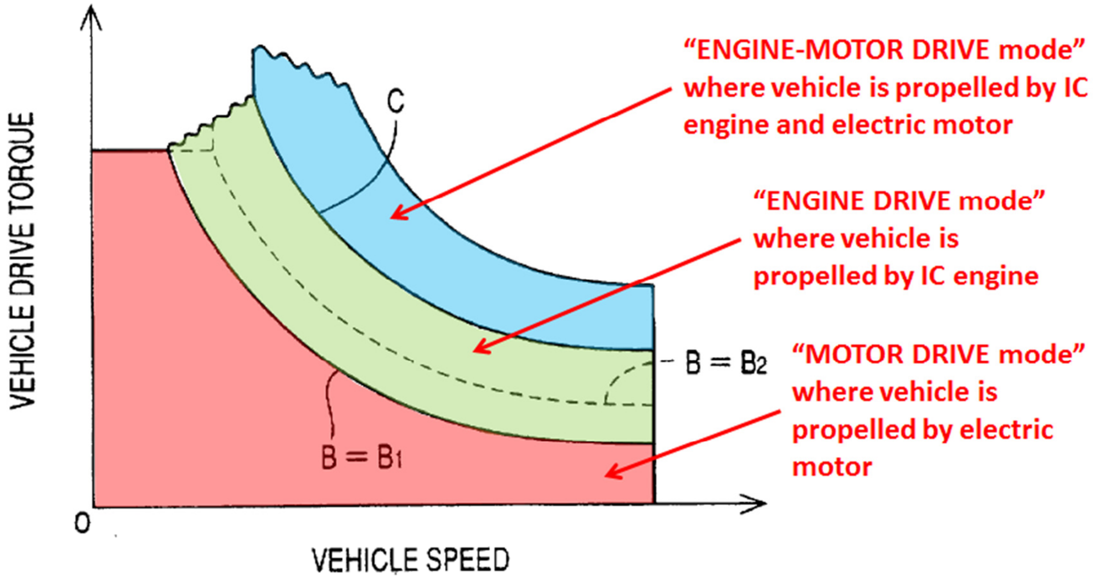
447. Ibaraki ’882 discloses a controller that selects an operational mode (motor, engine, or both) according to a drive source selecting “data map” stored in memory:

> The controller 128 includes drive source selecting means 160 illustrated in the block diagram of FIG. 9. The drive source selecting means 160 is adapted to select one or both of the engine 112 and the motor 114 as the drive power source or sources, **according to a drive source selecting data map** stored in memory means 162. That is, the controller 128 has a MOTOR DRIVE mode in which the motor 114 is selected as the drive power source, an ENGINE DRIVE mode in which the engine 112 is selected as the drive power source, and an ENGINE-MOTOR DRIVE mode in which both the engine 112 and the motor 114 are selected as the drive power sources.

(Ex. 1940 [Ibaraki '882] at 20:38-49, emphasis added.)

448. Figure 11 below exemplifies this data map: "An example of the drive source selecting data map is illustrated in the graph of FIG. 11, which represents a predetermined relationship between the vehicle drive torque and running speed V and the above-indicated three drive modes." (Ex. 1940 [Ibaraki '882] at 20:49-53.)

FIG. 11



Ex. 1940 [Ibaraki '882] at Fig. 11 (annotated)

449. In order to determine the correct "drive mode" the controller plots a point representing the "vehicle running condition" on the data map of Fig. 11. This "vehicle running condition" is represented by a "vehicle drive torque" (Y-axis) at any given "vehicle speed" (X-axis).

> Described more specifically, the drive source selecting means 160 selects the MOTOR DRIVE mode **when the vehicle running condition as represented by the current vehicle drive torque and speed V** is held within the range below the first boundary line B. When the **vehicle running condition** is held within the range between the first and second boundary lines B and C, the drive source selecting means 160 selects the ENGINE DRIVE mode. When the **vehicle running condition** is in the range above the second boundary line C, the drive

> source selecting means 160 selects the ENGINE[-MOTOR] DRIVE mode.

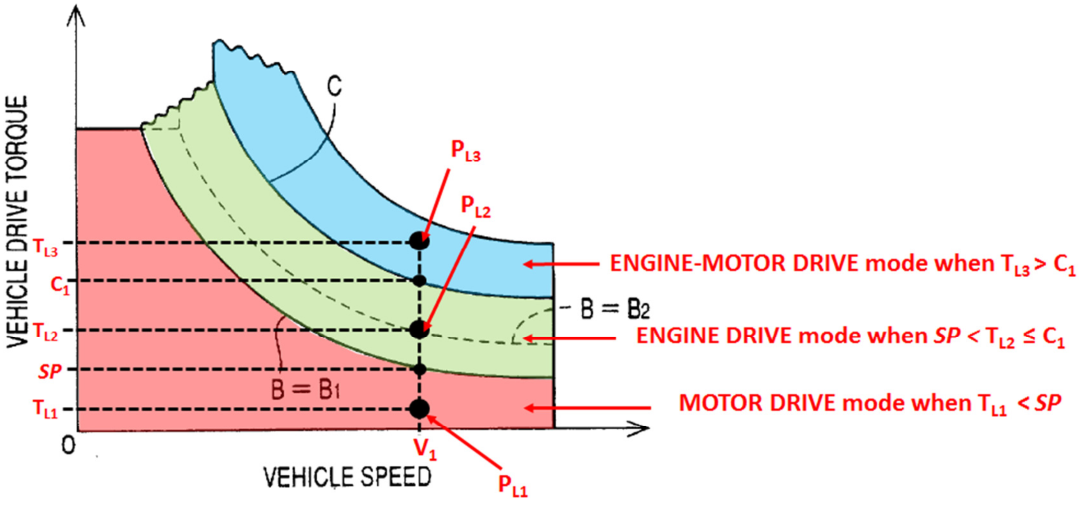
(Ex. 1940 [Ibaraki '882] at 20:58-21:1, emphasis added.)

450. Based on Figure 11, I have plotted three points corresponding to a "required drive power P_L" at a given vehicle speed (V_1). Each point (P_{L1}, P_{L2} and P_{L3}) corresponds to a different "vehicle running condition" within one of the three respective drive modes. (Ex. 1940 [Ibaraki '882] 24:6-30.) Each "vehicle running condition" is further disclosed by Ibaraki '882 as being determined by the "vehicle drive torque" (T_{L1}, T_{L2}, and T_{L3}) at that vehicle speed (V_1). (Ex. 1940 [Ibaraki '882] at 23:67-24:2.) Because Ibaraki defines P_L as "required drive power," a person having ordinary skill in the art would have understood that the corresponding "vehicle drive torque" (T_L) represents the torque required to propel the vehicle or *road load* at a given vehicle speed (V_1).[24]

---

[24] Because Figure 11 is a graph expressed with "vehicle drive torque" along the y-axis and "vehicle speed" along the x-axis, any point plotted on the graph would be understood as relating to a required drive power value (*i.e.* P_L) because "Power=Torque * Rotational Speed."

FIG. 11



Ex. 1940 [Ibaraki '882] at Fig. 11 (annotated)

451. A person having ordinary skill in the art would have also understood that line B in Figure 11 defines a *setpoint* that varies with speed.

452. It is my opinion that Ibaraki '882 discloses mode control using *road load* and operating an engine above a torque *setpoint*.

B. Severinsky '970

453. I understand that U.S. Patent No. 5,343,970 by Severinsky ("Severinsky '970") was filed on September 21, 1992, issued on September 6, 1994, and is therefore prior art to the '634 Patent. Exhibit 1941 is a true and accurate copy of Severinsky '970.

454. Severinsky '970 describes a strategy that determines mode selection based on *road load*. Figure 3 of Severinsky '970 below depicts an embodiment having an internal combustion engine 40 and an electric traction motor 20, each operable to

provide torque to the vehicle wheels 34.

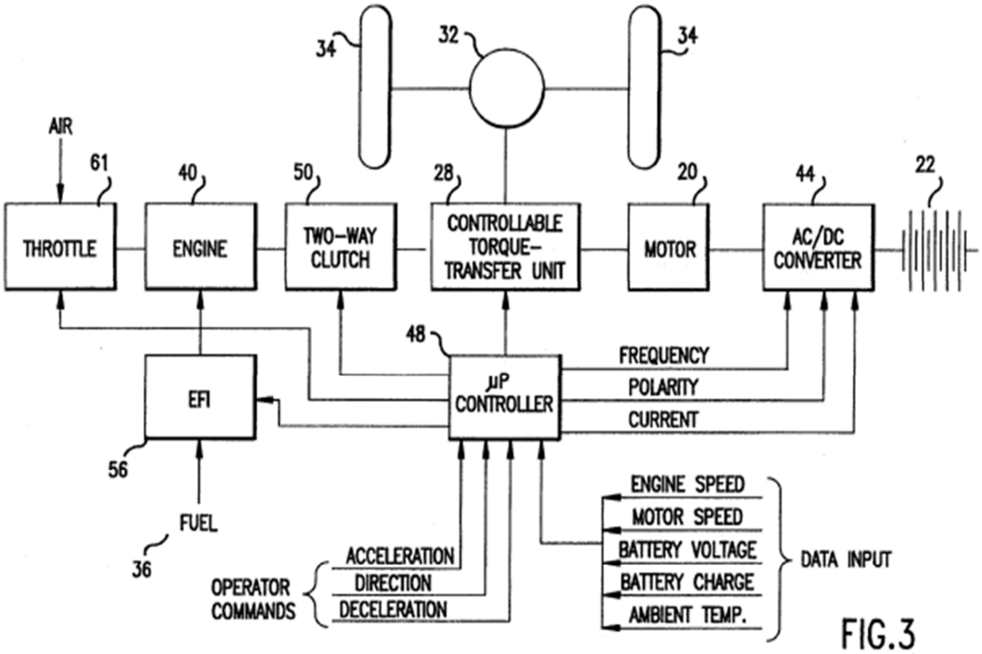


FIG.3

Ex. 1941 [Severinsky ’970] Fig. 3

455. Severinsky ’970 discloses a *setpoint* (60% of maximum torque or MTO) defining the efficient operating range of the engine based on output torque.

> It will be appreciated that according to the invention the internal combustion engine is **<u>run only</u>** in the near vicinity of its **<u>most efficient operational point</u>**, that is, such that it **<u>produces 60-90% of its maximum torque whenever operated</u>**.

(Ex. 1941 [Severinsky ’970] at 20:63-67, emphasis added.)

> **<u>When the engine can be used efficiently</u>** to drive the vehicle forward, e.g. in highway cruising, **<u>it is so employed</u>**. **<u>Under other circumstances, e.g. in traffic, the electric motor alone drives the vehicle forward</u>** and the internal combustion engine is used only to charge the batteries as needed.

(Ex. 1941 [Severinsky ’970] at 7:11-16, emphasis added.)

456. In other words, Severinsky '970 expressly discloses that "when the engine can be used efficiently" – *i.e.*, when it will produce "60-90% of its maximum torque" – "it is so employed." (Ex. 1941 [Severinsky '970] at 7:11-16 and 20:63-67.)

457. The lower end of the 60-90% range disclosed by Severinsky '970 would also be known as a *setpoint* below which the engine does not operate. A person of ordinary skill in the art would have understood that the 60% efficient torque limit disclosed by Severinsky '970 is an example of the recited *setpoint.* A person of ordinary skill in the art would have therefore understood that Severinsky '970 teaches mode control using *road load.*

458. Severinsky '970's description of acceleration/hill climbing also shows that is used *road load* for mode switching. When the operator needs additional torque to accelerate from motor mode, Severinsky '970 first enters an engine-motor acceleration/hill climbing mode, followed by a highway cruising mode:

> Thus FIG. 4 indicates that the flow of energy in heavy traffic or for reversing is simply from battery 22 to electric motor 20; torque flows from the motor 20 to the wheels 34. Under these circumstances, **electric motor 20 provides all of the torque needed to move the vehicle**. Other combinations of torque and energy flow required under other circumstances are detailed below in connection with FIGS. 5-9. **For example, if the operator continues to command acceleration, an acceleration/hill climbing mode illustrated in FIG. 6 may be entered, followed by a highway cruising mode illustrated in FIG. 5**.

(Ex. 1941 [Severinsky '970] at 10:63-11:6, emphasis added.)

459. This disclosure describes how control strategy of Severinsky ’970 evaluates the torque requirements of the vehicle when determining whether to operate the motor, the engine, or both to propel the vehicle.

460. The ’634 Patent also confirms that Severinsky ’970 teaches a hybrid vehicle that selects an operational mode by determining the torque required, *i.e.*, the *road load,* requirements.

> **Turning now to detailed discussion of the inventive control strategy according to which the hybrid vehicles of the invention are operated: as in the case of the hybrid vehicle system shown in the [Severinsky] ’970 patent,** and as discussed in further detail below, the vehicle of the invention is **operated in different modes depending on the torque required**, the state of charge of the batteries, and other variables[.] Throughout, the object is to operate the internal combustion engine only under circumstances providing a significant load, thus ensuring efficient operation.
>
> * * *
>
> Where the **road load** exceeds the engine's maximum torque for a relatively short period less than T, the traction motor (and possibly also the starting motor) are used to provide additional torque, **as in the '970 patent** and above.

(Ex. 1901 [’634 Patent] at 35:3-12, 44:65-45:2, emphasis added.)

461. The ’634 Patent also confirms that the torque-based control strategy disclosed by Severinsky ’970 is the same control strategy employed by the hybrid vehicle of the ’634 Patent.

> **<u>According to an important aspect of the invention of the [Severinsky] '970, substantially improved efficiency is afforded by operating the internal combustion engine only at relatively high torque output levels,</u>** typically at least 35% and preferably at least 50% of peak torque. When the vehicle operating conditions require torque of this approximate magnitude, the engine is used to propel the vehicle; when less torque is required, an electric motor powered by electrical energy stored in a substantial battery bank drives the vehicle; when more power is required than provided by either the engine or the motor, both are operated simultaneously. <u>The same advantages are provided by the system of the present invention</u>, with further improvements and enhancements described in detail below.

(Ex. 1901 ['634 Patent] at 25:11-25:24, emphasis added.)

462. Based on the specification of Severinsky '970 and the admissions of the '634 Patent, it is my opinion that Severinsky '970 discloses mode control using *road load*, and operating the engine above a *setpoint*.

IX. CONCLUSION

463. 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.

464. 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 penalty of perjury that the foregoing is true and accurate to the best of my ability.

Executed on: February 24, 2015

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