

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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JTEKT CORPORATION

Petitioner,

v.

GKN AUTOMOTIVE LTD.

Patent Owner.

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IPR Case No.: IPR2016-00046

U.S. Patent No. 8,215,440

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**DECLARATION OF JEFFREY L. STEIN  
IN SUPPORT OF THE PATENT OWNER'S RESPONSE**

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**Updated Exhibit List**

<b>Exhibit No.</b>	<b>Description</b>	<b>Date</b>	<b>Identifier</b>
2001	NHTSA Publication, Summary of Fuel Economy Performance	Dec. 15, 2014	NHTSA Publication
2002	NHTSA Press Release	Aug. 28, 2012	
2003	All-Wheel Drive BorgWarner Book	2009	BorgWarner Textbook
2004	Gassman GKN Seamless Drivelines Article	Sept. 2009	
2005	Honda Worldwide Article entitled <i>Honda Develops World's First Super Handling AllWheel Drive</i>	April 1, 2004	Honda Worldwide Article
2006	Institution of Mechanical Engineers Article entitled <i>Four Wheels On Demand</i>	April 2015	Institution of Mechanical Engineers Article
2007	Meritor White Paper entitled <i>Building on Rich Heritage and Designing More Value and Efficiencies</i>	2012	Meritor 2012 White Paper
2008	Elsevier White Paper entitled <i>An experimental investigation of spin power losses of a planetary gear set</i>	2015	Elsevier 2015 White Paper
2009	S. Renjith et al., <i>CFD based Prediction of Spin Power Loss of Automotive Differential System</i> , SAE Technical Paper 2015-01-2783 (2015)	2015	2015 Tata SAE Paper
2010	Andreev et al., <i>Driveline Systems of Ground Vehicles - Theory and Design</i>	2010	Andreev Book
2011	Engineering Dictionary definition of "coupling", <a href="http://www.engineering-dictionary.org/coupling">http://www.engineering-dictionary.org/coupling</a> , retrieved January 26, 2015	Jan. 2016	

Exhibit No.	Description	Date	Identifier
2012	V. Vantsevich, <i>All-Wheel Driveline Mechatronic Systems: Principles of Wheel Power Management</i> , SAE Technical Paper 2006-01-0580 (2006)	April 2006	2006 SAE Paper
2013	R. Rajamani, <i>Vehicle Dynamics and Control</i> (2012)	2012	Vehicle Dynamics book
2014	How to Choose the Right ATV, <a href="http://www.atv.com/products/how-to-choose-the-right-atv-622.html">http://www.atv.com/products/how-to-choose-the-right-atv-622.html</a> , retrieved January 28, 2015	Jan. 2016	ATV article
2015	Institution Decision, Paper 7	March 25, 2016	Institution Decision
2016	Disclaimer of claims 1, 4 and 5	June 2016	Disclaimer
2017	Stein Declaration	June 2016	Stein Decl.
2018	Bosch Automotive Handbook, 4 <sup>th</sup> Edition	1996	Bosch Handbook
2019	K Newton, et al., <i>The Motor Vehicle</i> , 11 <sup>th</sup> Edition	1989	Newton Textbook
2020	Transcript of Deposition of Steven Becker	June 2, 2016	Becker Transcript
2021	D. Danesin et al., <i>Driveline Layout Influence on Four Wheel Drive Dynamics</i> , SAE Technical Paper 2004-01-0860	March 2004	2004 SAE Paper
2022	<a href="https://www3.epa.gov/fueleconomy/">https://www3.epa.gov/fueleconomy/</a>	February 23, 2016	
2023	Prosecution History of the '440 Patent		'440 Prosecution History
2024	<a href="http://www.topgear.com/car-news/frankfurt-motor-show/meet-boffins-behind-new-ford-focus-rss-revolutionary-4wd-system">http://www.topgear.com/car-news/frankfurt-motor-show/meet-boffins-behind-new-ford-focus-rss-revolutionary-4wd-system</a>	Sept. 16, 2015	Topgear Website

Exhibit No.	Description	Date	Identifier
2025	U.S. Patent No. 9,003,925	April 14, 2015	The '925 Patent
2026	<a href="http://www.gkn.com/frankfurt/news-and-Media/Pages/GKN-supplies-innovative-AWD-system-to-Ford-Focus-RS.aspx">http://www.gkn.com/frankfurt/news-and-Media/Pages/GKN-supplies-innovative-AWD-system-to-Ford-Focus-RS.aspx</a>	Sept. 14, 2015	
2027	R. L. Piziali, et al., <i>Evaluation of a Proposed ATV Design Modification</i>	1994	1994 SAE Paper
2028	<a href="http://www.autonews.com/article/20151221/RETAIL/312219981/gm-seeks-a-market-beyond--the-snow-belt-for-awd-models">http://www.autonews.com/article/20151221/RETAIL/312219981/gm-seeks-a-market-beyond--the-snow-belt-for-awd-models</a>	Dec. 21, 2015	Autonews Article
2029	<a href="http://gas2.org/2015/12/23/general-motors-will-introduce-dual-clutch-awd-on-more-cars/">http://gas2.org/2015/12/23/general-motors-will-introduce-dual-clutch-awd-on-more-cars/</a>	Dec. 23, 2015	Gas2.org Article
2030	<a href="http://www.prnewswire.com/news-releases/gkn-driveline-honored-with-two-automotive-news-pace-awards-300249970.html#continue-jump">http://www.prnewswire.com/news-releases/gkn-driveline-honored-with-two-automotive-news-pace-awards-300249970.html#continue-jump</a>	April 12, 2016	PR Newswire Awards Article
2031	<a href="http://www.greencarcongress.com/2013/09/20130905-gkn.html">http://www.greencarcongress.com/2013/09/20130905-gkn.html</a>	Sept. 5, 2013	Green Car Congress Article
2032	Automotive News Pace Award	April 18, 2016	Automotive News Pace finalists
2033	Curriculum Vitae of Jeffrey L. Stein		Stein CV
2034	P. Borio, et al., <i>Evaluation Criteria for AWD Vehicles System Analysis</i>	May 2004	SAE 2004-01-2086
2035	<a href="http://aeplus.com/news/land-rover-introduces-on-demand-all-wheel-drive">http://aeplus.com/news/land-rover-introduces-on-demand-all-wheel-drive</a>	Aug. 24, 2013	

<b>Exhibit No.</b>	<b>Description</b>	<b>Date</b>	<b>Identifier</b>
2036	Andreev et al., <i>Driveline Systems of Ground Vehicles - Theory and Design</i>	2010	Andreev Book
2037	All-Wheel Drive BorgWarner Book	2009	BorgWarner Textbook

I, Jeffrey L. Stein, hereby declare as follows:

1. I am making this declaration at the request of Patent Owner GKN Automotive Ltd. (“GKN”) in the matter of *inter partes* review of U.S. Patent No. 8,215,440 (“the ‘440 patent”).

**I. Education, Experience, and Qualifications**

2. I am currently a Professor of Mechanical Engineering at the University of Michigan, Ann Arbor Campus, and the former Associate Director of the Automotive Research Center at the University of Michigan. I have studied, taught and/or practiced in the relevant automotive engineering design and control technology for over 30 years.

3. I received my Ph.D. degree in Mechanical Engineering from Massachusetts Institute of Technology in 1983. I received a Masters of Science degree in Mechanical Engineering and a Bachelors of Science degree in Mechanical Engineering from Massachusetts Institute of Technology in 1976.

4. In my capacity as a graduate student, I studied under Prof. J. Karl Hedrick, one of the world’s leading authorities in automotive engineering. I did research with him on the dynamics of large trucks. We studied the impact of the truck design on the ride quality. Specifically to determine the role of the fifth wheel location on the magnitude of potentially harmful cab motions on the driver.

5. In my capacity as a Professor, I teach undergraduate and graduate

courses in mechanical design, dynamics, systems and control engineering. In my capacity as a Professor, I also conduct research in the area of automotive system design and control as well as machine design and control. In several of my research projects, my students and I discovered unique ways to model, design and control automotive powertrains including four wheel drive driveline systems.

6. In addition to being the former Associate Director of the Automotive Research Center at the University of Michigan, I am also the former Principle Investigator (PI) of the project “A Multi-Scale Design and Control Framework for Dynamically Coupled Sustainable and Resilient Infrastructures, with Application to Vehicle-to-Grid Integration.” I am currently the PI of a project “Sustainable Transportation for a 3rd Century: An Interdisciplinary Approach to Addressing the Last Mile Problem for Enhanced Accessibility.” In my work at the Automotive Research Center, and on these projects, I have developed computer-based methods for facilitating the design evaluation of automotive powertrains including multi-wheel drivelines.

7. From 1983 through 1987 and 1991 through the present, I have also worked as an Independent Consultant concentrating in the area of design and risk analysis of mechanical systems and manufacturing machines. Much of this work is in the automotive engineering field and most of it particularly germane to the area of automotive powertrains. Some examples include: transfer cases for on-demand

four-wheel drive, automated mechanical transmissions, hybrid electric vehicle drivetrain design and control, wireless ignition modules and value added automotive glass.

8. From 1988 through 1991, I was also employed as an Independent Consultant for Failure Analysis Associates (now known as Exponent) in San Francisco, California, focusing on the design and risk analysis of mechanical systems and manufacturing machines.

9. I am a registered Professional Engineer in the State of Michigan, and am a member of several professional engineering organizations including the Society of Automotive Engineers, National Society of Professional Engineers, the American Society of Mechanical Engineers, the Society of Manufacturing Engineers, the Institute of Electrical and Electronic Engineers and the American Society for Engineering Education.

10. In my work, I have had a number of opportunities to deal with U.S. Patents. This work has included infringement and validity analysis in the areas of automotive transfer case design and control, automated mechanical transmissions, hybrid electric vehicle powertrain design and control, automotive interior lighted mirror design, automotive shipping containers, CNC machine tool control, agricultural seed meters, medical beds and automated chemical immunoassay machines.

11. I have authored over 70 journal articles, including at least 7 articles that are related to powertrain design and control. I have also contributed to over 125 refereed conference papers, including at least 9 papers that are related to design and control of powertrains.

12. My Curriculum Vitae is submitted herewith as Exhibit 2033, and provides a listing of all publications on which I am a named author.

## **II. Compensation and Prior Testimony**

13. I am being compensated at a rate of \$500 per hour to provide analysis and testimony in this *inter partes* review proceeding. My compensation is not contingent on the outcome of any matter or the specifics of my testimony. I have no financial interest in the proceeding.

14. I have previously provided expert testimony in over 16 patent-related matters. My Curriculum Vitae, provided in Exhibit 2033, identifies some of the areas in which I have previously provided expert testimony.

## **III. The Person Of Ordinary Skill In The Art In The Relevant Field And In The Relevant Timeframe**

15. I have reviewed U.S. Patent No. 8,215,440 (“the ‘440 patent”).

16. Based on my review of these materials, I believe that the relevant field for purposes of the ‘440 patent is four-wheel drive systems in vehicles.

17. As described in Section I above, I have extensive experience in the

relevant field, including experience relating to driveline componentry, design and architecture. Based on my experience, I have an established understanding of the relevant field.

18. I understand that a “person of ordinary skill in the art” is one who is presumed to be aware of all pertinent art as of the relevant timeframe, thinks along conventional wisdom in the art, and is a person of ordinary creativity. I understand that the level of skill in the art is evidenced by the prior art references. It is my understanding that the ‘440 Patent is to be interpreted based on how it would be read by a person of ordinary skill in the art. It is my understanding that factors such as the education level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, the prior art solutions to those problems, and the speed at which innovations are made may help establish the level of skill in the art. I understand that a person of ordinary skill in the art is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above.

19. I have been informed that the relevant timeframe is on or before May 6, 2008.

20. It is my opinion that a person having ordinary skill in the art at the relevant timeframe would be someone with a mechanical engineering degree and at least some experience in driveline mechanics and/or design.

21. Based on my experience, I have an understanding of the capabilities of a person of ordinary skill in the relevant field as of May 6, 2008. I have supervised and directed many such persons over the course of my career.

#### **IV. State of the Art as of the Relevant Timeframe**

##### **A. Drivelines in General; 2WD and 4WD**

22. A drivetrain (or driveline<sup>1</sup>) is a vehicular system that “provide[s] the thrust and tractive forces required to overcome running resistance and induce motion.” (Ex. 2018, Bosch Handbook at 571-572.)<sup>2</sup> One of ordinary skill in the art understands a driveline of a vehicle to be a collection of components that distribute the power from the engine/transmission system to the wheels of the vehicle for the purpose of propelling the vehicle.

23. In a typical two-wheel drive (2WD) vehicle, the engine provides power through a transmission and then to a drive shaft and a single differential. (See Ex. 2018, Bosch Handbook at 571-572.) The differential splits the power from the engine to the connected left and right wheels, as is further elaborated on below. Thus, in 2WD, two primary wheels receive the driving force from the

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<sup>1</sup> The terms “driveline” and “drivetrain” can be used interchangeably.

<sup>2</sup> Ex. 2018 [Bosch Handbook] is a true and accurate copy of excerpts from the 1996 Bosch Automotive Handbook that is published by the SAE.

engine to “drive” the vehicle, while two secondary, non-driven wheels spin freely.

24. In a typical four-wheel drive (4WD) vehicle, a secondary driveline is used to drive the secondary set of wheels. In 4WD, all four wheels are being powered to propel the vehicle. There is typically an additional differential between the secondary wheels, accomplishing a similar purpose as the differential between the primary wheels (*i.e.*, distributing power between the left and right wheels of the secondary drive axis.) In addition, a transfer case allows the power to be split between the primary and secondary drivelines.

25. It is also a well-known principle that the 4WD system can be disengaged or shut down. This can save fuel. This is particularly useful for a typical passenger car that is used almost exclusively (depending somewhat on the region and weather patterns) on pavement with good tractive surface conditions, reducing the need for 4WD.

26. 4WD systems were initially designed such that the transition between 2WD and 4WD would have to be accomplished while the vehicle was idling. (Ex. 2019, Newton Textbook, p. 636.)<sup>3</sup> This is because a clutch was used to activate the 4WD system. One such type of clutch is a dog clutch, which provides a positive

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<sup>3</sup> Ex. 2019 [Newton Textbook] is a true and accurate copy of excerpts from Newton’s “The Motor Vehicle,” 11<sup>th</sup> Edition published in 1989.

(i.e., no slip) engagement between two mating parts. (*Id.* at 635.) The dog clutch is typically engaged when the two sides of the clutch are not rotating, or rotating at the same speed, so that the mechanical components can be meshed. A switch or button was provided in the vehicle to enable the driver to activate 4WD during idling conditions. (Ex. 1001, ‘440 patent at 1:38-53.) Switching during driving was mostly not an option due to the unavailability of any synchronization of speeds on either side of the clutch, unless the vehicle was idling. (*Id.*)

27. Another type of clutch to disengage the secondary driveline is a friction clutch. A friction clutch allows two sides of the clutch to be engaged and disengaged even when the two sides are rotating at different speeds. This allowed for automatic, computerized switching between 2WD and 4WD without requiring that the vehicle be idling. (Ex. 2019, Newton Textbook, p. 636.)

28. Engagement and disengagement of the secondary driveline is a characteristic of 4WD vehicles. Other vehicles, typically known as “all-wheel drive” (AWD) vehicles, do not require a device for “switching” between 2WD and 4WD, because power is transferred to all four wheels all the time. (*See* Ex. 2037, BorgWarner Textbook generally, at 14, 28-34.)<sup>4</sup> The power delivery can be

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<sup>4</sup> <sup>4</sup> Ex. 2037 is a true and accurate copy of excerpts from the All-Wheel Drive BorgWarner Textbook, published in 2009.

facilitated by an interaxle or center differential in the transfer case. (*Id.* at 54.) This permits the power to be split between the primary and secondary wheels to provide longitudinal equalization as will be explained more fully below. Similar to the 4WD vehicles described above, AWD vehicles can be on-demand AWD, in which power is distributed to the primary axle at all times but only to the secondary axle as required. (*Id.* at 56.)

## **B. The Differential**

29. The differential allows the power to be distributed to the left and right wheels. (*See* Ex. 2018, Bosch Handbook at 571-572.) It also allows the two wheels to spin at different speeds to allow, for example, the vehicle to travel around corners with the outside wheel covering more ground (and therefore spinning faster) than the inside wheel. (*Id.*) This is often called transverse equalization. (Ex. 1001, ‘440 patent, 1:61-2:18.) In addition, the differential can be utilized to split the power between the primary and secondary axles. This allows the primary and secondary axles to spin at different speeds to allow, for example, the vehicle to travel around corners with the primary wheels covering a different amount of ground than the secondary wheels. This is called longitudinal equalization.

30. Throughout the course of vehicular history, different types of differentials have been developed. Conventional differentials are not well-

equipped to accommodate a difference in traction amongst the two wheels across the differential. With a conventional differential, if one wheel was on ice and the other wheel on the other side of the differential was on dry pavement, then power from the engine would go to the wheel on the ice, causing it to spin and the other wheel would receive almost no power. (Ex. 2019, Newton Textbook, p. 634.)

31. Engineers then designed what is now known as limited slip differentials, which provide more control to the overall design for adjusting the power split between the left and right wheels. Limited slip differentials use a clutch-like element in their design to assure that some power always goes to both wheels. (*Id.* at 634-638). In the example provided above with the one wheel on ice and the other wheel on dry pavement, the clutch-like element in the differential would assure that some of the power would be transferred to the wheel on the dry pavement to propel the vehicle and reduce slippage and lack of traction of the wheel on the ice. (*Id.*)

### **C. Designing a Driveline**

32. Driveline dynamics analysis started in the early 1900s. “The first publication, as far as is known, was written in 1905.” (Ex. 2012, 2006 SAE Paper at 3.) Since that time, the process for designing a driveline and its various components has evolved with the trained knowledge and experience from engineers, researchers, and companies. (Ex. 2012, 2006 SAE Paper at 3.)

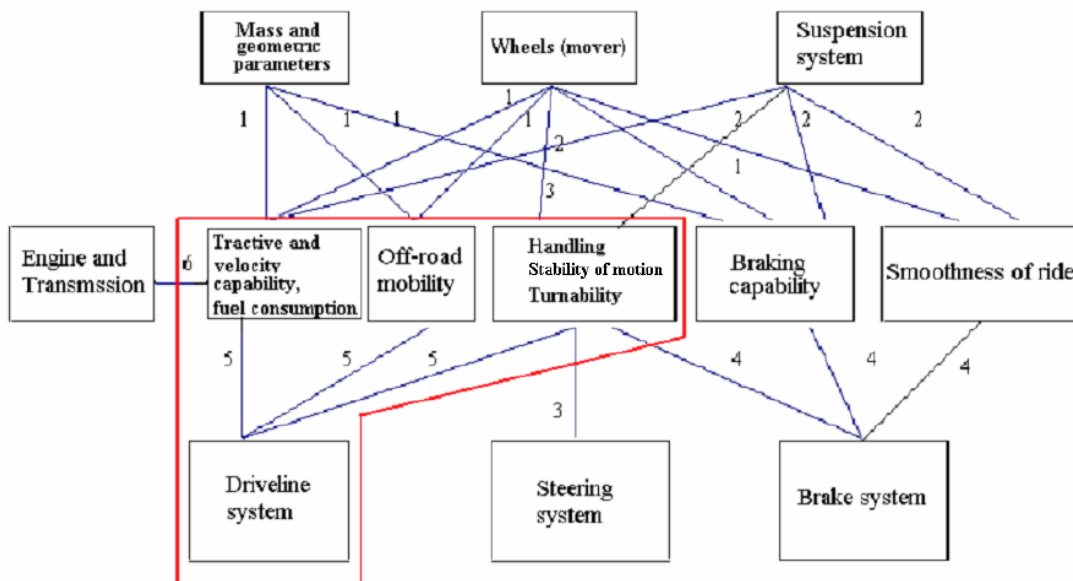
33. The main objective for the design of a driveline system is to optimally distribute the power to the wheels in order to achieve the desired performance that the particular vehicle's manufacturer is seeking, given a set of road conditions, terrain conditions, and modes of operation relevant to their customers. "Dynamics and performance of vehicles with four or more drive wheels result[s] from vehicle operational or functional properties such as energy/fuel efficiency, cross-country mobility, tractive and velocity properties, vehicle turnability, and stability of motion and handling." (*Id.* at 4.) And, with the given road conditions provided by the vehicle's manufacturer, "the same vehicle with a constant total power at the drive wheels, but with different power distributions among the drive axles and left and right wheels of each axle will perform differently." (*Id.*) In other words, the same vehicle with a different driveline component can perform differently.

34. This is due to the inherent connection between the driveline system and the vehicle's operational properties. The 2006 SAE publication authored by Dr. Vladimir Vantsevich<sup>5</sup> outlined the connection between the driveline system and various "operational properties," which include tractive and velocity capability, fuel consumption, off-road mobility, handling, stability of motion, and

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<sup>5</sup> Vladimir Vantsevich is one of the world's leading researchers in driveline systems.

turnability. (*Id.* at 4.) This connection is illustrated below:



**Ex. 2012, 2006 SAE Paper at 4.**

35. As is clear from this representation, any change in the design of the driveline system must also take into consideration the resulting changes in the tractive and velocity capability, the fuel consumption, the off road capabilities, as well as the handling, stability of motion, and turnability.

36. Notably, Mr. Becker generally agrees with Figure 3 of the Vantsevich paper, and specifically the interconnection between the driveline system and various “operational properties,” which include tractive and velocity capability, fuel consumption, off-road mobility, handling, stability of motion, and turnability. (Ex. 2020, Becker Transcript, pp. 94-99.) To these operational properties, Mr. Becker further adds NVH and durability. (*Id.* at p. 99.)

37. The mode of operation (e.g., speed, acceleration, cornering, hill climbing, etc.) is of importance because the operational properties such as mobility, fuel consumption of the vehicle depend on the behavior of the vehicle. This behavior is known as the “vehicle dynamics,” which is controlled by such things as the vehicle mass, geometry, and suspension components (also shown in the figure above). The vehicle dynamics are also affected by the driver’s actions through the steering, braking, and throttle commands and the response by the engine, transmission and driveline. All of these interactions are shown in the figure above. For example, when accelerating, the tractive torque being applied to a wheel reduces the available traction for cornering. Another example is during cornering, the outside tires experience more load and thus have more tractive force available than when traveling in a straight line. (Ex. 2037, BorgWarner Textbook, at 152-158.)

38. With the advent of computer control systems in the vehicle, the options for driveline systems have increased. This is sometimes referred to as the “mechatronic revolution” in vehicles. New concepts, improved operational performance, and flexibility have been provided with the introduction of the computers, sensors and actuators in the vehicle. The development of mechatronic systems has also created the potential for networking of different vehicle systems together. For example, referring to the Figure above, the actions of the driveline

system components are inherently dependent on activity of the steering and/or braking system as described in the above paragraph. Improved vehicle performance can be attained by measuring the behavior of the vehicle (e.g., longitudinal and lateral acceleration) and control the driveline components based on these measurements. In addition, driveline controllers can be explicitly aware of state of the other vehicle systems (e.g., steering, braking, etc.) and use this information in the control of the driveline. This mechatronic revolution has spurred the development of new driveline components including new differential designs. For example, a standard open differential as described above allows one wheel on ice to spin with little to no torque going to the wheel with traction. Limited slip, which typically uses a clutch to absorb some power, ensures that at least some power goes to the wheel with traction. While this improves traction it operates well only based on a simple feedback mechanism. (Ex. 2037, BorgWarner Textbook at 134-147). Computerized control of driveline components can improve traction under a wide variety of conditions and modes of operation by employing sophisticated algorithms based on measurements of the state of other driveline components, other vehicle systems and the performance of the vehicle as a whole. (*Id.*; *see also* Ex. 2036, Andreev Book at 116-118.)<sup>6</sup>

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<sup>6</sup> Ex. 2036 is a true and accurate copy of excerpts from the Andreev et al.

39. Driveline design methodologies need to account for this complex interplay between the desired operational performance, the road/terrain conditions, and the general vehicle state or properties. Indeed, there are several sequential principles of wheel power management that are to be taken into consideration when designing a driveline system. First, one should specify the required kinematic parameters of the vehicle in motion to determine the total power required for vehicle motion, while also finding optimum combinations of the total power distributions to the drive wheels that correspond to given kinematic parameters of the vehicle. (Ex. 2012, 2006 SAE Paper, at 5.) Simply put, this principle describes using Newton's Laws of motion to determine the power needed to achieve the desired vehicle motion. (Ex. 2036, Andreev Book at 115.) Thus, central to this first principle is determining the total power required based on a given operational mode (desired vehicle motion) and the road/terrain conditions, and the vehicle dynamics. The desired vehicle motion (mode of operation) determines the outcome of the whole design process. Therefore, a person having ordinary skill in the art would first ask – what is the mode of operation, what are the vehicle dynamics associated with this type of vehicle, and what are the

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Textbook, titled “Driveline Systems of Ground Vehicles - Theory and Design,” published in 2010.

road/terrain conditions?

40. Second, “[t]he optimum combinations of power distributions to the drive wheels should also be determined in a way of providing the extreme values of criteria of vehicle operational properties in the specified modes of operation and in the given road/terrain conditions.” (Ex. 2012, 2006 SAE Paper, at 5.) This step is for “synthesizing laws and algorithms for controlling driveline mechanisms and subsystems of a particular vehicle.” (*Id.*) The “laws and algorithms” used by the control system within the driveline will vary when different driveline components are chosen, because, for example, “some wheel power distributions that are optimal from the point of the tractive and velocity properties can bring harm to other vehicle operational properties such as turnability and handling.” (*Id.*) Likewise, “[s]ome power distributions may be optimal in terms of vehicle operational properties, but they could not satisfy the kinematic requirements to vehicle motion.” (*Id.*)

41. Third, based on the optimal wheel distributions, one would have to “synthesize and establish optimal characteristics for a hypothetical driveline system.” (*Id.*) Like the first and second principles above, this principle is implemented while there is still no actual, physical, working driveline system on the vehicle yet. (*Id.*)

42. And fourth, once one has the optimal driveline system characteristics

synthesized, one can then finally begin designing a driveline system that implements the optimal (or near optimal) characteristics. (*Id.* at 6.) It is at this time that the set of particular power dividing units (i.e., the actual structure) can be selected for interaction with the other vehicle systems (e.g., steering system, brake system, suspension system, etc.). (*Id.*)

43. With the physical components in place in the drive line, a validation of the optimal characteristics should follow by, for example, utilizing actual performance analysis. (*Id.*)

44. Given the understanding of the four principles above, it is clear that many factors influence the design of a driveline. It is also clear that it would not be a simple process to replace one component for another in an existing driveline. The physical characteristics of one physical component (e.g., differential, clutches, etc.) affect the controls and performance of other components in the driveline and other systems in the vehicle (e.g., suspension, braking, etc.). What is clear from these basic driveline design principles is that many factors influence the final design of any given vehicle. The designer starts by asking what operational performance factors are desired under what mode of operation, for what type of terrain, and for what type of vehicle. As Dr. Vantsevich writes in his textbook, “a

number of driveline systems with various combinations of PDU<sup>7</sup> mechanisms and systems could be researched analytically for a given vehicle or vehicles based on some criteria of the vehicle's properties *from the point of view of its operation and customer satisfaction.*" (Ex. 2036, Andreev Book at 114, emphasis added.)

45. These driveline design principles do not attempt to arrange various driveline components in a simple mix-and-match operation. A mix-and-match operation would not produce the desired (let alone optimal) performance of the vehicle. This means that a quick decision to eliminate a particular driveline component for splitting power and replace it with a different driveline component would be a drastic change, as not only would it change local driveline behavior such as altering the power split ratio, but it would also subsequently affect other vehicle performance attributes such as fuel economy, handling, etc. The principles outlined above are well-known to those of ordinary skill in the art. ("Principles 1 to 4 have been verified and validated in many research projects.") (*Id.*)

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<sup>7</sup> "PDU" stands for "power-dividing units," which includes "open differentials and positively locked units, limited slip differentials with all kinds of torque biases, mechanically and electronically locked differentials, viscous couplings, NoSPINs, and . . . torque-vectoring or torque-management systems." (Ex. 2036, Andreev Book at xv.)

46. Once an initial decision is made to test the feasibility of the new driveline component, then the four principles outlined above are adhered to until a new design is chosen. And even after the initial design is chosen, multiple rounds of simulation and testing are required to verify over a variety of driving conditions, road conditions, driver demands, etc. and compliance with driveline and vehicle system level design requirements. (Ex. 2021, 2004 SAE Paper, p. 3.)<sup>8</sup>

47. Simultaneous to the decision to implement one new driveline component, it is fairly typical that incremental changes to *other* driveline components are made by other engineers. For example, the Environmental Protection Agency (EPA) has strict requirements for fuel economy and emission that cause vehicle engineers to constantly tweak and refine the design of even minor components. (See Ex. 2022, <https://www3.epa.gov/fueleconomy/>.)<sup>9</sup> This creates the need for testing and re-testing once the new driveline component is designed, to assure that all component level and system level design requirements

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<sup>8</sup> Ex. 2021 is a true and accurate copy of an SAE publication titled “Driveline Layout Influence on Four Wheel Drive Dynamics,” that I understand was published in March, 2004.

<sup>9</sup> Ex. 2022 is a true and accurate copy of the EPA fuel economy data located at <https://www3.epa.gov/fueleconomy/>, last updated February 23, 2016.

are met amongst all of the other driveline components.

48. One of skill in the art would therefore understand that the decision to replace one driveline component for another would not be a simple task.

#### **D. Vehicle Dynamics**

49. The dynamic behavior of the vehicle is a product of the properties of the driveline components. These vehicle dynamics determine how a vehicle will accelerate, ride, brake, and navigate through a curve. (Ex. 2037, BorgWarner Textbook, p. 149.)

50. At the outset, 2WD (both rear-wheel drive and front-wheel drive) and AWD affect basic acceleration properties of the vehicle differently. For example, since 2WD vehicles rely on friction available at two wheels, AWD can accelerate better under slipper conditions because AWD vehicles take advantage of the friction available at all four wheels. (*Id.* at 153.) While the added friction available in AWD vehicles provides a greater potential for acceleration as compared to 2WD, this potential may exceed what the vehicle's entire driveline can provide, depending on the other components in the driveline. *Id.*

51. Another vehicle dynamic affected by the driveline components in the vehicle is cornering. In cornering, lateral tractive forces are developed at the tires by forcing them to run at an angle relative to their direction of travel. (*Id.* at 154.) In an "understeer" scenario, the vehicle steers less than expected, causing the

vehicle to make a larger radius turn than desired. *Id.* In an “oversteer” scenario, the vehicle is “fish-tailing,” where the rear end of the vehicle begins to come around the corner faster than the front end of the vehicle. *Id.* In AWD vehicles, the forces involved in accelerating the vehicle are spread over four wheels instead of just two. Because the tractive components of all the tires are being used for longitudinal traction less lateral tractive force is available for cornering. *Id.* In addition, a center differential provided on an AWD vehicle can split the torque between the front and rear of the vehicle according to different “torque split” ratios, which affect the oversteering and understeering amounts accordingly. *Id.*

52. Another vehicle dynamic affected by the driveline components in the vehicle is braking. For example, an anti-lock brake system (ABS) may be implemented to regulate wheel slip during braking, to keep deceleration near its peak capability while maintaining vehicle steering and stability. (*Id.* at 162.) A natural interaction between ABS and AWD vehicles is provided. When the AWD system is actively coupling both the front and rear axles, the ABS system may not be able to bring one of the wheels back up to vehicle speed due to the driveline coupling. This is known as “reference velocity sneak-down.” (*Id.*) The control system of the ABS and AWD must be integrated (communicated) to accommodate accordingly. (*Id.* at 162-163.)

## V. The ‘440 Patent

53. The ‘440 patent, entitled “Drive Train for a Vehicle with Connectable Secondary Axle,” is directed to a selectively connectable 4WD driveline system having a primary axle and a secondary axle. A paramount concept of the ‘440 patent is reducing the fuel consumption associated with the “power loss” of the secondary drivetrain in four-wheel drive (4WD) vehicles. (Ex. 1001, ‘440 patent, Abstract.) To reduce the power losses and increase fuel efficiency, a “shut down section of a drive train located between the switch-on device and the side shaft couplings is uncoupled both from the primary axle and from the secondary drive wheels, such that there is no more power loss in this shutdown section.” (*Id.*)

54. Four-wheel drive systems were well known prior to the ‘440 Patent. But, the ‘440 patent outlines several disadvantages to the then-current 4WD systems in the “Description of Related Art” section. (*Id.* at 1:31-2:49.) First, since power is transmitted to all four wheels during 4WD, some sort of differential mechanism is required to equalize the speeds of the wheels when traveling around curves:

care should be taken that the drive wheels of the primary axle and the drive wheels of the secondary axle in particular travel different trajectories when driving round curves . . . which without a corresponding speed difference balance would lead to tensions in the drive train. In order to lower tensions caused by different drive wheel

speeds on primary axle and secondary axle longitudinal equalization or respectively longitudinal differential is to be provided. Tensions caused by different drive wheel speeds of the drive wheels of the secondary axle are offset by a transverse equalization usually formed by transverse differential.

(*Id.* at 1:62-2:6, emphasis added.)

55. Prior to the filing date of the '440 patent, people skilled in the art knew that differentials were the components used in vehicles to equalize the distribution of torque to the left and right wheels. The Bosch Automotive Handbook reflects this:

The differential unit compensates for discrepancies in the respective rotation rates of the drive wheels: between inside and outside wheels during cornering, and between different drive axles on AWD vehicles. With rare exceptions for special applications, the differential is a bevel-gear drive unit. When the output bevel gears on the left and right sides (most common arrangement) are of equal dimensions, the differential gears act as a balance arm to equalize the distribution of torque to the left and right wheels.

(Ex. 2018, Bosch Handbook, 571-572.)

56. While improved mobility is provided by these differential systems, there are certain performance trade-offs, such as a “drive train clearly more complex in the structural aspect” . . . “resulting in increased fuel consumption.”

(Ex. 1001, '440 patent at 2:12-18.)

57. And, even when the secondary axle is not being powered (i.e., the vehicle is operating in 2WD mode), the non-operating components of the 4WD system impair fuel efficiency.

whenever the secondary axle not is [sic] connected ... [t]he components of the secondary drive train however are still being driven either by the vehicle drive via the primary axle and/or by the secondary drive wheels or respectively dragged along passively, without transmitting drive power. This gives rise to friction losses (bearing friction, churning losses, friction of gear wheel engagement, etc.) and the rotating masses of the secondary driven train components (differential, intermediate shaft, couplings, etc.) are to be accelerated or respectively relented constantly with the vehicle during dynamic driving. This power loss contributes significantly to the fact that fuel consumption in a vehicle with connectable secondary axle even with uncoupled secondary axle is noticeably higher than in a vehicle having no drivable secondary axle.

(*Id.* at 2:27-40, emphasis added.)

58. These performance problems due to power losses in the unused 4WD system are particularly burdensome if the 4WD system is used in only limited situations. The '440 patent notes:

If it is also considered that the operating times in which the connectable secondary axle is actually integrated actively in the whole

drive train constitute only a minimal portion of the total operating times of a vehicle with connectable secondary axle, it follows that a not inconsiderable quantity of fuel could be saved over the total operating period. Clients wanting a vehicle which provides a selectively connectable secondary axle must consider increased consumption however, even if they barely make use of connecting.

(*Id.* at 2:40-49.)

59. It is therefore clear that the ‘440 patent sets out to solve the problems of diminished fuel economy due to power losses in a switchable 4WD system, where the use of the 4WD system is limited.

The aim of the invention is therefore to further develop a drive train of the type initially specified such that when the secondary axle is uncoupled, power loss is minimized. A further aim of the invention is to reduce the additional structural cost and the associated extra weight of a vehicle with connectable secondary axle, despite the possibility of longitudinal equalization between primary and secondary axle and the possibility of transverse equalization on the secondary axle.

(*Id.* at 2:53-61.)

60. The ‘440 patent sets out to solve these problems by providing a “shut down section” along the drivetrain in order to “shut down as many components as possible” when the vehicle is driven in 2WD. (*Id.* at 3:7-19.) Shutting down as many components as possible during 2WD would improve fuel efficiency and

decrease power losses, which is a paramount goal of the ‘440 patent. Having such a shutdown section “makes it possible to completely shut down a majority of the secondary drive train with the secondary axle uncoupled. The drive train components belonging to the shutdown section of the secondary axle drive train consequently cause no power loss.” (*Id.* at 3:20-22.)

61. The ‘440 patent describes a novel drivetrain with “frictionally engaged couplings” instead of a differential. (*Id.* at 2:55-57.) The “[f]rictional engaged couplings are provided particularly to match the speed of both components of the secondary drive train uncoupled from the vehicle drive and from the drive wheels of the secondary axle.” (*Id.* at 3:24-28, emphasis added.) “Transmitting the secondary drive train output to the secondary axle therefore preferably occurs *not via a conventional differential gearbox*, but via a purely coupling-controlled axle drive *without differential*.” (*Id.* at 2:37-41.) “[T]he axle drive unit 9 of FIG. 3 is designed without differential. Here two frictionally engaged working side shaft couplings 4 transmit the secondary drive output to the side shafts 12 of the secondary axle 2.” (*Id.* at 6:38-42.)

62. These frictionally engaged side shaft couplings work to provide longitudinal equalization between the wheels of the primary axle and the wheels of the secondary axle. The side shaft coupling couple side shafts of the secondary axle to the upstream portion of the secondary axle. (*Id.* at 3:41-44.) The

frictionally engaged working side shaft couplings also provide transverse equalization (*i.e.*, between the wheels of the secondary axle). Thus, the side shaft couplings eliminate two components such as differentials that would otherwise accomplish these two equalization tasks.

The added advantage here is that not only transverse equalization but at the same time also longitudinal equalization can be guaranteed via the side shaft couplings. Consequently the side shaft couplings form drive output distribution without differential between the primary axle and the secondary axle similarly to longitudinal differential when the secondary axle is connected. Separately provided longitudinal equalization, for example in the form of a regulated longitudinal differential, can be omitted.

(*Id.* at 3:45-54.)

63. The “side shaft couplings” are illustrated below in Figures 3 and 5 of the ‘440 patent, labeled as element 4.

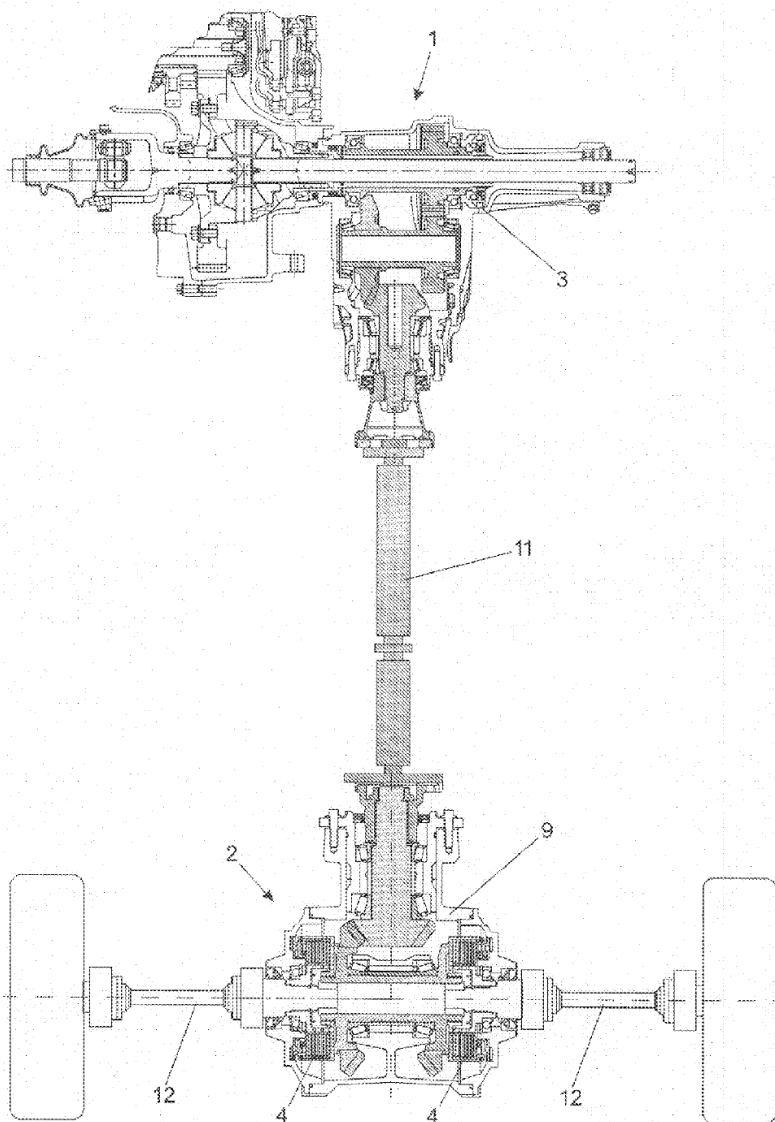


FIG. 3

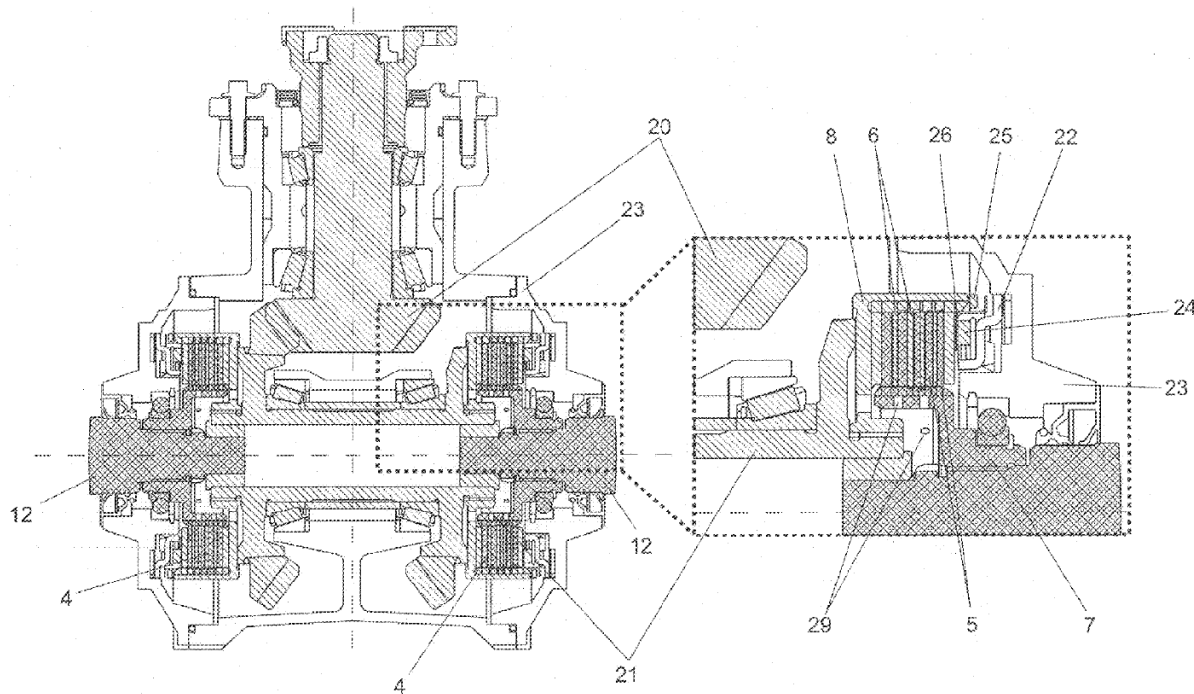


FIG. 5

64. The '440 patent also solves the problems of power losses in secondary drivetrains by creating a large shutdown section and eliminating the complexity associated with differentials by utilizing both the frictionally engaged coupling and the side shaft couplings. "As mentioned, the invention is described within the scope of a drive train concept, wherein switching off the all-wheel drive is done at the rear axle via both couplings." (*Id.* at 10:5-7.)

65. According to the '440 patent, the side shaft couplings 4 and the switch-on device 3 cooperate together to disengage and re-engage the shutdown section. A key concept in the '440 patent is that *the combination* of frictional engagements at the side shaft couplings 4 and switch-on device 3 are required in order to accomplish the shutdown of the secondary driveline: "Taken by itself,

neither the side shaft couplings 4 nor the switch-on device 3 could execute the fundamental inventive idea; with respect to the invention rather they cooperate synergistically.” (*Id.* at 6:53-56.) (*See also id.* at Abstract, 7:6-21.)

66. Additional benefits are provided by the ‘440 patent’s drivetrain with frictionally engaged couplings and side shaft couplings. For example, yaw<sup>10</sup> can be produced without the added power loss of a limit differential.

With this type of axle drive without differential, in addition to simultaneous transverse and longitudinal equalization other functions are also conceivable, such as that of an active-yaw differential, in which a yawing moment can be produced specifically by the individual actuation of the couplings. Any limit values can also be shown by the individually adjustable side shaft couplings, so that the functions of limit differential can also be realized. Omitting a plurality of otherwise necessary drive train components (wheel hub switching, transverse and longitudinal differential) makes a cost-optimized and weight-optimized configuration of the drive train possible.

(*Id.* at 3:55-65.) In other words, adjusting the individual side shaft coupling can control the yaw angle of the vehicle (i.e., the angle to the left or right from its center vertical axis). This can affect the vehicle performance. For example, the

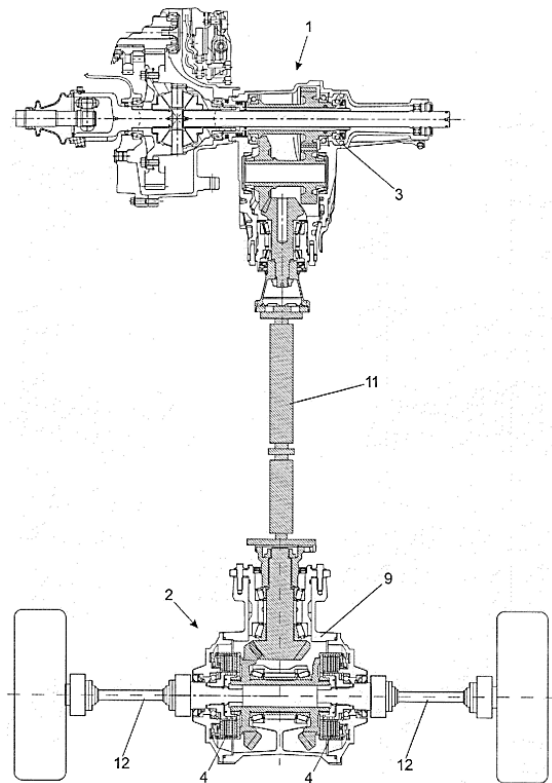
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<sup>10</sup> Yaw is an indication of how far the vehicle is angled left or right from its center vertical axis. (Ex. 2013, Vehicle Dynamics Book at 5-6.)

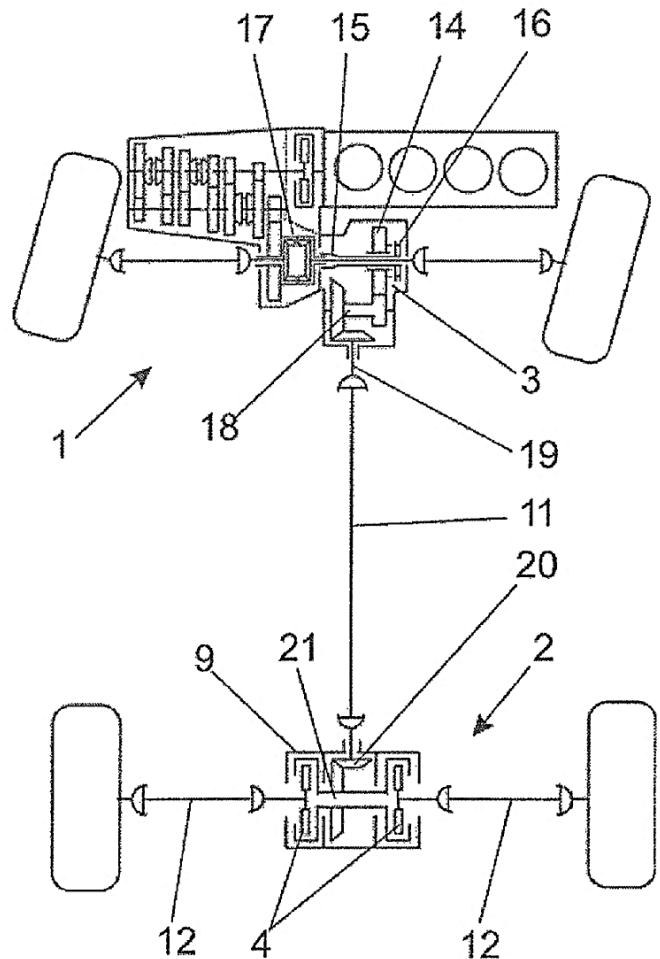
handling of the vehicle will be changed to have more or less over steer or under steer. (*See* ¶61 above.)

67. Below are Figures 3 and 8 of the ‘440 patent. The drivetrain shown includes a front primary axle 1 that is permanently driven by the engine, and a rear secondary axle 2 that is disconnectable in 2WD mode – allowing significant portions of the drivetrain to be inoperative in 2WD. (Ex. 1001, ‘440 patent at 5:17-19, 6:34-37.) The schematic of Figure 8 corresponds to the drivetrain shown in detail in Figure 3. (*Id.* at 8:63-64.) A switch on device 3 is located near the front of the vehicle and disengages spur gear step 14 to decouple engine output torque from the rear secondary axle 2. (*Id.* at 7:11-16, 6:49-52.) The switch-on device 3 frictionally engages via frictional synchronization 16 to selectively transfer the power from the primary to the second axle during operation of the vehicle. (*Id.* at Abstract, 7:6-21.) By decoupling the rear secondary axle 2 from the engine, the “section of the secondary drive train . . . located between side shaft couplings 4 and switch-on device 3 is inoperative.” (*Id.* at 6:35-37.) “Because the switch-on mechanism and/or the side shaft couplings have frictionally engaged couplings, it can be that when the secondary axle is uncoupled, the shutdown section of the secondary drive train located between the switch-on device and the side shaft couplings is uncoupled both from the primary axle and from the secondary drive wheels, such that there is no more power loss in this shutdown section, whereby

connecting the secondary drive train during travel is possible all the same and losses in comfort and practicability do not have to be tolerated.” (*Id.* at Abstract, emphasis added.)



**Ex. 1001, '440 Patent, Fig. 3**



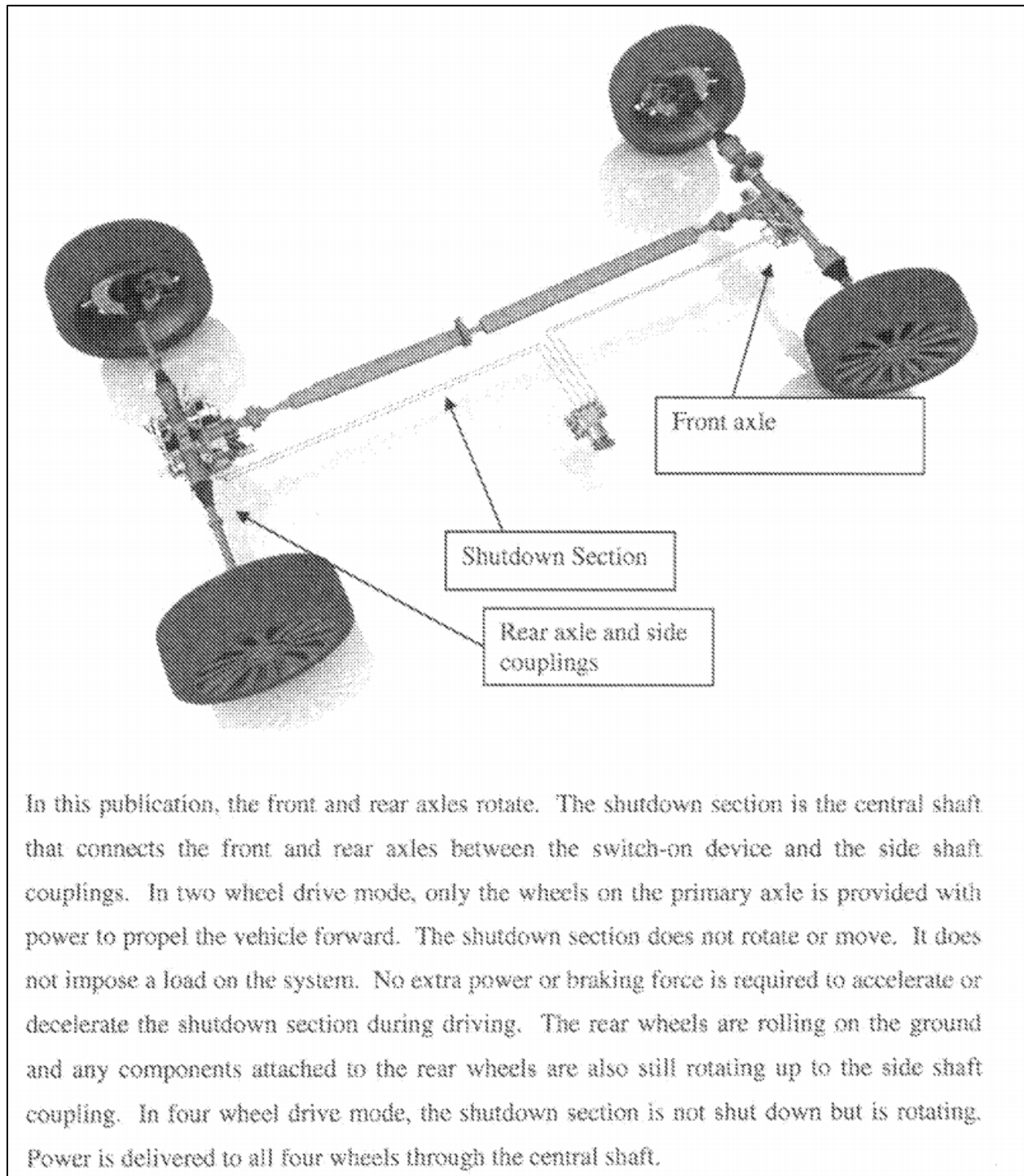
**Ex. 1001, '440 Patent, Fig. 8**

68. Consistent with the earlier-described solution of the '440 patent in ¶¶60-68 above, the rear axle drive unit 9 is provided *without* a rear differential. (*Id.* at 8:61-64.) Instead, an additional decoupling is provided by an opposing pair of frictionally-engaged side shaft couplings 4. The side shaft couplings “transmit the

secondary drive output to the side shafts 12 of the secondary axle.” (*Id.* at 6:39-42; 8:61-64.) “To shut down the secondary drive train the side shaft couplings 4 are opened and the secondary drive train is uncoupled from the permanently driven part of the drive train via the switch-on device 3.” (*Id.* at 6:49-52.) The drive unit 9 without differential, shown in these figures, accomplishes the goals of solving the problems outlined above in ¶¶53-59. For example, providing a torque decoupling on either side of the drive unit 9 allows idling of additional drivetrain components which would otherwise rotate. “This [Fig. 3] configuration . . . makes it possible to completely shut down a majority of the secondary drive train with the secondary axle uncoupled. The drive train components belonging to the shutdown section of the secondary axle drive train consequently cause no power loss.” (*Id.* at 3:20-24.)

69. It is my understanding that statements made during prosecution of a patent application are also relevant to the issued patent. During the prosecution of the application that ultimately led to the ‘440 patent, the inventors also discussed the importance of utilizing a combination of both the side shaft couplings and the switch-on device for shutting down the shutdown of the secondary driveline. For example, the following drawing and explanation was made by the Applicant, in which the Applicant explained that the shutdown section is the portion “between the switch-on device and the side shaft couplings.” (Ex. 2023, ‘440 Prosecution

History at 243.)



## **VI. Analysis and Opinion**

### **A. Ground 2 Based on a Combination of Teraoka and Watanabe**

70. It is my understanding that JTEKT is attempting to combine the teachings of Teraoka with the teachings of Watanabe to arrive at the claimed invention of claims 2 and 3.

#### **1. The Teraoka Reference**

71. It is my understanding that Exhibit 1002 is purported to be an accurate English-language translation of the Teraoka reference, which was published in Japanese. My opinions below are based on the English-language translation identified as Exhibit 1002.

72. Teraoka is entitled to a “Four-wheel drive system.” (Ex. 1002, Teraoka, [Title of the Invention].) A “two-four switching mechanism” is provided to selectively switch between 2WD and 4WD by selectively transferring power to a secondary drivetrain. The problem “to be solved” in Teraoka involves drag associated with the secondary drivetrain: “[Problem] To simplify the configuration while greatly reducing the drag torque of the coupling which is uncoupled during two-wheel drive travel.” (Ex. 1002, Teraoka, [Problem].)

73. Teraoka discloses a drivetrain structure having a two-four switch mechanism 7 that selectively transfers power to from the engine to the secondary drivetrain. In other words, the two-four switch mechanism 7 works to switch

between 2WD and 4WD. Teraoka teaches that this two-four switch mechanism 7 is a dog clutch. See, for example, paragraph [0040] of Teraoka in which the two-four switching mechanism 7 is specifically referred to as a dog clutch:

[0040] As shown in FIG. 1, this four-wheel drive vehicle comprises a transverse engine 1 (prime mover), a transmission 3, a transfer case 5, **a two-four switching mechanism 7 (dog clutch)** and direction changing gear set 9 which form a part of the transfer case 5, a front differential 11, front axles 13 and 15, left and right front wheels 17 and 19, rear wheel side propeller shaft 21, final speed reduction gear set 23 (final speed reduction mechanism), rear differential 25 (differential device), rear axles 27 and 29, left and right rear wheels 31 and 33 (wheels disengaged when in two-wheel drive), etc.

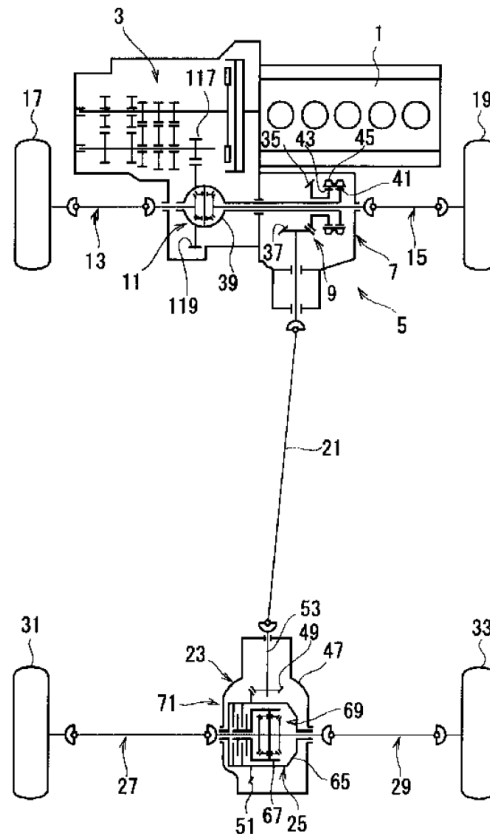
Ex. 1002, Teraoka at 5 (emphasis added).

74. Four-wheel drive is accomplished as follows: “When the two-four switching mechanism 7 is coupled, the driving force of the engine 1 is transmitted to the rear wheel side power transmission system, and when it is uncoupled, the rear wheel side power transmission system is disengaged.” (Ex. 1002, Teraoka, [0043].) More specifically, and as illustrated in Figure 1 of Teraoka reproduced below,

when the two-four switching mechanism [7] and the coupling [clutch mechanism 71] are coupled, the driving force of the prime mover [engine 1] is transmitted from the transfer case [5] and two-four switching mechanism [7] to the final speed reduction mechanism [23]

and subjected to speed reduction, after which it is distributed from the coupling [clutch mechanism 71] via the differential device [51] to the left and right wheel sides [27, 29], and the vehicle enters a four-wheel drive state.

(Ex. 1002, Teraoka, [0024].)



**Teraoka, Fig. 1**

75. Two-wheel drive is accomplished as follows:

in two-wheel drive state, as described above, the two-four switching mechanism 7 and clutch mechanism 71 are uncoupled and the rear wheel side power transmission system is disengaged.

Here, due to uncoupling of the two-four switching mechanism 7, rotation of the power transmission system (especially the large mass propeller shaft 21) stops from the two-four switching mechanism 7 to outer case 65, which is the input side member of the clutch mechanism 71, and to the outer plates 121, 123 of the main clutch 89 and pilot clutch 87.

(Ex. 1002, Teraoka, [0075]-[0076].)

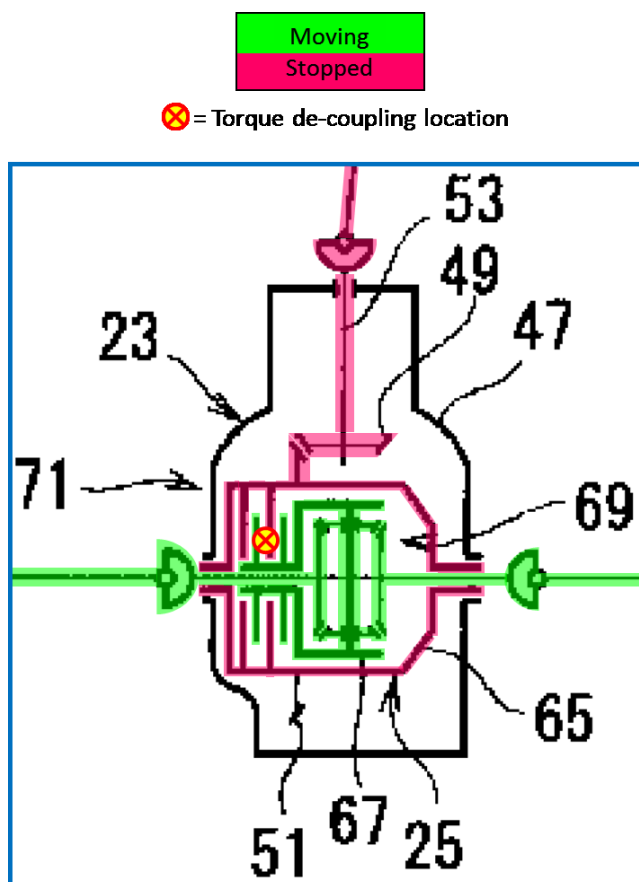
76. Switching between 2WD and 4WD can be accomplished by controlling the simultaneous coupling and decoupling of the two-four switching mechanism 7 and the clutch mechanism 71:

The controller simultaneously couples the two-four switching mechanism 7 and clutch mechanism 71 when switching from two-wheel drive state to four-wheel drive state and simultaneously uncouples them when switching from four-wheel drive state to two-wheel drive state.

(Ex. 1002, Teraoka, [0070].)

77. Below I have annotated Figure 1 of Teraoka to illustrate the relative moving and non-moving parts of the secondary drivetrain and secondary axle when the vehicle is in 2WD. When the vehicle is in 2WD, the system has rotating components (shaded green) that continue to rotate, as well as stopped components (shaded pink) that can be stopped even while the vehicle travels. A torque decoupling location in the clutch mechanism 71 is also marked, which represents

the transition point along the drivetrain between the rotating components and the non-rotating components. When the clutch mechanism 71 is disengaged, this torque de-coupling location is the point where any rotational movement caused by the rear wheels is, in principle, not transferred. While not shown in the figure below, in 4WD all of the pink-shaded components would rotate.



**Teraoka, Fig. 1 (annotated)**

78. As shown in Figure 1 above, a large portion of the secondary axle (shown in green) is still rotating, including portions extending through the differential 25, which causes frictional losses that are avoided in non-differential

systems such as the one described in the '440 patent.

## **2. The Watanabe Reference**

79. It is my understanding that Exhibit 1003 is purported to be an accurate English-language translation of the Watanabe reference, which was published in Japanese. My opinions below are based on the English-language translation identified as Exhibit 1003.

80. It is my understanding that JTEKT admits that Teraoka does not disclose the claimed “side shaft couplings” for each side shaft of the secondary axle, which I understand is required by the claims of the '440 patent. It is my understanding that JTEKT relies on the teachings of Watanabe as purportedly disclosing these limitations.

81. The Watanabe patent is entitled “Power Transmission Device.” (Ex. 1003, Watanabe, Title of the Invention.) Watanabe is concerned with oil flow to friction plates within a vehicle. According to Watanabe, when multiple-plate clutches contained in a case are packed compactly, there is very little space between the individual plates, which creates trouble for lubricating oil to flow to the friction plates. (Ex. 1003, Watanabe, at 2.) Watanabe therefore identifies a single problem in the “Problems to be Solved by the Invention” section as follows: “Hence, the present invention has an object to provide a power transmission device in which friction plates do not suffer from lack of lubrication, seizing, or the like.”

(*Id.*)

82. The disclosure of Watanabe focuses on solving these problems associated with friction plates, in the context of “a power transmission system for a four-wheel-drive (4WD) car.” (*Id.* at 3.) The friction plates subject to the invention of Watanabe are described as “multiple plate clutches 89 and 91.” (*Id.*)

83. Consistent with Watanabe’s goal of solving problems associated with oil delivery to such clutches, Watanabe describes a flow path in which “[o]il pressure is supplied to oil ports 137 and 139 of the actuators 133 and 135 via a control valve device 143 and oil passages 145 and 147 from an oil pressure source 141.” (*Id.* at 4.) “Tightening, adjustment of tightening force, and release, etc., of the multiple plate clutches 89 and 91 are performed by adjusting this oil pressure.” (*Id.*)

84. Watanabe teaches activating and deactivating a 2WD mode and a 4WD mode by changing the oil pressure supplied to the multiple plate clutches 89, 91. For example, the 4WD mode is entered by increasing the oil pressure at the clutches 89, 91 so that the “multiple plate clutches 89 and 91 are tightened” and the “rear wheels 25 and 27 are driven.” (*Id.* at 4.) Then, to enter 2WD mode, the “supply of oil pressure is halted” so that the “multiple plate clutches 89 and 91 are released” and “torque transmission to the rear wheels 25 and 27 is cut off, and the rear wheels 25 and 27 spin freely.” (*Id.*)

85. In switching between 2WD and 4WD, Watanabe teaches altering clutch pressure to either allow or prevent power from the engine to transfer to the already-rotating rear axle. This can provide switching between 2WD and 4WD “without requiring an intermittent mechanism such as a 2-4 switching mechanism” because “the 2-4 switching mechanism is unneeded.” (Ex. 1003, Watanabe at p. 4) It is therefore my opinion that the disclosure of Watanabe is not concerned at all with increasing fuel economy by reducing losses caused by drag and churning losses of the spinning parts, even when those spinning parts are not necessary for power transmission. (Ex. 2004, Gassman GKN Seamless Drivelines Article at 73.) Watanabe is not directed to the issue of power loss or decoupling any secondary driveline from a primary driveline.

### **3. Combination of Teraoka with Watanabe**

86. It is my opinion that it would not have been obvious to a person having ordinary skill in the art to combine the clutches 89, 91 of Watanabe with the drivetrain of Teraoka.

#### **a. Eliminating a Bevel Gear Differential to Reduce Weight is not a “Well-Known Goal” in Drive Line Systems**

87. It is my understanding that Steven J. Becker has opined that “it would have been obvious to replace the clutch 71 and differential 25 of Teraoka with a side-shaft coupling on each side of the secondary axle without differential gearing

in between, as doing so would achieve the well-known goals of eliminating the bevel gear differential, therefore reducing the weight and fuel consumption of the vehicle.” (Ex. 1005, Becker Declaration, ¶45.) Said another way, Mr. Becker is of the opinion that “reducing the weight” associated with a differential is “a well-known goal.” Notably, no citation is offered to support Mr. Becker’s opinion.

88. This opinion by Mr. Becker is incorrect for several reasons. First, prior to the filing date of the ‘440 patent, driveline systems routinely utilized a differential on the drive axle to help distribute drive power between the drive wheels. (Ex. 2019, Newton Textbook, at 634-635.)

89. And even today, the use of differentials is still prevalent. (Ex. 2009, 2015 Tata SAW at 1; Ex. 2012, 2006 SAE Paper at 3, 6.) And yet even with public demand for (and federal regulations requiring) increased fuel efficiency, differentials still exist in current vehicles. *Id.* If it was such a “well-known goal” to reduce weight by substituting a clutch assembly for the differential while still maintaining the same functionality and reliability, there would be no need for differentials in current vehicles. And, regarding Teraoka in particular, the fact that Teraoka retained a differential and *added* a single clutch is evidence that it was not such a “well-known goal” to reduce weight by substituting the differential for a clutch, else Teraoka would have added another clutch instead of keeping the differential.

90. The fact that the use of differentials was routine prior to the ‘440 patent, and remains routine today, is evidence that weight savings by eliminating the differential is not a “well-known goal.”

91. Moreover, it is not well-known or even true that substituting a differential gearing for a clutch assembly would, in fact, reduce the weight of the vehicle. For example, even *GKN’s own dual-clutch system* that replaces a differential has been discussed as providing desirable “torque vectoring” at the cost of a slight addition to the vehicle’s weight: “The beauty of GKN’s clutch system is that, *for a small weight penalty*, a car can actually ‘vector,’ or infinitely juggle torque between each wheel, rather than the more simple cheating way of braking an inside wheel on a corner to load up a mechanical differential.” (Ex. 2024, Topgear website, emphasis added.)<sup>11</sup> This same logic would apply to the relevant timeframe; it would not have been well-known to one of ordinary skill in the art prior to the filing date of the ‘440 patent that a replacement of a differential with a clutch(es) would reduce weight.

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<sup>11</sup> Ex. 2024 is a true and accurate copy of a Topgear web article located at <http://www.topgear.com/car-news/frankfurt-motor-show/meet-boffins-behind-new-ford-focus-rss-revolutionary-4wd-system>, dated September 16, 2015.

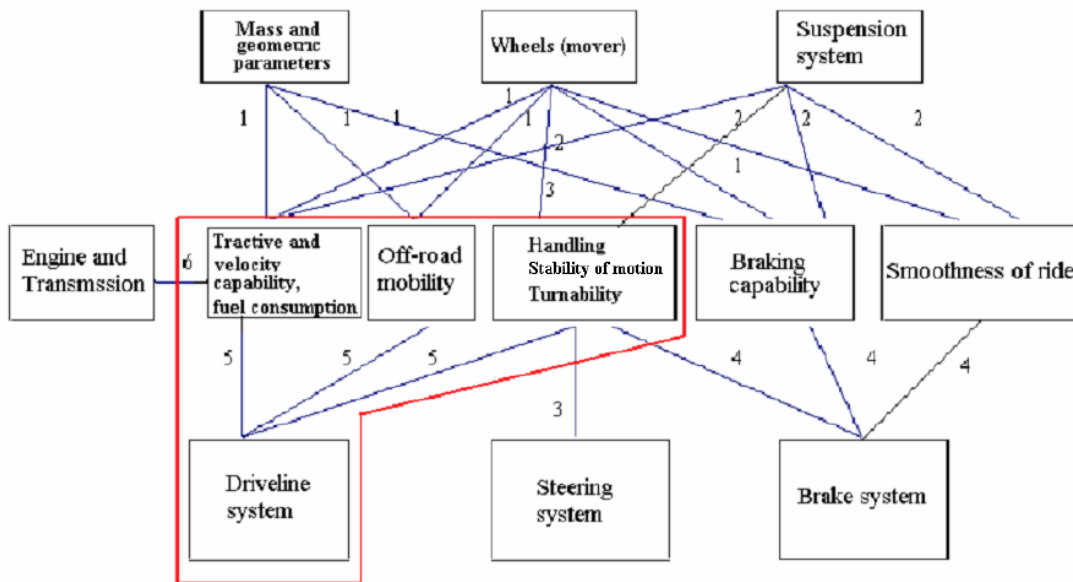
**b. Replacing the Differential with Side Shaft  
Couplings Would Not be a Simple Substitution**

92. It is also my understanding that Mr. Becker opines that replacing the differential with two multiple plate clutches would be a “simple substitution that yields predictable results.” I disagree with this opinion.

93. The design objective for driveline in vehicles is to optimally distribute the power to the vehicle wheels. “The function of the automotive drivetrain is to provide the thrust of tractive forces required to overcome running resistance and induce motion.” (Ex. 2018, Bosch Handbook at 554.) Drivelines vary amongst different vehicle types, and are individually tailored and designed in order to achieve the desired vehicle performance (*i.e.*, operation properties) that the designer or manufacturer is seeking. (See ¶¶34-37 above.) Drivelines are designed based on a set of given anticipated road conditions, terrain conditions, and a mode of operation relevant to their customers. (See ¶¶33-48 above.)

94. As explained in the State of the Art section above, the connection between the driveline system and some various operation properties is shown in the figure below. The boxes along the center line of this figure are main operational properties (*i.e.*, functions and requirements) of any given vehicle. Around the perimeter of these operational properties are the various vehicle components or systems that effect or control the operational properties. As can be seen within the red line, the driveline system is directly responsible for the

performance of the tractive and velocity capability, the fuel consumption, the off road capabilities, as well as the handling, stability of motion, and turnability.



**Ex. 2012, 2006 SAE Paper, Fig. 3**

95. As clear from this representation, any change in the design of the driveline system must also take into consideration the resulting changes in the tractive and velocity capability, the fuel consumption, the off road capabilities, as well as the handling, stability of motion, and turnability.

96. Even after a particular PDU is selected, computerized virtual experimentation of that PDU is necessary to assure compliance and capabilities with the desired fuel consumption, the off road abilities, as well as the handling, stability of motion, and turnability (*See Ex. 2012, 2006 SAE Paper at Fig. 3, above.*) Virtual experimentation would be necessary because “[t]he relationships

about driveline characteristics, suspensions, tires, steer, operating conditions, driver behavior and so on, are so complicated for an [*sic*] 4WD vehicle that is [*sic*] unavoidable to design 4WD [without] considering virtual experimentation.” (Ex. 2021, 2004 SAE Paper, p. 3.)

97. The mode of operation (e.g., speed, acceleration, cornering, hill climbing, etc.) is of importance because the operational properties such as mobility, fuel consumption of the vehicle depend on the behavior of the vehicle. This behavior is known as the “vehicle dynamics,” which is controlled by such things as the vehicle mass, geometry, and suspension components (also shown in the figure above). The vehicle dynamics are also affected by the driver’s actions through the steering, braking, and throttle commands and the response by the engine and transmission. All of these interactions are shown in the figure above.

98. As explained above in the State of the Art, ¶¶32-48, when designing a driveline for a given vehicle, there are four principles of wheel power management that are to be taken into consideration. Given the understanding of these four principles, one of ordinary skill in the art would understand that many factors influence the design of a driveline. It is also clear that it would not be a simple process to replace one component for another in an existing driveline. The physical characteristics of one physical component (e.g., differential, clutches, etc.) affect the controls and performance of other components (e.g., wheels, suspension,

braking, etc.). What is clear from the basic design principles is that many factors influence the final design of any given vehicle. The designer starts by asking what operational performance factors are desired under what mode of operation, for what type of terrain, and for what type of vehicle. As Dr. Vantsevich writes in his textbook, “a number of driveline systems with various combinations of PDU<sup>12</sup> mechanisms and systems could be researched analytically for a given vehicle or vehicles based on some criteria of the vehicle’s properties *from the point of view of its operation and customer satisfaction.*” (Ex. 2036, Andreev Book at 114, emphasis added.)

99. In considering a decision to replace the differential with some other type of power-dividing unit (PDU), an engineer would be given a plethora of choices to make. Side-shaft couplings (e.g., clutches) would be one of many, many potential PDUs. Dr. Vantsevich has classified many of these PDUs in the table shown below:

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<sup>12</sup> “PDU” stands for “power-dividing units,” which includes “open differentials and positively locked units, limited slip differentials with all kinds of torque biases, mechanically and electronically locked differentials, viscous couplings, NoSPINs, and . . . torque-vectoring or torque-management systems.” (Ex. 2036, Andreev Book at xv.)

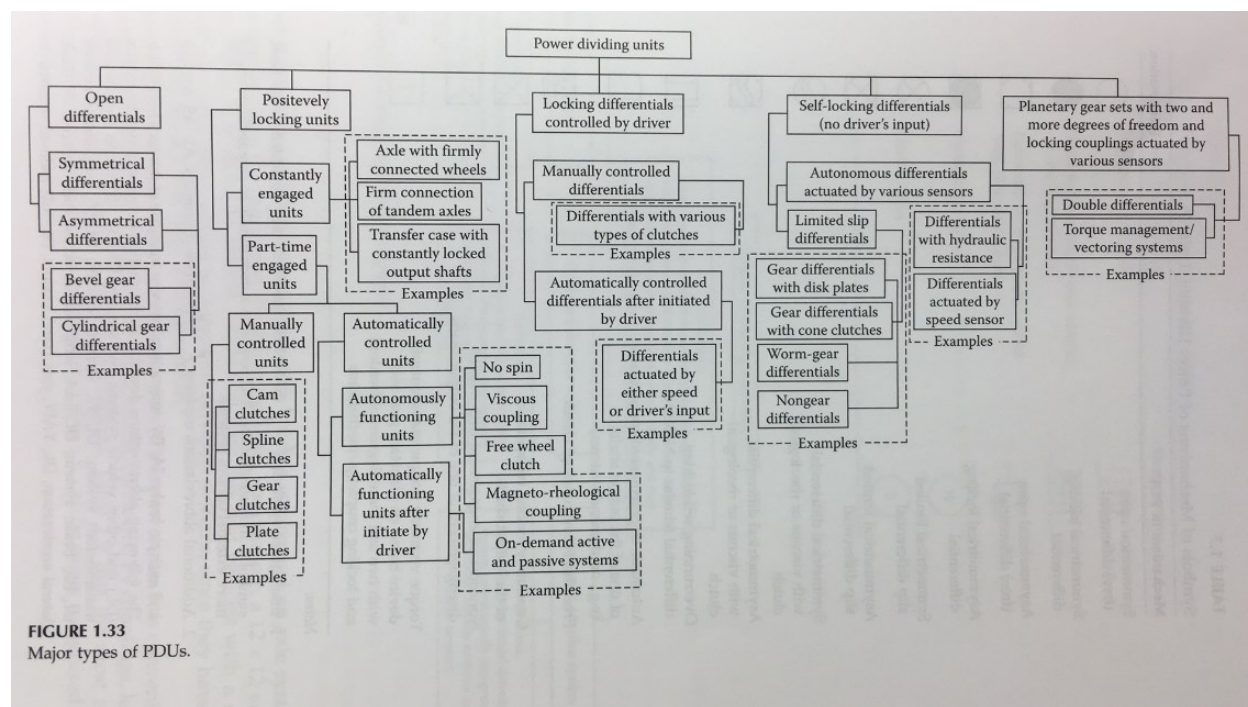


FIGURE 1.33  
Major types of PDUs.

### Ex. 2036, Andreev Book at 37

100. Replacing one particular PDU for another PDU in a vehicle would therefore not be a simple mix-and-match operation. As Dr. Vantsevich further outlines in an SAE paper he authored, “a vehicle with four drive wheels has three power dividing units. The first one is the transfer case. Two more units are installed on the front and rear axles. *See* Figure 2. As seen from this, combinations of the mechanisms and subsystems that could be employed for these three PDUs are practically uncountable.” (Ex. 1012, 2006 SAE at 4, Figure 2.)

101. Without adhering to the design principles outlined above, such a mix-and-match operation would likely not produce the desired (let alone optimal) performance of the vehicle. This means that a decision to eliminate a differential

and replace it with a pair of clutches would not be a simple substitution to yield predictable results.

102. On this subject, Mr. Becker's testimony is contradictory, he on the one hand states that the driveline design process requires on the order of 100 plus people over a two-year period that involves many distinct departments and processes but then concludes that available driveline components and control strategies can be routinely mixed and matched:

Q. and so in your experience how long does that sort of if there's a ground-up design that's being worked on for a drive line system, how long would that take?

A. The whole process?

Q. Yes.

A. To what point?

Q. To where it's ready to go into a vehicle following testing and validation.

A. Sure. Our current design cycles are usually in the two-year range.

Q. Okay. And that again would entail this group of 100 plus people that you were referring to?

A. Yeah, that's just on the OEM side. That's not talking about suppliers.

Ex. 2020, Becker Transcript at 59-60.

103. Mr. Becker's testimony then goes on to list the myriad of departments involved in developing driveline concept over this two-year design period:

Q. Can you list for me the different departments that are involved in working together to ultimately design the drive line system from scratch all the way through validation?

A. So you start out with your advanced concepts people. They're going to have the interaction with the marketing group. Sadly enough. So you develop what features they want capable for the vehicle. Then you're going to have the drive line systems group broken down into transmission, drive shaft and if it's an all-wheel drive system and that you're going to have your PTU group your rear axle or rear differential module groups and sometimes the prop shaft people will also do the half shafts for the RDM. Other times it's a whole axle group your going to have the real axle group the knuckle joint hubs and attachment to the wheels and that defines your full drive line system which is basically everything downstream of the engine. That's going to start the design process. They're going to interact with suppliers as well as the internal manufacturing people for packaging envelope and shape and size which means that they need to put lump sums together with the modeling group. They're going to create a 3-D model using these lump systems of the various components to define a packaging envelope for each one of the segments of the drive line. That's then going to develop into concept drawings so you'll have the CAD groups and they're going to pass their initial CAD models off to

the FEA or finite element and simulation group. That's and that going to trigger starting to work with the electronics guys for the controls and how to actuate the various systems and what size actuation systems they're going to use. Predominantly now, products are using electronic control or electronic motor actuation or solenoid actuated. . . the transmission group still is required to interact with the engine group for the meeting of the transmission to the engine. Then you're going to have your cafe and fuel economy group their input as far as weights and efficiencies so whether we get a double clutch transmission or a standard transmission, automatics, manuals, again that's going to have feedback from marketing and business development as to what they figure the estimated market size is for the product and the projected volumes determine the paths we will follow for manufacturing so at that point we will start tying in the production guys as far as manufacturing methods that are available and costs and timing. There's going to be the project management group that's going to start setting up the began the charts and product timing windows backing out each component to design concept function and ultimate delivery schedule for the early prototypes. Your simulation groups meanwhile working in the background evaluating a few of the various designs with the designers and the drafters. Their teams are meeting with -- they usually is a cross-functional team of manufacturing people, simulation people and the core engineering and test development and verification people to sort of synthesize how that plan's going to go together. I think we're now to the point where we've got a concept together.

Ex. 2020, Becker Transcript at 60-63.

104. Notably, according to Mr. Becker, the driveline design process is even more complicated for an all-wheel drive system:

Q. Are all-wheel drive systems more complicated than four-wheel -- than front wheel drive systems in terms of the drive line design aspect of it?

A. Definitely. In the all-wheel drive configuration you then have interaction more with the electronics guys and you have a schema approach where it's a -- do you want to follow a torque vectoring concept or do you want to use a brake actuation control more of a mild all wheel drive systems versus a stronger all-wheel drive system. Then there's going to be the interactions with marketing and things as to the performance you wants out of a vehicle.

(Ex. 2020, Becker Transcript, 65-66.)

105. Given the complexity of driveline design, I disagree with Mr. Becker's testimony that driveline components and control strategies can be routinely mixed and matched:

Q. So let's say over the last decade if you had an array of components that are available and an array of control strategies is it possible then to effectively somewhat routinely mix and match those components and control strategies to achieve whatever end vehicle characteristics you're looking for?

A. Initial concept and cost no object, sure.

(Ex. 2020, Becker Transcript at 119.)

106. Looking at just one effect of a change in the PDU of the vehicle – handling – it becomes clear that driveline components and control strategies cannot be mixed and matched in a “predictable” way. To understand the impact on handling of a change in the PDU, computer simulation models would be used to estimate longitudinal performances, lateral dynamics and fuel consumption of the car with the new PDU component. (Ex. 2034, SAE 2004-01-2086, at 6.)<sup>13</sup> The traction capabilities, given known tire characteristics, would be simulated based on the new PDU. *Id.* Simulated yaw velocity and sideslip angles data would be obtained and evaluated. (*Id.* at 7.) Tuning of the PDU can be done to assure the results are within the boundaries of what would be sufficient for that particular vehicle’s performance expectations (e.g., sports car, sport utility vehicle, etc.). *Id.* Additional yaw rate data can be obtained for various acceleration rates because “[t]o quantify the traction capability, the lateral acceleration at maximum longitudinal acceleration is usually calculated.” (*Id.* at 8.) The data plots would

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<sup>13</sup> Ex. 2034 is a true and accurate copy of an SAE publication titled “Evaluation Criteria for AWD Vehicles System Analysis,” that I understand was published in May 2004.

help quantify how, for example, a vehicle equipped with one type of PDU would follow a different path than a different vehicle equipped with a different PDU during the turn. (*Id.* at 8-9.) The above descriptions are just examples of the various tests that would be required to assure that the selected PDU would maintain desired handling characteristics; other tests would have to be run to assure other characteristics are also maintained (e.g., tractive and velocity capability, fuel consumption, off road capabilities, etc.) (*See* ¶¶34-36 above.)

107. Indeed, if one were to replace the mechanical differential of Teraoka a pair of controllable clutches such as those disclosed in Watanabe, the replacement would require an entirely new control system for the automatic control of the clutches. U.S. Patent No. 9,003,925 (Exhibit 2025, “the ‘925 patent”) is a U.S. Patent with a listed assignee being GKN. It is my understanding that this patent is not prior art, but it is a GKN patent filed after the ‘440 patent that shows interactive controls of clutches as opposed to a mechanical differential. This patent teaches a vehicle having a pair of clutch packs acting as a selective power distributing unit for controllably activating 4WD. (Ex. 2025, the ‘925 patent at Abstract, 2:47-3:4; Figs. 1, 3.) A large portion of this patent describes the interactive controls of the clutch packs to selectively distribute power to the rear axle in 4WD mode. (*See*, e.g., 4:65-5:26; 5:58-67.) For example, the vehicle is equipped with “a plurality of sensors monitoring numerous factors such as speed,

wheel slip, whether brakes are being applied, steering angle, yaw rate, throttle, steering angle, and another other [*sic*] factors that affect handling and traction of the automotive vehicle. For example, the controller may sense that a particular wheel is in a spin condition and then will activate the appropriate individual motor 109 or 110 to engage the appropriate clutch packs 62, 64.” (Ex. 2025, the ‘925 patent, 5:19-26.) The clutches can be controlled to allow “only a certain percentage of power . . . to each wheel depending on the road conditions and what is being sensed by the on board computer sensor.” (*Id.* at 5:64-67.) Such a computerized clutch pack for distributing power to the wheels of the secondary axis would require an entirely new interactive control system that would take large amounts of efforts to implement if being substituted for a mechanical differential that requires no computerized controls.

108. In addition, the combination of Teraoka with Watanabe would be inoperable without the addition of sensors, controllers and algorithms to utilize and control the clutches. Without those, the clutches would not allow for transverse and longitudinal equalization. The drivetrain would fail. In addition, the utilization of the clutches to improve vehicle performance would depend on inputs from the steering system, brake system, and engine system. None of these are provided in either Teraoka or Watanabe.

109. Mr. Becker seems to be concluding that the substitution of the

secondary drive train of Teraoka with the secondary drivetrain of Watanabe is a “simple substitution” because procedures could be employed, albeit complex and lengthy, to substitute the two:

Q. So what would be entailed, when you're talking about simple substitution, what are the kinds of steps that an engineer would have to take in substituting the secondary drive train of Teraoka with the secondary drive train of Watanabe?

A. Sure. Well you would have to adapt your control scheme or create your control scheme. You would have to source the parts. You'd have to size the parts for durability. You'd have to adapt the housing to accommodate the geometry. You'd have to perform your stress analysis calculations to see where the weak points are then do your modeling for NVH and friction losses and then yeah then it's performance testing.

Q. But essentially that's routine that sort of the set of processes that you just went through?

A. I don't consider any of it routine. It is what we do in the auto industry.

Q. Okay. But so okay, when you say simple substitution, what does that term mean to you?

A. It means it's a matter of following the typical procedures of the auto industry.

Q. And Or vehicle design industry because it could apply to other vehicles.

Q. Okay. And that includes the various processes and methodologies that you just outlined?

A. Exactly.

(Ex. 2020, Becker Transcript at 144-146.)

**c. A Person of Ordinary Skill in the Art Would Not Have Been Motivated To Modify Teraoka Based On The Teachings Of Watanabe**

110. As explained above in ¶72, Teraoka identifies the problem to be solved as: “To simplify the configuration while greatly reducing the drag torque of the coupling which is uncoupled during two-wheel drive travel.” (Ex. 1002, Teraoka at p. 2.) Teraoka notes that unnecessarily rotating parts can create unwanted drag, which can lead to “wear, vibration, noise, etc. of the various parts as well as affecting fuel efficiency due to energy loss.” (*Id.* at [0017]; see also *Id.* at [0020].)

111. Teraoka purportedly solves these problems by providing a “simpler” coupling with fewer rotating parts, thereby reducing drag:

Furthermore, the four-wheel drive system of the present invention, which allows the drag torque to be reduced simply by providing a coupling, has a simpler configuration and reduces the number of parts, weight and cost as compared to the prior art example, which requires a dog clutch 535 in addition to the coupling 521 in order to reduce drag torque.

(Ex. 1002, Teraoka at [0031].)

112. The Watanabe patent is entitled “Power Transmission Device.” (Ex. 1003, Watanabe, Title of the Invention.) As stated early in ¶81, Watanabe is concerned with oil flow to friction plates within a clutch pack. According to Watanabe, when multiple-plate clutches contained in a case are packed compactly, there is very little space between the individual plates, which creates trouble for lubricating oil to flow to the friction plates. (Ex. 1003, Watanabe, at 2.) Watanabe therefore identifies the “Problem[] to be Solved by the Invention” as follows: “Hence, the present invention has an object to provide a power transmission device in which friction plates do not suffer from lack of lubrication, seizing, or the like.” *Id.*

113. While Watanabe describes a 4WD vehicle utilizing a two-clutch system rather than a differential, Watanabe is not directed to the issue of power loss or drag reduction. Instead, Watanabe is directed to improving “lubrication, seizing, or the like” of the clutches.

114. Since the goal of Teraoka is to reduce drag for fuel efficiency purposes, one of ordinary skill in the art would understand that any modification of Teraoka should be done to coincide with the goal of reducing drag. This is consistent with the problem-solution approach to designing driveline systems. (See ¶¶32-48 above.) However, Watanabe discloses structure that is focused on supplying fluid to the clutches to prevent seizing of the clutches. (See ¶¶81-85 above.) One of ordinary skill in the art would therefore not be motivated to modify Teraoka based on the teachings of Watanabe as there is no clear identification that doing so would be in line with Teraoka's explicit goal of reducing drag of rotating parts.

115. Stated differently, I understand that because the proposed modification of Teraoka with Watanabe would render the reference inoperable for its intended purpose—reducing drag—the proposed obviousness combination lacks a motivation to combine.

116. Moreover, Teraoka teaches incorporating its single clutch 71 within the differential housing with the goal of saving on packaging space:

Moreover, since the clutch mechanism 71 is arranged inside the differential carrier 47, it is easy to lubricate the inner plates 125, 127 and outer plates 121, 123, making it possible to improve durability, *as well as achieving greater compactness of the whole device as compared to when the clutch mechanism 71 is provided separately,*

which can be advantageously made use of in terms of the vehicle mounting layout characteristics.

(Ex. 1002, Teraoka, [0092], emphasis added.)

117. Substituting Teraoka's differential design with Watanabe's dual clutch design would likely require more space to accommodate the dual clutch system. The substitution would likely be heavier as well.

GKN was awarded the Ford Focus RS programme just 18 months ahead of launch. In that time GKN engineers designed and integrated both the Torque Vectoring Rear Drive Module (RDM), as well as the Power Transfer Unit (PTU) and CVJ sideshafts into the base front wheel drive platform. This required major reconfiguring of the system componentry to fit the packaging space available. GKN's in-house software and calibration teams worked in collaboration with Ford and its vehicle dynamics engineers on new control algorithms for the torque vectoring system to give the driveline four different driving modes.

(Ex. 2026, <http://www.gkn.com/frankfurt/news-and-Media/Pages/GKN-supplies-innovative-AWD-system-to-Ford-Focus-RS.aspx>.)<sup>14</sup>

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<sup>14</sup> Ex. 2026 is a true and accurate copy of a GKN web article located at <http://www.gkn.com/frankfurt/news-and-Media/Pages/GKN-supplies-innovative-AWD-system-to-Ford-Focus-RS.aspx>, dated September 14, 2015.

The beauty of GKN's clutch system is that, *for a small weight penalty*, a car can actually 'vector', or infinitely juggle torque between each wheel, rather than the more simple cheating way of braking an inside wheel on a corner to load up a mechanical differential.

(Ex. 2024, Topgear website, emphasis added.)

118. One of ordinary skill in the art would therefore not be motivated to replace the differential design of Teraoka with the dual clutch design of Watanabe due to packaging and weight concerns.

119. Additionally, as stated above in ¶72, Teraoka's goal is to improve fuel efficiency (e.g., by reducing drag). One of the vehicle dynamics that would be affected by a decision to replace a differential with a dual-clutch design is vehicle cornering. (*See* State of the Art, ¶51, above.) Under in line motion and turns under regular road conditions, a dual clutch system such as Watanabe's would have to modulate the dual clutches to accurately distribute the required torque to each individual wheel. Doing so would be less fuel efficient than a differential based system such as Teraoka's. The loss in fuel efficiency would be due at least in part to the required efforts to operate the clutch (slipping losses and friction associated with activating and modulating the dual clutches). These types of losses are magnified in a dual-clutch system because of the amount of required modulation of the clutches entering, during, and exiting turns. Thus, I understand that because the proposed modification of Teraoka with Watanabe would render

the reference inoperable for its intended purpose—reducing drag and improving fuel efficiency—the proposed obviousness combination lacks a motivation to combine.

120. And finally, Watanabe’s two clutch mechanism can be used to adjust “the distribution ratio of the drive power between the rear wheels” and more specifically to selectively apply a yawing moment to either the rear wheels or adjust the size of the yawing moment during cornering to improve steering characteristics. (Ex. 1003, Watanabe at 4-5.) On the other hand, Teraoka’s clutches fail to provide any drive power control between the rear wheels. (Ex. 1002, Teraoka at 6, 9.) A person of ordinary skill in the art would have to carefully consider these differences rather than making a “simple substitution” to exchange one of these systems for another.

**d. Combining Watanabe With Teraoka Would be  
Hindsight Reconstruction of the Claims**

121. I understand hindsight reconstruction of a challenged patent claim is impermissible.

122. The process of designing a driveline is problem-solution oriented, in order to achieve the desired performance for that the particular vehicle’s manufacturer is seeking, given a set of road conditions, terrain conditions, and modes of operation relevant to their customers. (See ¶¶32-48 above.) Because Teraoka strives to reduce drag in its differential in order to maximize fuel economy

of its driveline system, one skilled in the art would have been discouraged from implementing teachings from Watanabe that would replace the differential with a pair of clutches unless the clutches do, in fact, reduce drag and improve fuel efficiency. No such teachings are provided in Watanabe. Therefore, a person of skill in the art would not reasonably have been led to implement the clutches of Watanabe into the driveline of Teraoka without having the benefit of GKN's claims to use as a guide.

123. This is highlighted by the fact that the disclosure of the '440 patent and its prosecution history explained that a key to the invention is the cooperation between both the side shaft couplings and the switch-on device for shutting down the shutdown section of the driveline. For example, the '440 patent states: "Taken by itself, neither the side shaft couplings 4 nor the switch-on device 3 could execute the fundamental inventive idea; with respect to the invention rather they cooperate synergistically." (Ex. 1001, the '440 patent, 6:53-56.) Indeed Teraoka teaches a switch-on device without two side shaft couplings, while Watanabe teaches two couplings while discrediting the need for a switch-on device. Only hindsight would allow for such a combination of the two.

**B. Ground 3 Based on a Combination of Teraoka and Burrows**

124. It is my understanding that JTEKT is attempting to combine the teachings of Teraoka with the teachings of Burrows to arrive at the claimed

invention of claims 6 and 7.

### **1. The Burrows Reference**

125. It is my understanding that JTEKT admits that Teraoka does not expressly disclose the claimed “speed synchronization” that “is supported by the at least one side shaft coupling,” which I understand is required by the claims of the ‘440 patent. It is my understanding that JTEKT relies on the teachings of Burrows as rendering these claim limitations obvious.

126. The Burrows reference, entitled “Four Wheel Drive Driveline Transition,” is directed to motor vehicles, e.g., “all terrain vehicles which have selective two wheel drive or four wheel drive.” (Ex. 1004, Burrows at 1:2-4.) All-terrain vehicles (ATVs) are designed for aggressive off-road 4WD capability, in which the driver straddles a seat and uses handlebars for steering. (Ex. 2027, 1994 SAE Paper at 4.)<sup>15</sup> During aggressive driving of ATVs, a switch from 2WD to 4WD “may be felt by the driver as an unacceptable jerk, i.e. a spasmodic acceleration.” (*Id.* at 1:23-2:3.) Burrows sets off to smooth the jerky, spasmodic switches from 2WD to 4WD in aggressively-accelerating driving situations in these types of vehicles. The invention of Burrows assures that the “transition to

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<sup>15</sup> Ex. 2027 is a true and accurate copy of an SAE publication titled “Evaluation of a Proposed ATV Design Modification” that I understand was published in 1994.

engagement of four wheel drive occurs in two stages, reducing any acceleration jerk perceived by the driver.” (Ex. 1004, Burrows at Abstract.)

127. Burrows discloses various multi-step control strategies to transition from 2WD to 4WD. One of these strategies is a two-step embodiment for use with friction clutches, where the non-rotating parts of the secondary drive system are engaged and the system waits for them to be brought up to speed. (Ex. 1004, Burrows at 9-10.) Once the correct speed is reached a second step is employed to engage the primary drive train with the secondary drive while the vehicle is moving. (*Id.*) This promotes smooth engagement as perceived by the driver:

Changing from two wheel to four wheel drive is controlled so that [1] the auxiliary drive line 21 is reconnected to either the engine 11 or the second pair of wheels, typically the rear wheels 14, 15, to rotate at least part of the auxiliary drive line 21 for a sufficient time period prior to [2] fully reconnecting it to provide drive torque to the rear wheels 14, 15. Thus transition to engagement of four wheel drive occurs in two stages, reducing any acceleration jerk perceived by the driver.

(Ex. 1004, Burrows, Abstract.)

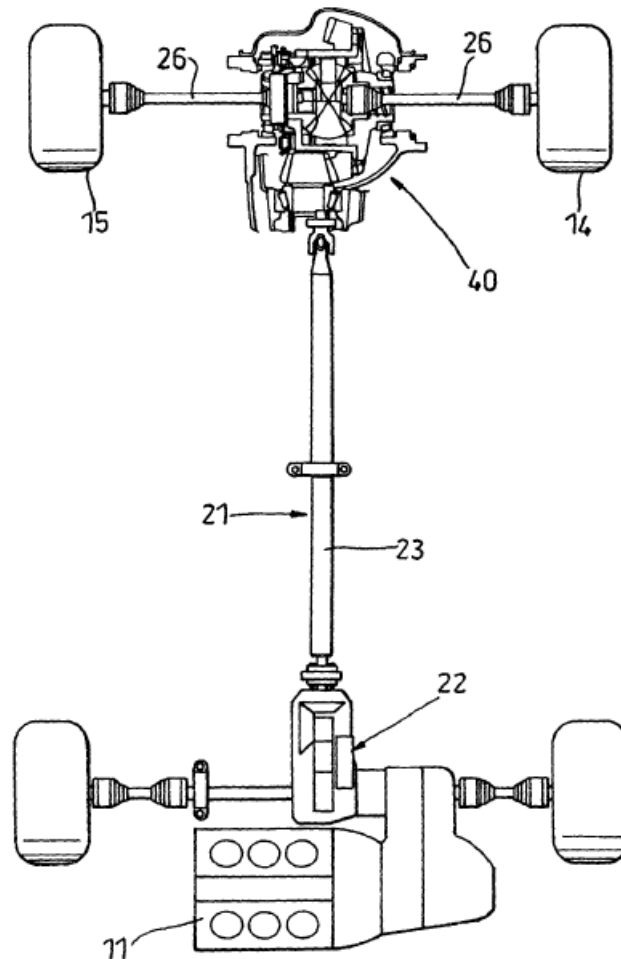
128. Another of these strategies is employed for embodiments with a differential having a dog clutch or one-way clutch for disconnecting the auxiliary driveline 21. Burrows discloses that this strategy can be implemented using the vehicle schematic shown in Figure 2, in which an engine 11 along the main drive

line provides power to a differential 40 along the auxiliary drive line. The differential 40 has a dog clutch or one-way clutch, as well as “a synchronizer [*sic*] device.” (*Id.* at 8:5-6.) According to this particular strategy:

A control strategy for operation of a dog clutch for a dynamic change in two wheel drive mode causes [1] the clutch 22 to spin-up the auxiliary driveline 21 to the best estimated synchronization speed for connection to the rear wheels 14, 15. The clutch 22 would then [2] disengage quickly whilst simultaneously the synchronizer device would [3] smoothly engage the dog clutch. The clutch 22 then [4] re-engages quickly.

(*Id.* at 8:7-11.)

129. The synchronization process of the driveline of Figure 2 (below) would work as follows. As the vehicle is being driven in 2WD, the engine 11 propels the primary driveline's wheels (shown as rear wheels in Figure 2.) When 4WD is desired, the friction clutch 22 at the main driveline would close to “spin-up the auxiliary driveline 21.” (*Id.*) Then, once a synchronous speed is achieved between the primary driveline and the auxiliary driveline, the differential 40 with the dog clutch at the secondary driveline would engage to “lock” the secondary driveline to the primary driveline.



**Fig. 2**

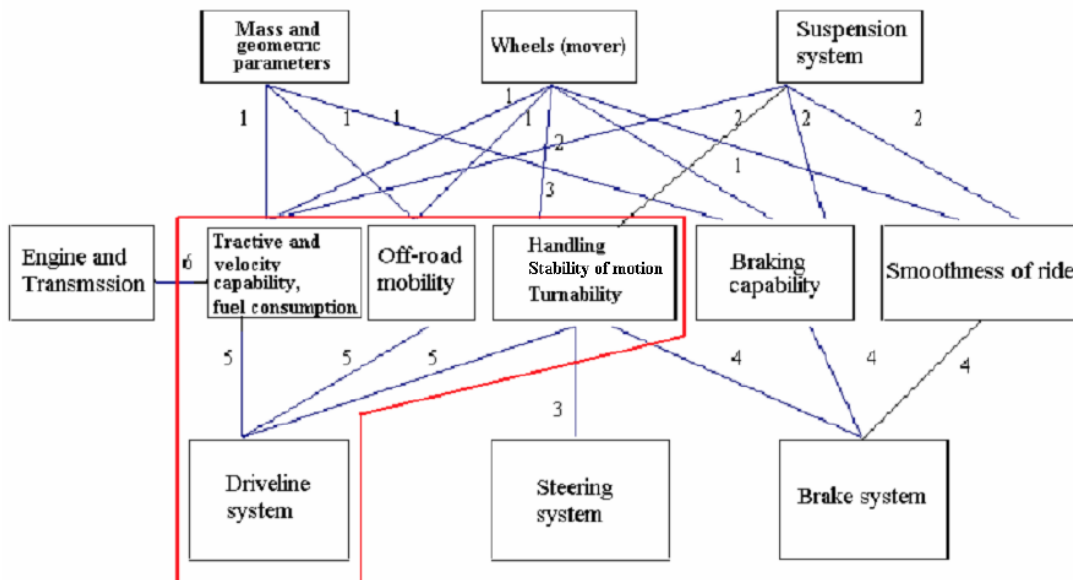
130. A third control strategy is taught for “off road” embodiments monitoring an array of vehicle operating conditions and wanting to enter 4WD more rapidly and automatically. In this “off-road” mode, one clutch is engaged to keep driveline 21 spun up continually and a second clutch is engaged when needed. The controller in Burrows can “predict when four wheel drive should be engaged and . . . automatically spin-up the auxiliary driveline 21 ready for automatic connection into four wheel drive mode.” (*Id.* at 10.)

## 2. Combination of Teraoka with Burrows

131. It is my opinion that it would not have been obvious to a person having ordinary skill in the art to implement rear axle speed synchronization in the vehicle of Teraoka in view of the teachings of Burrows.

### a. A Person Having Ordinary Skill in the Art Would Not Have Reason to Combine the Synchronization Techniques of Burrows into the Vehicle of Teraoka

132. Dr. Vladimir Vantsevich outlined the connection between the driveline system and various “operational properties,” which include tractive and velocity capability, fuel consumption, off-road mobility, handling, stability of motion, and turnability. (*Id.* at 4.) This connection is illustrated below:



**Ex. 2012, 2006 SAE Paper at 4.**

133. Any modification of the structure of the driveline system must

therefore take into consideration the resulting changes in the tractive and velocity capability, the fuel consumption, the off road capabilities, as well as the handling, stability of motion, and turnability.

134. The mode of operation (e.g., speed, acceleration, cornering, hill climbing, etc.) is of importance because the operational properties such as mobility, fuel consumption of the vehicle depend on the behavior of the vehicle. This behavior is known as the “vehicle dynamics,” which is controlled by such things as the vehicle mass, geometry, and suspension components (also shown in the figure above). The vehicle dynamics are also affected by the driver’s actions through the steering, braking, and throttle commands and the response by the engine and transmission. All of these interactions are shown in the figure above.

135. As explained above in the State of the Art, ¶¶39-46, when designing a driveline for a given vehicle, there are four principles of wheel power management that are to be taken into consideration.

136. Because the driveline system is interconnected with a large number of vehicle functions, the desired vehicular operational performance factors dictate the design. The first of four main principles adhered to in designing a driveline is that one must determine the total power required based on a given operational mode (desired vehicle motion) and the road/terrain conditions, and the vehicle dynamics. In other words, the driveline designer starts by asking what operational

performance factors are desired under what mode of operation, for what type of terrain, and for what type of vehicle. As Dr. Vatsovich writes in his textbook, “a number of driveline systems with various combinations of PDU<sup>16</sup> mechanisms and systems could be researched analytically for a given vehicle or vehicles based on some criteria of the vehicle’s properties *from the point of view of its operation and customer satisfaction.*” (Ex. 2036, Andreev Book at 114, emphasis added.)

137. Burrows is directed to an all-terrain vehicle (ATV) having selective 2WD and 4WD. (Ex. 1004, Burrows at 1:1-6.) ATVs are known for their off-road capabilities, giving the driver the ability to quickly accelerate and tightly steer the vehicle better than passenger cars over off-road terrains. (Ex. 2027, 1994 SAE Paper at 4.) Burrows sets out to solve a problem of “unacceptable jerk, i.e. a spasmodic acceleration” associated with the ATV when transitioning to 4WD. (*Id.* at 1:23-2:3.)

138. A designer tasked with designing a driveline, and working through the

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<sup>16</sup> Again, “PDU” stands for “power-dividing units,” which includes “open differentials and positively locked units, limited slip differentials with all kinds of torque biases, mechanically and electronically locked differentials, viscous couplings, NoSPINs, and . . . torque-vectoring or torque-management systems.” (Ex. 2036, Andreev Book at xv.)

four principles outlined above, would arrive at a very different driveline configuration for an ATV as opposed to a passenger car. This is due in part to the desired vehicular operational performance, which impacts the very first of these four principles – that one must determine the total power required *based on a given operational mode (desired vehicle motion) and the road/terrain conditions, and the vehicle dynamics*. (See ¶39 above; Ex. 2012, 2006 SAE Paper, at 5.) In short, the driveline would be designed and tailored to operate as an all-terrain vehicle (with the increased acceleration, handling, and turning capabilities on uneven and unpaved terrain) as compared to a passenger car.

139. Ex. 2027, 1994 SAE Paper is titled “Evaluation of a Proposed ATV Design Modification.” This publication supports the basic design principles outlined by Dr. Vantsevich, while applying these design principles to ATVs:

Successful development of a product requires the consideration and balancing of many design parameters. Proposals to modify designs that have been fully implemented and put into production are often made by people who were not involved in the original design process. Such proposals, commonly focusing on a specific aspect of the product, must be evaluated in the context of the overall product and its intended use by consumers; a design change may improve performance in one area but compromise performance in another, or even introduce new problem areas.

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Proposals to modify designs that have been fully implemented and put into production are often made by those outside and isolated from the original design process. These proposals may be made in the absence of all the experience and knowledge of the primary designer(s); the rationale for some or all of the trade-offs made during the initial design process may not be known. Though such proposals commonly focus on a specific aspect of the product, it is imperative that they be evaluated in the context of the overall product and its intended use by consumers.

(Ex. 2027, 1994 SAE Paper at 3 and 4.)

140. Understanding these design principles with both passenger cars and ATVs, one of ordinary skill in the art would not find synchronization techniques of an ATV's driveline (Burrows) to be a well-suited for a passenger vehicle's driveline (Teraoka). Doing so would require a complete re-testing of the driveline while adhering to the four main principles described above.

141. The synchronization techniques of Burrows would add unnecessary complexity to the vehicle. The synchronization control strategy outlined in Burrows accounts for "unacceptable jerk, i.e. a spasmodic acceleration" during use of an ATV in off-road conditions. (Ex. 1004, Burrows at 1:23-2:3.) This would be done by controls that place a priority on reducing the jerk and spasmodic accelerations that occur frequently with off-road driving on an ATV. Meanwhile, the passenger vehicle of Teraoka is more suited for typical, more subdued on-road

driving conditions. One of ordinary skill in the art, tasked with attempting to synchronize the speeds of the two-four switching mechanism of Teraoka, would not turn to a control strategy specifically designed for all-terrain conditions, as doing so would add complexity in the controls that is not needed and not justifiable.

**b. The Becker Declaration Fails to Properly Define What Is Being Combined And How the Combination Would be Achieved**

142. It is my understanding that an obviousness analysis should include a discussion of exactly *what* structure is being combined, and *how* that structure would be combined.

143. As explained above in ¶¶126-129, Burrows discloses at least three, distinct speed synchronizer mechanisms. In the basic 2-stage synchronization method, the transition from 4WD to 2WD

is controlled so that the auxiliary drive line 21 is reconnected to either the engine 11 or the second pair of wheels, typically the rear wheels 14, 15, to rotate at least part of the auxiliary drive line 21 for a sufficient time period prior to fully reconnecting it to provide drive torque to the rear wheels 14, 15. Thus transition to engagement of four wheel drive occurs in two stages, reducing any acceleration jerk perceived by the driver.

(Ex. 1004, Burrows, Abstract (emphasis added).)

144. According to Burrows, in order to “spin-up the auxiliary driveline 21

to the correct rotation speed . . . the first clutch connection should be engaged with the driveline for a minimum time period before the second clutch connection is completed. This time period is related to the speed of the vehicle.” (Ex. 1004, Burrows at 11.) When the driveline structure includes a dog clutch, Burrows recommends a separate four-stage synchronization method. (*Id.* at 10.)

145. By comparison, in Teraoka “[t]he controller simultaneously couples the two-four switching mechanism 7 and clutch mechanism 71 when switching from two-wheel drive state to four-wheel drive state and simultaneously uncouples them when switching from four-wheel drive state to two-wheel drive state.” (Ex. 1002, Teraoka at [0072] (emphasis added).)

146. However, the Becker Declaration never identifies which of the at least three multi-stage synchronizer mechanisms taught in Burrows would be suitable for combination with Teraoka, or how any of the multi-stage synchronization processes taught in Burrows could be integrated with Teraoka’s existing driveline – which is not directed to ATV applications – and what other modifications would need to be made thereafter.

**c. Teraoka Teaches Away from Implementing the Clutch of Burrows**

147. Teraoka teaches a dog clutch as its two-four switching mechanism for engaging and disengaging the secondary drive axle. See, for example, paragraph [0040] of Teraoka in which the two-four switching mechanism 7 is specifically

referred to as a dog clutch.

148. The use of a dog clutch as the two-four switching mechanism is for reduction in drag, which is otherwise present in multi-plate clutches such as the two-four switching clutch 22 of Burrows: “Since the dog clutch used in the two-four switching mechanism, unlike a friction clutch such as a multi-plate clutch, does not produce drag torque, it is especially well suited for the present invention, the object of which is to reduce drag torque.” (Ex. 1002, Teraoka at [0037].)

149. This passage from Teraoka confirms the knowledge of one of ordinary skill in the art that multi-plate clutches produce drag torque, while dog clutches do not produce drag torque. Reducing drag torque is the stated goal of Teraoka. *Id.* One of ordinary skill in the art would therefore not turn to Burrows and use its multi-plate wet clutch 22 in place of the dog clutch of Teraoka, as doing so would increase the drag in the system. Doing so is, in fact, specifically taught away from by Teraoka: “Since the dog clutch used in the two-four switching mechanism, unlike a friction clutch such as a multi-plate clutch, does not produce drag torque, it is especially well suited for the present invention, the object of which is to reduce drag torque.” (Ex. 1002, Teraoka at [0037].)

150. I understand that because the proposed modification of Teraoka with Burrows would render the reference inoperable for its purpose—reducing drag—the proposed obviousness combination lacks a motivation to combine.

**d. Combining Burrows with Teraoka Would be  
Hindsight Reconstruction of the Claims**

151. I understand hindsight reconstruction of a challenged patent claim is impermissible.

152. Burrows has a field of endeavor of maximizing vehicular capabilities by switching between 2WD and 4WD, specifically in an “all-terrain vehicle” in which driving over a “challenging terrain” is more prevalent.

153. Regarding synchronization, Burrows teaches that the process be done *quickly* in order to rapidly switch to 4WD to account for the rapid, perhaps often frequent changes in terrain realized by the all-terrain vehicle: the clutch 22 is used to “spin-up the auxiliary driveline 21 to the best synchronisation [*sic*] speed” before engaging the dog clutch in the differential, then the clutch 22 “*disengage[s]* *quickly*” while the synchronizer device engages the dog clutch, and after which the “clutch 22 then re-engages *quickly*.” (Ex. 1004, Burrows at 8:7-11.) This “*quick*” transition from 2WD to 4WD under all-terrain conditions accounts for what is usually accomplished with “unacceptable jerk, i.e. a spasmodic acceleration” in all-terrain conditions. (*Id.* at 1:25-2:3 and 8:7-11.)

154. Indeed, one of ordinary skill in the art would understand that a transition from 2WD to 4WD in an all-terrain vehicle should happen as quick as possible, to account for rapid changes in road terrain conditions that all-terrain vehicle are designed to drive on. Burrows is focused on such a transition.

155. Transitioning from 2WD to 4WD as quickly as possible can be done at the expense of undesirable fuel usage. In contrast, Teraoka strives to switch between 2WD and 4WD while *maximizing fuel economy*. (See, e.g., Ex. 1002, Teraoka at [0011], [0017], [0026], [0030], [0078], [0085], [0086], [0088], [0120], and [0122].) These paragraphs teach switching between 2WD to 4WD while *improving fuel efficiency*.

156. Since Teraoka strives to maximize fuel economy of its driveline system, one skilled in the art would have been discouraged from taking steps that would, in fact, degrade fuel economy. A person of skill in the art would therefore not reasonably have been led to implement the synchronizing mechanism of Burrows into the driveline of Teraoka without having the benefit of GKN's claims to use as a guide.

157. Furthermore, SAE articles supports the basic design principles outlined by Dr. Vantsevich in the context of ATVs. (See Ex. 2027, 1994 SAE Paper at 3-5.) Understanding that the process to design a driveline suited for a passenger vehicle such as Teraoka takes a significant amount of development, synthesizing, and testing, one of ordinary skill in the art would not reasonably have been led to implement the synchronization technique of the ATV of Burrows without having the benefit of GKN's claims to use as a guide.

## VII. Secondary Considerations and Conclusions

158. It is my understanding that objective evidence relevant to the issue of obviousness, sometimes referred to as “secondary considerations,” must also be evaluated in determining obviousness. Secondary considerations can include evidence of commercial success, long-felt but unsolved needs, failure of others, and unexpected results.

159. It is my opinion that there are several instances of objective indications that would evidence a conclusion that the claims of the ‘440 patent are not obvious.

160. Several publications have praised the industry success of GKN’s own dual-clutch driveline system with a shutdown section and disconnectable secondary axle, known by the name of “Twinstar.” The Twinstar system was first introduced in the Range Rover Evoque vehicle, and since then has expanded to the Buick LaCrosse, Cadillac XT5, the GMC Acadia and several other GM vehicles. (See, generally, Ex. 2028, Autonews Article;<sup>17</sup> *see also* Ex. 2029, Gas2.org Article.

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<sup>17</sup> Ex. 2028 is a true and accurate copy of an Autonews web article located at <http://www.autonews.com/article/20151221/RETAIL/312219981/gm-seeks-a-market-beyond--the-snow-belt-for-awd-models>, dated December 21, 2015.

<sup>18</sup>) It is my understanding that the Twinstar system has been/is slated for introduction in 24 vehicle launches between 2015-2019.

161. GKN received a 1<sup>st</sup> place 2016 Pace award regarding its collaborative work with Ford on the development of the torque vectoring capability for Twinstar. I further understand that the Twinstar technology has recently been nominated for another Automotive News PACE Innovation Award. (Ex. 2030, PR Newswire Article.)

162. The Twinstar system adds two electronically controlled clutches to the rear axle in place of the traditional mechanical differential, which I understand is a subject of the '440 patent. (*Id.*) The cited articles explain the benefits of “torque vectoring,” which is a “way to not only send power to a wheel with traction but also enhance cornering ability by delivering more power to the outside wheel, which helps the car turn.” (Ex. 2029, Gas2.org Article.) This is accomplished by a “twin clutch system” that enables application of “torque to one or both wheels independently, enabling the vehicle’s dynamic torque vectoring functions across its

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<sup>18</sup> Ex. 2029 is a true and accurate copy of a Gas2.org web article titled “General Motors Will Introduce Dual Clutch AWD On More Cars,” located at <http://gas2.org/2015/12/23/general-motors-will-introduce-dual-clutch-awd-on-more-cars/>.

entire speed range.” (Ex. 2026, <http://www.gkn.com/frankfurt/news-and-Media/Pages/GKN-supplies-innovative-AWD-system-to-Ford-Focus-RS.aspx>.)

The benefits of implementing the Twinster dual-clutch mechanism into controllably connectable AWD vehicles is also noted: The Twinster can “disconnect the rear wheels entirely in certain circumstances to boost fuel economy on the open road,” and so “[a]s OEMs get more and more worried about saving fuel, having these twin clutches is the most efficient way to disconnect the rear while still being able to offer all wheel drive to customers who need it.” (Ex. 2029, Gas2.org Article.) Through the introduction of the combination of a shutdown section and a switching mechanism in the driveline, the disconnect function helps boost fuel economy.

163. The success of the program is planning to spread to other GM vehicles as well. (Ex. 2029, Gas2.org Article.)

164. Furthermore, the combination of the fictionally-engaged side shaft couplings with the switch-on mechanism for shutting down a portion of the driveline has been praised in the industry for being part of “several new technologies which, combined, can lower fuel consumption by up to 11.4% and reduce CO<sub>2</sub> emissions by up to 9.5%” in the 2014 Range Rover Evoque. (Ex.

2031,<sup>19</sup> Green Car Congress Article; Ex. 2030, PR Newswire Article.<sup>20</sup>) The combination of the side shaft couplings and the switch-on mechanism are noted to allow a switch between 2WD and 4WD within a mere 300 milliseconds, limiting the amount of time for any transitional power losses. (*Id.*)

165. This commercial success and long-felt need in the industry is possible due to the hardware and structure of the Twinstar GKN device (explained above), which is the subject of the ‘440 patent. The implementation of the dual-clutch mechanism instead of a differential, coupled with the ability to switch between 2WD and 4WD modes, has allowed this commercial success. Such evidence is consistent with my opinion that it would not have been obvious at the time of the invention of the ‘440 patent to combine the teachings of Teraoka with either Watanabe or Burrows to arrive at the claimed invention.

166. I conclude that the lack of motivation to combine either the Watanabe

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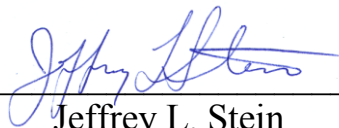
<sup>19</sup> Ex. 2031 is a true and accurate copy of a Green Car Congress web article titled “GKN Driveline on-demand all-wheel drive system contributes to improved fuel consumption in 2014 Range Rover Evoque,” dated September 5, 2013.

<sup>20</sup> Ex. 2030 is a true and accurate copy of a PR Newswire article titled “GKN Driveline honored with two Automotive News PACE awards,” dated April 12, 2016.

or Burrows references with Teraoka establishes non-obviousness, and that this conclusion is further bolstered by the presence of industry praise and commercial success for the claimed invention.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: June 7, 2016

  
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Jeffrey L. Stein