

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LIBERTY ENERGY INC. AND LIBERTY ENERGY SERVICES LLC,
Petitioners,

v.

U.S. WELL SERVICES HOLDINGS, LLC,
Patent Owner.

Case IPR2025-00105
Patent No. 11,959,533

DECLARATION OF DR. ROBERT A. DURHAM

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4. 22[c]: a plurality of input pinion gears, each driven by a respective one of the plurality of electric motors;	280
5. 22[d]: a main gear driven by the plurality of input pinion gears, the main gear comprising external gear teeth that mate with external gear teeth of the plurality of input pinion gears;	280

6. 22[e]: a sun gear driven by the main gear and connected to the main gear by a shaft;280
7. 22[f]: planetary gears driven by the sun gear, the planetary gears each comprising external gear teeth that mate with external gear teeth of the sun gear; and280
8. 22[g]: a final drive gear driven by the planetary gears, the final drive gear comprising internal gear teeth that mate with the external gear teeth of the planetary gears; and281
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I, Robert A Durham, hereby declare as follows:

I. INTRODUCTION & QUALIFICATIONS

1. My name is Dr. Robert A. Durham. I make this declaration based upon my own personal knowledge and, if called upon to testify, would testify competently to the matters contained herein.

2. I have been asked to provide technical assistance in the *inter partes* review of U.S. Patent No. 11,959,533, which I may abbreviate as “the ’533 Patent” or refer to as the “Challenged Patent.” This declaration is a statement of my opinions on issues related to the unpatentability of claims of the ’533 Patent. I am being compensated at my normal hourly rate for my analysis, plus reimbursement for expenses. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

3. In formulating my opinions, I have relied upon my knowledge, training, and experience in the relevant art. My qualifications are stated more fully in my curriculum vitae, which has been provided as Appendix A. My CV also lists publications on which I am a named author and identifies parties on behalf of whom I have previously provided expert testimony within the past four years. Here, I provide a brief summary of my qualifications.

4. I am a consulting engineer with experience in a number of technical areas. I have expertise in the oil and gas industry from drilling and completion to

downstream. I have been working with oil field production companies, refining and chemical plants and equipment manufacturers and technology development companies, as a consultant, for nearly twenty years. My work relates to the subject matter of the '533 Patent, which I describe below in Section VI (“Overview of the Challenged Patent”).

5. I received my Bachelor of Science in Electrical Engineering and Master of Engineering and Technology Management degrees, from the University of Tulsa in 1992 and 1997, respectively. After years of professional work and research I received my Ph.D. in Engineering Management from Kennedy Western University in 2004.

6. I have also served in positions of leadership in the Petroleum and Chemical Industry Committee (PCIC) of the Institute of Electrical and Electronics Engineers (IEEE) for nearly twenty years. IEEE is the world’s largest technical professional association. The PCIC is the premier forum for the exchange of electrical applications technology related to the petroleum and chemical industry. From 2005 – 2012, I served as secretary, then vice chair and then ultimately chair of the Production Subcommittee of the PCIC. The Production Subcommittee is the primary method for PCIC members to communicate technical papers related to drilling, well head, and facilities operations of oil and gas wells. In 2013, I was appointed as Vice-Chair of the Standards Subcommittee of the PCIC, a role which

transitioned to Chair in 2014. I served as Chair until 2022. The Standards Subcommittee of the PCIC is the Sponsor of IEEE standards relating to electrification and electrical equipment operations in the Oil and Gas Industry. The PCIC Standards Subcommittees sponsors nearly 50 electrical and oil and gas related standards. In September 2022, I was elected as an Executive Officer of the PCIC. I will serve as an Executive Officer for a total of eight years, serving two-year terms in each of the following positions: Secretary; Vice Chair; Chair; and Chair of Advisory and Awards.

7. My peers have recognized my contributions, particularly in the area of electrical equipment in the oil and gas industry. Because of this recognition, in 2019 I was elevated to the grade of Fellow of the IEEE for “contributions to submersible electrical equipment analysis and multi-point ground methods in hazardous petroleum and chemical environments.” The IEEE Fellow grade is limited to the top 0.1% of the membership of IEEE worldwide.

8. I have worked directly in the area of electrification of oil and gas fields both as an employee and as a consulting engineer. From 2000 until the end of 2002, I was employed as Manager of Electric Infrastructure for New Dominion, LLC (NDL). In that capacity I administratively owned and was responsible for all electrical equipment including overhead power lines, transformers, switchgear, drives and motors throughout NDL’s production, exploration and drilling areas.

9. After a brief stint as Vice President for EDG Power Group, responsible for Engineering and Project Management of generation and co-generation facilities across the U.S., I transitioned to the role of consulting engineer. In that role I have served as consulting engineer relating to the design, construction, and analysis of all kinds of power systems, especially those in the oil and gas industry. This has included not only design and selection of equipment but also analysis of failures of equipment in the oil and gas field from drilling / completion sites to production facilities, midstream and downstream (refinery) locations.

10. In addition, I am a principal of PEDOCS, Inc., an oil and gas production company operating over 50 oil and gas production wells in Oklahoma. As such, I am familiar with operations of oil and gas wells including well stimulation, completion, hydraulic fracturing and production.

11. I have been familiar with oil and gas drilling, fracturing (fracking), completion, production, midstream and downstream operations for over twenty years.

12. I have been familiar with power distribution, including generation transmission and distribution equipment. As an employee I worked as a design and construction engineer for generation facilities for Central and Southwest (now American Electric Power AEP). I was also responsible for design and construction of generation facilities when employed by EDG Power Group, as discussed above.

While at AEP, I spent three years as a transmission planner, responsible for modeling transmission systems and developing plans for increased power distribution capacities at high voltages. While at New Dominion LLC, I owned and was responsible for design, construction and maintenance of several hundred miles of medium voltage (5 – 25 kV) distribution lines, switchgear, drives and motors used for oil and gas drilling, completion and production. Over the last ~ 20 years I have consulted with numerous clients ranging from utilities to oil and gas development and production companies on the design, upgrades and maintenance of generation and power distribution facilities.

13. I have been familiar with the design, installation, tuning, and programming of process control systems for nearly my entire career. As an engineering intern, and later as engineer, for Central & Southwest (now AEP), I was responsible for the design, configuration and installation of control systems for continuous process operations in power generation applications. These included relatively simple systems, such as process air control or treatment of water for general use, so called “service water”. Additionally, I worked on much more advanced control systems such as boiler water feed, ASD (VFD) control for combustion air, and control of the entire steam generating, recovery and reuse process for steam driven turbines. As chief electrical engineer (later VP of Engineering & PM) at EDG Power Group, I had primary responsibility for the design

and configuration of control systems for gas turbine generators, as well as heat recovery systems to heat water for use in associated applications, such as refinery steam or hot water driven heating / cooling operations. Further, I have consulted on several control system projects, both inside and outside the oil and gas industry, over the past 20 plus years as a consultant. I am a licensed professional controls engineer.

14. I have been familiar with Occupational Safety and Health Administration (“OSHA”) and its responsibilities at oil and gas locations. I have consulted and investigated incidents on multiple oil and gas sites where OSHA has also performed investigations with regard to injuries and fatalities that have occurred at oil and gas locations, including drilling, fracturing and completion operations. As Principal Scientist of THEWAY Labs, part of my responsibilities include overseeing the Health Safety and Environmental (HSE) program at THEWAY Labs, including establishing policies and procedures commensurate with OSHA requirements at all locations, including requirement for oil and gas sites.

15. I am the author or co-author of over fifty published papers and five books. A list of publications that I have authored over the last thirty years is included in my professional CV, which is attached as Appendix A.

16. Therefore, based on my education, professional experience of over 30 years, and scholarly books and publications, I am an expert in the relevant field of the ’533 Patent and have been an expert in this field since before the ’533 Patent was

filed with the United States Patent and Trademark Office (“USPTO”). I am familiar with how a person having ordinary skill in the art would have understood and used the terminology found in the ‘533 Patent at the time of filing.

II. TASK SUMMARY AND MATERIALS REVIEWED

17. I have been asked to review the Challenged Patent and its prosecution history, to provide an understanding of the technology relevant to the Challenged Patent, to review certain prior-art references, and analyze whether or not those references disclose or teach limitations of claims from the Challenged Patent. The opinions stated in this declaration are from the perspective of a person of ordinary skill in the art (POSITA).

III. LIST OF EXHIBITS

18. In forming my opinions, I have reviewed the Challenged Patent, its prosecution history and references cited by the Examiner, the materials cited in the List of Exhibits, and the materials cited throughout my declaration.

Ex.	Description
1001	U.S. Patent No. 11,959,533 to Oehring et al. entitled “Multi-plunger Pumps and Associated Drive Systems” (the “’533 Patent”)
1002	File History for U.S. Patent No. 11,959,533
1003	Declaration of Dr. Robert Durham

1004	U.S. Patent Publication No. 2020/0256429 to Buckley, “Electric Drive Pump for Well Stimulation,” (“Buckley”) filed September 25, 2018 and published August 13, 2020.
1005	U.S. Provisional Application No. 62/562,943 to Buckley et al., “Electric Drive Pump for Well Stimulation,” (“Buckley Provisional”) filed September 25, 2017.
1006	U.S. Patent Publication No. 2015/0361736 to Bergan et al., “Heave Compensation Winches,” (“Bergan”), filed June 13, 2014 and published December 17, 2015.
1007	United States Patent No. 4,100,822 to Rosman, “Drive System for a Moving Mechanism,” (“Rosman”) filed April 19, 1976 and granted July 18, 1978.
1008	U.S. Patent Publication No. 2016/0533267 to Payne et al., “Well Fracturing Systems with Electrical Motors and Methods of Use” (“Payne”), filed March 3, 2016 and published September 8, 2016.
1009	Chinese Publication No. CN103742382A to Yi, “Fracturing Pump Transmission System and Fracturing Truck,” (“Yi”), filed December 30, 2013 and published April 23, 2014.
1010	Certified English Translation of Yi and Translator’s Declaration
1011	Merriam-Webster Online Dictionary, “Pinion,” captured by the Internet Archive on August 17, 2017, available at https://web.archive.org/web/20170817030125/https://www.merriam-webster.com/dictionary/pinion .
1012	D. T. Jelaska, Gears and Gear Drives. John Wiley & Sons, 2012.
1013	V. Tutterow and A. T. McKane, “Variable Speed Pumping: A Guide to Successful Applications,” Europump and Hydraulic Institute, 2004.
1014	August, R. et al., “Dynamics of Planetary Gear Trains,” NASA Contractor Report 3793, June 1984 (“August”).
1015	U.S. Patent Publication No. 2016-03690609 to Morris et al., “Mobile Fracturing Pump Transport for Hydraulic Fracturing of Subsurface Geological

	Formations,” (“Morris”), filed August 31, 2016 and published December 22, 2016.
1016	United States Patent No. 6,907,667 to Joyner et al., “Method for Facilitating the Assembly of a Universal Joint,” (“Joyner”) filed October 14, 2002 and granted June 21, 2005.
1017	Karassik, Igor J., et al., “Pump Handbook,” McGraw-Hill, 2008.
1018	Intentionally omitted
1019	Intentionally omitted
1020	Intentionally omitted
1021	Intentionally omitted
1022	Declaration of Sylvia Hall-Ellis, Ph.D.
1023	Claim Listing for Claims of ’533 Patent
1024	Morton, M., “Unlocking the Earth: A Short History of Hydraulic Fracturing,” GEO ExPro, Vol. 10, No. 6, December 2013 (https://geoexpro.com/unlocking-the-earth-a-short-history-of-hydraulic-fracturing/) (last accessed September 16, 2024).
1025	Wells, B.A., Wells, K.L., “Shooters – A “Fracking” History,” American Oil & Gas Historical Society, https://aoghs.org/technology/hydraulic-fracturing , last updated March 7, 2024.
1026	Montgomery, Carl T., Smith, Michael B., “Hydraulic Fracturing, a History of an Enduring Technology,” Journal of Petroleum Technology 62 (12), December 2010.
1027	Bourgoyne, Adam T. Jr., et al., “Applied Drilling Engineering,” Society of Petroleum Engineering Textbook Series, Volume 2, 1986.
1028	Vasilliou, Marius S., “Historical Dictionary of the Petroleum Industry,” Second Edition, Rowman & Littlefield, 2018.

1029	U.S. Patent Publication No. 2013/0306322 to Sanborn et al., entitled “System and Process for Extracing Oil and Gas by Hydraulic Fracturing” (filed Dec. 7, 2012 and published Nov. 21, 2013).
1030	U.S. Patent Publication No. 2012/0255734 to Coli et al., entitled “Mobile, Modular, Electrically Powered System for Use in Fracturing Underground Formations” (filed April 6, 2012 and published Oct. 11, 2012).
1031	Gardner Denver GD-2500 Quintuplex Well Servicing Pump Operating and Service Manual, captured by the Internet Archive on Sept. 17, 2005, available at < https://web.archive.org/web/20120917102614/http://www.quincieoilfield.com/pdf/3.0%20Gardner%20Denver/2500/GD2500Q%20Op%20&%20Service%20Manual.pdf >.
1032	Merriam-Webster Online Dictionary, “Quintuple,” captured by the Internet Archive on February 2, 2017, available at < https://web.archive.org/web/20170202121725/https://www.merriam-webster.com/dictionary/quintuple >.
1033	Mark’s Standard Handbook for Mechanical Engineers, Eleventh Edition, McGraw-Hill Companies, New York, 2007.
1034	Nesbitt, B., “Handbook of Pumps and Pumping: Pumping Manual International,” Elsevier, 2006.
1035	Langewis, Jr., C. and Gleeson, C. W., “Practical Hydraulics of Positive Displacement Pumps for High-Pressure Waterflood Installations,” Society of Petroleum Engineers, February 1971.
1036	Lewis, M. J. T., “Gearing in the ancient world,” Pergamon Press Ltd. 1993.
1037	Mabie, H. H., Reinholtz, C. F., “Mechanics and Dynamics of Machinery,” (4th Ed., 1987), John Wiley & Sons.
1038	Pawar, P. V. and Kulkarni, P. R., “Design of two stage planetary gear train for high reduction ratio,” International Journal of Research in Engineering and Technology, vol. 4, no. 6, pp. 150-157, June 2015.

1039	Camara, John A., "Electrical Engineering Reference Manual for the Electrical and Computer PE Exam," 6th ed. (Professional Publications, Inc. 2002), ISBN: 1-888577-56-8.
1040	Fink, Donald G., Standard Handbook for Electrical Engineers, 13th ed. (McGraw-Hill, New York: 1993), ISBN: 0-07-020984-7.
1041	U.S. Patent Publication No. 2011/0241590 to Horikoshi et al., entitled "Motor Driving Apparatus Having Fault Diagnostic Function" (filed Feb. 11, 2011 and published Oct. 6, 2011).
1042	Roethemeyer, Dale E., Yankaskas, David R., "Evolution of Motor and Variable Frequency Drive Technology," in ACEEE Summer Study Proceedings on Energy Efficiency in Industry, 1995, pp. 541-552.
1043	U.S. Patent No. 3,186,222 to Martin, "Well Signaling System," filed July 28, 1960 and issued June 1, 1965.
1044	U.S. Patent No. 3,075,136 to Jones, "Variable Pulse Width Parallel Inverters," filed August 31, 1961 and issued January 22, 1963.
1045	U.S. Patent No. 3,262,036 to Clarke et al, "Means for Smoothly Varying the Speed of a Star-Connected Polyphase Induction Motor," filed September 19, 1962 and issued July 19, 1966.
1046	Shepherd, William and Stanway, Jack, "Unbalanced Voltage Control of 3-Phase Loads by the Triggering of Silicon Controlled Rectifiers," IEEE Transactions on Industry and General Applications, no. 3, pp. 206-216, 1965.
1047	Hickok, H. N., "Adjustable Speed—A Tool for Saving Energy Losses in Pumps, Fans, Blowers, and Compressors," IEEE Transactions on Industry Applications, no. 1, pp. 124-136, 1985.
1048	DeWinter, Frank A. and Kedrosky, Brian J., "The Application of a 3500-hp Variable Frequency Drive for Pipeline Pump Control," in IEEE Transactions on Industry Applications, Vol. 25, No. 6, 1019-1024 1989.
1049	Perrin, M., Kohn, G., Mugford, S., Seggewiss, G., "Induction Motors, Reciprocating Compressors and Variable Frequency Drives," Record of Conference Papers. IEEE Industry Applications Society 44th Annual

	Petroleum and Chemical Industry Conference, 15-17 Sept. 1997 1997, pp. 1-9, doi: 10.1109/PCICON.1997.648162.
1050	Lockley, B., Wood, B., Paes, R., DeWinter, F., “IEEE Std 1566 - The Need for a Large Adjustable Speed Drive Standard,” in 2006 Record of Conference Papers - IEEE Industry Applications Society 53rd Annual Petroleum and Chemical Industry Conference, 11-15 Sept. 2006, pp. 1-10, doi: 10.1109/PCICON.2006.359687.
1051	Manz, L. B., "The motor designer's viewpoint of an adjustable speed drive specification," IEEE Industry Applications Magazine, vol. 1, no. 1, pp. 16-21, 1995.
1052	Baseer, M., “Electric Machines and Adjustable Speed Drives,” in University of Bradford Electric and Telecommunications Research Seminar Series, 8th Workshop Proceedings, April 1, 2009, 131-134.
1053	U.S. Patent No. 9,410,410 to Broussard et al., entitled “System for Pumping Hydraulic Fracturing Fluid using Electric Pumps” (filed Nov. 16, 2012 and issued Aug. 9, 2016).
1054	Johns, Cort MacLean, “Industrial Revolutions: From Ctesibius to Mars,” ABC Book Center, 2021.

IV. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE

19. After reviewing the materials identified in the List of Exhibits, I have concluded that each of the Challenged Claims of the '533 Patent would have been obvious to a person of ordinary skill in the art, based on the following grounds.

Ground	'533 Claims	Basis for Challenge
1A	1-4, 10-13	Obvious over <i>Buckley</i> in view of <i>Bergan</i> , <i>August</i> , <i>Joyner</i> , <i>Morris</i>

1B	1, 3, 4, 10, 12, 13	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris</i>
2A	5, 6, 14, 15	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, Karassik</i>
2B	5, 6, 14, 15	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, Karassik</i>
3A	7, 16	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, Payne</i>
3B	2, 7, 11, 16	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, Payne</i>
4A	8, 9, 17, 18, 22	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, Rosman</i>
4B	8, 9, 17, 18	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, Rosman</i>
5A	19	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, the Knowledge of a POSITA and, in the alternative, Jelaska</i>
5B	19	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, the Knowledge of a POSITA and, in the alternative, Jelaska</i>
6A	20, 21	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, the Knowledge of a POSITA and, in the alternative, Jelaska and Tutterow</i>
6B	20, 21	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, the Knowledge of a</i>

		POSITA and, in the alternative, <i>Jelaska and Tutterow</i>
7A	23	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, Rosman, Payne</i>
7B	22, 23	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, Rosman, Payne</i>
8A	24, 25	Obvious over <i>Buckley</i> in view of <i>Bergan, August, Joyner, Morris, Rosman, Payne, Karassik</i>
8B	24, 25	Obvious over <i>Yi</i> in view of <i>Bergan, August, Joyner, Morris, Rosman, Payne, Karassik</i>

V. LEGAL STANDARDS

A. LEVEL OF ORDINARY SKILL IN THE ART

20. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to the patent-in-suit as well as the level of ordinary skill in that art at the time of the claimed invention. The “art” is the field of technology to which the patent is related.

21. I have been instructed by counsel that the person of ordinary skill in the art (“POSITA”) is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. I further understand that the factors that may be considered in

determining the level of skill include: the types of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field. I understand that not all such factors may be present in every case, and one or more of them may predominate.

B. LEGAL STANDARD FOR CLAIM CONSTRUCTION

22. I understand that the first step in determining whether a patent claim would have been anticipated or obvious is to ascertain how a POSITA would have understood the claim terms.

23. I have been instructed by counsel on the law regarding claim construction and patent claims, and I understand that a patent may include two types of claims: independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim, or it can further depend from another dependent claim. I understand that a dependent claim includes all the limitations that it recites, in addition to all the limitations recited in the claim(s) from which it depends.

24. It is my understanding that in proceedings before the USPTO, the claims of a patent are to be construed under what is referred to as the “Phillips standard.” I understand that this means that claim terms of a patent are given the

meaning the terms would have to a POSITA, in view of the description provided in the patent itself and the patent's file history.

25. I understand that to determine how a person of ordinary skill would understand a claim term, one should look to those sources available that show what a person of skill in the art would have understood the disputed claim language to mean. I understand that, in construing a claim term, one looks primarily to the intrinsic patent evidence, including the words of the claims themselves, the remainder of the patent, and the patent's prosecution history. I understand that extrinsic evidence, which is evidence external to the patent and the prosecution history, may also be useful in interpreting patent claims when the intrinsic evidence itself is insufficient.

26. I understand that words or terms should be given their ordinary and accepted meaning unless it appears that the inventors were using them to mean something else. In making this determination, the claims, the remainder of the patent, and the prosecution history are of paramount importance. Additionally, the patent and its prosecution history must be consulted to confirm whether the patentee has acted as its own lexicographer (i.e., provided its own special meaning to any disputed terms), or intentionally disclaimed, disavowed, or surrendered any claim scope.

27. In comparing the claims of the Challenged Patent to the prior art, I have considered the Challenged Patent and its file history in light of the understanding of a person of skill at the time of the alleged invention.

C. ANTICIPATION

28. It is my understanding that the claims of a patent are anticipated by a prior art reference if each and every element of the claim is found either explicitly or inherently in a single prior art reference or system. I understand that inherency requires a showing that the missing descriptive matter in the claim is necessarily or implicitly present in the allegedly anticipating reference, and that it would have been so recognized by a POSITA. In addition, I understand that an enabling disclosure is a disclosure that allows a POSITA to make the invention without undue experimentation. Although anticipation typically involves the analysis of a single prior art reference, I understand that additional references may be used to show that the primary reference has enabling disclosure, to explain the meaning of a term used in the primary reference, and/or to show that a characteristic is inherent in the primary reference.

D. OBVIOUSNESS

29. I understand that the prior art may render a patent claim “obvious.” I understand that two or more prior art references (e.g., prior art articles, patents, or publications) that each disclose fewer than all elements of a patent claim may

nevertheless be combined to render a patent claim obvious if the combination of the prior art collectively discloses all elements of the claim and one of ordinary skill in the art at the time would have been motivated to combine the prior art in such a way. I understand that this motivation to combine need not be explicit in any of the prior art, but may be inferred from the knowledge of one of ordinary skill in the art at the time the patent was filed. I also understand that one of ordinary skill in the art is not an automaton, but is a person having ordinary creativity. I further understand that one or more prior art references, articles, patents or publications that disclose fewer than all of the elements of a patent claim may render a patent claim obvious if including the missing element would have been obvious to one of skill in the art (e.g., the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system).

30. I understand that under the doctrine of obviousness, a claim may be invalid if the differences between the invention and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a POSITA to which the subject matter pertains.

31. To assess obviousness, I understand that I am to consider the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in the art, and any secondary considerations to the extent they exist.

32. I understand that any evidence of secondary indicia of non-obviousness should be considered when evaluating whether a claimed invention would have been obvious to one of ordinary skill at the time of invention. These secondary indicia of non-obviousness may include, for example:

- a long felt but unmet need in the prior art that was satisfied by the claimed invention;
- commercial success of processes claimed by the patent;
- unexpected results achieved by the invention;
- praise of the invention by others skilled in the art;
- the taking of licenses under the patent by others; and
- deliberate copying of the invention.

33. I understand that there must be a nexus between any such secondary indicia and the claimed invention.

34. It is also my understanding that there are additional considerations that may be used as further guidance as to when the above factors will result in a finding that a claim is obvious, including the following:

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;

- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;
- the claimed subject matter would have been “obvious to try” choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent’s claims; and
- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

35. Finally, I understand that a claim may be deemed invalid for obviousness in light of a single prior art reference, without the need to combine references, if the elements of the claim that are not found in the reference can be supplied by the knowledge or common sense of one of ordinary skill in the relevant art.

E. PRIORITY DATE

36. I understand that, subject to the next paragraph, the asserted “priority date” of a patent is the earlier of: (a) the date on which a patent application is filed; or (b) the date on which an earlier-filed patent application is filed if the patentee claims the benefit of priority to that earlier-filed patent application.

37. I understand that it is not enough for a patent to merely claim the benefit of an earlier-filed application, but that additional criteria must be met. In particular, the prior application itself must describe the claimed invention, and must do so in sufficient detail that one skilled in the art can clearly conclude that the inventor invented the claimed invention as of the filing date sought. First, I understand that a priority-date analysis is on a claim-by-claim basis. Second, I understand that, in order for a patent claim to be entitled to the filing date of an earlier patent application, a “Section 112 analysis” must be conducted. I am informed that a “Section 112” analysis encompasses looking to the earlier patent application, and ascertaining whether that earlier patent application meets both the written-description and enablement requirements as of the filing date of the earlier application. I understand that it is not enough that the claim would have been obvious from the earlier application, but that application itself must describe the claimed invention.

38. I understand that in order to satisfy the written description requirement the earlier application must reasonably convey to those skilled in the art that the inventors had possession of the subject matter of the patent as of the filing date of the earlier application. I have been informed that it is the disclosures of the earlier patent application that count, and that while the meaning of terms, phrases, or diagrams in the earlier patent application must be interpreted from the vantage point of one skilled in the art, all of the claimed limitations must appear in the

specification. Further, I understand that this analysis is not a question of whether one skilled in the art might be able to construct the claimed invention from the teachings of the disclosure. The question is not whether a claimed invention is an obvious variant of that which is disclosed in the specification; rather, I understand that an earlier application must itself describe each of the claim limitations.

39. I also understand that in order to satisfy the enablement requirement, the earlier application must enable a person of ordinary skill in the art to practice the claimed invention without undue experimentation.

VI. OVERVIEW OF THE CHALLENGED PATENT

40. I have reviewed U.S. Patent No. 10,655,435 (“the ’533 Patent”), which is entitled “Smart Fracturing System and Method.” I understand that the patent was filed on October 25, 2018, and that it was issued on May 19, 2020. The ’533 Patent claims priority to Provisional application No. 62/577,056 filed on October 25, 2017.¹

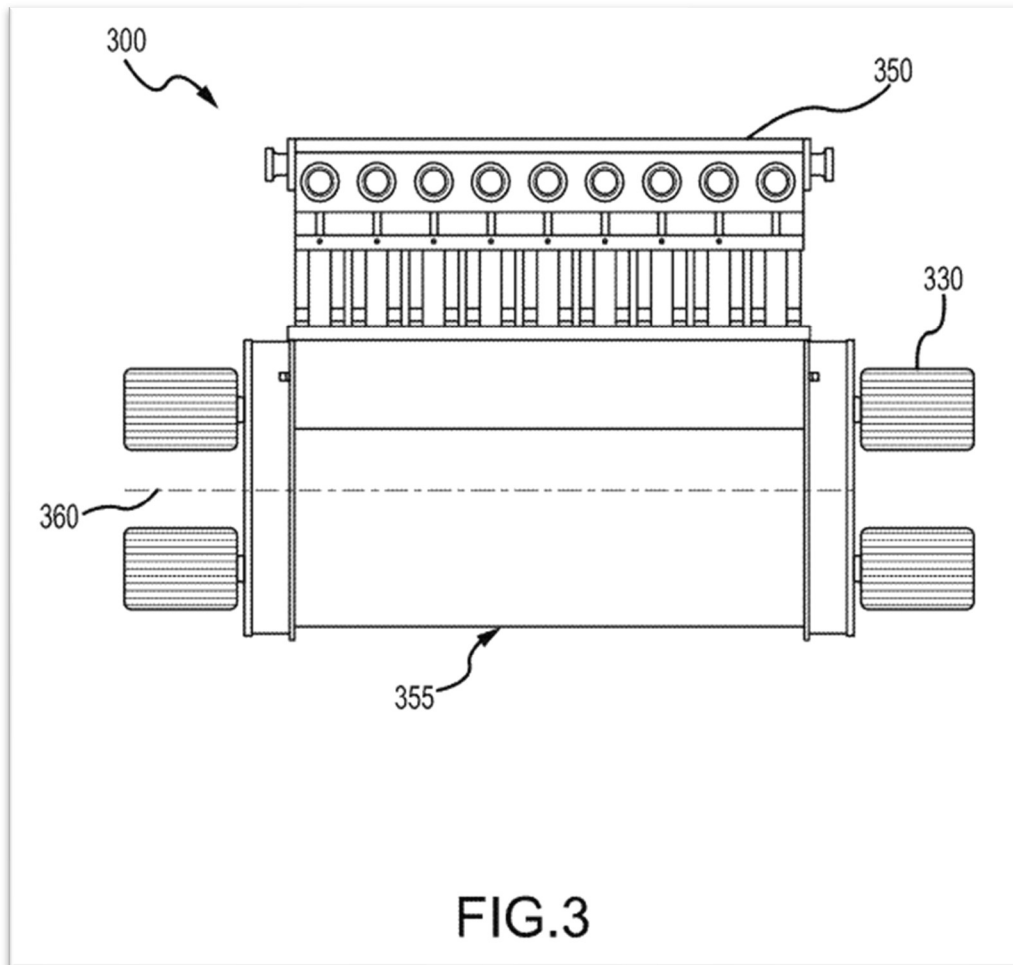
A. THE SUBJECT MATTER OF THE CHALLENGED PATENT

41. The ’533 Patent generally relates to “drive systems for reciprocating plunger-style pumps used in hydraulic fracturing operations, and more particularly to multi-plunger hydraulic fracturing pumps and associated drive systems.”²

¹ Ex. 1001 Cover.

² Ex. 1001, 1:22-25.

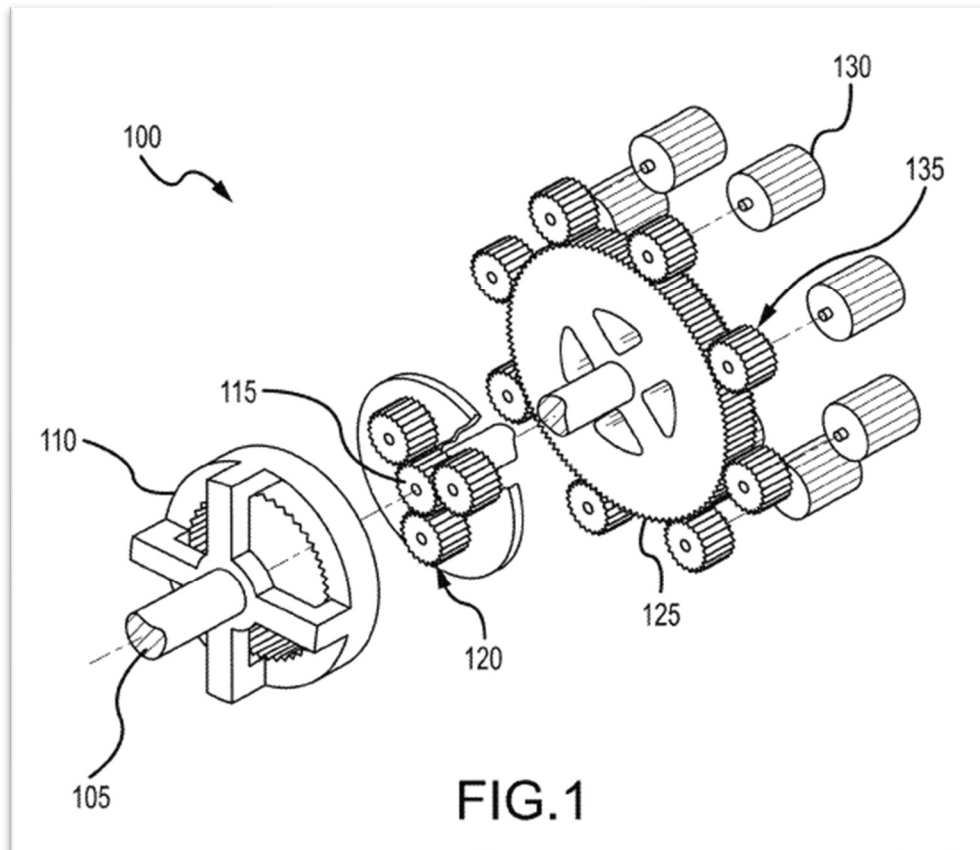
42. The system taught by the '533 Patent includes a “multi-plunger hydraulic pump” that is powered by a “plurality of motors,” which may be electric motors or hydraulic motors.³ Figure 3 of the '533 Patent depicts this configuration:⁴



³ Ex. 1001, 2:50-3:7.

⁴ Ex. 1001 ('533 Patent), Fig. 3 (showing pump 300, multi-plunger fluid end 350, motors 330, and crankshaft centerline 360, *id.*, 8:41-64).

43. The system further includes a “planetary gear train having a plurality of input pinion gears in rotational contact with each of the plurality of motors.”⁵ An example of this planetary gear train is depicted in Figure 1 below:⁶



44. Further, the electric motors may be connected to a “variable frequency drive (VFD)” that “control[s] the speed of the plurality of motors.”⁷

⁵ Ex. 1001, 2:62-64.

⁶ Ex. 1001, Fig. 1.

⁷ Ex. 1001 3:2-24.

B. THE CHALLENGED CLAIMS OF THE '533 PATENT

45. The Challenged Claims of the '533 Patent, which are Claims 1-20, are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Ex. ⁸	Description
1[p]	1. A hydraulic fracturing system for fracturing a subterranean formation comprising:
1[a]	a multi-plunger hydraulic fracturing pump configured to pump fluid to a wellbore associated with the subterranean formation, the multi-plunger hydraulic fracturing pump comprising a pump crankshaft;
1[b]	a plurality of motors positioned to power the multi-plunger pump; and
1[c]	a planetary gear train positioned to translate power from the plurality of motors to the pump crankshaft of the multi-plunger hydraulic fracturing pump,
1[d]	the planetary gear train comprising: a plurality of input pinion gears connected to the plurality of motors,
1[e]	and a final drive gear connected to the pump crankshaft of the multi-plunger hydraulic fracturing pump by a plurality of arms extending from the final drive gear.
2	2. The hydraulic fracturing system of claim 1, wherein the plurality of motors comprises a plurality of electric motors, and each of the plurality of input pinion gears is connected to a respective one of the plurality of electric motors.

⁸ Citations to patents are made by column and line cite; citations to patent publications are made by paragraph number; citations to Exhibit 1002 are made with reference to the Bates-stamped pagination; citations to other exhibits are made to the page number of the document itself.

3	3. The hydraulic fracturing system of claim 1, wherein the multi-plunger hydraulic fracturing pump has three plungers.
4	4. The hydraulic fracturing system of claim 1, wherein the multi-plunger hydraulic fracturing pump has five plungers.
5	5. The hydraulic fracturing system of claim 1, wherein the multi-plunger hydraulic fracturing pump has seven plungers.
6	6. The hydraulic fracturing system of claim 1, wherein the multi-plunger hydraulic fracturing pump has nine plungers.
7	7. The hydraulic fracturing system of claim 1, further comprising a variable frequency drive (VFD) associated with the plurality of motors and configured to control a pump rotational speed of the multi-plunger hydraulic fracturing pump.
8	8. The hydraulic fracturing system of claim 1, wherein the planetary gear train comprises a main gear that contacts each of the plurality of input pinion gears, wherein the main gear comprises external gear teeth that mate with external gear teeth of the plurality of input pinion gears.
9[a]	9. The hydraulic fracturing system of claim 8, wherein the planetary gear train comprises: a sun gear connected to the main gear by a shaft extending from the main gear; and
9[b]	a plurality of planetary gears that each contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.
10[p]	11. A hydraulic fracturing method comprising:
10[a]	by operation of a multi-plunger hydraulic fracturing pump of a hydraulic fracturing system, pumping fluid to a wellbore associated with a subterranean formation, the multiplunger hydraulic fracturing pump comprising a pump crankshaft;

10[b]	powering the multi-plunger pump with a plurality of motors;
10[c]	translating power from the plurality of motors to the multi-plunger hydraulic fracturing pump through a planetary gear train,
10[d]	wherein translating power through the planetary gear train comprises translating power through: a plurality of input pinion gears that are driven by the plurality of motors; and
10[e]	a final drive gear that drives the pump crankshaft, wherein the final drive gear is connected to the pump crankshaft by a plurality of arms extending from the final drive gear.
11	11. The hydraulic fracturing method of claim 10, wherein the plurality of motors comprises a plurality of electric motors, and each of the plurality of input pinion gears is driven by a respective one of the plurality of electric motors.
12	12. The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has three plungers.
13	13. The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has five plungers.
14	14. The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has seven plungers.
15	The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has nine plungers.
16	16. The hydraulic fracturing method of claim 10, comprising, by operation of a variable frequency drive (VFD), controlling a pump rotational speed of the multi-plunger hydraulic fracturing pump.
17	17. The hydraulic fracturing method of claim 10, wherein translating power through the planetary gear train comprises translating power through a main gear that contacts each of the plurality of input pinion gears, wherein the main gear comprises external gear teeth that mate with external gear teeth of the plurality of input pinion gears.

18[a]	18. The hydraulic fracturing method of claim 17, wherein translating power through the planetary gear train comprises translating power through: a sun gear connected to the main gear by a shaft extending from the main gear; and
18[b]	a plurality of planetary gears that contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.
19	19. The hydraulic fracturing method of claim 10, comprising limiting a maximum pump speed of the multi-plunger hydraulic fracturing pump, wherein the maximum pump speed is limited by a selection of a gear ratio of the planetary gear train and a speed at which the plurality of motors operate.
20	20. The hydraulic fracturing method of claim 19, wherein the maximum pump speed correlates with a critical plunger speed of the multi-plunger hydraulic fracturing pump.
21	21. The hydraulic fracturing method of claim 19, wherein the maximum pump speed is 5% over a critical plunger speed of the multi-plunger hydraulic fracturing pump.
22[p]	22. A hydraulic fracturing system for fracturing a subterranean formation, the hydraulic fracturing system comprising:
22[a]	a plurality of electric motors;
22[b]	a planetary gear train connected to the plurality of electric motors, the planetary gear train comprising:
22[c]	a plurality of input pinion gears, each driven by a respective one of the plurality of electric motors;
22[d]	a main gear driven by the plurality of input pinion gears, the main gear comprising external gear teeth that mate with external gear teeth of the plurality of input pinion gears;
22[e]	a sun gear driven by the main gear and connected to the main gear by a shaft;

22[f]	planetary gears driven by the sun gear, the planetary gears each comprising external gear teeth that mate with external gear teeth of the sun gear; and
22[g]	a final drive gear driven by the planetary gears, the final drive gear comprising internal gear teeth that mate with the external gear teeth of the planetary gears; and
22[h]	a multi-plunger hydraulic fracturing pump that pumps fluid to a wellbore and comprises a pump crankshaft that is driven by the final drive gear of the planetary gear train, the final drive gear connected to the pump crankshaft by a plurality of arms extending from the final drive gear.
23	23. The hydraulic fracturing system of claim 22, further comprising a variable frequency drive (VFD) associated with the plurality of motors and configured to control a pump rotational speed of the multi-plunger hydraulic fracturing pump.
24	24. The hydraulic fracturing system of claim 23, wherein the multi-plunger hydraulic fracturing pump comprises seven plungers.
25	25. The hydraulic fracturing system of claim 23, wherein the multi-plunger hydraulic fracturing pump comprises nine plungers.

C. PROSECUTION HISTORY OF THE '533 PATENT

46. The Patent Office issued a first Non-Final Office Action November 13, 2023, rejecting Claims 21-24, 31-34, 40, and 47-48 as being obvious over U.S. Patent Publication 2020/0256429 (“*Buckley*”) in view of U.S. Patent Publication 2015/0361736 (“*Bergan*”), rejecting Claims 25-27, 35-37, and 49-50 as being obvious over *Buckley* in view of *Bergan* and U.S. Patent Publication 2017/0114625 (“*Norris*”), rejecting Claims 28-29, 38-39, and 43 as obvious over *Buckley* in view of *Bergan* and U.S. Patent No. 4,100,822 (“*Rosman*”), rejecting Claims 41 and over

Buckley in view of Bergan and U.S. Patent No. 8,851,850 (“*Mail*”), and rejecting Claims 44-46 over *Buckley* in view of *Bergan*, *Rosman*, and *Norris*.⁹ The Patent Office also issued a nonstatutory double patenting rejection of claims 21-27, 31-37, 40-42, 47, 49, and 50 based on claims 1-20 of the ’258 Patent.¹⁰

47. In response, the Applicant amended the independent claims to include the subject matter of “allowable” dependent Claim 30: “...wherein a final drive gear is connected to the pump crankshaft by a plurality of arms extending from the final drive gear.”¹¹ Applicant further argued that the nonstatutory double patenting rejection was rendered moot by the amendments to the independent claims, because that rejection was not applied to the subject matter of Claim 30.¹² Following these amendments, the Patent Office issued a notice of allowance on December 26, 2023.¹³

D. PRIORITY DATE OF THE ’533 PATENT

48. The application leading to the ’533 Patent was filed on July 24, 2023 as U.S. Application 18/357,271 and as a continuation of U.S. Patent App. 16/827,166, which was filed March 23, 2020 as a continuation of U.S. Patent App. 16/210,807, which was filed on December 5, 2018.¹⁴ Application 18/357,271 claimed priority to

⁹ Ex. 1002 (’533 Patent File History), 157-172.

¹⁰ Ex. 1002 (’533 Patent File History), 174.

¹¹ Ex. 1002 (’533 Patent File History), 140-147.

¹² Ex. 1002 (’533 Patent File History), 145.

¹³ Ex. 1002 (’533 Patent File History), 101.

¹⁴ Ex. 1001 Cover.

provisional application No. 62/594,912, which was filed on December 5, 2017.¹⁵

For purposes of this Declaration, I assume that the priority date of the '533 Patent is December 5, 2017, the effective filing date of the 62/594,912 Provisional Application.

VII. LEVEL OF ORDINARY SKILL IN THE ART

49. A person of ordinary skill in the art would have either (1) a Bachelor of Science in Mechanical Engineering, Electrical Engineering, Petroleum Engineering or an equivalent field as well as at least 2 years of academic or industry experience in the oil and gas industry, including well drilling, completion, or production, or (2) at least four years of industry experience in the oil and gas industry including well drilling, completion, or production.

VIII. CLAIM CONSTRUCTION

50. It is my opinion that a POSITA would understand all the claim terms to have their plain and ordinary meaning, and I have applied the plain and ordinary meaning, in the context of the '533 Patent, for all claim terms.

IX. TECHNOLOGY BACKGROUND AND STATE OF THE ART

51. In the subsections below, I describe some of the basic principles of engineering that would have been used, or at least considered for use, on a hydraulic

¹⁵ Ex. 1001 Cover.

fracturing site. The principles discussed in the subsections below would have been well-known to a POSITA in the 2018 timeframe, and long before.

A. HISTORY OF HYDRAULIC FRACTURING

52. Fracturing the hydrocarbon-bearing formations is a technique that has been used to increase or speed up oil and gas production for nearly as long as oil and gas production has existed. As early as the 1850's fracturing methods used explosives such as gunpowder ignited by red-hot iron or nitroglycerin "torpedoes."¹⁶ Hydraulic fracturing, in its modern form of pumping using pumps and valves to control fluids and proppants (*e.g.*, sand) pumped into the formation, began in the 1940s using a process developed by Stanolind Oil and used by Halliburton in the mid-continent region.¹⁷ Early hydraulic fracturing in the 1940s and 1950s used frac pumps that could operate at around 1500 Hp.¹⁸

¹⁶ Ex. 1024 (*Morton*).

¹⁷ Ex. 1025 (*Wells*).

¹⁸ Ex. 1026 (*Montgomery*) pg 26.



53. The expansion of directional and horizontal drilling extended the use of hydraulic fracturing into previously underdeveloped “tight” formations, including shale.¹⁹ In oil and gas exploration, directional drilling is a technique for accessing hydrocarbon-bearing formations (oil and gas formations) that are not located immediately beneath the surface location or to increase the amount of formation exposed to the wellbore. In directional drilling, some tool or process is used to cause the wellbore to deviate from the vertical to reach previously inaccessible formation locations, to expose more of the hydrocarbon-bearing formation to the wellbore, or to drill several wells from a single surface location, such as an offshore platform or a land-based drilling pad. Like most oil and gas industry developments “the early drilling of directional wells was clearly motivated by economics.”²⁰ The offshore

¹⁹ Ex. 1024 (*Morton*).

²⁰ Ex. 1027 (*Bourgoyne*) pg 351.

fields of California spawned the technology that led to modern directional and horizontal drilling. In the 1930s, directional drilling was used in the Huntington Beach, California field to reach an offshore oil-bearing formation from a well initiated on an onshore pad.

54. Throughout the 1980s, directional drilling increased, particularly on offshore pads and in the Austin Chalk trend of central Texas. Horizontally deviated wells were drilled into the chalk to intersect several of the natural fractures, allowing for transport of the hydrocarbons into the wellbore. This was combined with artificial fracturing to increase the flowrate of hydrocarbons. By at least 1986, horizontal drilling techniques were well-known and heavily developed. In 1986, the “first successful multifracture horizontal well is drilled in Wayne County, West Virginia.”²¹ This well used directional drilling to cause the wellbore to enter a more or less horizontal orientation (parallel to the surface of the earth) and combined it with advanced hydraulic fracturing techniques to not only expose large lengths of the hydrocarbon formation to the wellbore, but also to create artificial cracks or “fractures” in the formation from multiple locations to allow the hydrocarbons to “leak” out of the formation into the wellbore.

²¹ Ex. 1028 (*Vassiliou*) xliii.

55. The use of horizontal drilling and fracturing systems in shale formations led to the United States vastly increasing its oil and especially natural gas production—starting in the 1980s and continuing to the present day.²²



56. As more formation is exposed to be fractured, horizontal wells use much higher volumes of fracturing fluid and proppant than vertical wells. This requires the use of more and bigger blending and pumping systems. As discussed by Sanborn, pumping systems of 32,000 hp were typically used as early as 2012 with the pumps being driven by electric motors and VFDs.²³ Other references, such as

²² Ex. 1025 (*Wells*) at 9 (showing a 2011 map from the Energy Information Administration showing shale plays where hydraulic fracturing is common).

²³ Ex. 1029 (*Sanborn*) [0005], [0009], [0012], [0017] – [0018], [0038], [0040].

Coli, suggest systems of pumps as large as 2,500 hp each, being driven by electric motors with VFDs, with total system power as high as 40,000 hp were used in the same period (four trailers, each with four 2500 hp pumps operating in parallel).²⁴ These pumps are typically triplex or quintuplex positive displacement (plunger) type pumps.²⁵

B. TYPES OF PUMPS – FRACTURING PUMP CHAIN

57. The basics of hydraulic fracturing have not changed significantly since 1949 when Halliburton first commercialized the “hydrafrack” process.²⁶ Hydraulic fracturing still involves pumping water (or another fluid) blended with a proppant (*e.g.*, sand) and other chemicals into the downhole reservoir at a sufficient pressure to crack (fracture) the downhole rock. The sand-water mixture is then forced into the cracks, where the sand keeps the cracks (fractures) open to allow hydrocarbons, such as oil and natural gas, to flow out of the formation into the well bore. What has changed are the pressures and flow rate of the fracturing jobs, the sizes of equipment and the particular proppants, chemicals, and liquids used.

58. A modern fracturing process requires multiple pumps operating together as a system to provide fracturing fluid with the suitable composition at the

²⁴ Ex. 1030 (*Coli*) [0009], [0011], [0013], [0014], [0016] - [0018], [0049], [0065] – [0066], FIG. 2

²⁵ Ex. 1029 (*Sanborn*), at [0005]; Ex. 1021 (*Coli*), at [0011].

²⁶ Ex. 1024 (*Morton*), 87.

right flow rate²⁷, and at a pressure sufficient to fracture the formation. At the beginning of the pumping chain are the water transfer pumps. These pumps operate at a relatively low pressure to move water from storage (e.g., ponds, tanks) to the blender or the hydration unit.

59. In the blender, the water is mixed with a proppant, such as sand, resin-coated sand, or ceramics, to form the fracturing slurry. Other chemicals, such as acids, gels, friction reducers, biocides, and the like, are added to the slurry. Dry products, such as sand, are transported into the blender tub using gravity, conveyors, or augers. Liquid products, such as acids, are transported into the blender tub using various sizes and types of pumps. These are typically relatively small horsepower pumps operating at lower pressures, as the blender tub operates at more or less ambient pressures.

60. Once the fracturing slurry is blended to the proper makeup and consistency, it is transferred to the fracturing pumps using a blender discharge pump. This pump typically operates at a higher pressure than the water or chemical transfer pumps for several reasons. First, the viscosity of the slurry is typically higher than that of water, which requires higher pressures to move the same volume of slurry. Second, the slurry is heavier than plain water, requiring additional horsepower to

²⁷ “Flowrate,” “flow rate,” “flow-rate,” and “pump rate” are used interchangeably in the industry and herein.

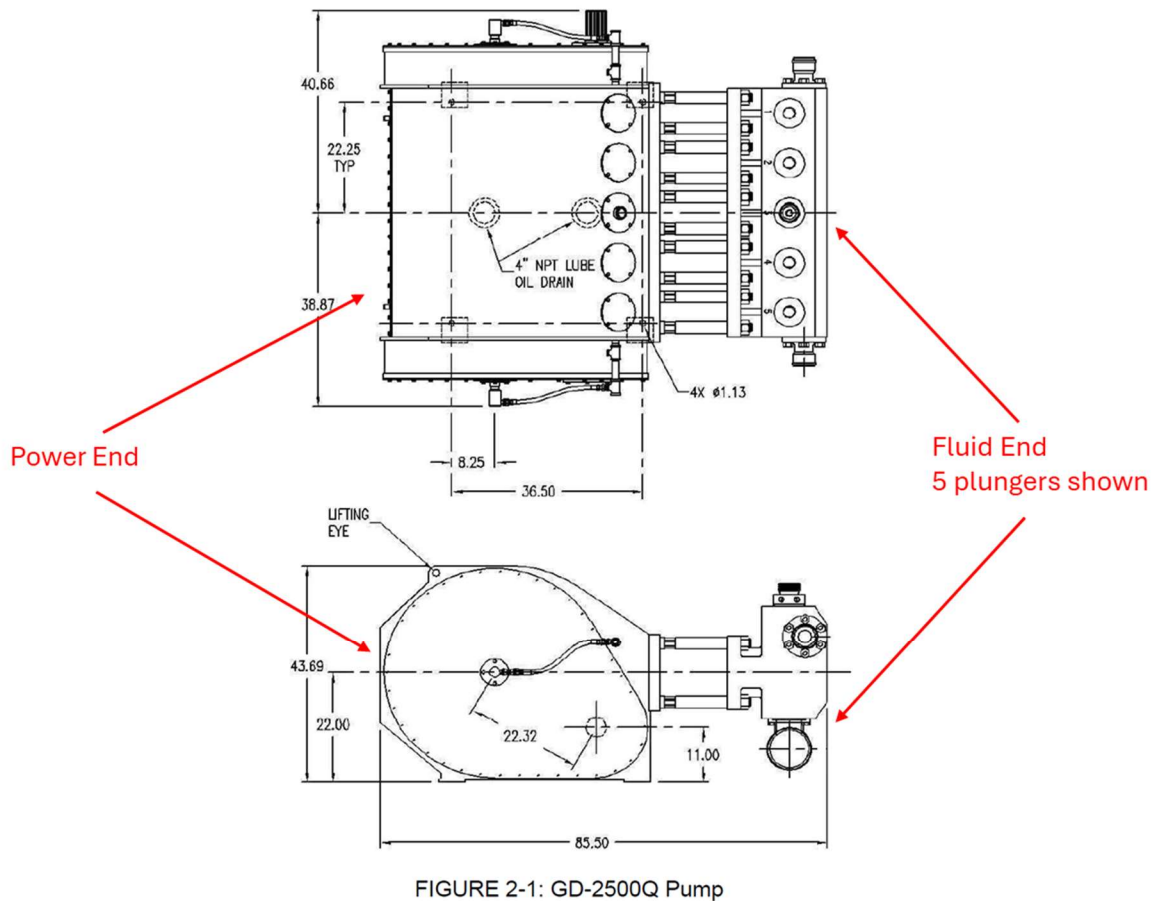
move the slurry (as compared to plain water). Finally, the large fracturing pumps are piston (or plunger) positive displacement pumps, requiring a higher suction (input) pressure to ensure flow sufficient to prevent cavitation, as explained below.

61. A common type of pump used in fracturing operations is a plunger (piston) pump. A fracturing plunger (or piston) pump works similarly to a car engine without the step of igniting the fuel to provide energy to the shaft. In a plunger (piston) pump, the shaft is rotated by an external power source, such as an engine or electric motor. Pistons (plungers), typically 3-5, are arranged along the shaft and connected so that the rotational motion of the shaft is translated into the linear motion of the pistons. As the shaft rotates, the plunger (piston) moves away from the head, creating suction which draws the slurry into the piston chamber. As the plunger (piston) moves toward the head, pressure is created which drives the fluid out of the chamber and down the line to and into the wellbore.

62. One example of a plunger pump commonly used in fracturing is a Gardner Denver “GD-2500Q Quintuplex Well Servicing Pump.” Gardner Denver describes the GD-2500Q as a “high horsepower, high rod load multi-purpose pump for various applications such as oil and gas well fracturing and acidizing.”²⁸ Gardner describes that “[t]he GD-2500Q quintuplex pump uses only two major assemblies:

²⁸ Ex. 1016 (Gardner) pg 9.

power end and fluid end.”²⁹ A “quintuplex”³⁰ pump has 5 cylinders. In the case of the GD-2500Q Gardner provides Figure 2.1 which shows the dimensions and key components of the GD02500Q.



Ex. 1016 (Gardner) Figure 2.1

Figure 2-5 Provides further detail of the fluid end, showing the front suction covers for 5 plunger cylinders.

²⁹ Ex. 1016 (Gardner) pg. 10.

³⁰ See, e.g., Ex. 1032 (Merriam-Webster online dictionary definition of “quintuple”: “having five units or members”).

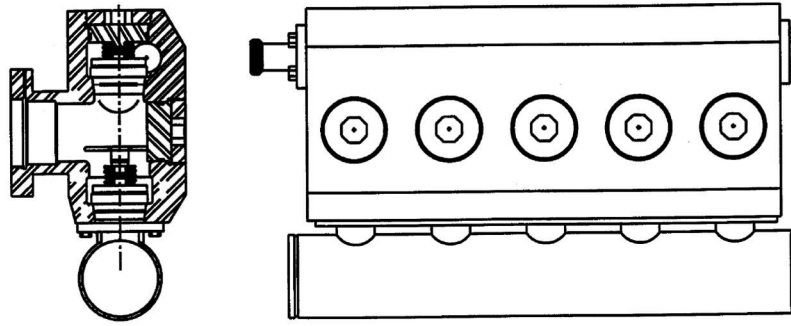


FIGURE 2-5: GD-2500Q Fluid End

63. A key characteristic of these type of fracturing pumps is that the same amount of liquid is discharged from the pump with every stroke, largely independent of the pressure downstream. For example, *Marks* (Ex. 1019) teaches that “[a] displacement pump (also called positive-displacement or just p-d) is a pump which imparts energy to the pumpage (the material pumped) by trapping a fixed volume at suction (inlet) conditions, compressing it to discharge pressure, then pushing it into the discharge (outlet) line.”³¹ Further, *Marks*’ teaches reciprocating pump is a displacement pump which reciprocates the pumping element (piston, plunger or diaphragm). The capacity of a reciprocating pump is proportional to its speed and is relatively independent of discharge pressure.”³²

64. Accordingly, the flow rate of a positive displacement pump is a function of the “fixed volume” trapped in the cylinder and the number of times that the cylinder is emptied in a given period of time. The “fixed volume” of the cylinder

³¹ Ex. 1033 (*Marks*) pg 14-2.

³² Ex. 1033 (*Marks*) pg 14-2.

is a function of the cylinder cross sectional area (CSA) and the stroke length. The CSA is a function of the cylinder diameter (d).³³

$$CSA = \frac{\pi d^2}{4}$$

$$volume = \frac{\pi d^2}{4} \times stroke length$$

The number of times the cylinder is emptied is a function of the pump speed. For a given pump arrangement, as speed goes up, the number of times the cylinder is emptied increases and flowrate increases and vice versa. Similarly, at a given speed if stroke length or cylinder diameter increase, the fixed volume goes up and flowrate increases. For a fixed flowrate, the required pump speed is inversely related to both stroke length and cylinder diameter. In other words, if the fixed volume increases, the number of times the cylinder must be emptied would decrease, assuming volume does not change.

65. As one example, Gardner provides specifications of the GD-2500Q Quintuplex well servicing pump. Specifications of the pump indicate a stroke length of 8.0 inches.³⁴ As shown below, the GD-2500Q is available with plunger size (diameters) between 3.75 and 6.75 inches. The table provides flowrates for pump speeds between 100 and 330 RPM.

³³ Ex. 1034 (*Nesbitt*), 140 (showing “displacement” of a single-cylinder pump to be the CSA of the cylinder multiplied by the stroke length).

³⁴ Ex. 1016 (Gardner) pg 14.

Plunger Size	Displacement per Revolution	Displacement at Pump RPM - Well Stimulation Application							
		100		150		250		330	
in.	gal/rev.	GPM	PSI	GPM	PSI	GPM	PSI	GPM	PSI
3.75	1.91	191	17800	287	13500	478	8100	631	6100
4	2.17	217	15600	326	11800	544	7100	718	5400
4.5	2.75	275	12400	413	9300	688	5600	908	4200
5	3.40	340	10000	510	7600	850	4500	1121	3400
5.5	4.11	411	8300	617	6300	1028	3800	1357	2800
5.75	4.49	449	7600	674	5700	1124	3400	1483	2600
6	4.89	489	6900	734	5300	1223	3200	1615	2400
6.5	5.74	574	5900	861	4500	1436	2700	1895	2000
6.75	6.19	619	5500	929	4200	1548	2500	2044	1900
Input Power	BHP	2200		2500		2500		2500	

Ex. 1016 (Gardner) pg 14

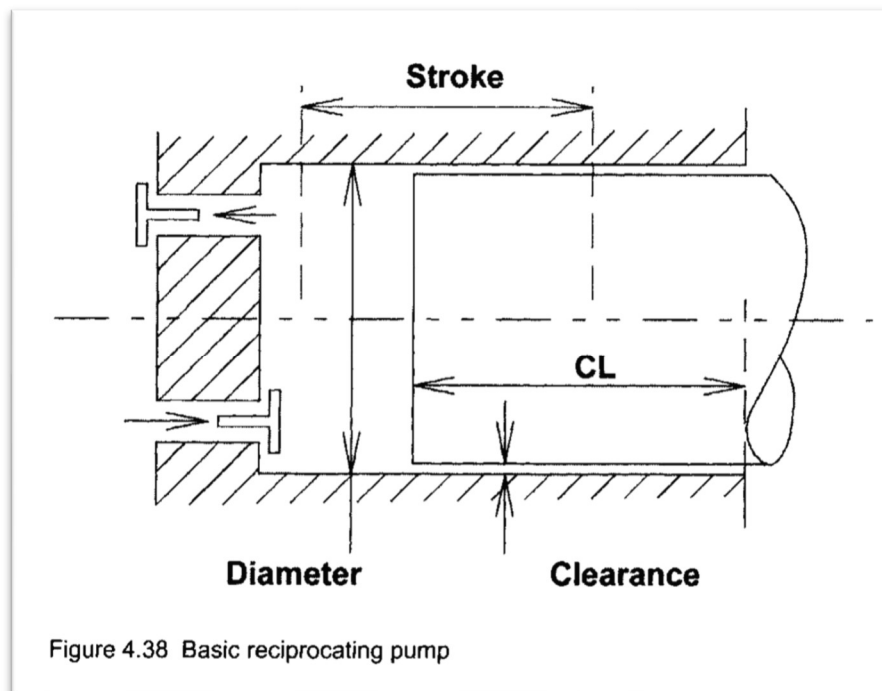
66. Since in the GD-2500Q the stroke length is fixed, the relationship between speed, plunger size and flowrate is shown in the table. For example, for a flow of ~620 GPM, a POSITA could select: a 6.75" plunger size and operate just above 100 RPM; a 5.5" plunger size and operate a little above 150 RPM; a 4.5" plunger size and operate below 250 RPM; or a 3.75" plunger size and operate at a little below 330 RPM. Thus, there is an inverse relationship between volume (stroke length and plunger size) and flowrate.

67. As another example, *Nesbitt* teaches in a “basic” “single cylinder reciprocating pump shown in Figure 4.38 [] the ideal flow is delivered is calculated from”³⁵ the following equation:

$$Q_{th} = 0.001 \times s \times \frac{\pi d^2}{4} \times n/60 \quad (\text{Equ 4.25})$$

where:

- Q_{th} = theoretical flow (cc/s)
 n = strokes per minute (1/minute)
 d = piston [plunger] diameter (mm)
 s = stroke (mm)



³⁵ Ex. 1014 (*Nesbitt*) pg 140.

68. By mathematically rearranging Equation 4.25, to calculate pump speed with a fixed stroke length and flowrate yields the following equation:

$$n = \frac{Q_{th} \times 60 \times 4}{0.001 \times s \times \pi d^2}$$

In order to calculate stroke length with a fixed flowrate and pump speed, equ 4.25 would be arranged as follows:

$$s = \frac{Q_{th} \times 60 \times 4}{0.001 \times n \times \pi d^2}$$

As can be seen from each of the above equations, there is an inverse relationship between stroke length (and piston/plunger diameter) and pump speed for a fixed flowrate. This is an inherent characteristic of plunger pumps. For a pump with more than one cylinder (e.g. quintuplex pump with 5 cylinders), the above equation would be simply multiplied by the number of cylinders in order to obtain the total flowrate from the pump.

69. The result of the above is that flow for a given pump at a particular pump speed is relatively constant, while pressure changes as downstream conditions change. Accordingly, as fracturing begins, reducing the downstream impedance of the fluid flow system, pressure tends to drop as flow rate stays relatively constant. Conversely, pressure rises with a relatively stable flow rate as downstream impedance increases. As a boundary condition, if a valve is closed downstream of a fracturing pump, flow rate through the pump will remain relatively constant while

pressure rises extremely fast. Pressure will continue to rise until some condition reduces the downstream impedance. This is typically equipment failure, such as pump seals, piping failure, or rupturing of valve bodies.

70. As shown by *Gardner*, the flowrate of a plunger pump is a function of the speed of the pump, the diameter of the plunger and the length of the stroke.

71. Because the plungers are so large (~5" in diameter with ~8" stroke), a large amount of fluid must flow into the cylinder on each stroke. This tends to lower the suction pressure, as the void of the plunger must be filled by the incoming slurry. If the suction pressure gets too low, then cavitation occurs. Cavitation is the condition where bubbles form in the liquid because the vapor pressure of the liquid is higher than the suction pressure. When the bubbles collapse, such as when the piston reaches the bottom of its stroke, noise, vibration and damaging forces are created. To avoid cavitation and the associated problems, the suction pressure must be maintained higher than the fluid's vapor pressure of the fluid (e.g., slurry), even during the intake phase of the piston. This is called maintaining a Net Positive Suction Head (NPSH). The amount of NPSH necessary to avoid cavitation is dependent on many factors, including the suction line design, pump speed, suction valve spring strength, and temperature and viscosity of the fluid. *Gardner* teaches several methods to reduce or eliminate cavitation. These techniques include, for

example, using a suction stabilizer or pulsation damper, changing the supply line design, and reducing pump speed.³⁶

Cavitation, Fluid Knock or Hammer.	1. Improper suction system layout.	1. See recommended system layout in manual.
	2. Low suction pressure.	2. See Low Suction Pressure problem.
	3. Suction stabilizer and pulsation damper not used.	3. Install suction stabilizer and pulsation damper.
	4. Defective stabilizer or damper.	4. Repair and recharge or replace.
	5. High fluid temperature or viscosity.	5. Reduce pump speed.
	6. High fluid vapor pressure.	6. Increase NPSH.
	7. High acceleration head.	7. Increase supply line size. Decrease supply line length.
	8. Suction valve spring too stiff. with low NPSH.	8. Use weaker spring.
	9. Air/Gas in pumped fluid.	9. Allow more settling time in supply tank. Reduce pump speed.
	10. Air entering suction line.	10. Repair suction line.
	11. Air entering charging pump.	11. Tighten or replace shaft packing or seal.
	12. Air entering or charge gas escaping from suction stabilizer.	12. Repair and recharge stabilizer
	13. Multiple pumps operating in phase.	13. Use a suction stabilizer on each pump. Separate lines may also be needed.

C. PUMPING AND CAVITATION

72. Cavitation in pumping, including in positive displacement (e.g. plunger) pumps, has been a well known problem. Cavitation is described when “the

³⁶ Ex. 1016 (Gardner) pg 30.

incoming liquid [into a pump] is at a pressure with insufficient margin above the vapour pressure, then vapour cavities or bubbles appear [] [t]his phenomenon is known as cavitation.”³⁷ Cavitation has at least three negative effects on a pumping system:³⁸

1. The collapsing cavitation bubbles can erode the vane surface, especially when pumping water-based liquids.
2. Noise and vibration are increased, with possible shortened seal and bearing life.
3. The cavity areas will initially partially choke the impeller passages and reduce the pump performance. In extreme cases, total loss of pump-developed head occurs.

Accordingly, it was known to avoid cavitation in pumping systems.

73. *Tutterow* further teaches that “[t]he amount by which the pressure in the pump inlet exceeds the liquid vapour pressure is expressed as a head of liquid and referred to as Net Positive Suction Head Available (NPSHA). This is a characteristic of the system design. The value of NPSH needed at the pump suction to prevent the pump from cavitating is known as NPSH Required (NPSHR).”³⁹

³⁷ Ex. 1013 (*Tutterow*) pg 20; see also Ex. 1033 (Marks) pg 14-2.

³⁸ Ex. 1013 (*Tutterow*) pg 20

³⁹ Ex. 1013 (*Tutterow*) pg 20

74. Further, NPSHR “varies approximately with the square of speed in the same way as pump head.”⁴⁰ Accordingly, a 10% reduction in pump speed would result in a 19% reduction in NPSHR and an 10% increase in speed would require a 21% increase in NPSHR. In any given system, a reduction in pump speed would reduce the risk of cavitation. It follows then that there is a specific speed that would eliminate cavitation for any given pump system. It further follows that as speed increases, cavitation increases.

75. With specific regard to PD pumps, “a PD pump needs the incoming liquid to have a pressure margin above liquid vapour pressure to prevent cavitation within the suction passages or pumping chamber.”⁴¹ PD pumps also have an additional problem outlined by *Tutterow*:⁴²

The cavities [cylinders] on a positive displacement pump open and close as the pump operates and the liquid must flow quickly enough at the pump suction to fill the cavities completely with liquid. If the cavities do not fill with liquid, there will be a void, and apparent cavitation, resulting in a loss of both flow and pressure performance. If the speed is increased, this filling process becomes more

⁴⁰ Ex. 1013 (*Tutterow*) pg. 21.

⁴¹ Ex. 1013 (*Tutterow*) pg. 30.

⁴² Ex. 1013 (*Tutterow*) pg. 30.

problematical, limiting the maximum speed. With viscous liquids, [such as fracturing fluid] the effect is more severe.

76. *Langewis* describes use of positive displacement pumps used to inject produced water into the formation in a waterflood oil & gas operation. The pumps described in *Langewis* are very similar in design and function as those used in hydraulic fracturing. *Langewis* describes “Net positive suction head (NPSH) is defined as the head, in feet of liquid above vapor pressure, required at the suction inlet of the pump to completely fill each cylinder on the suction stroke.”⁴³ *Langewis* further describes NPSH required mathematically:

$$NPSH_{required} = H_a + H_g - H_{vp}$$

77. H_g represents “minimum pressure required for acceptable pump performance”. Further, *Langewis* teaches that “[t]he value of H_g should be obtained from the pump manufacturer. This term is a function of the diameter of the plunger, *speed of the pump*, type of valve used, valve-spring load and tolerance of the equipment. therefore, all pump manufacturers should have this value for their pumps.”⁴⁴

78. The maximum speed of operation of a positive displacement pump to prevent cavitation is the lower of the speed that keeps NPSHR below NPSHA and

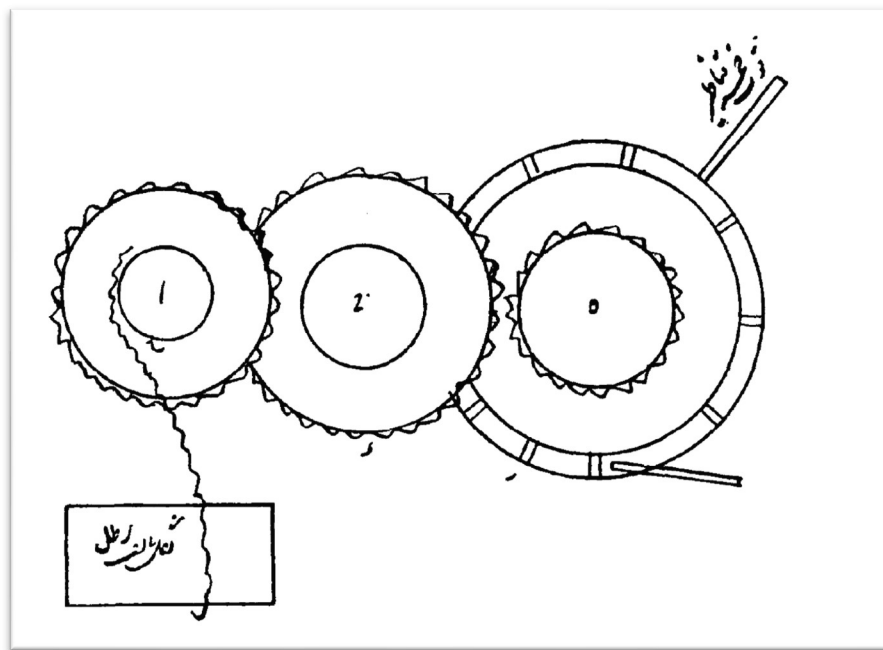
⁴³ Ex. 1035 (*Langewis*) pg. 174.

⁴⁴ Ex. 1035 (*Langewis*) pg. 174-175.

that speed which allows sufficient time for the cylinders to completely fill based on the NPSHA.

D. GEARING MECHANISMS

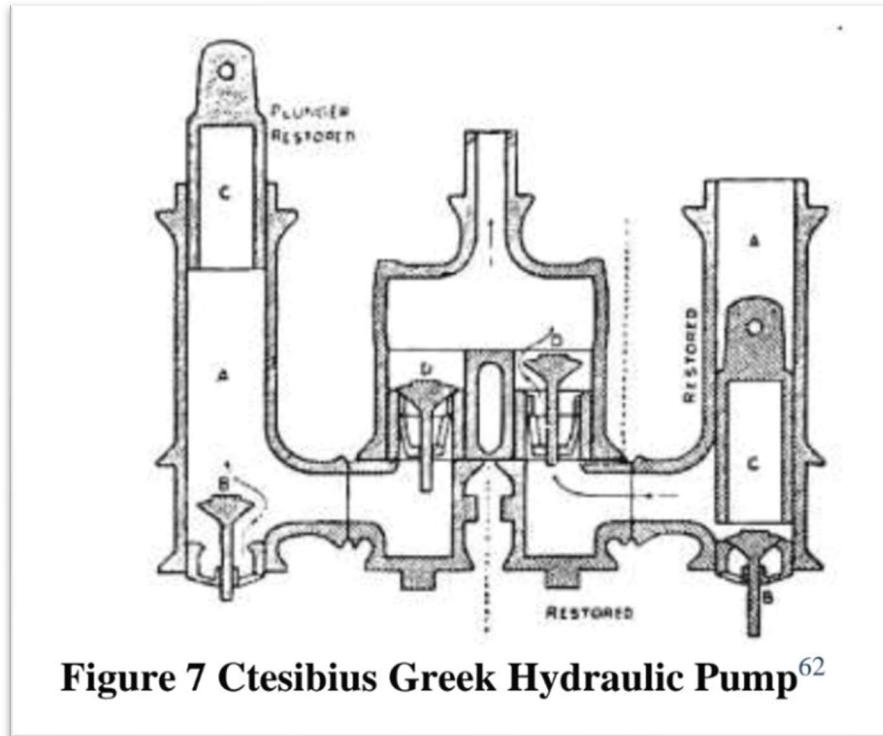
79. Gearing mechanisms to drive loads (e.g. pumps) at a different speed than their drive mechanisms (i.e. motors) have been known for centuries. Gears have been known in the art since at least the 3rd century B.C.⁴⁵ Geared mechanisms were developed in Alexandria, Egypt by Greek mechanics, under the Greek Ptolemies in the Alexandrian “Museum”. Hero describes gears which mesh in the same plane and multiplies force by meshing gears with different numbers of teeth.⁴⁶



⁴⁵ Ex. 1036 (*Lewis*) pg 110.

⁴⁶ Ex. 1036 (*Lewis*) pg 110.

80. Interestingly, it was in this same period and location that hydraulic pumps were developed by Ctesibius, also a member of the Musaeum.⁴⁷



Ex. 1054 (*Johns*) Figure 7

81. The oldest physical artifact containing gears is the Antikythera mechanism, which dates to the first century B.C. The Antikythera mechanism contained “at least 30 gear wheels” and was used to calculate the positions of, at least, the sun and the moon based on a date input.⁴⁸

⁴⁸ Ex. 1036 (*Lewis*) pg 111.

82. As discussed above, it was known for several gears to be used together, known as a “gear train”. Further it was known that gear trains can change the speed and direction of the input power. As described in *Mabie*, “given the input angular velocity to a gear train, it is important to be able to determine easily the angular velocity of the output gear and its direction of rotation.”⁴⁹ When a gear train is driven by a driving force such as a motor “the angular velocity [i.e. speed] of the driver will be known from the speed of the motor, and it is necessary only to multiply the speed of the drive by a factor to find the speed of the last gear in the train [i.e. speed of the load].”⁵⁰ Accordingly, by knowing the ratio of the gear train and the speed of the motor, the speed of the output of the gear train, connected to the load, can be calculated by simple multiplication. Further, if the desired speed of the driven load is known, that speed can be controlled by proper selection of the gear ratio and/or the speed of the motor. *Nesbitt* describes gearboxes applied to drive pumps and teaches that “[g]earboxes can be applied to any shaft speed and any ratio is popular.”⁵¹

83. There are two fundamental concepts when dealing with gear drives (gearboxes). The first is *efficiency*. Efficiency is “unproductive power

⁴⁹ Ex. 1037 (*Mabie*) pg 245.

⁵⁰ Ex. 1037 (*Mabie*) pg 246.

⁵¹ Ex. 1014 (*Nesbitt*) pg 281.

expenditure”.⁵² The second is a *transmission ratio* which is the ratio of the speeds of the input and the output. In order to explain these concept, *Jelaska* teaches “The mechanical drive driving shaft receives power P_1 at speed of rotation n_1 from the prime mover driven shaft, and the mechanical drive driven shaft supplies power $P_2 < P_1$ at speed of rotation n_2 to the operational machine driving shaft [e.g. load or pump].”⁵³ Efficiency η is the ratio between power out and power in (always less than 100%).

$$\eta = \frac{p_2}{p_1} = \frac{p_1 - \text{losses}}{p_1} = 1 - \text{losses}/p_1$$

84. Transmission ratio i is the ratio of the driving shaft speed (n_1 below) and driven shaft speed (n_2 below). It is also the ratio of the angular velocity ω of the input shaft (ω_1 below) and the output shaft (ω_2 below).⁵⁴

$$i = \frac{n_1}{n_2} = \frac{\omega_1}{\omega_2}.$$

Accordingly any combination of input speed (driving speed) and transmission ratio (i) defines the output speed of the gear train.

85. *Mabie* teaches that “[t]o obtain a desired gear ratio it is often advantageous to design a gear train so that one of the gears will have a planetary motion. With this motion, a gear will be so driven that it not only rotates about its

⁵² Ex. 1012 (*Jelaska*) pg 3.

⁵³ Ex. 1012 (*Jelaska*) pg 2-3.

⁵⁴ Ex. 1012 (*Jelaska*) pg. 3.

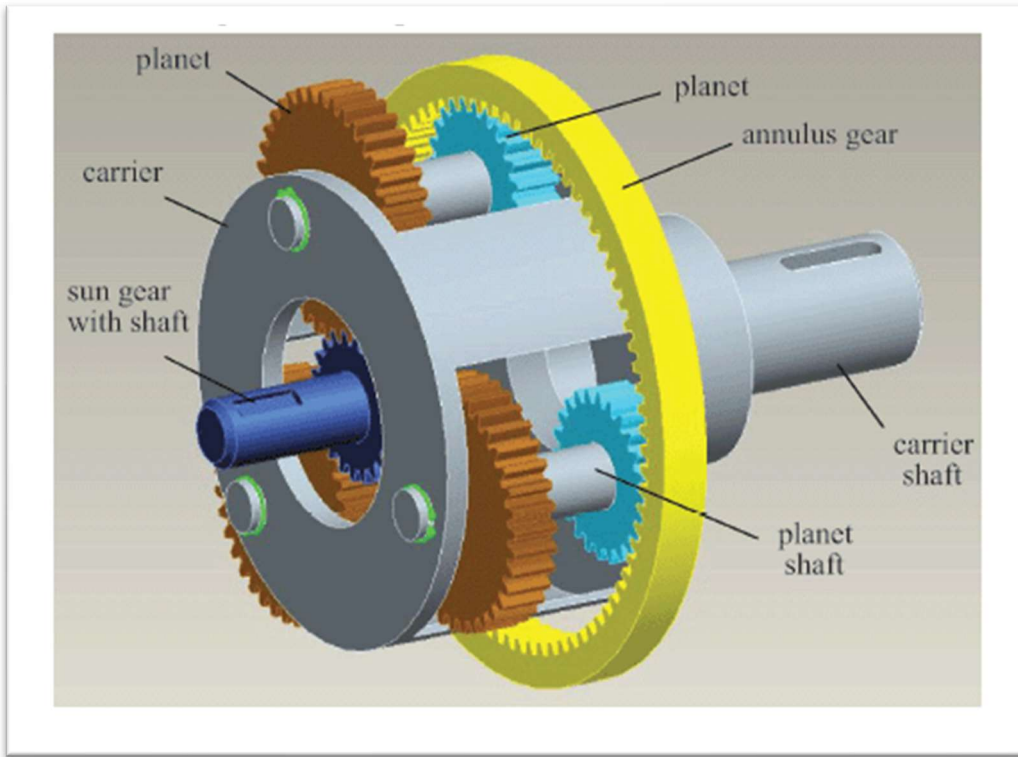
own center but at the same time its center rotates about another center.”⁵⁵ Such an arrangement is known as a “planetary gear train”. Because of the motion of the various gears “a planetary gear train is referred to as an epicyclic, or cyclic, gear train.”⁵⁶ These arrangements “find many applications in machine tools, hoists, aircraft propellor reduction drives, automobile transmissions, aircraft servo-drives and many others.”⁵⁷ *Nesbitt* teaches that “[e]picycle gearboxes are popular for larger and high speed applications[] Epicyclic gearboxes can be used as a variable ratio transmission by adding a small control drive.”⁵⁸ *Jelaska* provides an image of a planetary gear train.

⁵⁵ Ex. 1037 (Mabie) pg 248.

⁵⁶ Ex. 1037 (Mabie) pg. 248.

⁵⁷ Ex. 1037 (Mabie) pg 533.

⁵⁸ Ex. 1034 (*Nesbitt*) pg. 282.

Ex. 1012 (*Jelaska*) Plate 2

86. Not only were planetary gear trains known for changing the speed of a single motor to a single load (e.g. pump), such gear trains were known for combining several motors to drive a single load. For example, *Jelaska* describes that “[planetary] differential trains having two or more degrees of freedom are used for dividing the single rotary motion into two or more, or *for joining several rotary motions into one*. A common simple differential train having one sun gear, one annulus gear and a carrier with three planets is demonstrated in Figure 6.4 [Plate 2

above].”⁵⁹ As an example, *Jelaska* describes a planetary gear train “with two inputs of power [] and one output.”⁶⁰

87. Planetary gear trains are commonly used in applications where there is a need for “high torque in compact (a high torque/volume) and light (a high torque/weight ratio) package.”⁶¹ Further, a planetary gear train has advantage in lubrication as the lubrication “is continuously redistribute, “*pushed and pulled*” or “*mixed*” into the gear contacts, ensuring lubrication practically in any mounting position and at any speed”.⁶² Overall, planetary gear trains “have a high torque density, [are] compact, [have] low inertia and can be grease lubricated for life,”⁶³ which are all advantageous in an industrial application.

E. ALTERNATING CURRENT (AC) SYSTEMS

88. It was general engineering knowledge that Alternating Current (AC or a.c.) power systems are those in which “Alternating waveforms have currents and voltages that vary with time in a symmetrical manner ... for the most part, the variations are sinusoidal in time.”⁶⁴ The use of the term alternating current indicates “that the current is produced by the application of a sinusoidal voltage. This means

⁵⁹ Ex. 1012 (*Jelaska*) pg. 333.

⁶⁰ Ex. 1012 (*Jelaska*) pg. 361.

⁶¹ Ex. 1038 (Pawar) pg. 150.

⁶² Ex. 1038 (Pawar) pg. 151.

⁶³ Ex. 1038 (Pawar) pg. 151.

⁶⁴ Ex. 1039 (EE-Reference) p. 27-1.

that the flow of electrons changes directions, unlike DC circuits where the flow of electrons is unidirectional”⁶⁵

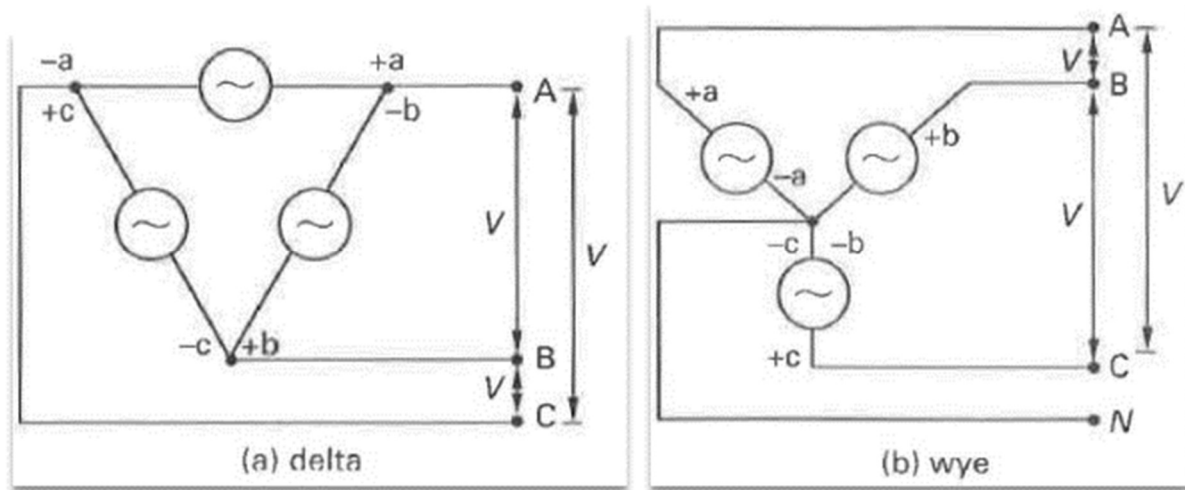
89. Single-phase AC systems are those in which there is a single voltage source driving the current. For single-phase systems, at least two connections to the load are needed in order for current to flow. These are generally referred to as “hot” and “neutral” connections, or “L1” and “L2” when used with motor connections. A separate ground wire is often used to provide personnel and equipment protection and to allow protective devices to operate effectively.

90. Three-phase AC systems are those in which there are three voltage sources driving current. Those three sources can be provided by a single physical structure such as an “AC generator that produces three equal sinusoidal voltages,” which “are 120° apart in phase.”⁶⁶ As described in EE-Reference, “a six conductor transmission line could be used to transmit the three voltages” by treating them as three separate single phase voltages, but “it is more efficient to interconnect the windings.”⁶⁷ Two connection types are delta and wye, as shown in Figure 34.2 from *EE Reference*.

⁶⁵ Ex. 1039 (EE-Reference) pg. 27-1.

⁶⁶ Ex. 1039 (EE-Reference) pg. 34-1

⁶⁷ Ex. 1039 (EE-Reference) pg. 34-2.



Ex. 1039 (EE-Reference) p. 34-2.

91. Delta connected power systems require three phase-wires (plus a ground if required). Wye connected power systems require three phase-wires plus a neutral (plus a ground if required)⁶⁸. The neutral wire carries any imbalance from the loads back to the source.

92. It was general engineering knowledge that there are several benefits to using three-phase systems over single-phase systems, particularly in the context of large electrical loads such as large electric motors.⁶⁹

Three-phase energy distribution systems use fewer and smaller conductors and, therefore are more efficient than multiple single-phase systems providing the same power. Three-phase motors provide a uniform torque, not a pulsating torque as do single-phase motor. Three-phase induction motors do not require additional starting windings or

⁶⁸ Certain balanced three phase wye connected system are operated with only three wires, though this is limited in application primarily to single loads, such as a three-phase motor.

⁶⁹ Ex. 1039 (EE-Reference) pg. 34-1.

associated switches. When rectified [converted to DC], three-phase voltage has a smoother waveform and less ripple to be filtered out.

This is due to the difference in power relationships between single-phase and three-phase systems. The power relationship for single-phase systems is:

$$P = V \cdot I$$

while the power relationship for three-phase systems is:

$$P = \sqrt{3} \cdot V \cdot I^*$$

Thus, for a three-phase system, current is reduced by a factor of $\sqrt{3}$ (~1.73) as compared to a single-phase system. This allows for smaller conductors, decreased losses and increased efficiency. As a result, nearly all larger power systems are configured as three-phase systems.

F. ELECTRIC MOTORS

93. It was general engineering knowledge that electric motors are a subset of rotating electric machinery (rotating machines) in which electric power is converted to rotational mechanical energy.

Rotating machines are broadly categorized as AC and DC machines. Both categories include machines that use [electric] power (i.e. motors) and those that generate [electric] power (alternators and generators). Most machines can be constructed in either single-phase or polyphase [three-phase] configurations, although single-phase machines may be outclassed in terms of economics and efficiency. . . . Large AC motors are almost always three-phase.

Ex. 1039 (EE-Reference) p. 40-1.

94. Electric motors have been manufactured to one or more standards, depending on the application and size. As an example, motors up to 500 horsepower (Hp) are manufactured at least to the specifications of National Electrical Manufacturer's Association (NEMA) Standard MG-1.⁷⁰ Severe duty motors larger than 500 Hp used in oil & gas applications are manufactured to the specifications of American Petroleum Institute (API) standard 541.

95. The National Electrical Manufacturer's Association (NEMA) was founded in the 1920s and is an ANSI- (American National Standards Institute) accredited Standards Developing Organization (SDO) made up of business leaders, electrical experts, engineers, scientists, and technicians. NEMA convenes a neutral forum for Members to discuss industry-wide concerns and objectives under a legal umbrella by trained NEMA Staff.

96. It is inherent that electric motors have a plurality of connections to the power source in order to operate. As in all electric circuits, there must be a complete path between the power source (e.g., generator) and the load (motor) in order for current to flow and for the electric equipment (motor) to operate. The complete path requires a minimum of two connections for each load, generally designated as L1 and L2 for single phase or DC motors and L1, L2 and L3 for three phase motors.

⁷⁰ Severe duty motors smaller than 500 Hp used in oil & gas applications are manufactured to the specifications of IEEE 841, one of the IEEE standards for which I am responsible.

G. ADJUSTABLE SPEED DRIVES / VARIABLE FREQUENCY DRIVES

97. By way of background, a Variable Frequency Drive (VFD) is another term for and type of Adjustable Speed Drive (ASD). ASD is the preferred term. Nevertheless, based on my experience, the term VFD has been commonly used, so I also use the terms interchangeably in this declaration.

98. Standard industrial motors have a fixed speed tied to the frequency of the alternating current (AC) electric power being supplied to them. The “synchronous speed” of the motor is determined using the following equation:⁷¹

$$n_s = f(2/p)60 = \frac{120f}{p}$$

Where:

n_s = synchronous speed of the motor (rpm)

f = frequency (hertz)

p = # of poles in the motor (a function of design and construction)

For example, a 4 pole motor supplied with 60 Hz AC power (US standard) would have a synchronous speed of 1800 RPM, as shown below.

$$n_s = 60(2/4)60 = 1800$$

99. “Synchronous” motors run exactly at the synchronous speed. “Induction” motors run at a somewhat slower speed because of the interaction of the

⁷¹ Ex. 1039 (EE-Reference) pg. 40-4.

electrical field inside the motor with the conductors of the rotor, which is a function of the construction of the motor. The difference between an induction motor's rated speed and the synchronous speed of a motor of the same construction is referred to as "slip" and is calculated as follows:⁷²

$$s = \frac{(N_s - N_r)}{N_s} \times 100\%$$

Where

s = slip(%)

N_s = synchronous speed of the motor (rpm)

N_r = rated speed of the motor (rpm)

For example, a 4 pole induction motor operating at 1% slip would have a rated speed of 1782 rpm ($1800 - 1\% \times 1800$).

100. In order to control the speed of these motors at other than their rated speed, the frequency of the power being supplied to the motor must change. As discussed below, an ASD (VFD) performs this function.

101. *Standard Handbook for Electrical Engineers* from 1993 describes the basic operation of an ASD (VFD) as follows:⁷³

In order to supply an adjustable frequency to an ac motor, the incoming constant-frequency [fixed frequency] voltage or current must first be

⁷² Ex. 1039 (EE-Reference) pg. 40-7

⁷³ Ex. 1040 (Fink) p 20-85.

rectified to a dc current or voltage. This dc voltage or current is then inverted to an adjustable frequency output. This is accomplished by power semi-conductor devices.

These devices allow current to flow in only one direction. They act as electronic switches. Various types can be fired on and off at certain times in the cycle. This selected firing allows control of the resultant voltage or current.

Exhibit 1040 contains true and correct copies of pages from the Fink reference. As an additional example, Horikoshi (filed in 2011) describes that such an ASD (VFD) was known for three-phase AC power as well:⁷⁴

Providing a motor driving apparatus, which is connected to a three-phase AC power supply and which comprises an AC/DC converter for converting three-phase AC power supplied from the three-phase AC power supply into DC power and a DC/AC converter for converting the DC power output from the AC/DC converter into three-phase AC power for supply to a motor, is known.

102. The outgoing DC-AC converter modifies the frequency and/or voltage of the waveform in order to control the speed and torque delivered by the motor.

103. One of the more common ASD topologies, particularly for larger motors is a “pulse-width modulated (PWM)” drive topology. PWM drives have a number of advantages over other drive topologies including “high line-side power factor (near unity),” and the “distortion seen by the electrical network is ... reduced.”⁷⁵ Additionally, “high dynamic performance can also be realized. Full

⁷⁴ Ex. 1041 (Horikoshi) [0004].

⁷⁵ Ex. 1040 (Fink) pg. 20-89.

torque can be maintained and controlled throughout the speed range – even at zero speed.”⁷⁶

104. One of the methods of determining the power of a rotating piece of equipment (e.g. a motor) is the well-known relationship: Power = (Torque) x (rotational speed). This formula is expressed as: $P = \tau \cdot \omega$. As can be seen by this relationship, torque and rotational speed of an object are inversely related for a given power, such that for a given power, torque is increased by reducing rotational speed (and vice versa). Thus, by controlling the speed and torque (inherently a function of PWM drives), the drive is also controlling the power of a motor, and maintaining that power within the operating range of the motor.

105. The history of Adjustable Speed Drives (ASDs, sometimes referred to as Variable Frequency Drives or VFDs) began in 1958 with the advent of silicon controlled rectifiers (SCRs), a type of power electronics that could be turned on or off in order to allow power flow. The first motor drives using this new SCR technology were DC motor drives, and by the early 1960s “DC SCR drives [were] readily available for industrial applications”⁷⁷

⁷⁶ Ex. 1040 (Fink) pg. 20-89.

⁷⁷ Ex. 1042 (Roethemeyer) pg. 543.

106. By 1960, SCRs were being used in oil and gas operations, albeit on a relatively small scale, as evidenced by Exhibit 1027, US patent 3,186,222 which was filed on July 28, 1960.

107. By at least August, 1961, pulse width modulated (PWM) drives were being used for motor drives. Jones (General Electric) developed “Variable Pulse Width Parallel Inverters” and filed US Patent 3,075,136 on August 31, 1961. “[B]y employing a rectified alternating voltage input, the inverter can be readily adapted for use as a frequency changer...in a power supply system for the operations of motors at various speeds”⁷⁸

108. By 1962 a “Means for Smoothly Varying the Speed of a Star-Connected Polyphase [3 phase] Induction Motor” had been developed.⁷⁹

109. By 1965 it was known in industry that “a 3-phase induction motor can be controlled, in this manner [by using SCRs], in order to give a range of torque-speed characteristics suitable for fan control.”⁸⁰ The motor Shepherd was controlling with his VFD was a 3 horsepower motor. However, over the next 20 years, the technology of ASDs rapidly improved. By 1985, SCRs and GTOs (Gate TurnOff Thyristors) were being used for large motor ASDs.⁸¹ These devices were “large,

⁷⁸ Ex. 1044 (“Jones”), 1:20-30.

⁷⁹ Ex. 1045 (“Clarke”), US Patent 3,262,036.

⁸⁰ Ex. 1046 (“Shepherd”), Introduction.

⁸¹ Ex. 1042 (“Roethemeyer”) pg 543.

bulky and expensive” and had “marginal acceptance” throughout industry as a whole.⁸² However “certain industries like petro/chem and textile” showed larger acceptance, largely because of the very large motors used in those industries.⁸³

110. One of the main benefits of an ASD, other than the means to control the speed of the motor in order to control the output of the driven equipment (e.g. pumps), is the energy savings from reducing speed of the motor. Historically, with direct coupled AC motor driven equipment, a pump or fan was run at a constant speed and the pressure and flowrate of the process fluid was controlled by control valves, dampers, or other control devices that would open or close depending on the needs of the system. Other devices, such as the eddy current and magnetic drives varied the speed of the driven equipment while maintaining a constant speed on the motor. As the energy consumption of a motor is directly proportional to the speed of the motor (at a constant delivered torque), then as the speed of the motor is decreased, the energy consumption, and operational cost, of the motor also decreases. Since, in the 1980s, large drives were “large, bulky and expensive” they were applied first to large motors, such as those in the petrochemical industry and the textile industry, where the amount of savings could justify the expense and space of ASD installation.⁸⁴

⁸² Ex. 1042 (“Roethemeyer”) pg 543.

⁸³ Ex. 1042 (“Roethemeyer”) pg 543.

⁸⁴ See Ex. 1047 (Hickok) generally.

111. Between 1985 and 1989, bi-polar PWM technology had been developed, and drives became “smaller and more economical” which lead to “A greater acceptance among users”.⁸⁵ In this time frame as well, Insulated Gate Bipolar Transistors (IGBTs) were in use and “smaller drives packages with micro drives for smaller hp motors” had gained “A much larger acceptance. Micro drives have actually become commodities.”⁸⁶ As would make sense with any electronic technology, continued development led to smaller, less expensive devices that could be used where the energy savings would not justify larger, more expensive installations. This is analogous to the computer industry. The first digital computers were very large, requiring dedicated buildings, very expensive and could only be afforded by governments and very large corporations. As electronics progressed, they have come down to the point where a small, handheld device contains “More computing power than NASA” during the Apollo missions.

112. By at least 1988, very large VFD drives were in operation in petrochemical facilities. Frank DeWinter’s paper “The Application of a 3500-hp Variable Frequency Drive for Pipeline Pump Control” was presented to the IEEE Petroleum and Chemical Industry Conference in Dallas, TX in September 1988.⁸⁷ In this peer-reviewed publication, DeWinter discusses the expansion of a Canadian

⁸⁵ Ex. 1042 (“Roethemeyer”) pg 543-544.

⁸⁶ Ex. 1042 (“Roethemeyer”) pg 544.

⁸⁷ Ex. 1058 (“DeWinter”), 1019.

pipeline “from 130,000 barrels / day (bpd) to 185,000 bpd utilizing a 3500-hp adjustable speed drive. The unit is a variable frequency induction motor drive (VFD) supplied by GE Canada employing gate turn-off thyristors (GTOs).”⁸⁸ As DeWinter states “based on wide general industry acceptance of VFD’s, the technology was considered to be well established and accepted, and not of a ‘prototype’ nature. The VFD had to perform at least with the same degree of reliability as a control valve so as not to reduce the pipeline service factor.”⁸⁹ According to DeWinter, the installation would cost \$800,000 (Canadian) in 1986 dollars, but would generate approximately \$129,000 (Canadian) in overall operating cost savings in the first year alone. That is a good investment.⁹⁰

113. It is around this time that I gained my first exposure to ASDs. In 1990-1992, while employed by Public Service Company of Oklahoma, I was responsible for overseeing field installation of multiple ABB 4,500+ Hp VFDs for fans and pumps. These systems were, as Roethemeyer described them, “large, bulky and expensive,” requiring individual drive buildings for each pair of drives. However, the operational cost savings for these large motors more than justified the capital investment. As my career progressed I continued to design and oversee installation of smaller and smaller ASDs for various applications in power generation,

⁸⁸ Ex. 1048 (“DeWinter”) at Abstract.

⁸⁹ Ex. 1048 (“DeWinter”) pg 1020.

⁹⁰ Ex. 1048 (“DeWinter”) pg 1019.

petrochemical, and commercial environments. ASD technology has progressed now that even small, integer horsepower motors in residential applications, such as HVAC blowers and pool pumps, have become to be controlled by ASDs. ASDs were first applied to very large, several thousand horsepower motors, where the cost savings would justify their installation.

114. By at least 1997, “The use of variable frequency drives (VFD) is becoming increasingly popular with induction motor driven gas compressors.”⁹¹ To the motor and drive system, there is no significant difference between driving a reciprocating compressor or a reciprocating pump. Perrin’s paper describes applications of VFDs (ASDs) on 1500 – 3000 Hp installations.⁹²

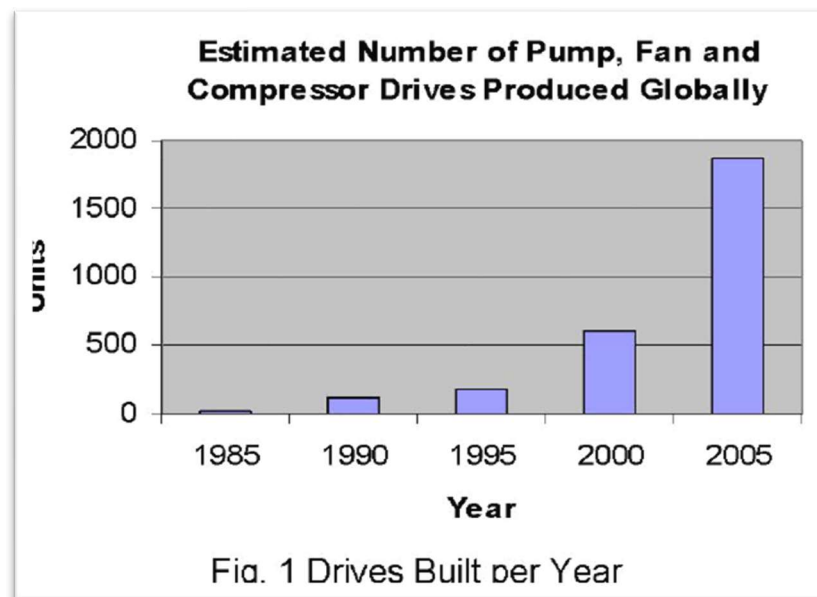
115. Installation of large ASDs in petroleum and chemical operations continued to increase. By the early 2000s, installations were so ubiquitous that industry, particularly the petroleum and chemical industry, recognized the need for standardization. This need led to the development of IEEE 1566 *Standard for Performance of Adjustable Speed Drives Rated 375 kW and Larger*. This standard was sponsored by Standards Subcommittee the Petroleum and Chemical Industry Committee of the IEEE. As discussed in the background section of my Declaration, I served as Chair of the Standards Subcommittee of the PCIC from 2013 – 2022. In

⁹¹ Ex. 1049 (“Perrin”) at Abstract.

⁹² Ex. 1049, pg. 3.

that role I was responsible for maintenance, update and oversight of IEEE 1566. IEEE 1566 continues as an Active standard today.⁹³

116. “Lockley”, published in 2006, contains a description of the need for and development of IEEE 1566. “Adjustable Speed Drives have been used in process application for some time on applications into many tens of MWs [MegaWatts, ~1,000 Hp] and from below 300 rpm up to about 20 000 rpm.”⁹⁴ Fig. 1 from Lockley showed the number of “pump fan and compressor” ASDs built annually between 1985 and 2005.



Ex 1050 “Lockley” Fig. 1.

⁹³ See Ex. 1050 (Lockley) generally

⁹⁴ Ex. 1050 (Lockley) pg. 1.

117. “Work stated in 2000 on an IEEE standard for large ASDs...the standard was approved in late 2005 and published in 2006”.⁹⁵ So, by 2006 large ASD installations had become so ubiquitous, particularly in the Petroleum and Chemical Industry, that the drives themselves had become standardized. As described by *Tutterow* by 2004, “Variable speed drives [VFDs] in pump systems are now a mature technology which can generate large benefits to the user in cost savings and reliability improvements.”⁹⁶

118. ASDs (VFDs) were also known to be used to control motors in hydraulic fracturing operations. By at least 2012, Coli “an electrically powered fracturing system”⁹⁷ that used variable frequency drives to control the speed of the fracturing pumps. Coli discloses how the electrification of the fracturing operation can improve costs,⁹⁸ efficiency,⁹⁹ safety,¹⁰⁰ and environmental impact.¹⁰¹ Regarding safety, Coli discloses that “[e]lectric motors controlled via variable frequency drive are far safer and easier to control than conventional diesel powered equipment.”¹⁰² Coli explains that because “electric motors are controlled by variable frequency

⁹⁵ Ex. 1050 (Lockley) pg. 2

⁹⁶ Ex. 1013 (*Tutterow*) pg. 1.

⁹⁷ Ex. 1030 (Coli) at Abstract.

⁹⁸ Ex. 1030 (Coli) at [0075].

⁹⁹ Ex. 1030 (Coli) at [0077].

¹⁰⁰ Ex. 1030 (Coli) at [0066].

¹⁰¹ Ex. 1030 (Coli) at [0080].

¹⁰² Ex. 1030 (Coli) at [0066].

drives [] the control software and variable frequency drives [“VFD”] calculate a maximum current available to the motors.”¹⁰³

119. Similarly, by 2012, *Broussard* taught “[a] system for hydraulically fracturing an underground formation” that “includes a plurality of electric pumps fluidly connected to the well, and configures to pump fluid into the wellbore at high pressure so that the fluid passes from the wellbore into the [formation] and fractures the formation.”¹⁰⁴ *Broussard* further teaches that the “electric pumps” comprises “pumps 10 [that] are powered by electric motors 14.”¹⁰⁵ “In addition,” *Broussard* teaches “each electric motor 14 can be equipped with a variable frequency drive (VFD) [] that controls the speed of the electric motor 14, and hence the speed of the pump 10.”¹⁰⁶

120. Using a single ASD to control the speed/torque of multiple motors has also been well-known. For example, in 1993 *Manz* described differences in applications of ASDs to various kinds of motors. As part of this description, *Manz* describes “load sharing where multiple motors are used with a single ASD” when describing ASD use with high starting torque NEMA D motors.¹⁰⁷ Reciprocating pumps are an application known to have high starting torque. As another example,

¹⁰³ Ex. 1030 (Coli) [0065].

¹⁰⁴ Ex. 1053 (*Broussard* at Abstract).

¹⁰⁵ Ex. 1053 (*Broussard*) 3:23.

¹⁰⁶ Ex. 1053 (*Broussard*) 3:39 – 42.

¹⁰⁷ Ex. 1035 (*Manz*) pg. 18.

in 2009 *Baseer* described one of the advantages of using ASD is “[a] single ASD ca[n] control more [than] one motors at once, so ASD can be known as multi-motor control.”¹⁰⁸

X. OVERVIEW OF THE PRIOR ART

A. BUCKLEY(Ex. 1004)

1. Status of Buckley

121. “*Buckley*” is a publication of a United States Patent Application, U.S. Patent Publication No. 2020/0256429. *Buckley* is entitled, “Electric Drive Pump for Well Stimulation.” *Buckley* was filed at the PCT on September 25, 2018, and published on August 13, 2020. *Buckley* claims priority to U.S. Provisional Application No. 62,562,943 filed September 25, 2017 (Ex. 1005, “*Buckley Provisional*”). The filing date of the *Buckley Provisional* is before the earliest possible priority date of all challenged claims of the ’533 Patent, and the portions of *Buckley* on which I rely are supported by the *Buckley Provisional*.

2. Overview of the Disclosure of Buckley and Buckley Provisional

122. Like the ’533 Patent, *Buckley* describes a pumping system that “relates generally to hydraulic fracturing in oil and gas wells, and in particular to an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a

¹⁰⁸ Ex. 1052 (*Baseer*) pg 134.

well.”¹⁰⁹ Thus, *Buckley* is clearly from the same field of art as the ’533 Patent, and describes a fracturing pump that is similar to the pump described in the ’533 Patent.

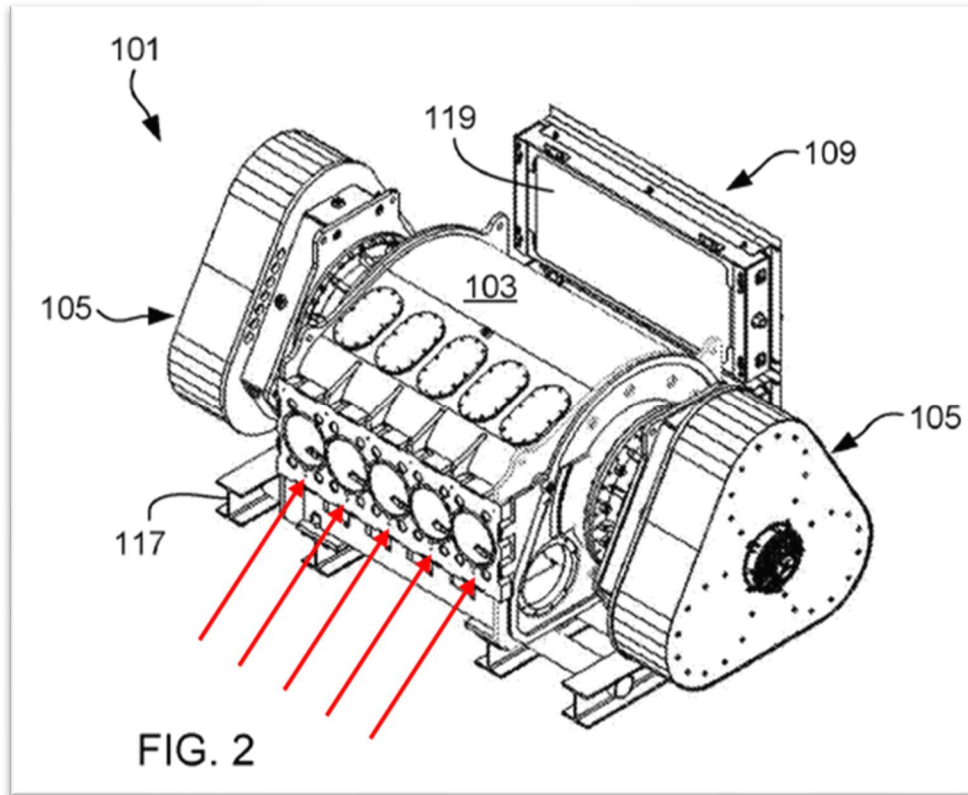
123. *Buckley* discloses that its electric drive pump system includes “a plurality of individual motors in selective configurations that work together to provide power to a power end,” and that the motors “are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid end” of the electric drive pump.¹¹⁰ *Buckley* describes several scenarios where multiple motors are turned on at the same time to meet the output needs of the drive pump (e.g., when a “50% output is required,...the even numbered motors 111 are operative while the odd numbered motors 111 are deactivated or turned off.”).¹¹¹

124. Further, *Buckley* discloses five-plunger pumps, as depicted by annotated Figure 2 of *Buckley* and annotated Figure 2 of *Buckley Provisional*:

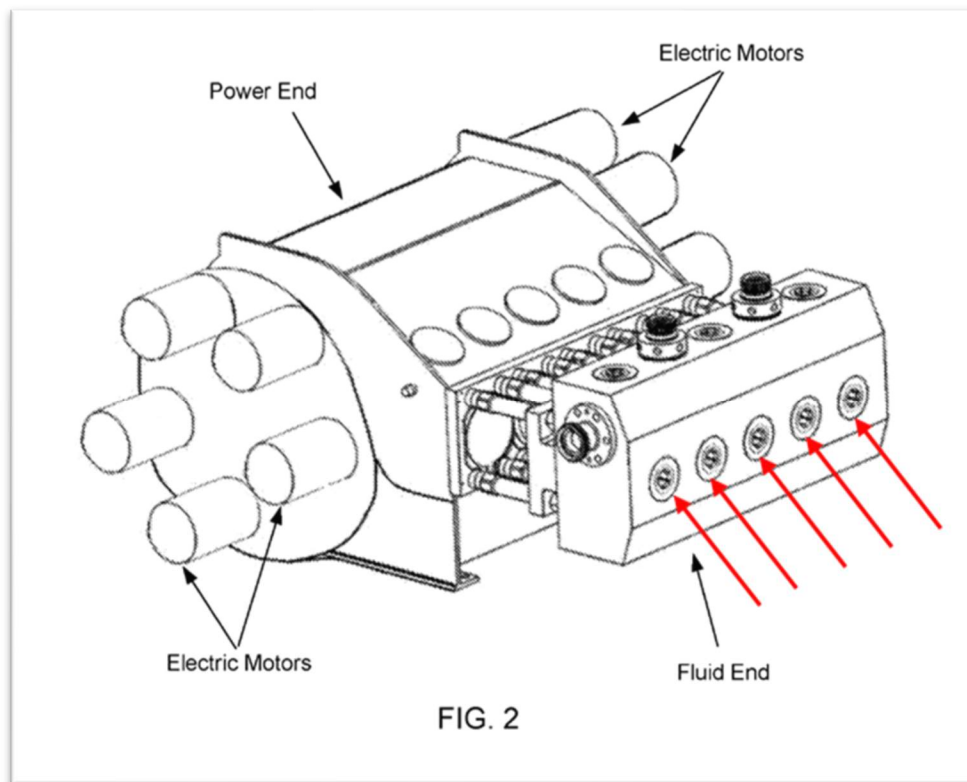
¹⁰⁹ Ex. 1004 (*Buckley*) [0001]; Ex. 1005 (*Buckley Provisional*) 2.

¹¹⁰ EX1004, [0009]; see also EX1005, 4 (“This system includes a series of electric motors of sufficient number needed to give the required output to operate the one or more fluid ends.”)

¹¹¹ See EX1004, [0057], Figs. 16-18; EX1005, 6, Figs. 4-6.



Ex. 1004 (*Buckley*), Fig. 2 (annotated).



EX1005 (*Buckley Provisional*), Fig. 2.

125. Thus, a POSITA would understand that *Buckley* discloses a multi-plunger fracturing pump that is simultaneously driven by multiple electric motors, similar to the pump described in the '533 Patent.

B. BERGAN(EX. 1006)

1. Status of Bergan

126. "*Bergan*" is a publication of a United States patent application, U.S. Patent Publication No. 2015/0361736. *Bergan* is entitled "Heave Compensation Winches." *Bergan* was filed June 13, 2014, and published December 17, 2015. Each of these dates is before the earliest possible priority date of all Challenged Claims of the '533 Patent.

2. Overview of the Disclosure of *Bergan*

127. *Bergan* discloses a hoisting system for use in oil and gas drilling that includes a rotatable drum driven by multiple electric motors.¹¹² *Bergan* further describes a “planetary gear system” that is used to couple the multiple electric motors to the load so the motors can drive the rotation of the load.¹¹³

128. Thus, *Bergan* is in a field of art—using multiple motors and a planetary gear system for driving a load in oil and gas drilling—that is highly relevant to the ’533 Patent, which describes using multiple motors and a planetary gear system for driving a fracturing pump, and a POSITA would understand that *Bergan* addresses the potential problem of coupling multiple electric motors to a load.

C. *ROSMAN*(EX. 1007)

1. Status of *Rosman*

129. “*Rosman*” is United States Patent No. 4,100,822. *Rosman* is entitled “Drive System for a Moving Mechanism.” *Rosman* was filed April 19, 1976, and granted July 18, 1978. Each of these dates is before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

¹¹² Ex. 1006 (*Bergan*), Abstract, [0003]-[0005], [0030].

¹¹³ Ex. 1006 (*Bergan*), [0032], Figs. 5, 6.

2. Overview of the Disclosure of *Rosman*

130. *Rosman* teaches the use of multiple smaller motors which combine power outputs through gearing to drive a larger, higher torque load.¹¹⁴ *Rosman* describes the use of “[p]lanetary transmission and gear boxes 22,” which are used “to develop the amount of torque necessary” to drive high-torque loads from “off-the-shelf” motors that “are known as fast rotating and hav[ing] lower torque output.”¹¹⁵ Thus, *Rosman* is highly relevant to the ’533 Patent, as it describes a gearing configuration for using multiple electric motors to drive a load, as is taught by the ’533 Patent.

D. *PAYNE* (EX. 1008)

1. Status of *Payne*

131. “*Payne*” is a publication of a United States patent application, U.S. Patent Publication No. 2016/0533267. *Payne* is entitled, “Well Fracturing Systems with Electrical Motors and Methods of Use.” *Payne* was filed March 3, 2016, and Published September 8, 2016. Each of these dates is before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of *Payne*

132. *Payne* describes a “system for stimulating oil or gas production from a wellbore [that] includes a hydraulic fracturing pump unit having one or more

¹¹⁴ See, e.g., Ex. 1007 (*Rosman*), 2:15-24, Figs. 1-4.

¹¹⁵ Ex. 1007 (*Rosman*), 4:54-62.

hydraulic fracturing pumps driven by one or more electrical fracturing motors, [and] a variable frequency drive (VFD) controlling the electrical fracturing motors.”¹¹⁶ *Payne* further discloses a programmable automation controller that can automatically shut off a VFD upon detecting an overpressure event in an associated fracturing pump.¹¹⁷ Thus, *Payne* is in a field of art—VFD-controlled electric motors for use with fracturing pumps—that is highly relevant to the ’533 Patent, which describes VFD-controlled, electric motor driven fracturing pumps.

E. Yi (Ex. 1009)

1. Status of Yi

133. “*Yi*” is a Chinese patent application publication entitled “Fracturing Pump Transmission System and Fracturing Pump” and published April 23, 2014. *Yi* was therefore publicly available before the earliest possible priority date of all Challenged Claims of the ’533 Patent. Petitioner has provided an English translation of *Yi* and a supporting translator affidavit (Ex. 1010).

2. Overview of the Disclosure of Yi

134. *Yi* discloses a “fracturing pump transmission system” wherein “multiple motors are used to drive the fracturing pump.”¹¹⁸ *Yi* teaches that “fracturing pump 5 is a crankshaft-type plunger pump,” and at the ends of the

¹¹⁶ Ex. 1008 (*Payne*), Abstract.

¹¹⁷ Ex. 1008 (*Payne*), [0039].

¹¹⁸ Ex. 1010 (*Yi* Translation), Abstract.

crankshaft are “power input gears 51, and each motor 4 engages at least with the power input gears 51 at one of end of the crankshaft-type plunger pump through a power output gear 41 whose pitch circle diameter is smaller than that of the power input gear.”¹¹⁹ Thus, POSITA would understand that *Yi* discloses a fracturing pump that is driven by multiple motors, similar to the pump described in the ’533 Patent.

F. JELAKSA (EX. 1012)

1. Status of Jelaska

135. “*Jelaska*” is a selection from the book titled *Gears and Gear Drives* by Damir *Jelaska* and was publicly available no later than May 16, 2013.¹²⁰ *Jelaska* is therefore publicly available before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of Yi

136. *Jelaska* is a textbook that describes various gearing systems, their underlying mathematical principles, and their applications.¹²¹ In particular, *Jelaska* describes the equation for the transmission ratio of a mechanical drive, which is defined as the ratio of the drive’s driving and driven shaft speeds of rotation.¹²²

¹¹⁹ Ex. 1010 (*Yi* Translation), [0044].

¹²⁰ Ex. 1022 (Hall-Ellis Declaration), ¶¶ 34-40, 62.

¹²¹ See generally Ex. 1012 (*Jelaska*).

¹²² Ex. 1012 (*Jelaska*), 3.

G. TUTTEROW (EX. 1013)**1. Status of Tutterow**

137. “Tutterow” is a book titled *Variable Speed Pumping: A Guide to Successful Applications* prepared at the Europump and Hydraulic Institute. Tutterow was publicly available no later than August 24, 2004.¹²³ Tutterow is therefore publicly available before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of Tutterow

138. Tutterow is a textbook that describes fundamental pumping principles, types of pumps, and techniques for controlling the speed of those pumps.¹²⁴ In particular, Tutterow describes the well-known phenomenon called “cavitation” and cavitation’s effects on pumping systems.¹²⁵

H. AUGUST (EX. 1014)**1. Status of August**

139. “August” is a book titled *Dynamics of Planetary Gear Trains*, by R. August *et al.*, and was publicly available no later than July 2, 1984.¹²⁶ August was therefore publicly available before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

¹²³ Ex. 1022 (Hall-Ellis Declaration), ¶¶ 41-47, 62.

¹²⁴ See generally Ex. 1013 (Tutterow).

¹²⁵ Ex. 1013 (Tutterow), 20, 30.

¹²⁶ Ex. 1022 (Hall-Ellis Declaration), ¶¶ 48-54, 62.

2. Overview of the Disclosure of *August*

140. *August* describes planetary gearing system operations and analyses, as well as the star arrangement variation of a planetary gearing configuration.¹²⁷

I. *MORRIS* (Ex. 1015)

1. Status of *Morris*

141. “*Morris*” is a U.S. Patent Application Publication filed on August 31, 2016, and published on December 22, 2016. Each of these dates is before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of *Morris*

142. *Morris* discloses a hydraulic fracturing system wherein a “prime mover” (e.g., an electric motor) is coupled to one or more pumps via “fixed couplings 1412,” such as “flex couplings and/or universal joint-based coupling.”¹²⁸

J. *JOYNER* (Ex. 1016)

1. Status of Joyner

143. “*Joyner*” is a U.S. Patent issued on June 21, 2005, which is before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of *Joyner*

144. *Joyner* discloses the components and arrangement of a universal joint.¹²⁹

¹²⁷ Ex. 1014 (*August*), 8-9, 149.

¹²⁸ Ex. 1015 (*Morris*), Abstract, [0094].

¹²⁹ Ex. 1016 (*Joyner*), 2:58-3:17, Fig. 1.

K. KARASSIK (EX. 1017)**1. Status of *Karassik***

145. “*Karassik*” is a book titled *Pump Handbook*, by Igor Karassik *et al*, and was publicly available no later than April 29, 2008.¹³⁰ *Karassik* was therefore publicly available before the earliest possible priority date of all Challenged Claims of the ’533 Patent.

2. Overview of the Disclosure of *Karassik*

146. *Karassik* describes pump theory and operation, including the use of seven- and nine-plunger pumps.¹³¹

XI. GROUND 1A: OBVIOUS OVER *BUCKLEY, BERGAN, AUGUST, MORRIS, AND JOYNER*

147. It is my opinion that *Buckley* in view of *Bergan, August, Morris, and Joyner* discloses, suggests, and renders obvious Claims 1-4 and 10-13 of the ’533 Patent.

A. MOTIVATION TO COMBINE**1. *Buckley, Bergan, and August***

148. A POSITA would have been motivated to combine the teachings of *Buckley* and *Bergan* to take advantage of *Bergan*’s teachings regarding how to connect multiple motors to drive a single rotary load.

¹³⁰ Ex. 1022 (Hall-Ellis Declaration), ¶¶ 55-62.

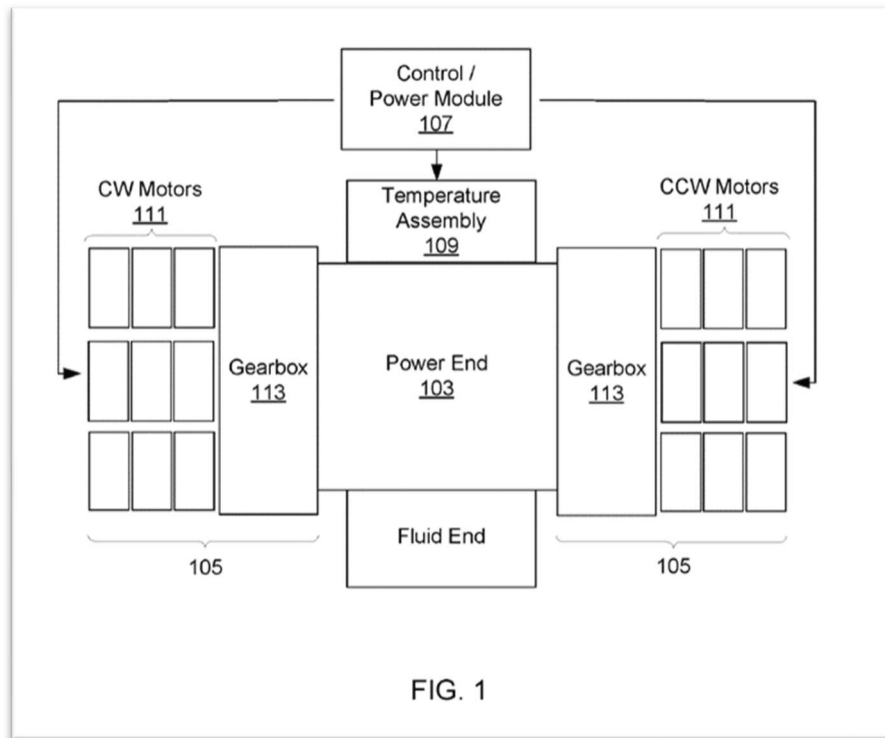
¹³¹ Ex. 1017 (*Karassik*), 3.11.

149. Initially, both *Buckley* and *Bergan* teach using multiple motors driving a single load in an oil and gas application. *Buckley* teaches using multiple motors to drive a single rotary load such as a fluid end of a fracturing pump. *Buckley* discloses that “[t]he electric drive pump system is configured to provide a plurality of individual motors in selective configurations that work together to provide power to a power end. The motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”¹³² *Buckley* teaches that the electric drive pump system is intended as an improvement of pumps used for “hydraulic fracturing procedure or “frac job,”¹³³ and that “[t]he present application relates generally to hydraulic fracturing in oil and gas well, and in particular to an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a well.”¹³⁴ Fig. 1 of *Buckley* displays the plurality of motors arranged around a gearbox and providing power to the “power end” of a pump.

¹³² Ex. 1004 (*Buckley*) [0009]; see also Ex. 1005 (*Buckley* Provisional) pg 4, 5 (“Selected gearing may be used to assist in mating the electric motors to the power end. ... Also a transfer gear system can be used if required.”)

¹³³ Ex. 1004 (*Buckley*) [0001]; see also Ex. 1005 (*Buckley* Provisional) pg. 2

¹³⁴ Ex. 1004 (*Buckley*) [0009]; see also Ex. 1005 (*Buckley* Provisional) pg. 2



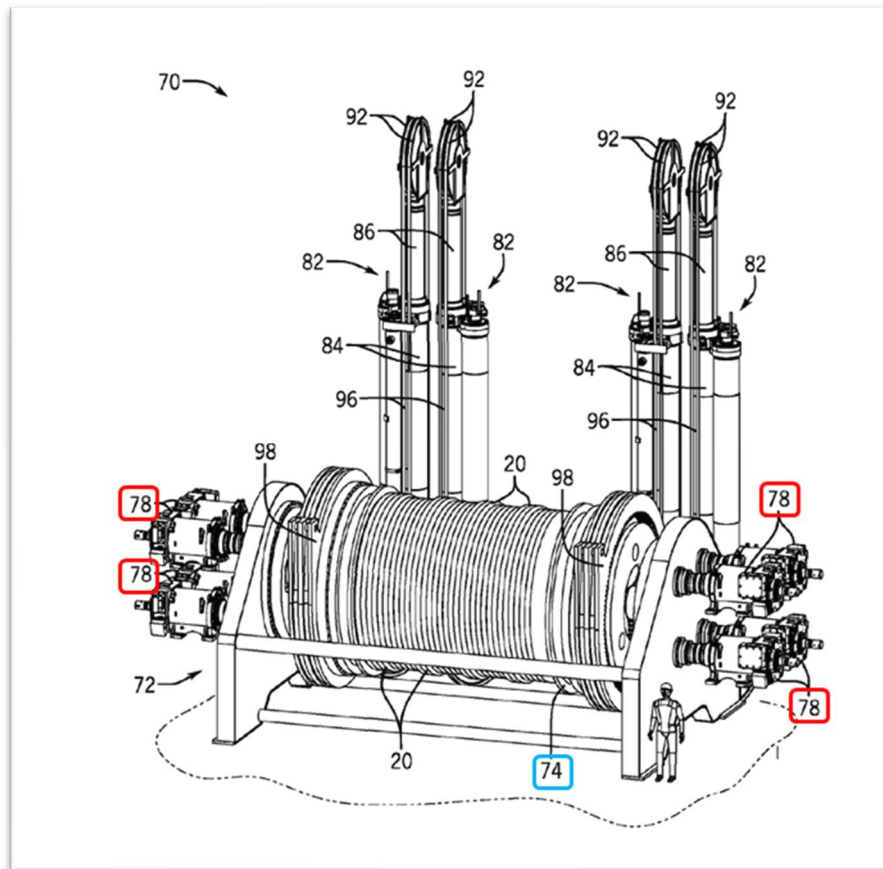
Ex. 1004 (*Buckley*) Fig. 1¹³⁵

150. A POSITA would have been motivated to look to other references to understand gearing configurations useful to connect multiple motors to drive a single load and would have understood that *Bergan* provides one such solution.

151. Like *Buckley*, *Bergan* teaches the use of a plurality of motors located around the shaft of the load (i.e. drum) and connected to the shaft via gearing systems, and was used in oil and gas drilling, which is at least a closely related field to hydraulic fracturing. For example, when describing Fig. 3, *Bergan* discloses “[m]otors 78 [annotated in red] can be operated to drive rotation of the drum 74

¹³⁵ See also Ex. 1005 (*Buckley Provisional*) Fig. 1, Fig. 2.

[annotated in blue] to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”¹³⁶

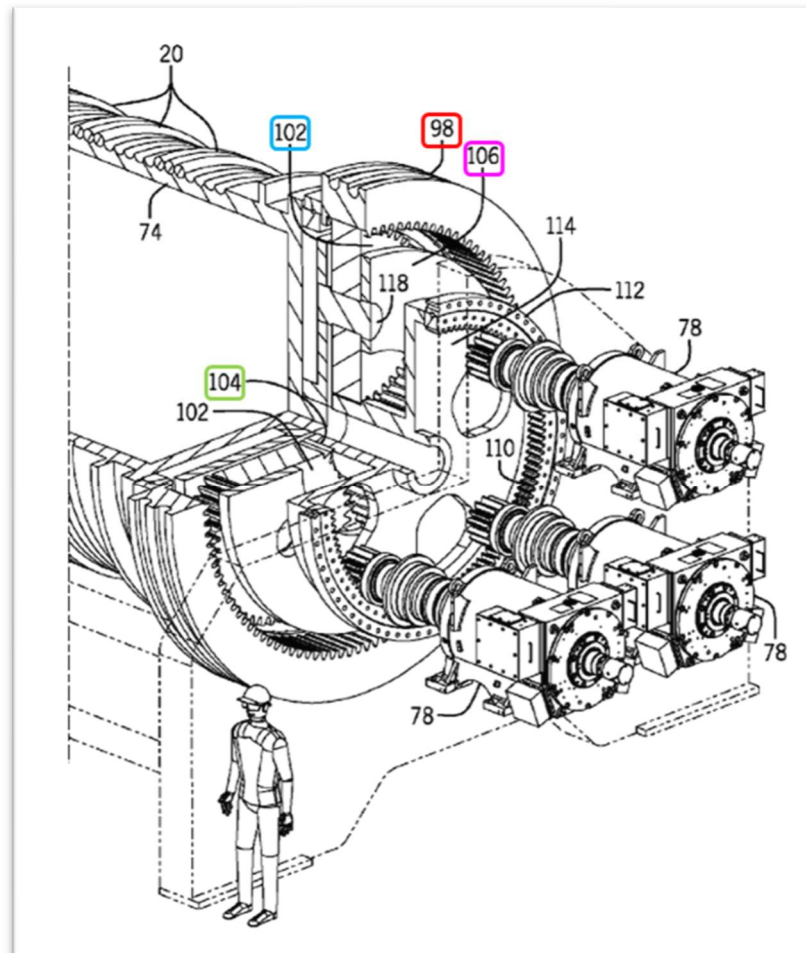


Ex. 1006 (*Bergan*) Fig. 3 (annotated)

152. *Bergan* further teaches the use of a planetary gear system to couple motors to the shaft. *Bergan* discloses “As generally shown in FIG. 4 and more specifically shown in FIGS. 5 and 6, the planetary gear system includes the ring gear 98 [annotated in red], planetary gears 102 [annotated in blue], and a sun gear 104

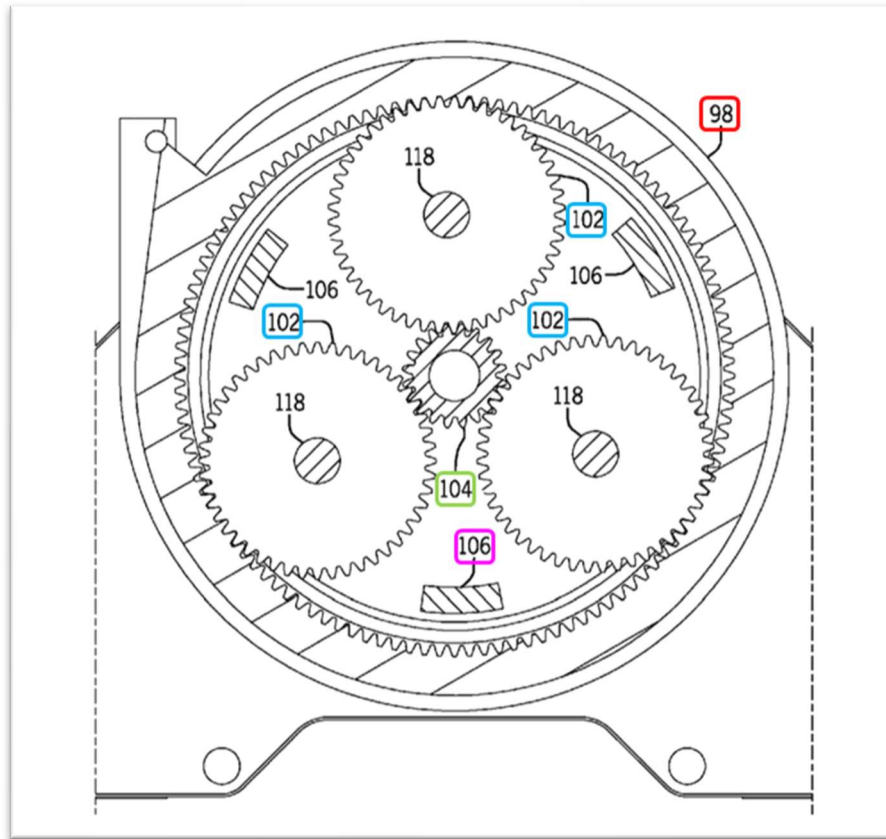
¹³⁶ Ex. 1006 (*Bergan*) [0030].

[annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in operation.”¹³⁷



Ex. 1006 (*Bergan*) Fig. 5 (annotated)

¹³⁷ Ex. 1006 (*Bergan*) [0032].



Ex. 1006 (*Bergan*) Fig. 6 (annotated)

153. A POSITA would have recognized that the planetary gear system of *Bergan* would have been useful in connecting the multiple motors of *Buckley* to *Buckley's* rotating load (i.e. the pump crankshaft) as planetary gear trains were known to be more compact, have a higher torque rating and have better lubrication than other gearing systems (e.g., fixed, parallel shaft gearboxes), and would have been motivated to incorporate a planetary gear train in the system of *Buckley* to gain these advantages from such a configuration.¹³⁸

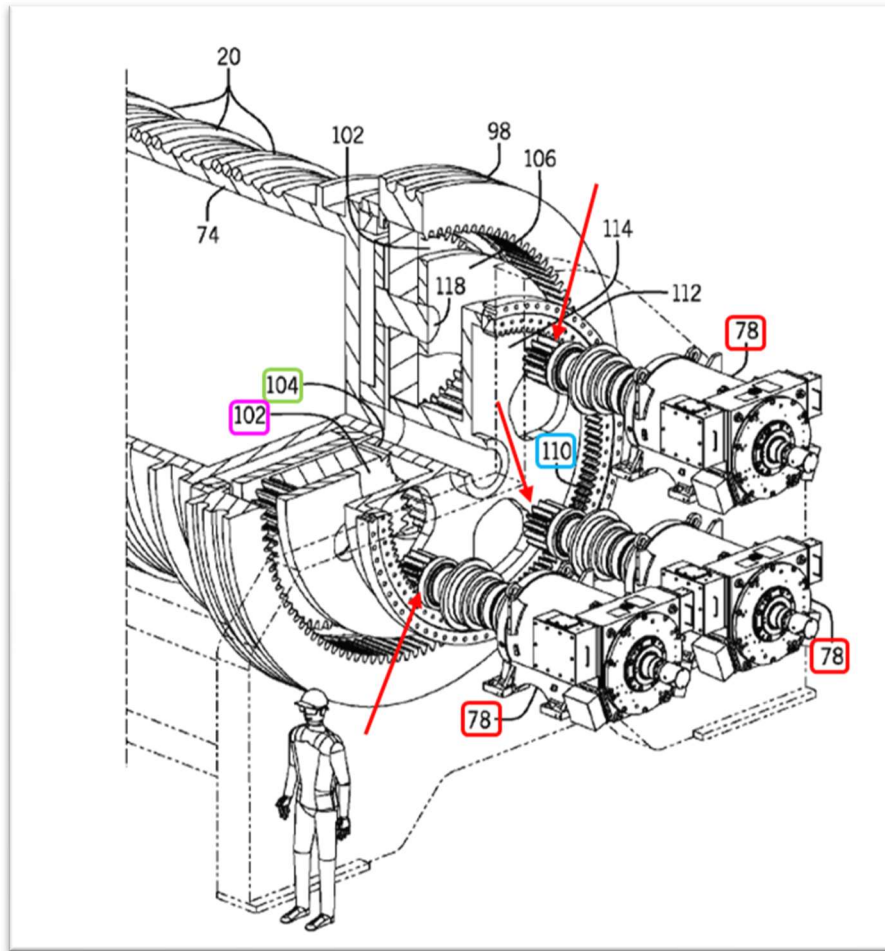
¹³⁸ See section IX.C above

154. Further, *Bergan* shows a specific configuration of gearing that would have been used to connect *Buckley's* plurality of motors to a single rotary load. For example, *Bergan* discloses “the motors 78 [annotated in red below] are connected to drive rotation of a gear 110 [annotated in blue below] of a slew bearing 112. The gear 110 is coupled to a sun wheel 114 having the sun gear 104 [annotated in green below] such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 [annotated in magenta] are mounted on axles 118 coupled to the carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”¹³⁹

155. *Bergan's* Figure 5 shows a perspective view of *Bergan's* gearing mechanism. Figure 5 further shows the motors 78 each rotationally coupled to an “input pinion” (not numbered, annotated with red arrows) allowing the motors to drive the gearing system. A “pinion” was known to be “a gear with a small number of teeth designed to mesh with a larger wheel or rack.”¹⁴⁰ The pinions annotated with red arrows mesh with the larger gear (wheel) 110.

¹³⁹ Ex. 1006 (*Bergan*) [0032]; *see also, e.g.*, [0014], [0035], [0041], Claims 4-6, 10, 16-18.

¹⁴⁰ Ex. 1011.



Ex. 1006 (*Bergan*) Fig. 5 (annotated)

156. A POSITA would have had a reasonable expectation of success in combining the teachings of *Buckley* and *Bergan*. Incorporating *Bergan*'s teachings of a planetary gear train and the use of "pinions" to connect the motors to the load is applying a known technique (planetary gear trains and motors with pinions) to improve similar devices (*Buckley*'s gearbox) in the same way. The results of the combination would have been predictable – transfer of rotational energy from *Buckley*'s motors to *Buckley*'s pump with straightforward, predictable changes in

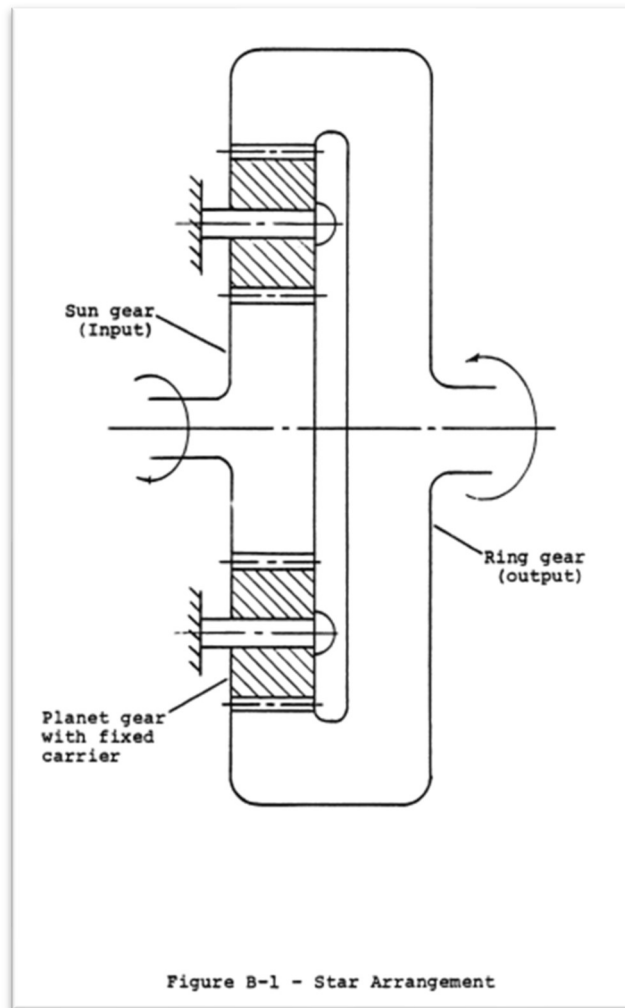
gear ratios and corresponding changes in speed and torque available. Additionally, *Bergan*'s teachings of planetary gear systems and motors with pinions was known in one field of endeavor (oil and gas drilling) and would have prompted a POSITA to use it in either the same field or a different one (oil and gas fracturing) based on design incentives (ability to connect multiple motors to a single load and the advantages of a planetary gear train described in Section IX.D) because the variations used for a pump—such as using appropriately-sized gears in a manner obvious to a POSITA—would have been predictable to one of ordinary skill in the art. As discussed above, the results of the combination would have been predictable – transfer of rotational energy from *Buckley*'s motors to *Buckley*'s pump with straightforward, predictable changes in gear ratios and corresponding changes in speed and torque available. Similarly, modifying *Buckley*'s pumping system to use *Bergan*'s planetary gearing system requires a simple substitution of one known element (*Bergan*'s planetary gearing system with obvious changes to gear sizes) for another (*Buckley*'s gearing system) to obtain the predictable result of transferring rotational energy from *Buckley*'s motors to *Buckley*'s pump. Thus, a POSITA would have been motivated to combine the teachings of *Buckley* and *Bergan* and would have had a reasonable expectation of success in doing so.¹⁴¹

¹⁴¹ I also understand that the U.S. Patent Office combined *Buckley* and *Bergan* in a similar manner during the prosecution of the '533 Patent. See Ex. 1002, 157-162 (Office Action analysis of *Buckley-Bergan* combination).

157. A POSITA would have been motivated to further combine the *Buckley-Bergan* combination with *August*. *August* teaches a modified planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are instead coupled to both a **fixed** carrier and a ring gear, where the ring gear is driven by the rotation of the planetary gears to produce an output rotation. This is a relatively minor variation of the planetary gear system of *Bergan*, using the same components. In the planetary gear system of *Bergan*, the carrier (attached to the planet gears) is allowed to rotate and drive the load (e.g. fracturing pump). In the star configuration of *August*, the ring gear is allowed to rotate, and the carrier (attached to the planet gears) is held fixed. The only significant change in operation of the system is a change in gear ratio from $\frac{N_R}{N_S} + 1$ to $-\frac{N_R}{N_S}$ where N_R and N_S are the number of teeth of the ring gear and sun gear respectively.¹⁴² Accordingly, incorporating *August*’s star arrangement would have predictable results, change in speed (and torque) based on a known relationship (ratio of the number of teeth of the ring gear and sun gear respectively).

158. Figure B-1 of *August* depicts this configuration from a side section view:

¹⁴² Ex. 1014 (*August*) pg. 151.



EX1014, 149.

159. A POSITA would have been motivated to combine the *Buckley-Bergan* combination with *August's* star arrangement, which would result in a modified planetary gearing system wherein *Bergan's* planetary gears 102 are coupled to a fixed carrier (as taught by *August*) and a rotatable ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan's* carrier 106, would serve as the output of the planetary gearing system to drive the pump crankshaft. This would allow for a different gear ratio as described above. A

POSITA, therefore, would be motivated to combine August, for example, to allow for a smaller gear ratio. Such a modification would involve a simple substitution of one known element (*August*'s star arrangement) for another (*Bergan*'s fixed-carrier gearing configuration) to obtain the predictable result of driving output rotation through *August*'s ring gear to *Buckley*'s pump crankshaft. Accordingly, a POSITA would have been motivated to combine *Buckley*, *Bergan*, and *August* and would have had a reasonable expectation of success in doing so.

2. *Morris and Joyner*

160. *Morris* discloses a hydraulic fracturing system wherein an electric motor is coupled to one or more fracturing pumps via “fixed couplings,” such as “flex couplings and/or universal joint-based coupling.”¹⁴³ *Morris* teaches that these couplings allow for easier removal and replacement of the motor (prime mover) and pump.¹⁴⁴ However, *Morris* provides little detail about how these couplings operate, likely because such couplings were so well-known. To the extent that such couplings were not already in the general knowledge of a POSITA, to fill in the blanks of *Morris*, a POSITA would have searched for other references to better understand details of such couplings that are not described in *Morris*. One such reference is *Joyner*, whose disclosure of particular details about universal joints and their

¹⁴³ Ex. 1015 (*Morris*), Abstract, [0094].

¹⁴⁴ Ex. 1015 (*Morris*) [0086] – [0087].

components would have been useful to a POSITA looking to implement the teachings of *Morris* to a practical system.¹⁴⁵ *Joyner* teaches the basic structure of universal joints, including connections using arms, as well as methods of assembling universal joints in order to reduce vibration, which is a stated concern of *Morris*. *Morris* teaches that the number of fixed couplings based on “vibrations from the pump need[ing] to be deflected to avoid affecting the operation of the prime mover.”¹⁴⁶ *Joyner* teaches positioning portions of the universal joint precisely “to prevent or minimize the occurrence of undesirable noise or vibration when the universal joint is operated.”¹⁴⁷

161. Further, a universal joint-based coupling, such as the one of *Joyner*, would allow for “rotat[ion] about non-aligned axes of rotation. As taught by *Joyner*, “[u]niversal joints are well known devices that provide a driving connection between two members that are adapted to rotate about non-aligned axes of rotation.”¹⁴⁸ This would allow shafts of the gearbox to drive the shaft of the pump while not requiring the pump to be perfectly in alignment with the shaft of the gearbox. The use of a universal joint would also have allowed for easier assembly of the gearbox-pump arrangement as well as have facilitated easier repair/replacement of the pump and/or

¹⁴⁵ Ex. 1016 (*Joyner*), 2:58-3:18 (describing components of a universal joint).

¹⁴⁶ Ex. 1015 (*Morris*) [0094].

¹⁴⁷ Ex. 1014 (*Joyner*) 5:11 – 17.

¹⁴⁸ Ex. 1016 (*Joyner*) 1:16 – 18.

gearbox. As was well known to a POSITA, fracturing pump seals wear over time and require repair / replacement of the pump and/or pump seals. Using a universal joint, such as the joint of *Joyner* would allow the pump to be replaced without going through the time-consuming process of precisely aligning the pump with the gearbox, allowing the pump to be replaced in the field if necessary.

162. Further, combining *Joyner*'s teachings regarding universal joint components to *Morris*'s universal joint-based coupling configuration is merely combining prior art elements (universal joint components as taught by *Joyner*) to known methods (*Morris*'s universal joint-based coupling) to yield predictable results (producing a universal joint-based coupling to join two rotating shafts). Accordingly, a POSITA would have been motivated to combine *Joyner*'s teachings regarding universal joint components with the *Morris*'s universal joint-based coupling and would have reasonably expected success in doing so.

3. *Buckley-Bergan-August and Morris-Joyner*

163. A POSITA would have been motivated to combine the pumping system of the *Buckley-Bergan-August* combination with the fixed couplings of *Morris-Joyner* combination such that the fixed couplings join the output shaft of the *Buckley-Bergan-August* combination's planetary gearing system (*i.e.*, the output shaft of *August*'s ring gear) with *Buckley*'s pump crankshaft. First, design incentives and market forces would have motivated a POSITA to incorporate *Morris*'s fixed

coupling configuration with the *Buckley-Bergan-August* combination's pumping configuration. This combination would allow for easier alignment of the prime mover (including the gear train) and the pump, and further limiting damage caused by vibration of the pump during operation, as well as facilitating easier removal and replacement of the prime mover or the pump, as taught by *Morris*.¹⁴⁹

164. Second, incorporating the *Morris-Joyner* combination's teaching of a universal joint-based coupling configuration is applying a known technique (universal joint-based couplings between two rotating shafts) to improve similar devices (the *Buckley-Bergan-August* pumping system) in the same way. The results of the combination would have been predictable: transfer of rotational energy from the *Bergan-August* planetary gearing system's motors to *Buckley's* pump crankshaft with universal joint-based couplings to reduce the effects of misalignment between the two components that may results from vibration of *Buckley's* pump. Further, design incentives and market forces would have motivated a POSITA to incorporate *Morris's* fixed coupling configuration to protect the *Buckley-Bergan-August* combination's pumping configuration from damages that would arise from vibration caused by *Buckley's* pump, and to allow for easier repair/replacement of the pump and/or motor, as taught by *Morris*. Accordingly, a POSITA would have been motivated to combine the *Buckley-Bergan-August* combination with the *Morris-*

¹⁴⁹ Ex. 1015 (*Morris*) [0086] – [0087], [0094].

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

B. INDEPENDENT CLAIM 1

165. As discussed in the following subsections, it is my opinion that the combination of *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 1 of the '533 Patent. As discussed in the following subsections, *Buckley*, *Bergan*, *August*, *Morris*, and/or *Joyner* disclose or render obvious each and every element of Claim 1.

1. 1[p]: “1. A hydraulic fracturing system for fracturing a subterranean formation comprising:”

166. *Buckley* discloses a hydraulic fracturing system.¹⁵⁰ *Buckley* discloses that “[t]he present application relates generally to hydraulic fracturing in oil and gas wells, and in particular to an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a well.”¹⁵¹ Further, *Buckley* teaches that “[h]ydraulic fracturing has been used for decades to stimulate production from conventional oil and gas wells,” that the process includes pumping fluid into a (downhole) formation, and that “[w]hen the fluid enters the formation, it fractures,

¹⁵⁰ I understand that the preamble may not be limiting. I include analysis of the preamble out of an abundance of caution.

¹⁵¹ Ex. 1004 (*Buckley*) [0001]; see also Ex. 1005 (*Buckley Provisional*) pg. 2

or creates fissures, in the formation.”¹⁵² As discussed above in Section IX.A, this is a typical and well-known part of hydraulic fracturing dating back to the 1940s.

167. Accordingly, *Buckley* discloses, and the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* renders the preamble obvious.

2. 1[a]: “a multi-plunger hydraulic fracturing pump configured to pump fluid to a wellbore associated with the subterranean formation, the multi-plunger hydraulic fracturing pump comprising a pump crankshaft;”

a) “a multi-plunger hydraulic fracturing configured to pump fluid into a wellbore associated with the subterranean formation”

168. *Buckley* discloses a multi-plunger hydraulic pump that is configured to pump fluid into a wellbore associated with the subterranean formation. Initially, the ’533 Patent admits that multi-plunger hydraulic fracturing pumps were known: “Multi-plunger hydraulic fracturing pumps, though known in the art, are typically limited to either triplex (three plungers) or quintuplex (five plungers) arrangements.”¹⁵³ *Buckley* discloses “an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a well.”¹⁵⁴ Further, *Buckley* describes “hydraulic fracturing [] consists of pumping fluid into a wellbore at high pressure

¹⁵² Ex. 1004 (*Buckley*) [0002]; see also Ex. 1005 (*Buckley Provisional*) pg. 2

¹⁵³ Ex. 1001 5:1-3.

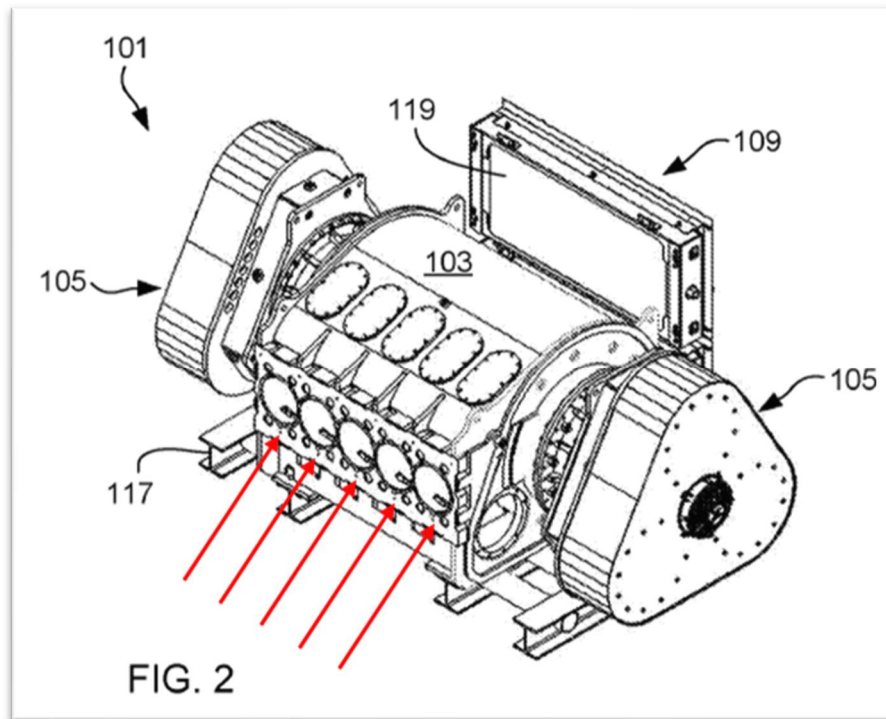
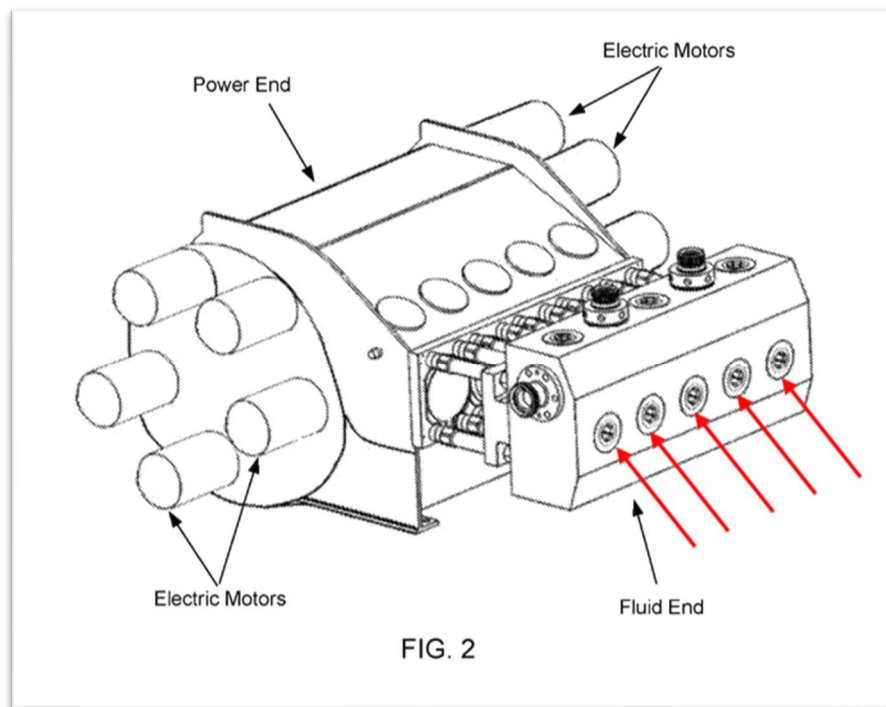
¹⁵⁴ Ex. 1004 (*Buckley*) [0001]; see also Ex. 1005 (*Buckley Provisional*) pg. 2

(sometimes as high as 50,000 PSI).”¹⁵⁵ Accordingly, *Buckley* teaches pumping fluid into the well and wellbore associated with the subterranean formation.

169. *Buckley*’s configuration contains “a plurality of individual motors in selective configurations that work together to provide power to a power end. The motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”¹⁵⁶ As discussed above in Section IX.B, the use of multiple plungers in a pump fluid end was well-known long before the ’533 Patent. Both *Buckley* and the *Buckley* provisional provide figures that show the use of a quintuplex (5 plungers) fluid end. In each figure, the 5 cylinders (annotated in red) are evident from the arrangement of the fluid end.

¹⁵⁵ Ex. 1004 (*Buckley*) [0002]; see also Ex. 1005 (*Buckley* Provisional) pg. 2.

¹⁵⁶ Ex. 1004 (*Buckley*) [0009];

Ex. 1004 (*Buckley*) Fig. 2Ex. 1005 (*Buckley Provisional*) Fig. 2

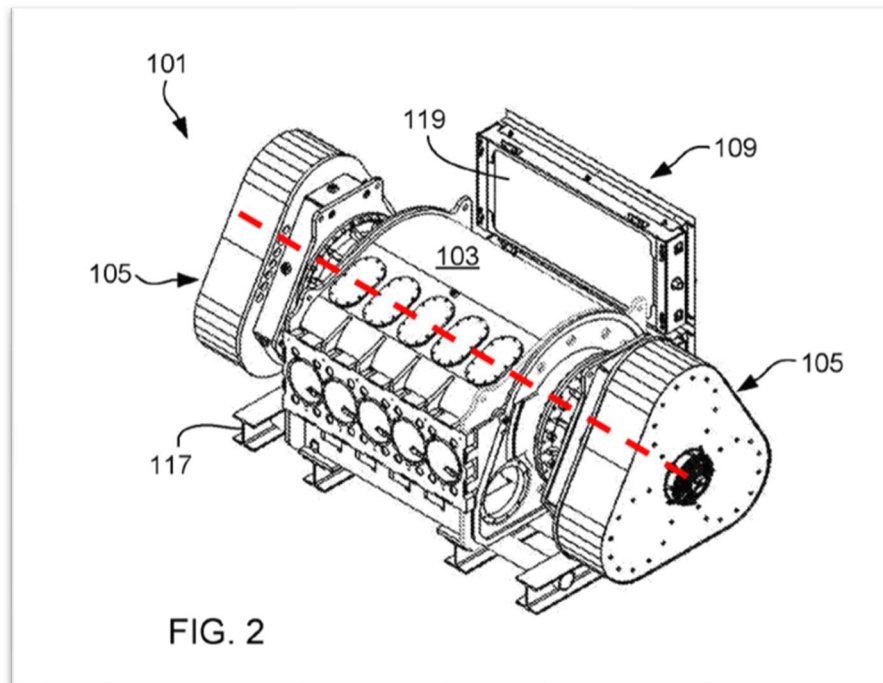
170. Accordingly, as *Buckley* discloses the use of a 5-plunger pump, *Buckley* discloses the use of a “multi-plunger” pump. To the extent that *Buckley* does not explicitly use the term “multi-plunger” when describing the pump, the use of a “multi-plunger” fracturing pump would have been obvious to a POSITA based on the general knowledge of a POSITA that such pumps were commonly used in fracturing operations (see section IX.A), the disclosure of *Buckley* including showing a multi-plunger fracturing pump in the figure(s), and the ’533 Patent’s admission that multi-plunger pumps are known in the art.

171. Further, *Buckley* teaches that “[h]ydraulic fracturing has been used for decades to stimulate production from conventional oil and gas wells. The practice consists of pumping fluid into a wellbore at high pressure (sometimes as high as 50,000 PSI). Inside the wellbore, large quantities of proppants are carried in suspension by the fracture fluid into the fractures. When the fluid enters the formation, it fractures, or creates fissures, in the formation. Water, as well as other fluids, and some solid proppants, are then pumped into the fissures to stimulate the release of oil and gas from the formation”¹⁵⁷ Accordingly, *Buckley* discloses that the fluid passes from the wellbore into the subterranean formation to fracture the subterranean formation, and the wellbore is associated with the formation.

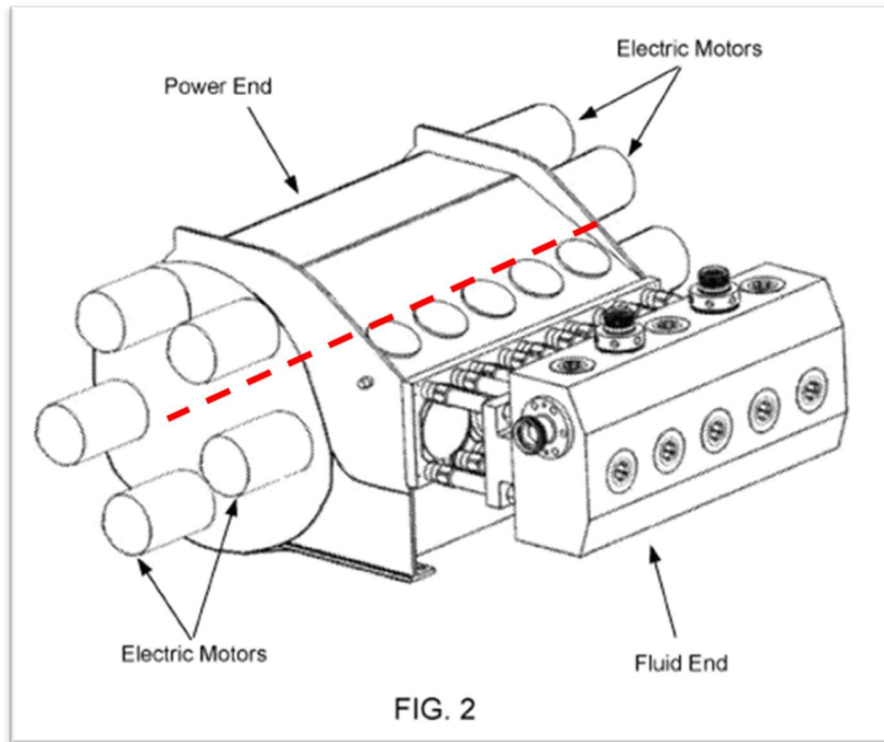
¹⁵⁷ Ex. 1004 (*Buckley*) [0002]; see also Ex. 1005 (*Buckley* Provisional) pg. 2

b) “the multi-plunger hydraulic fracturing pump comprising a pump crankshaft”

172. A POSITA would have understood that *Buckley*’s electric drive pump comprises a “pump crankshaft.” Although *Buckley* does not specifically identify its electric drive pump as comprising a “pump crankshaft,” a POSITA would have understood that *Buckley*’s electric drive pump comprises a crankshaft, which would have been located internally in the pump as shown by the red line in the below copies of the electric drive pumps disclosed by *Buckley* and *Buckley Provisional*:



Ex. 1004 (*Buckley*), Fig. 2 (annotated).



Ex. 1005 (Buckley Provisional), Fig. 2 (annotated).

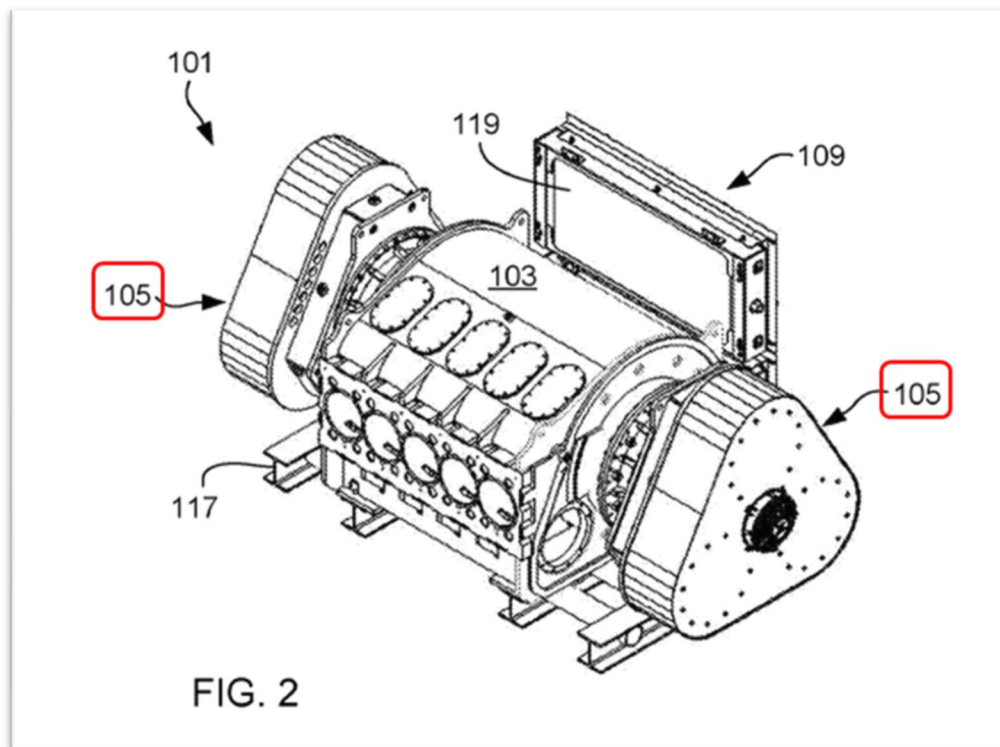
173. This understanding of *Buckley* is consistent with the examiner's rejection of Limitation 1[a] during prosecution, which was not contested by the applicant, where the examiner found that it is "inherent that crankshaft runs down axis of power end" of the pump as annotated.¹⁵⁸

3. 1[b]: "a plurality of motors positioned to power the multi-plunger pump; and"

174. *Buckley* discloses this limitation as well. *Buckley* discloses that "[t]he electric drive pump system is configured to provide a plurality of individual motors in selective configurations that work together to provide power to a power end. The

¹⁵⁸ Ex. 1002 (533 File History), 140-145, 158-159.

motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”¹⁵⁹ The plurality of motors is shown in the figures of both *Buckley* and its Provisional Application. Fig. 2 of *Buckley* shows “transmission assembly 105” (annotated in red) mounted to drive the pump.



¹⁵⁹ Ex. 1004 (*Buckley*) [0009]; see also Ex. 1005 (*Buckley* Provisional) p. 4 (“Referring now to Figures 1 and 2 in the drawings, a side view of a schematic of a power end in communication with a plurality of electric motors and a representative perspective view is illustrated. The power end includes a pump that is used to operate one or more fluid ends. [] This system includes a series of electric motors of sufficient number needed to give the required output to operate the one or more fluid ends. The precise number is dependent upon design constraints and engineering parameters. It is understood that more than one may be used. In Figure 1,[sic. Figure 2] a total of 10 are shown or implied, with 5 being located on either side of the power end.”)

Ex. 1004 (*Buckley*) Fig. 2 (annotated)

Fig. 9 of *Buckley* shows that transmission assembly 105 (annotated in red) comprises a plurality of “motors 111” (annotated in blue). These motors are positioned to provide power to the pump.

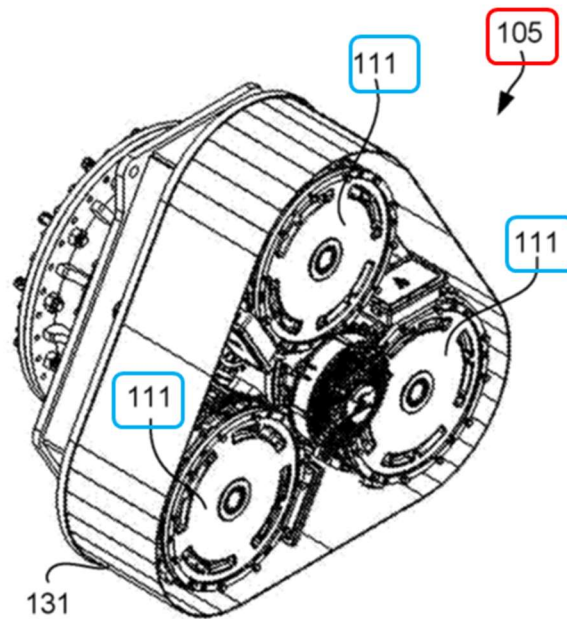
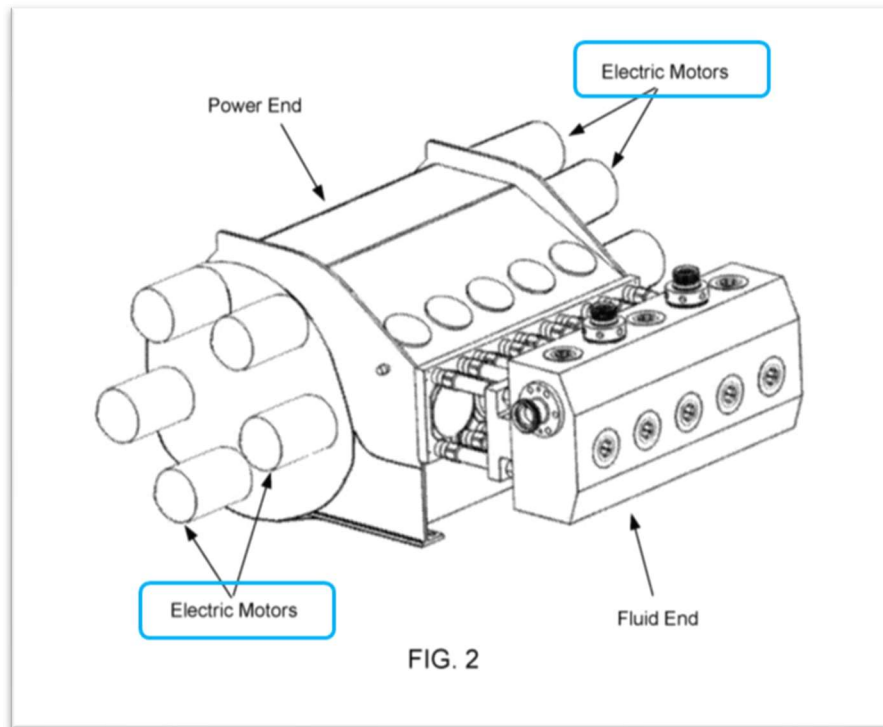


FIG. 9

Ex. 1004 (*Buckley*) Fig. 9 (annotated)

175. Similarly, *Buckley Provisional* Fig. 2 shows a “series of electric motors of sufficient number needed to give the required output to operate the one or more fluid ends [] a total of 10 [motors] are shown or implied (annotated in blue), with 5 being located on either side of the power end.”¹⁶⁰

¹⁶⁰ Ex. 1005 (*Buckley Provisional*) pg. 4.



Ex. 1005 (*Buckley Provisional*) Fig. 2 (annotated)

176. *Buckley* teaches that the “motors 111 may operate as a collective whole or independent of one another. Motors 111 can be used in a continuous duty cycle or as a sequenced duty cycle to meet the requirement of the pump's output.”¹⁶¹ Similarly, the *Buckley Provisional* teaches that “each electric motor is configured to produce a set amount of power (power max). The sizing of the plurality of motors can be such that they output equal or different amounts of power individually. Collectively, to some degree, a sufficient amount of power needs to be output from some number of the plurality of electric motors as is necessary to achieve the pump's

¹⁶¹ Ex. 1004 (*Buckley*) [0056] emphasis added.

output. It is understood that if each of the motors are independently operable, *some motors may be on while others are off*.”¹⁶²

177. Indeed, *Buckley* discloses various examples of operating multiple motors at the same time based on the output requirements of the drive pump. For example, when a “50% output is required, [] the even numbered motors 111 are operative while the odd numbered motors 111 are deactivated or turned off”; when “100% power is required [] all motors 111 are turned on”; and when “70% power is required...motors 1, 5, 9, and 13 are off while the others are on.”¹⁶³ To provide power to the pump, the motors are positioned to power the multi-plunger pump.

178. Accordingly, *Buckley* discloses a plurality of motors positioned to power the multi-plunger pump.

4. 1[c]: “a planetary gear train positioned to translate power from the plurality of motors to the pump crankshaft of the multi-plunger hydraulic fracturing pump,”

179. The combination of *Buckley*, *Bergan*, and *August* renders this limitation obvious. *Bergan* discloses, with respect to Figures 4-6, a “planetary gear system” that includes “ring gear 98 [annotated in red below], planetary gears 102 [annotated in blue], and sun gear 104 [annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in

¹⁶² Ex. 1005 (*Buckley Provisional*) pg. 5 emphasis added.

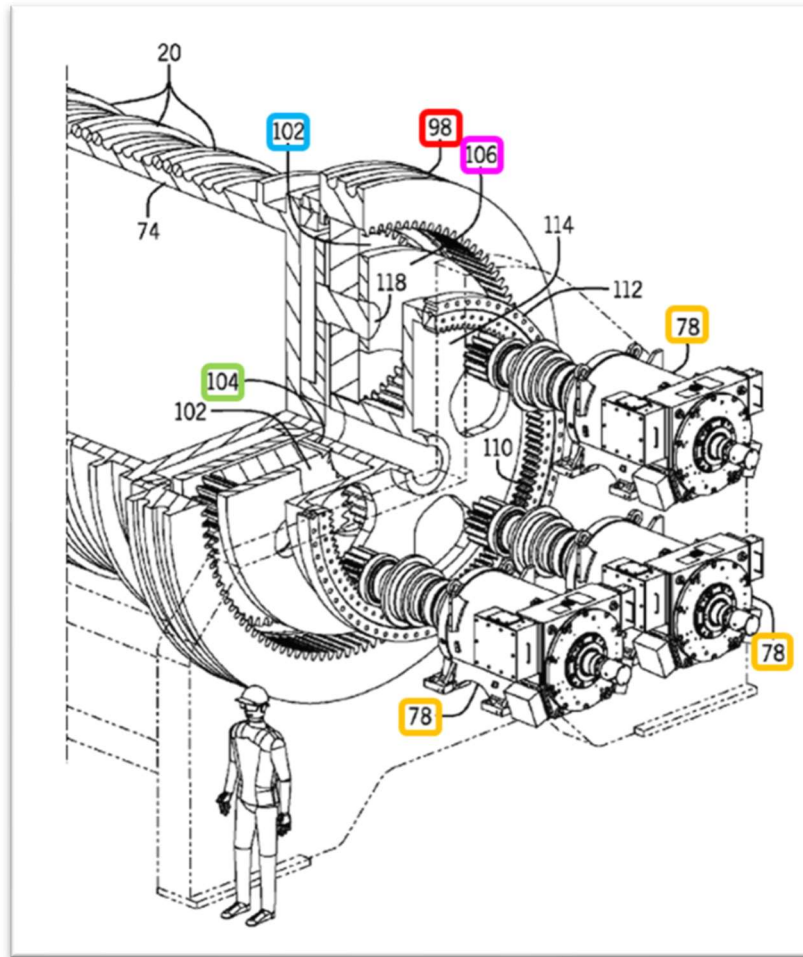
¹⁶³ Ex. 1004 (*Buckley*), [0057]; Figs. 16-18; Ex. 1005 (*Buckley Provisional*), pg. 6, Figs. 4-6.

operation,” the rotation of which drives the rotation of the load.¹⁶⁴ Further, *Bergan* discloses that “the motors 78 [annotated in orange] rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 are mounted on axles 118 coupled to the carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”¹⁶⁵

180. Figure 5 of *Bergan*, annotated below, depicts this configuration:

¹⁶⁴ Ex. 1006 (*Bergan*) [0032].

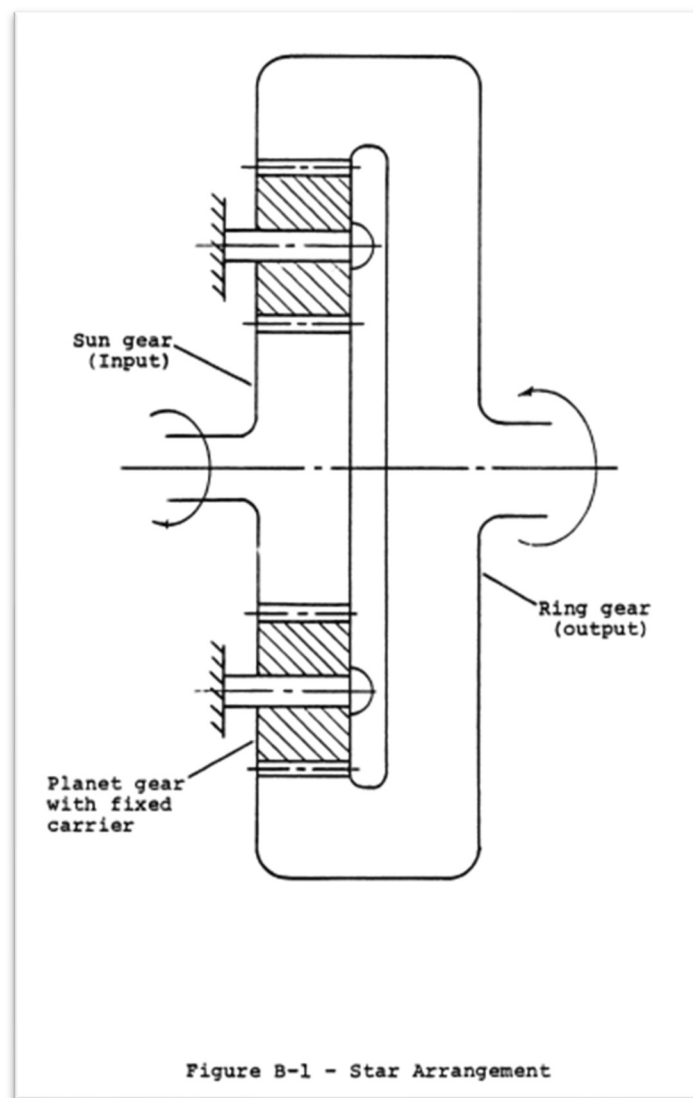
¹⁶⁵ Ex. 1006 (*Bergan*) [0032].



EX1006, Fig. 5 (annotated)

181. *August* describes a well-known variation of the planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are coupled to both a fixed carrier and a ring gear, and the rotation of the planetary gears drives the ring gear to produce an output rotation. This is a relatively minor variation of the planetary gear system of *Bergan*, using the same components. In the planetary gear system of *Bergan*, the carrier (attached to the planet gears) is allowed to rotate and drive the load (e.g. fracturing pump). In the star configuration of *August*, the

ring gear is allowed to rotate and the carrier (attached to the planet gears) is held fixed. The only change in operation of the system is a change in gear ratio from $\frac{N_R}{N_S} + 1$ to $\frac{N_R}{N_S}$ where N_R and N_S are the number of teeth of the ring gear and sun gear respectively.¹⁶⁶ Figure B-1 of August depicts this configuration from a side-section view:



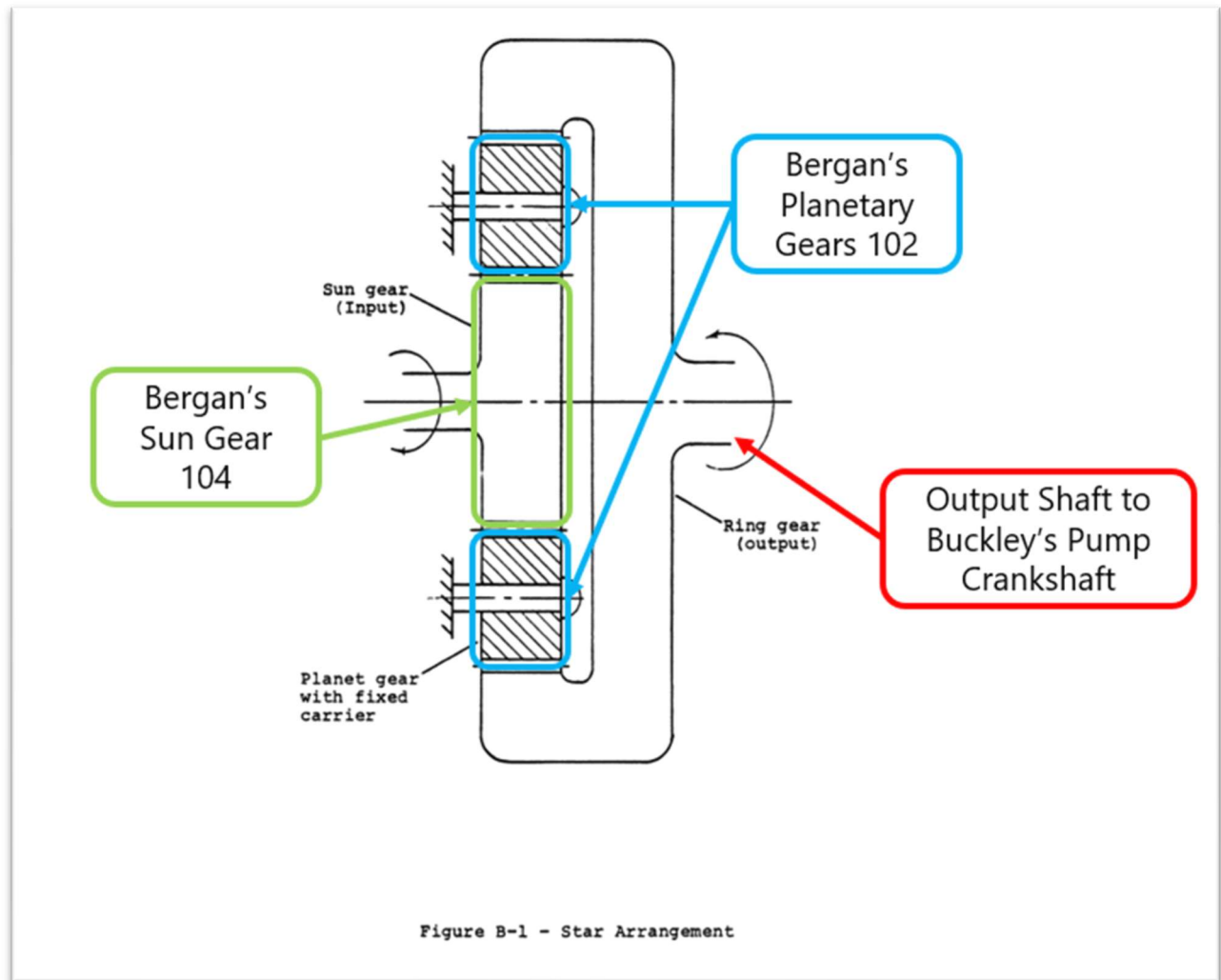
¹⁶⁶ Ex. 1014 (*August*) pg. 151.

Ex. 1014 (*August*), 149 (Fig. B-1).

182. As discussed above, modifying the *Buckley-Bergan* combination in view of *August*'s star arrangement would result in a well-known variation of a planetary gearing system wherein *Bergan*'s planetary gears 102 are coupled to a fixed carrier (as taught by *August*) and a ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan*'s carrier 106, would serve as the output of the planetary gearing system to drive the pump crankshaft.¹⁶⁷ Annotated Figure B-1 of *August* below shows how *August*'s ring gear would interact with *Bergan*'s gearing (including sun gear 104, annotated in green, and planetary gears 102, annotated in blue) and output to *Buckley*'s pump crankshaft¹⁶⁸ (annotated in red) when combined:

¹⁶⁷ See Section XI.A.1 above.

¹⁶⁸ As I discuss in more detail below regarding Limitation 1[e], under the *Buckley-Bergan-August-Morris-Joyner* combination, *August*'s ring gear outputs to *Buckley*'s pump crankshaft via the universal joint-based coupling taught by the *Morris-Joyner* combination.

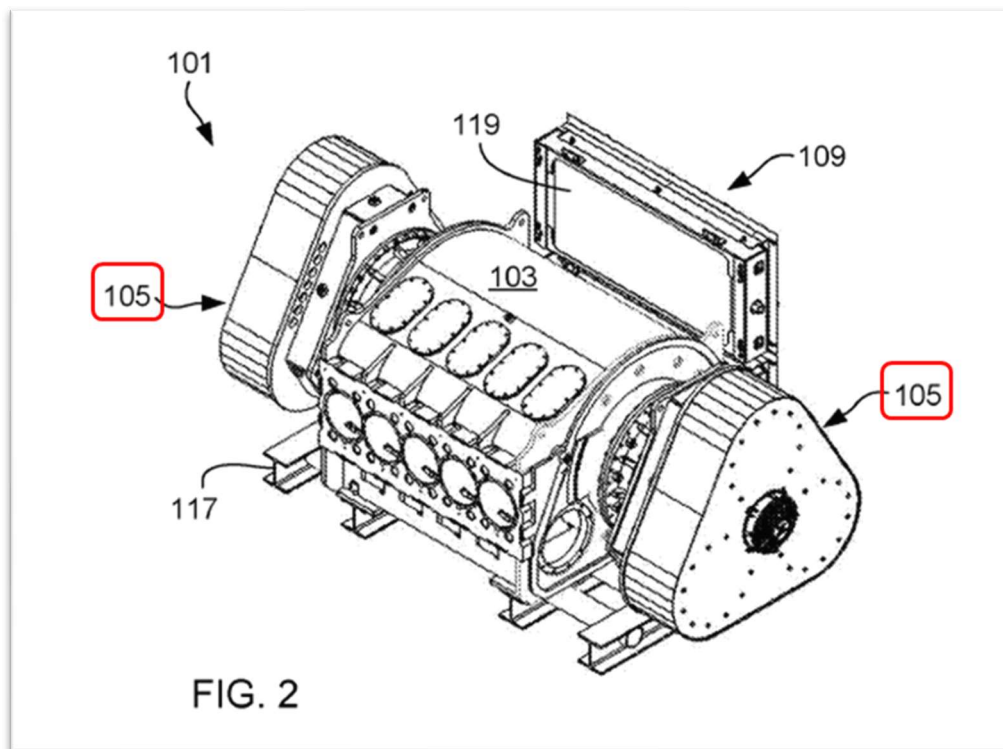


EX1014, Fig. B-1 (annotated).

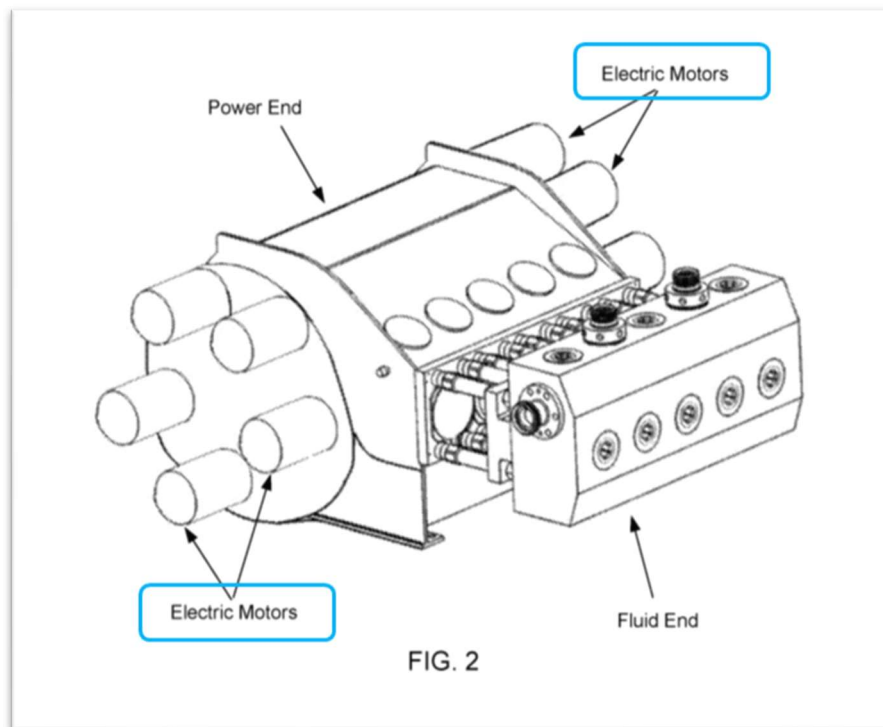
183. Accordingly, the *Buckley-Bergan-August* planetary gear train translates power from the plurality of motors to August's ring gear, which would be coupled to the crankshaft of *Buckley's* multi-plunger hydraulic fracturing pump in the combination. Thus, the combination of *Buckley* and *Bergan* with *August*, in view of *Morris* and *Joyner* renders this limitation obvious.

5. 1[d]: “the planetary gear train comprising: a plurality of input pinion gears connected to the plurality of motors,”

184. The combination of *Buckley*, *Bergan*, and *August* renders this limitation obvious. As discussed above, *Buckley* teaches a plurality of motors positioned to power the multi-plunger pump. In *Buckley*, figures show the motors located axially with the shaft of the pump fluid end.



Ex. 1004 (*Buckley*) Fig. 2 (annotated)



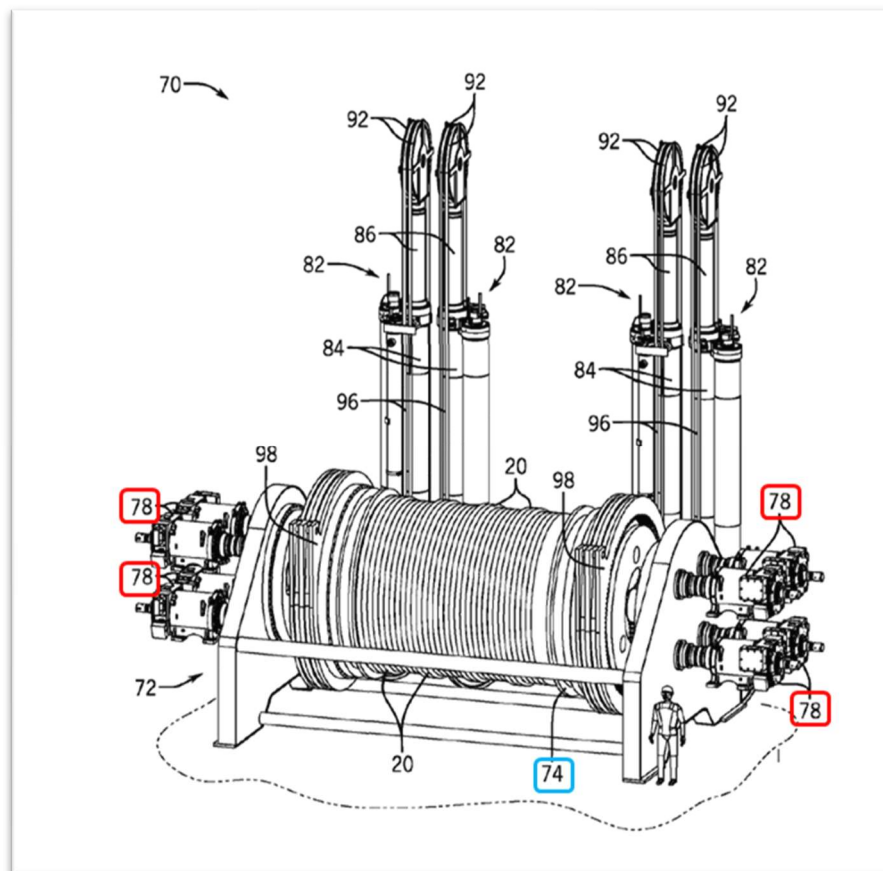
Ex. 1005 (*Buckley* Provisional) Fig. 2 (annotated)

185. *Buckley* further teaches, “[t]he motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”¹⁶⁹

186. Like *Buckley*, *Bergan* teaches the use of a plurality of motors located axially with the shaft of the load (i.e. drum) and connected to the shaft via gearing

¹⁶⁹ Ex. 1004 (*Buckley*) [0009]; see Ex. 1005 (*Buckley* Provisional) pg. 5 (“Selected gearing may be used to assist in mating the electric motors to the power end. As seen from Figure 1, these can be mounted at both ends of the pump, which apply the drive by means of any of the following: a gear/gears, chain or belt drive, or a combination of some or all. [] Also a transfer gear system can be used if required. This may depend on the orientation of the axis of the motor to the axis of the pump.”)

systems. For example, when describing Fig. 3, *Bergan* discloses, “[m]otors 78 [annotated in red] can be operated to drive rotation of the drum 74 [annotated in blue] to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”¹⁷⁰



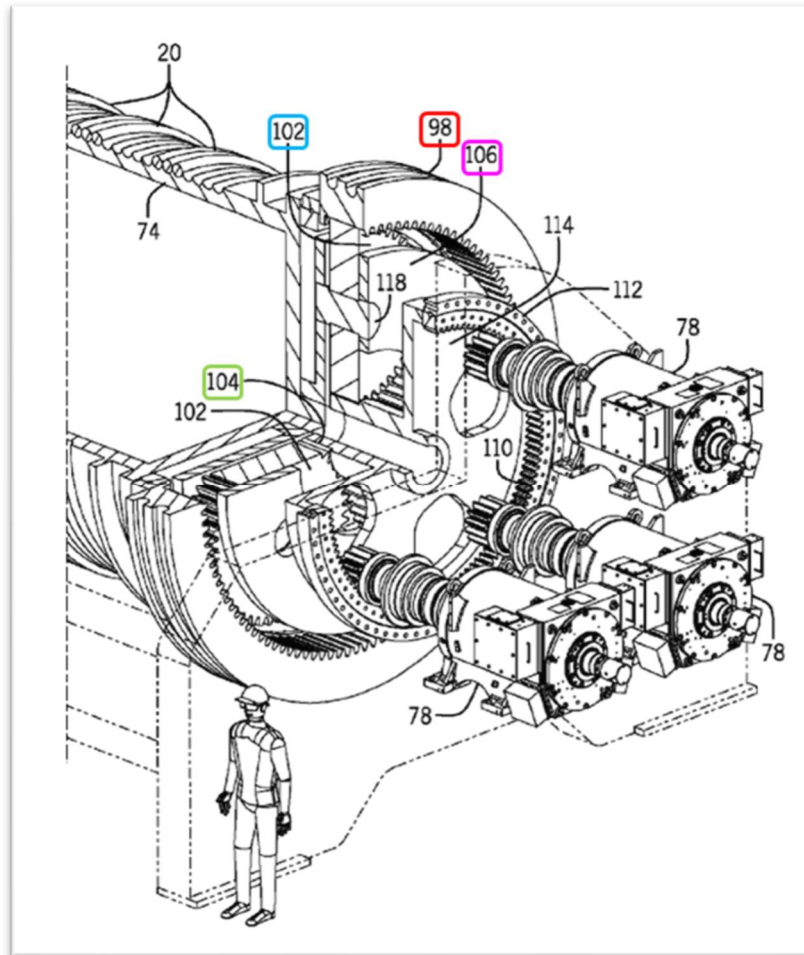
Ex. 1006 (*Bergan*) Fig. 3 (annotated)

187. *Bergan* further teaches using a planetary gear system to couple the motors to the shaft. *Bergan* discloses, “[a]s generally shown in FIG. 4 and more

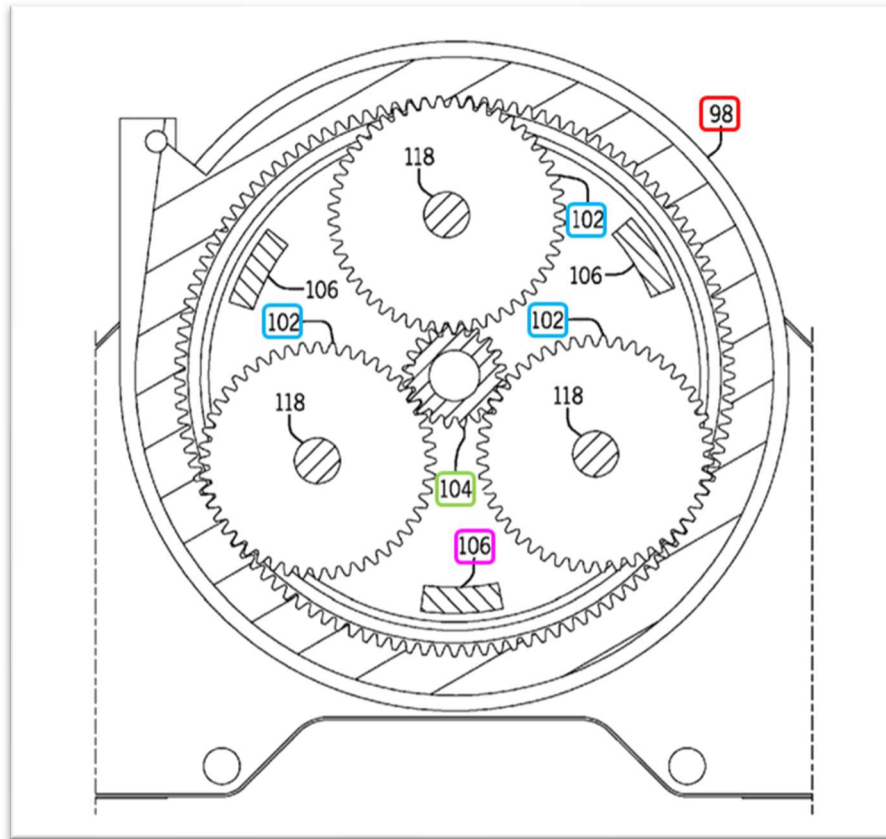
¹⁷⁰ Ex. 1006 (*Bergan* [0030])

specifically shown in FIGS. 5 and 6, the planetary gear system includes the ring gear 98 [annotated in red], planetary gears 102 [annotated in blue], and a sun gear 104 [annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in operation.”¹⁷¹ As discussed below, in combination with *August, Bergan*’s carrier is held fixed, and the ring gear (final gear) is connected to the pump.

¹⁷¹ Ex. 1006 (*Bergan*) [0032].



Ex. 1006 (*Bergan*) Fig. 5 (annotated)



Ex. 1006 (*Bergan*) Fig. 6 (annotated)

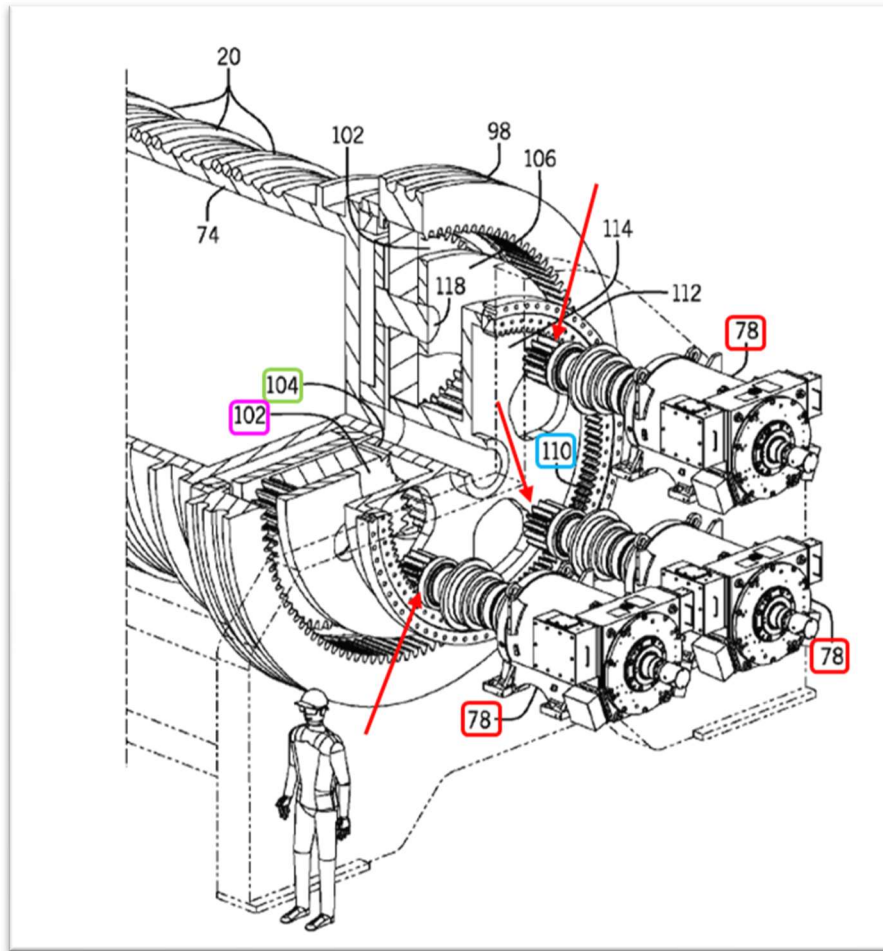
188. *Bergan* further discloses driving the planetary gear train with multiple motors. *Bergan* teaches “the motors 78 [annotated in red] are connected to drive rotation of a gear 110 [annotated in blue] of a slew bearing 112. The gear 110 is coupled to a sun wheel 114 having the sun gear 104 [annotated in green] such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 [annotated in magenta] are mounted on axles 118 coupled to the

carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”¹⁷²

189. Figure 5 shows a perspective view of *Bergan’s* gearing mechanism. Figure 5 further shows the motors 78, each connected to an “input pinion” (not numbered, annotated with red arrows), allowing the motors to drive the gearing system. A “pinion” was known to be “a gear with a small number of teeth designed to mesh with a larger wheel or rack.”¹⁷³ The pinions (annotated with red arrows) mesh with the larger gear (wheel) 110 (annotated in blue).

¹⁷² Ex. 1006 (*Bergan*) [0032]; *see also, e.g.*, [0014], [0035], [0041], Claims 4-6, 10, 16-18.

¹⁷³ Ex. 1011.

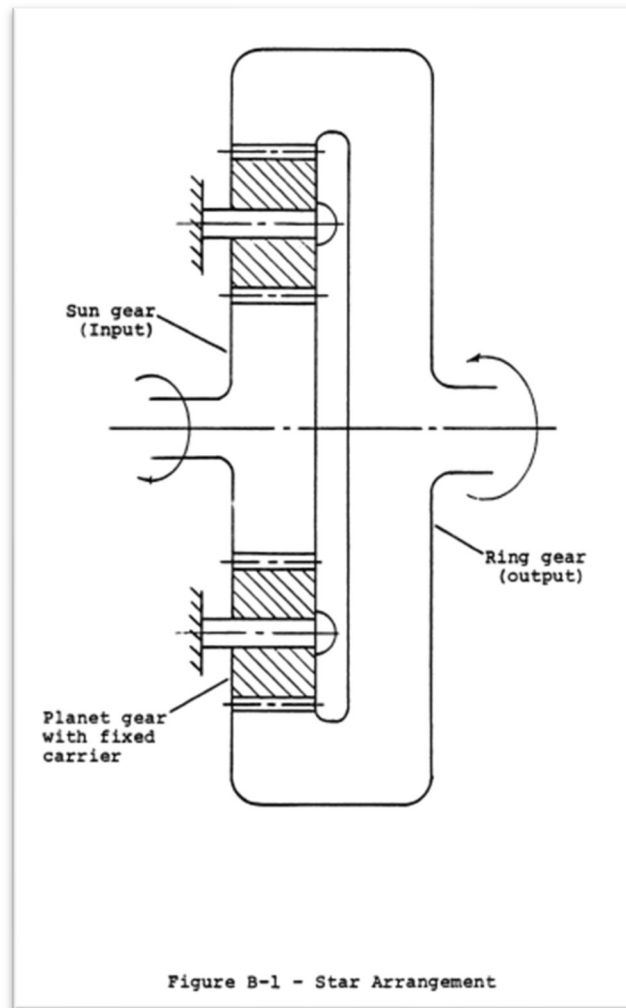
Ex. 1006 (*Bergan*) Fig. 5 (annotated)

190. Accordingly, *Bergan* discloses a planetary gear train having a plurality of input pinion gears, each connected with a motor. In the *Buckley-Bergan-August* combination, a POSITA would have understood that *Buckley*'s motors are connected to *Bergan*'s pinions, which are part of the *Bergan-August* modified planetary gear train discussed above with reference to Limitation 1[c]. Accordingly, *Bergan* discloses, and the combination of *Buckley* and *Bergan* with *August*, in view of *Morris* and *Joyner* renders Limitation 1[d] obvious.

6. 1[e]: “and a final drive gear connected to the pump crankshaft of the multi-plunger hydraulic fracturing pump by a plurality of arms extending from the final drive gear.”

191. First, *August*, in combination with the *Buckley-Bergan* system, teaches “a final drive gear.” As discussed above with reference to Limitation 1[c], *August* describes a well-known variation of the planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are coupled to both a fixed carrier and a ring gear, and the rotation of the planetary gears drives the ring gear to produce an output rotation. This is a relatively minor variation of the planetary gear system of *Bergan*, using the same components. In the planetary gear system of *Bergan*, the carrier (attached to the planet gears) is allowed to rotate and drive the load (e.g. fracturing pump). In the star configuration of *August*, the ring gear is allowed to rotate and the carrier (attached to the planet gears) is held fixed. The only change in operation of the system is a change in gear ratio from $\frac{N_R}{N_S} + 1$ to $\frac{N_R}{N_S}$ where N_R and N_S are the number of teeth of the ring gear and sun gear respectively.¹⁷⁴ Figure B-1 of *August* depicts this configuration from a side-section view:

¹⁷⁴ Ex. 1014 (*August*) pg. 151.



Ex. 1014 (*August*), 149 (Fig. B-1).

192. As discussed above, modifying the *Buckley-Bergan* combination in view of *August*'s star arrangement would result in a well-known variation of a planetary gearing system wherein *Bergan*'s planetary gears 102 are coupled to a fixed carrier (as taught by *August*) and a ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan*'s carrier 106, would serve as the output of the planetary gearing system to drive the pump crankshaft.¹⁷⁵

¹⁷⁵ See Section XI.A.1 above.

Accordingly, a POSTIA would have recognized that *August*'s ring gear teaches a “final drive gear.”

193. Second, the *Morris-Joyner* combination teaches combining two shafts via a plurality of arms. *Morris* discloses a hydraulic fracturing system wherein a “prime mover” is coupled to one or more pumps via “fixed couplings 1412,” such as “flex couplings and/or universal joint-based coupling.”¹⁷⁶ *Morris* explains that the use of such couplings facilitates pumping operations by accounting for misalignment between the prime mover and the pumps that may arise from vibrations of the pump during operation.¹⁷⁷

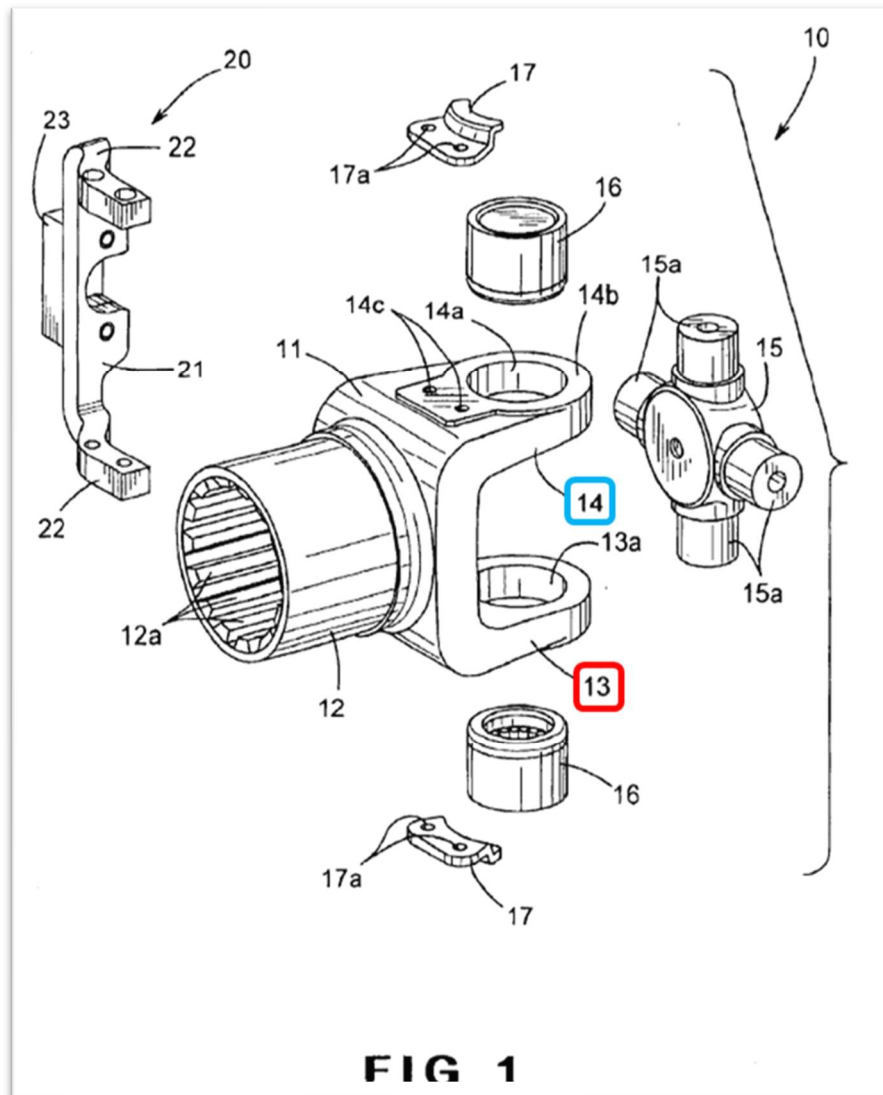
194. When the fixed coupling is implemented as a “universal joint-based coupling,” as taught by *Morris*, a POSITA would have understood that the fixed coupling comprises “a plurality of arms.” As explained by *Joyner* (Ex. 1016), universal joints are “are well known devices that provide a driving connection between two members that are adapted to rotate about non-aligned axes of rotation.”¹⁷⁸ Figure 1 of *Joyner* depicts the typical components of a universal joint, including a “yoke 11 including a sleeve portion 12 having a pair of opposed arms 13 [annotated in red] and 14 [annotated in blue] extending therefrom.”¹⁷⁹

¹⁷⁶ Ex. 1015 (*Morris*), Abstract, [0094].

¹⁷⁷ Ex. 1015 (*Morris*), Abstract, [0094].

¹⁷⁸ Ex. 1016 (*Joyner*), 1:16-18.

¹⁷⁹ Ex. 1016 (*Joyner*), 2:58-64.



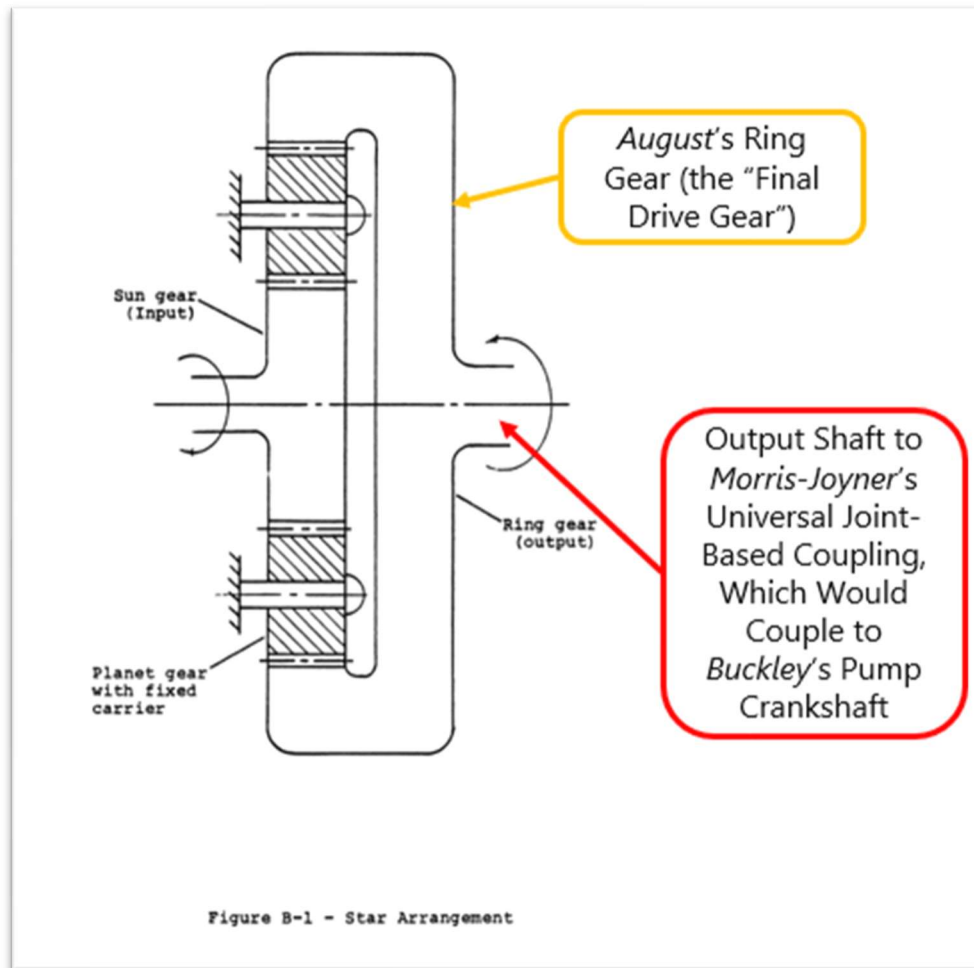
Ex. 1016 (Joyner), Fig. 1.

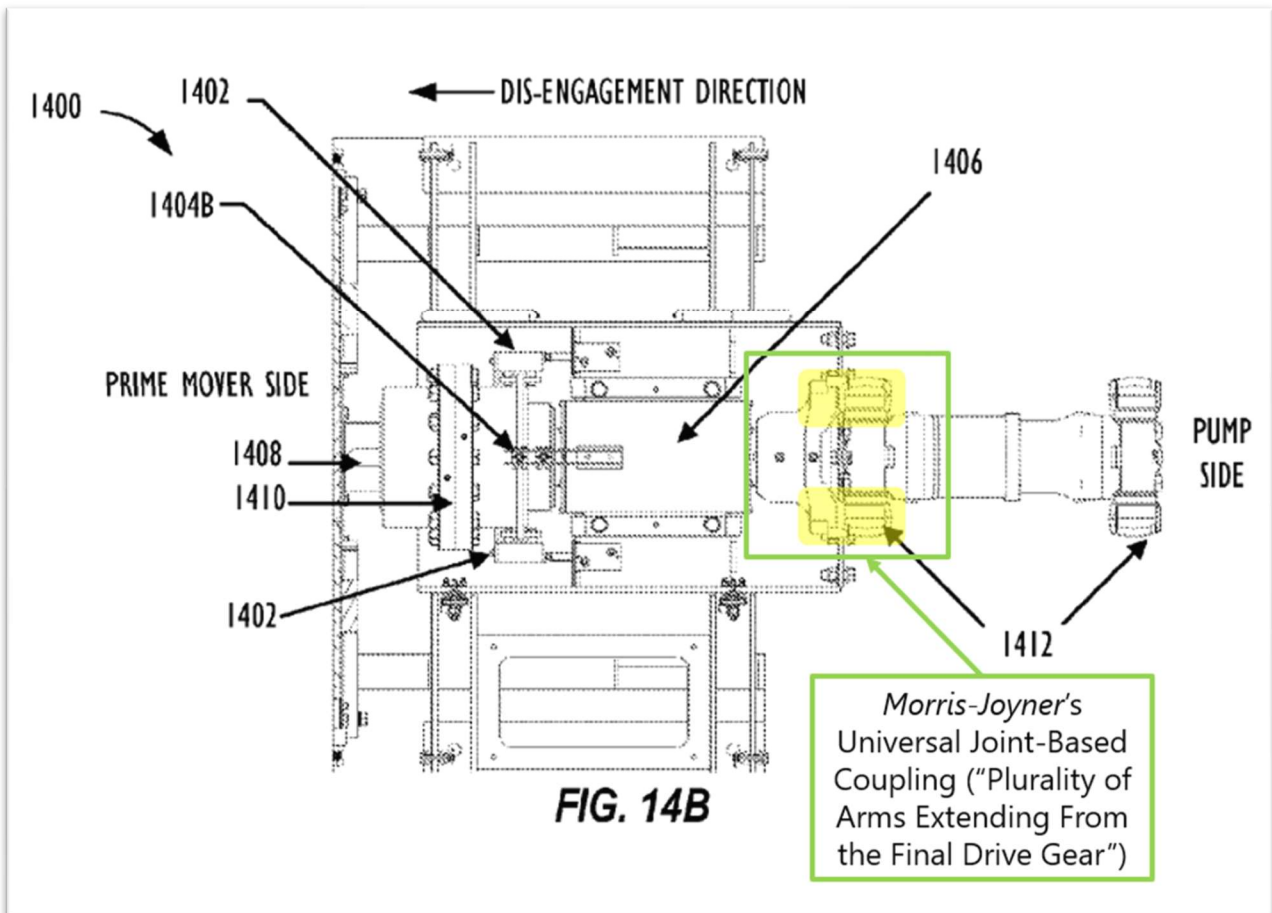
195. *Joyner* further explains that the sleeve portion 12 engages “with a drive shaft (not shown) or other member,” and that the arms of the yoke are coupled to opposite trunnions 15a of cross 15.¹⁸⁰ A POSITA would have understood that a complete universal joint comprises a second yoke 11 coupled to cross 15 (*e.g.*, to the

¹⁸⁰ Ex. 1016 (Joyner), 2:64-3:1, 3:19-27.

horizontal trunnions 15a when the first yoke is coupled to the vertical trunnions 15a) such that two drive shafts would have been coupled by the universal joint.

196. When the *Buckley-Bergan-August* pumping system is combined with the *Morris-Joyner* universal joint-based coupling, a POSITA would have understood that the output shaft of *August*'s ring gear (the "final drive gear") would have been coupled to the crankshaft of *Buckley*'s pump (the "pump crankshaft of the multi-plunger hydraulic fracturing pump") via a universal joint that comprises multiple arms ("by a plurality of arms extending from the final drive gear"), as taught by the *Morris-Joyner* combination, to limit damage caused by misalignment between the ring gear's output shaft and the pump crankshaft (as taught by *Morris*).



Ex. 1014 (*August*), Fig. B-1 (annotated)

Ex. 1015 (Morris), Fig. 14B (annotated, highlighting in yellow the arms of one yoke of the universal joint-based coupling).

197. Accordingly, the *Buckley-Bergan-August-Morris-Joyner* combination renders obvious Limitation 1[e].

C. DEPENDENT CLAIM 2: “2. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS CONNECTED TO A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”

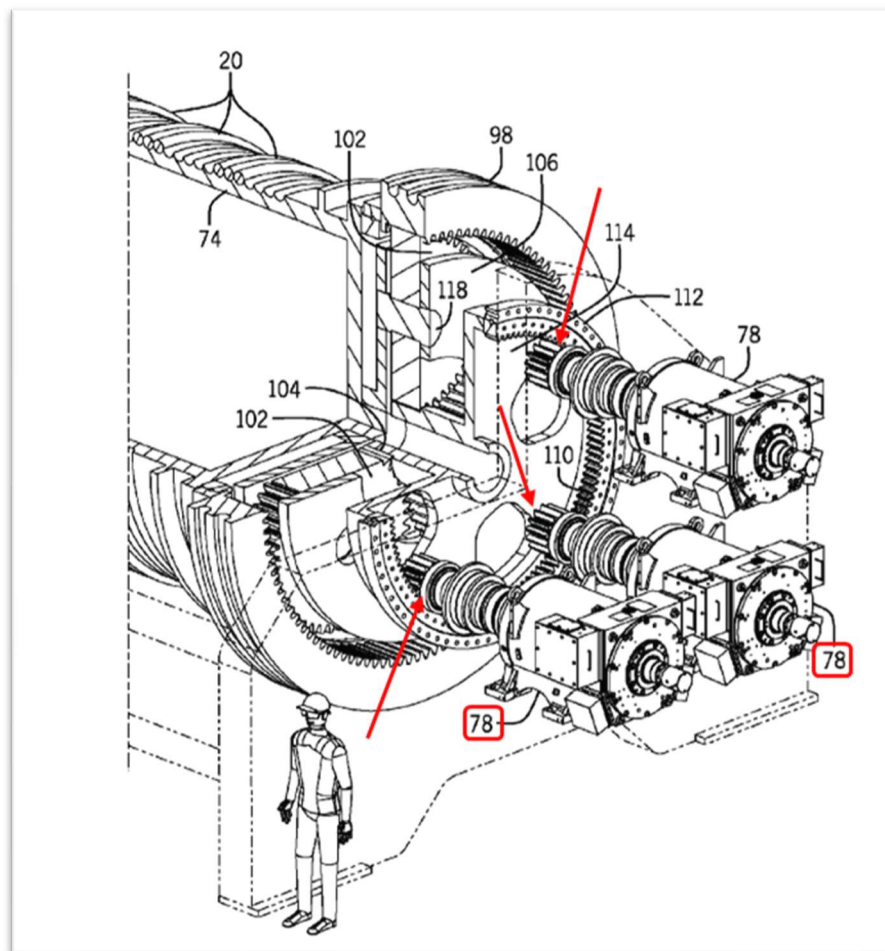
198. Dependent Claim 2 depends from Claim 1. In addition to the disclosures regarding Claim 1 disclosed above, both *Buckley* and *Bergan*, alone or in combination, disclose the additional limitations of Claim 2. As discussed above regarding limitation 1[b], and incorporated herein by reference, *Buckley* discloses “[t]he *electric drive pump system* is configured to provide a plurality of individual motors in selective configurations that work together to provide power to a power end. The motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”¹⁸¹ Accordingly, *Buckley* discloses electric motors.

199. *Bergan* also teaches the use of electric motors. As discussed above regarding limitation 1[c], and incorporated herein by reference, *Bergan* teaches

¹⁸¹ Ex. 1004 (*Buckley*) [0009] emphasis added; see also [0007], [00032] Figs 15-18, [0036], [0041] – [0042], Claims 1-15, 19, 20, 23, 24; see also Ex. 1005 (*Buckley* Provisional) p. 4 (“Referring now to Figures 1 and 2 in the drawings, a side view of a schematic of a power end in communication with a plurality of electric motors and a representative perspective view is illustrated. The power end includes a pump that is used to operate one or more fluid ends. [] This system includes a series of electric motors of sufficient number needed to give the required output to operate the one or more fluid ends. The precise number is dependent upon design constraints and engineering parameters. It is understood that more than one may be used. In Figure 1,[sic. Figure 2] a total of 10 are shown or implied, with 5 being located on either side of the power end.”)

“motors 78” to drive the planetary gear system claimed. *Bergan* further discloses, for example, “[m]otors 78 can be operated to drive rotation of the drum 74 to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”¹⁸²

200. And as discussed above with reference to Limitation 1[d], *Bergan* discloses that each motor is connected to the planetary gear system via a respective pinion (annotated with red arrow), as depicted in Figure 5 of *Bergan*:



¹⁸² Ex. 1006 (*Bergan*) [0030]

Ex. 1006 (Bergan), Fig. 5 (annotated)

201. The *Buckley-Bergan* combination therefore renders Claim 2 obvious.

D. DEPENDENT CLAIM 3: “3. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS THREE PLUNGERS.”

202. The '533 Patent admits that multi-plunger hydraulic fracturing pumps that meet the limitations of Claim 3 were known in the art.¹⁸³ And as discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Buckley* is a quintuplex (*i.e.*, five-plunger) pump, which has three plungers.¹⁸⁴ *Buckley* therefore discloses Claim 3.

E. DEPENDENT CLAIM 4: “4. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS FIVE PLUNGERS.”

203. The '533 Patent admits that multi-plunger hydraulic fracturing pumps that meet the limitations of Claim 4 were known in the art.¹⁸⁵ And as discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Buckley* is a quintuplex (*i.e.*, five-plunger) pump.¹⁸⁶ *Buckley* therefore discloses Claim 4.

¹⁸³ Ex. 1001 ('533 Patent), 5:1-3.

¹⁸⁴ See Section XI.B.2 above.

¹⁸⁵ Ex. 1001 ('533 Patent), 5:1-3.

¹⁸⁶ See Section XI.B.2 above.

F. INDEPENDENT CLAIM 10**1. 10[p]: “10. A hydraulic fracturing method comprising:”**

204. *Buckley* discloses the preamble to Claim 10.¹⁸⁷ *Buckley* discloses that “[t]he present application relates generally to hydraulic fracturing in oil and gas wells, and in particular to an electric drive pump used to drive a fluid end for the pumping of a fracturing fluid into a well.”¹⁸⁸ Further, *Buckley* teaches that “[h]ydraulic fracturing has been used for decades to stimulate production from conventional oil and gas wells,” and that the process includes pumping fluid into a (downhole) formation and that “[w]hen the fluid enters the formation, it fractures, or creates fissures, in the formation.”¹⁸⁹ *Buckley* discloses particular techniques for performing such fracturing using a multi-plunger pump.¹⁹⁰

205. *Buckley* further teaches a method and that “those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the various purposes of the present system.”¹⁹¹

206. Accordingly, *Buckley* discloses the preamble.

¹⁸⁷ I understand that the preamble may not be limiting. I include analysis of the preamble out of an abundance of caution.

¹⁸⁸ Ex. 1004 (*Buckley*) [0001]; see also Ex. 1005 (*Buckley* Provisional) pg. 2

¹⁸⁹ Ex. 1004 (*Buckley*) [0002]; see also Ex. 1005 (*Buckley* Provisional) pg. 2

¹⁹⁰ Ex. 1004 (*Buckley*) [0009], Fig. 2; see also Ex. 1005 (*Buckley* Provisional) pg. 4, Fig. 2.

¹⁹¹ Ex. 1004 (*Buckley*) [0016]; see also Ex. 1005 (*Buckley* Provisional) pg. 6.

2. **10[a]: “by operation of a multi-plunger hydraulic fracturing pump of a hydraulic fracturing system, pumping fluid to a wellbore associated with a subterranean formation, the multiplunger hydraulic fracturing pump comprising a pump crankshaft;”**

207. Except for being rewritten as a method claim, limitation 10[a] is essentially similar to limitation 1[a] and is rendered obvious by the combination of *Buckley* with *Bergan, August, Morris* and *Joyner* for the same reasons as those discussed above in Section XI.B.2.

3. **10[b]: “powering the multi-plunger pump with a plurality of motors;”**

208. Except for being rewritten as a method claim, limitation 10[b] is essentially similar to limitation 1[b] and is rendered obvious by the combination of *Buckley* with *Bergan, August, Morris* and *Joyner* for the same reasons as those discussed above in Section XI.B.3.

4. **10[c]: “translating power from the plurality of motors to the multi-plunger hydraulic fracturing pump through a planetary gear train,”**

209. Except for being rewritten as a method claim, limitation 10[c] is essentially similar to limitation 1[c] and is rendered obvious by the combination of *Buckley* with *Bergan, August, Morris* and *Joyner* for the same reasons as those discussed above in Section XI.B.4.

5. **10[d]: “wherein translating power through the planetary gear train comprises translating power through: a plurality of input pinion gears that are driven by the plurality of motors; and”**

210. Except for being rewritten as a method claim, limitation 10[d] is essentially similar to limitation 1[d] and is rendered obvious by the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* for the same reasons as those discussed above in Section XI.B.5.

6. **10[e]: “a final drive gear that drives the pump crankshaft, wherein the final drive gear is connected to the pump crankshaft by a plurality of arms extending from the final drive gear.”**

211. Except for being rewritten as a method claim, limitation 10[e] is essentially similar to limitation 1[e] and is rendered obvious by the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* for the same reasons as those discussed above in Section XI.B.6.

G. **DEPENDENT CLAIM 11: “11. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS DRIVEN BY A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”**

212. Except for being rewritten as a method claim, Claim 11 is essentially similar to Claim 2 and is rendered obvious by the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* for the same reasons as those discussed above in Section XI.C.

H. DEPENDENT CLAIM 12: “12. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS THREE PLUNGERS.”

213. Except for being rewritten as a method claim, Claim 12 is essentially similar to Claim 3 and is rendered obvious by the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* for the same reasons as those discussed above in Section XI.D.

I. DEPENDENT CLAIM 13: “13. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS FIVE PLUNGERS.”

214. Except for being rewritten as a method claim, Claim 13 is essentially similar to Claim 4 and is rendered obvious by the combination of *Buckley* with *Bergan*, *August*, *Morris* and *Joyner* for the same reasons as those discussed above in Section XI.E.

XII. GROUND 1B: OBVIOUS OVER YI, BERGAN, AUGUST, MORRIS, AND JOYNER

215. It is my opinion that *Yi* in view of *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claims 1, 3, 4, 10, 12, and 13 of the '533 Patent.

A. MOTIVATION TO COMBINE

1. Yi, Bergan, and August

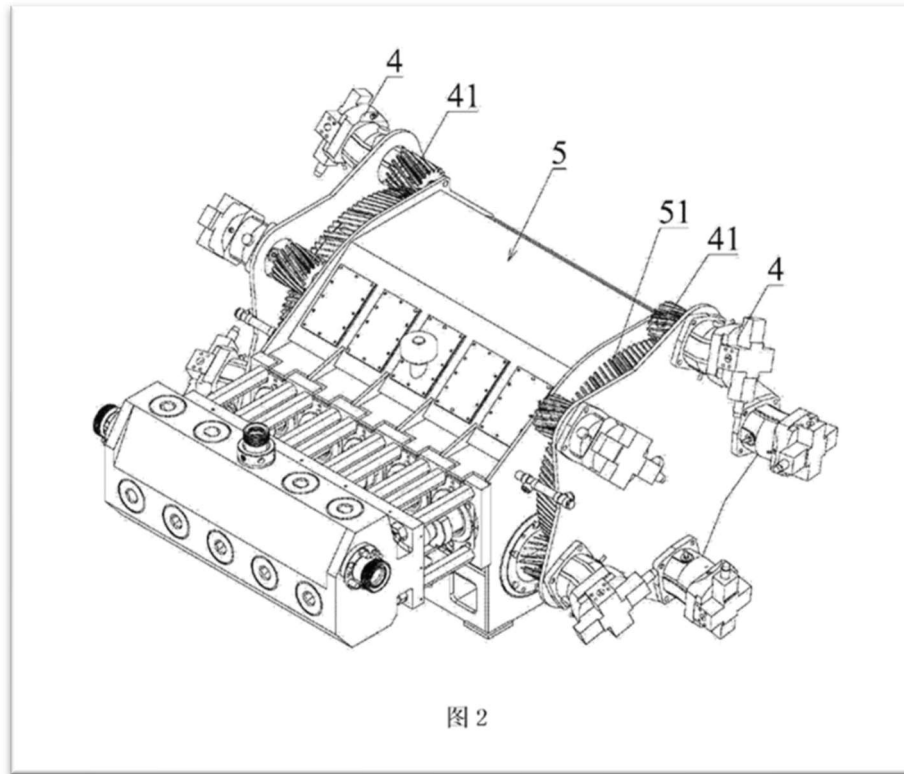
216. A POSITA would have been motivated to combine the teachings of *Yi* and *Bergan* to take advantage of *Bergan's* teachings regarding how to connect multiple motors to drive a single rotary load.

217. Initially, both *Yi* and *Bergan* teach using multiple motors driving a single load in an oil and gas application. *Yi* teaches using multiple motors to drive a single rotary load such as a fracturing pump. *Yi* discloses that “the fracturing pump transmission system includes one or more engines, multiple oil pumps, ***and multiple motors***. When there is one engine, the engine is used to drive multiple oil pumps. When there are multiple engines, each engine is used to drive at least one of the oil pumps. Each oil pump is connected to at least one of the motors, and ***all the multiple motors are used to drive the fracturing pump.***”¹⁹² *Yi* further discloses that the motors are powering the pump simultaneously. *Yi* teaches that during operation “the multiple motors 4 [] rotate, the multiple motors 4 drive the fracturing pump 5 to rotate.”¹⁹³

218. Fig. 2 of *Yi* displays the plurality of motors 4 arranged around a gearbox and providing power to the pump 5 through a series of pinions 41.

¹⁹² Ex. 1010 (*Yi* Translation) [0008].

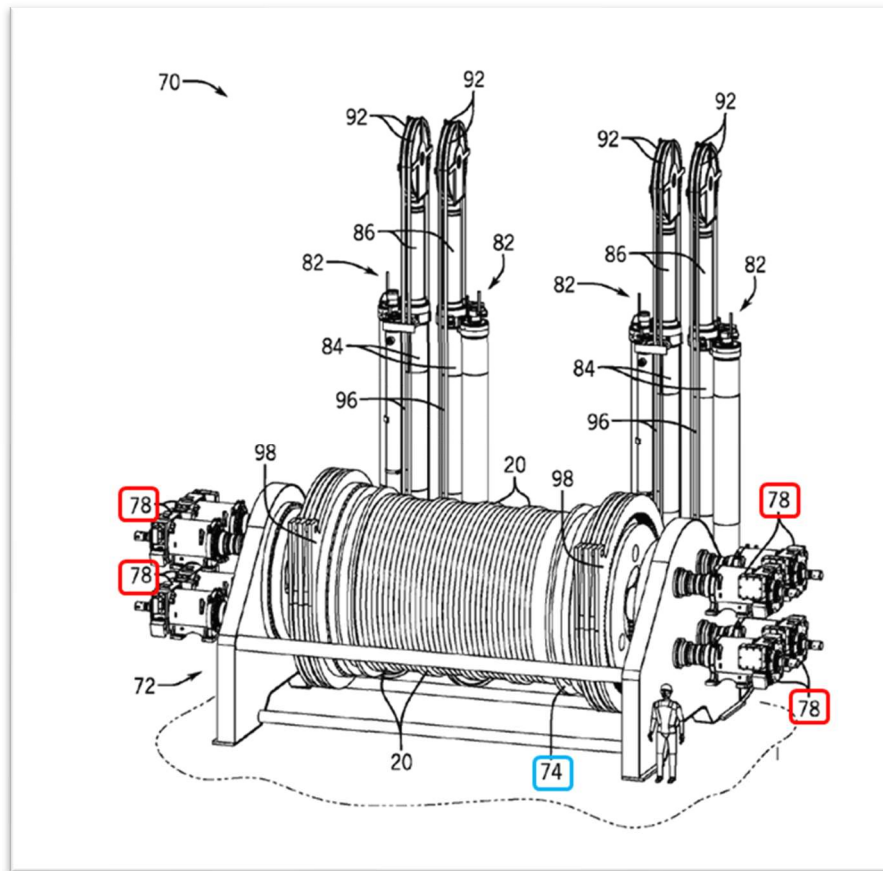
¹⁹³ Ex. 1010 (*Yi* Translation) [0046].

Ex. 1009 (*Yi*) Fig. 2

219. However, *Yi* provides little detail on precisely how to couple motors to the pinions 41 in *Yi*. A POSITA would have been motivated to look at other references showing multiple motors driving a rotary load to gain these additional details of how to connect the motors to the gearing or transfer gear system of *Yi*. *Bergan* provides these additional details.

220. Like *Yi*, *Bergan* teaches the use of a plurality of motors located axially with the shaft of the load (i.e. drum) and connected to the shaft via gearing systems and used in oil and gas drilling, which is at least a closely related field to hydraulic fracturing. For example, when describing Fig. 3, *Bergan* discloses “[m]otors 78

[annotated in red] can be operated to drive rotation of the drum 74 [annotated in blue] to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”¹⁹⁴

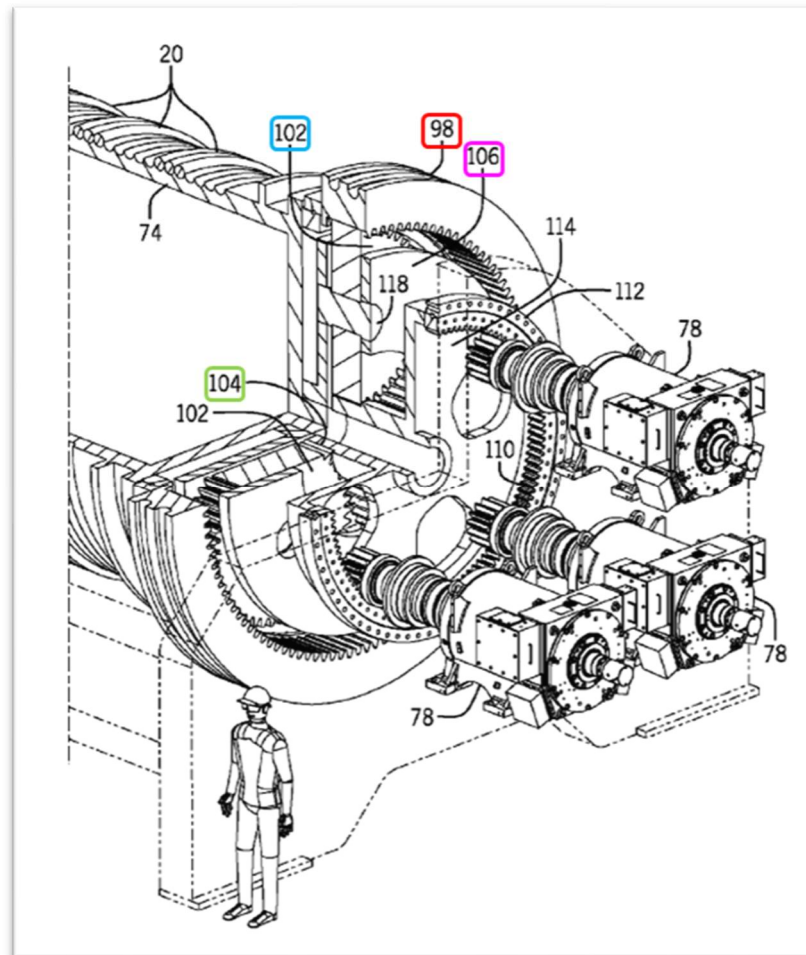


Ex. 1006 (*Bergan*) Fig. 3 (annotated)

221. *Bergan* further teaches the use of a planetary gear system to couple motors to the shaft. *Bergan* discloses “[a]s generally shown in FIG. 4 and more specifically shown in FIGS. 5 and 6, the planetary gear system includes the ring gear

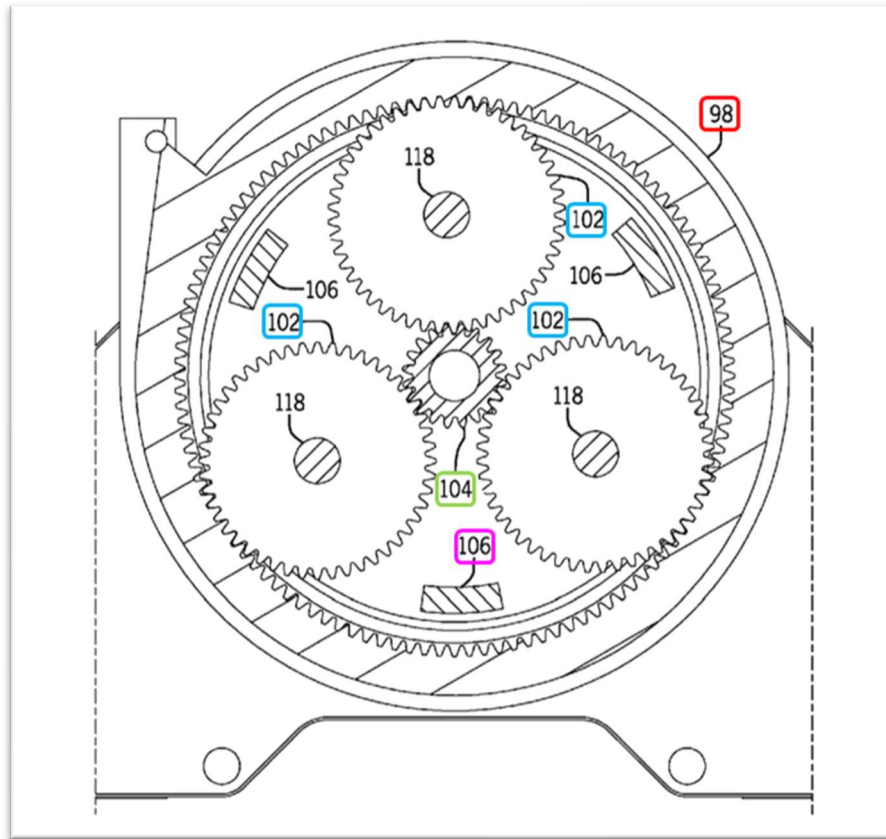
¹⁹⁴ Ex. 1006 (*Bergan*) [0030].

98 [annotated in red], planetary gears 102 [annotated in blue], and a sun gear 104 [annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in operation.”¹⁹⁵



Ex. 1006 (*Bergan*) Fig. 5 (annotated)

¹⁹⁵ Ex. 1006 (*Bergan*) [0032].



Ex. 1006 (*Bergan*) Fig. 6 (annotated)

222. A POSITA would have recognized that the planetary gear system of *Bergan* would have been useful in connecting the multiple motors of *Yi* to the rotating load as planetary gear trains were known to be more compact, have a higher torque rating and are better lubricated than other types of gearboxes (e.g., fixed, parallel shaft gearboxes) and would have been motivated to incorporate a planetary gear train in the system of *Yi* to gain these advantages from such a configuration.

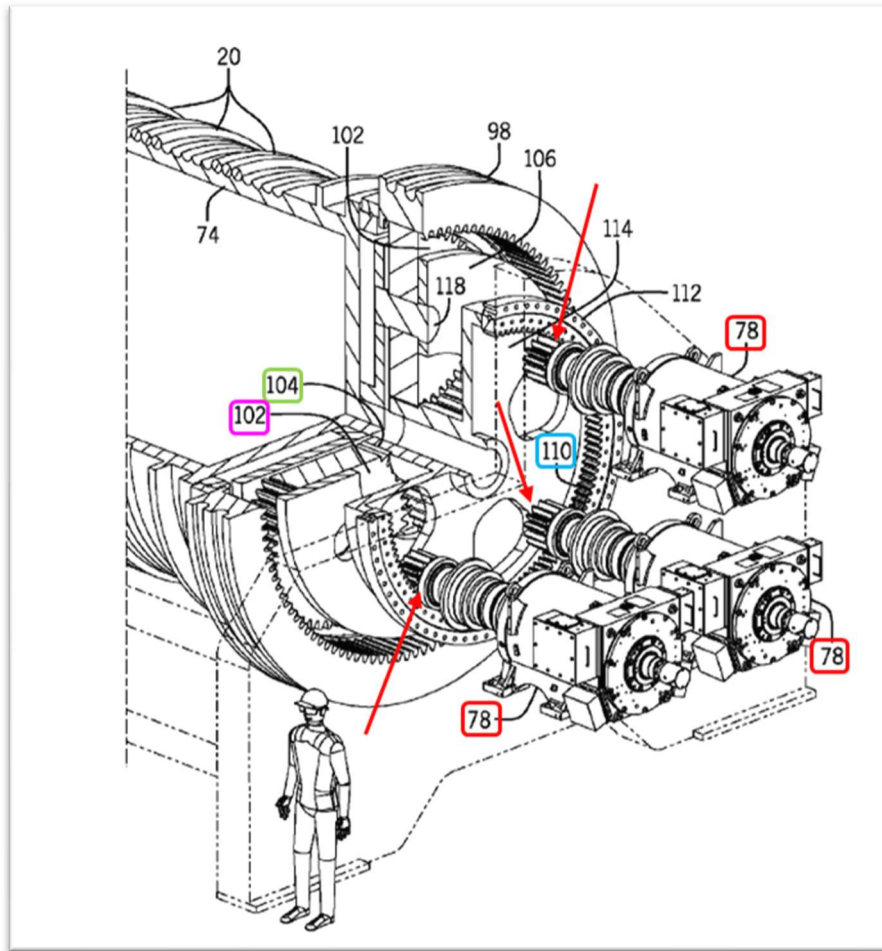
223. Further, *Bergan* fills in the blanks of *Yi* by showing the specific configuration of gearing that would have been used to connect *Yi*'s plurality of

motors to a single rotary load. For example, *Bergan* discloses “the motors 78 [annotated in red below] are connected to drive rotation of a gear 110 [annotated in blue below] of a slew bearing 112. The gear 110 is coupled to a sun wheel 114 having the sun gear 104 [annotated in green below] such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 [annotated in magenta] are mounted on axles 118 coupled to the carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”¹⁹⁶

224. Figure 5 shows a perspective view of *Bergan*’s gearing mechanism. Figure 5 further shows the motors 78 each rotationally coupled to an “input pinion” (not numbered, annotated with red arrows) allowing the motors to drive the gearing system. A “pinion” was known to be “a gear with a small number of teeth designed to mesh with a larger wheel or rack.”¹⁹⁷ The pinions annotated with red arrows mesh with the larger gear (wheel) 110.

¹⁹⁶ Ex. 1006 (*Bergan*) [0032]; *see also, e.g.*, [0014], [0035], [0041], Claims 4-6, 10, 16-18.

¹⁹⁷ Ex. 1011, pg. 4.



Ex. 1006 (*Bergan*) Fig. 5 (annotated)

225. A POSITA would have been motivated to incorporate *Bergan's* teaching of how to connect multiple motors to a single rotary load to “fill in the blanks” left by *Yi*.

226. In combination, a POSITA would have understood that *Yi's* motors would couple to *Bergan's* planetary gearing system via *Bergan's* input pinions (consistent with *Bergan's* teaching of coupling multiple motors to the planetary gearing system via the input pinions) and that *Bergan's* planetary gearing system

would couple to *Yi*'s pump crankshaft via *Bergan*'s carrier 106 (consistent with *Bergan*'s teaching of coupling carrier 106 to a rotating load), such that *Yi*'s motors would drive the rotation of *Buckley*'s pump crankshaft via *Bergan*'s planetary gearing system. Such a combination would involve scaling *Bergan*'s gears to sizes appropriate to *Yi*'s pumping system, which would have been obvious and common-sense changes for a POSITA.

227. A POSITA would have had a reasonable expectation of success in combining the teachings of *Yi* and *Bergan*. Incorporating *Bergan*'s teachings of a planetary gear train and the use of "pinions" to connect the motors to the load is applying a known technique (planetary gear trains and motors with pinions) to improve similar devices (*Yi*'s motor–pump gearbox) in the same way. The results of the combination would have been predictable – transfer of rotational energy from *Yi*'s motors to *Yi*'s pump with straightforward, predictable changes in gear ratios and corresponding changes in speed and torque available. Further, *Bergan*'s teachings of planetary gear systems and motors with pinions was known in one field of endeavor (oil and gas drilling) and would have prompted a POSITA to use it in either the same field or a different one (oil and gas fracturing) based on design incentives (ability to connect multiple motors to a single load and the advantages of a planetary gear train described in Section IX.D) because the variations used for a pump would have been predictable to one of ordinary skill in the art. As discussed above, the

results of the combination would have been predictable – transfer of rotational energy from *Yi*'s motors to *Yi*'s pump with straightforward, predictable changes in gear ratios and corresponding changes in speed and torque available.¹⁹⁸

228. A POSITA would have been motivated to further combine the *Yi-Bergan* combination with *August*. *August* teaches a modified planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are instead coupled to both a ***fixed*** carrier and a movable ring gear, where the ring gear is driven by the rotation of the planetary gears to produce an output rotation. This is a relatively minor variation of the planetary gear system of *Bergan*, using the same components. In the planetary gear system of *Bergan*, the carrier (attached to the planet gears) is allowed to rotate and drive the load (e.g. fracturing pump). In the star configuration of *August*, the ring gear is allowed to rotate and the carrier (attached to the planet gears) is held fixed.

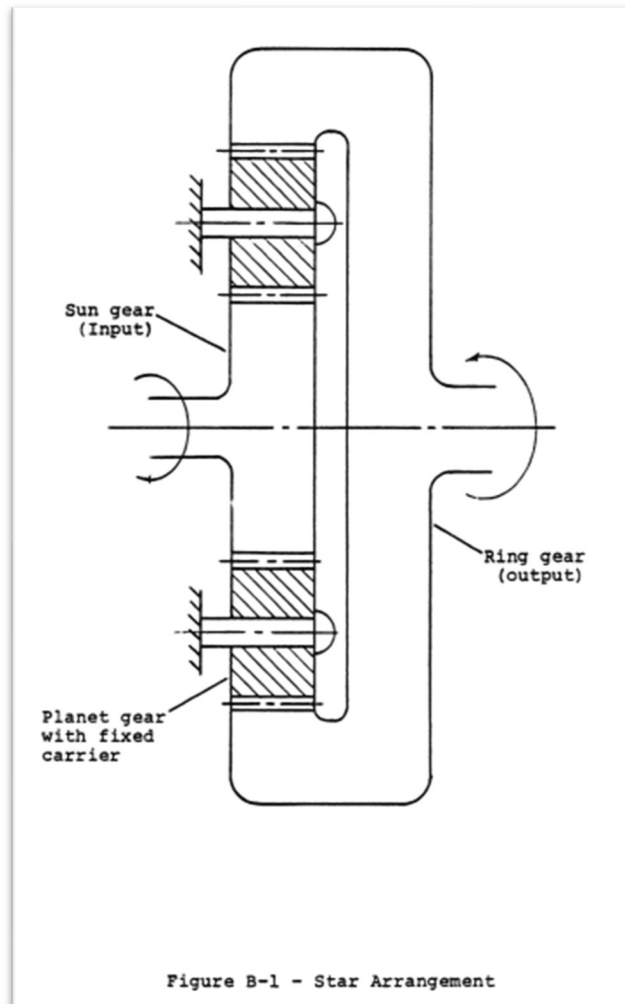
229. The only significant change in operation of the system is a change in gear ratio from $\frac{N_R}{N_S} + 1$ to $-\frac{N_R}{N_S}$ where N_R and N_S are the number of teeth of the ring gear and sun gear respectively.¹⁹⁹ Accordingly, incorporating *August*'s star arrangement would have predictable results, change in speed (and torque) based on

¹⁹⁸ As noted above, the U.S. Patent Office combined *Bergan* with a pumping system similar to *Yi* during the prosecution of the '533 Patent. See Ex. 1002, 157-162 (Office Action analysis of *Buckley-Bergan* combination).

¹⁹⁹ Ex. 1014 (*August*) pg. 151.

a known relationship (ratio of the number of teeth or the ring gear and sun gear respectively).

230. Figure B-1 of August depicts this configuration from a side section view:



EX1014, 149.

232. A POSITA would have been motivated to combine the *Yi-Bergan* combination with *August's* star arrangement, which would result in a modified planetary gearing system wherein *Bergan's* planetary gears 102 are coupled to a

fixed carrier (as taught by *August*) and a rotatable ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan*'s carrier 106, would serve as the output of the planetary gearing system to drive the pump crankshaft. This would allow for a different gear ratio as described above. A POSITA, therefore, would be motivated to combine *August*, for example, to obtain a lower gear ratio. Such a modification would involve a simple substitution of one known element (*August*'s star arrangement) for another (*Bergan*'s fixed-carrier gearing configuration) to obtain the predictable result of driving output rotation through *August*'s ring gear to *Yi*'s pump crankshaft. Accordingly, a POSITA would have been motivated to combine *Yi*, *Bergan*, and *August* and would have had a reasonable expectation of success in doing so.

2. *Morris and Joyner*

232. The motivation to combine *Morris* and *Joyner* is the same as discussed above with reference to Section XI.A.2, which is incorporated by reference.

3. *Yi-Bergan-August and Morris-Joyner*

233. A POSITA would have been motivated to combine the pumping system of the *Yi-Bergan-August* combination with the fixed couplings of the *Morris-Joyner* combination such that the fixed couplings join the output shaft of the *Yi-Bergan-August* combination's planetary gearing system (*i.e.*, the output shaft of *August*'s ring gear) with *Yi*'s pump crankshaft. First, design incentives and market forces

would have motivated a POSITA to incorporate *Morris's* fixed coupling configuration with the *Yi-Bergan-August* combination's pumping configuration. This combination would allow for easier alignment of the prime mover (including the gear train) and the pump, thereby limiting the damage caused by vibration of the pump during operation, as well as facilitating easier removal and replacement of the prime mover or the pump, as taught by *Morris*.²⁰⁰

234. Second, incorporating the *Morris-Joyner* combination's teachings of a universal joint-based coupling configuration is applying a known technique (universal joint-based couplings between two rotating shafts) to improve similar devices (the *Yi-Bergan-August* pumping system) in the same way. The results of the combination would have been predictable: transfer of rotational energy from the *Bergan-August* planetary gearing system's motors to *Yi's* pump crankshaft with universal joint-based couplings to reduce the effects of misalignment between the two components that may results from vibration of *Yi's* pump. Further, design incentives and market forces would have motivated a POSITA to incorporate *Morris's* fixed coupling configuration to protect the *Yi-Bergan-August* combination's pumping configuration from damages that would arise from vibration caused by *Yi's* pump, as taught by *Morris*. Accordingly, a POSITA would have been

²⁰⁰ Ex. 1015 (*Morris*) [0086] – [0087], [0094].

motivated to combine the *Yi-Bergan-August* combination with the *Morris-Joyner* combination and would have had a reasonable expectation of success in doing so.

B. INDEPENDENT CLAIM 1

235. As discussed in the following subsections, it is my opinion that the combination of *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 1 of the '533 Patent.

1. 1[p]: “1. A hydraulic fracturing system for fracturing a subterranean formation comprising:”

236. *Yi* discloses the preamble.²⁰¹ *Yi* teaches “The invention relates to the technical field of fracturing trucks and discloses a fracturing pump transmission system and a fracturing truck.”²⁰² Further, *Yi* describes “fracturing” to be “hydraulic fracturing for fracturing a subterranean formation”:

“Fracturing operations are one of the most important methods for modifying oil and gas reservoirs. For low-permeability oil and gas wells, fracturing is generally necessary to achieve stable production and increase output. A fracturing truck is the primary equipment used in fracturing operations. Its function is to inject high-pressure, large-volume fracturing fluid into the formation, causing it to crack open and injecting proppants (such as fracturing

²⁰¹ I understand that the preamble may not be limiting. I include analysis of the preamble out of an abundance of caution.

²⁰² Ex. 1010 (*Yi* Translation) Abstract.

sand) into the fractures to enhance the permeability of the formation, increase the fluidity of oil and gas, and improve the recovery rate of oil and gas.”²⁰³

A POSITA would have understood that the “formations” that are fractured are “subterranean formations” that contain oil and gas (hydrocarbon) reserves.

237. *Yi* describes the purpose of the invention as “provide a fracturing pump transmission system to effectively reduce the selection difficulty and cost of relevant components for the fracturing pump transmission system while also effectively improving the safety redundancy of the fracturing pump transmission system.”²⁰⁴

238. Accordingly, *Yi* discloses the preamble.

2. 1[a]: “a multi-plunger hydraulic fracturing pump configured to pump fluid to a wellbore associated with the subterranean formation, the multi-plunger hydraulic fracturing pump comprising a pump crankshaft;”

a) “a multi-plunger hydraulic fracturing configured to pump fluid into a wellbore associated with the subterranean formation”

239. *Yi* discloses a multi-plunger hydraulic pump that is configured to pump fluid into a wellbore associated with the subterranean formation. Initially, the ’533 Patent admits that multi-plunger hydraulic fracturing pumps were known: “[m]ulti-plunger hydraulic fracturing pumps, though known in the art, are typically limited

²⁰³ Ex. 1010 (*Yi* Translation) [0002].

²⁰⁴ Ex. 1010 (*Yi* Translation) [0007].

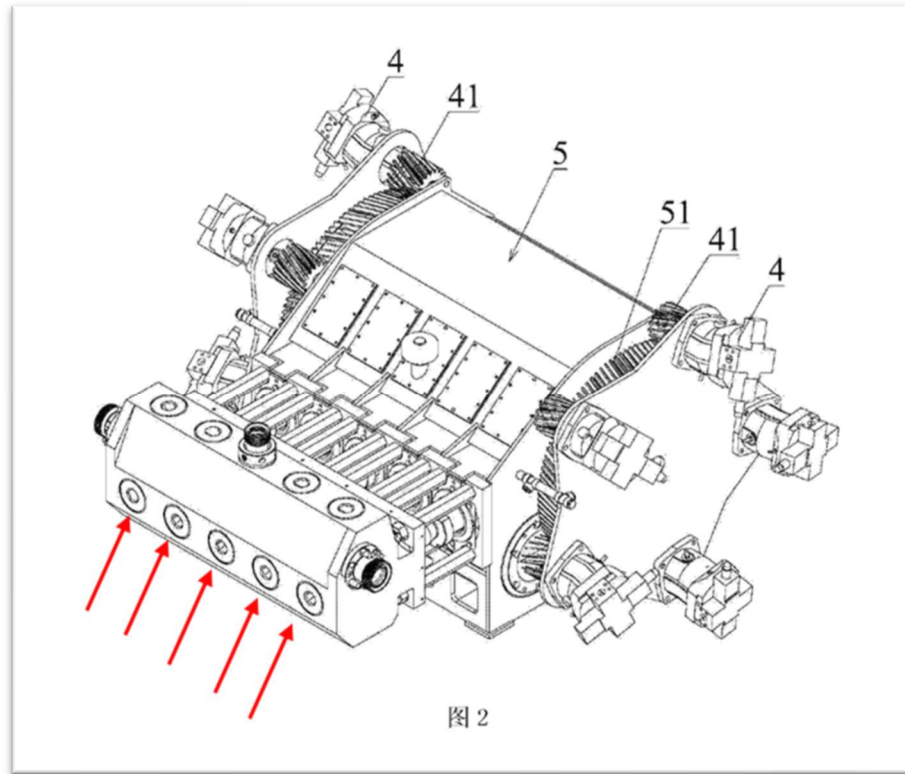
to either triplex (three plungers) or quintuplex (five plungers) arrangements.”²⁰⁵ *Yi* discloses “a fracturing pump transmission system and a fracturing truck.” *Yi* further teaches “[a] fracturing truck is the primary equipment used in fracturing operations. Its function is to inject high-pressure, large-volume fracturing fluid into the formation, causing it to crack open and injecting proppants (such as fracturing sand) into the fractures to enhance the permeability of the formation, increase the fluidity of oil and gas, and improve the recovery rate of oil and gas.”²⁰⁶ Further, *Yi* teaches “the fracturing pump 5 is a crankshaft-type plunger pump,” and that at “both ends of the crankshaft-type plunger pump, there are power input gears 51, and each motor 4 engages at least with the power input gears 51 at one end of the crankshaft-type plunger pump through a power output gear 41.”²⁰⁷ Because *Yi* teaches pumping fluid into the formation, *Yi* teaches pumping fluid into the well and wellbore associated with the subterranean formation.

240. As discussed above in Section IX.B, the use of multiple plungers in a pump fluid end was known long before the ’533 Patent. *Yi* further provides Fig. 2 which shows the use of a quintuplex (5 plungers) fluid end. In the figure, the 5 cylinders (identified with red arrows) are evident from the arrangement of the fluid end.

²⁰⁵ Ex. 1001 (’533 Patent) 5:1-3.

²⁰⁶ Ex. 1010 (*Yi* Translation) [0002].

²⁰⁷ Ex. 1010 (*Yi* Translation) [0044].



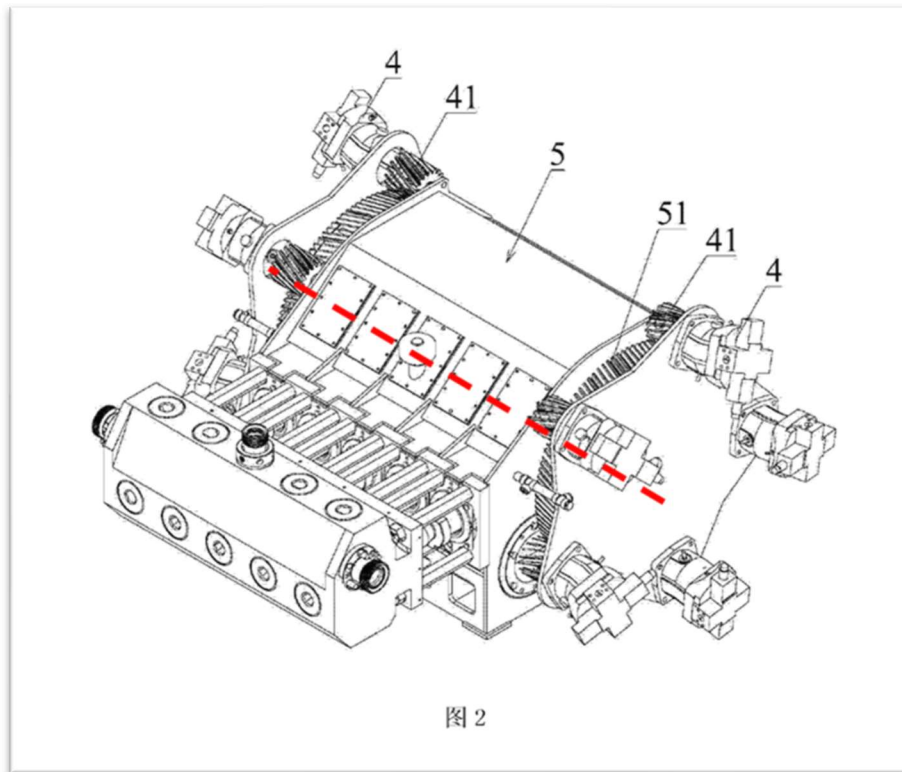
Ex. 1009 (Yi) Fig. 2 (annotated)

Accordingly, *Yi* discloses the use of a 5-plunger (“multi-plunger”) pump. To the extent that *Yi* does not explicitly use the term “multi-plunger” when describing the pump, the use of a “multi-plunger” fracturing pump would have been obvious to a POSITA based on the general knowledge of a POSITA that such pumps were commonly used in fracturing operations (see section IX.B) and the disclosure of *Yi* including showing a multi-plunger fracturing pump in the figure(s).

b) “the multi-plunger hydraulic fracturing pump comprising a pump crankshaft;”

241. A POSITA would have understood that *Yi*’s pump comprises a “pump crankshaft.” *Yi* discloses that its fracturing pump, “is a ***crankshaft***-type plunger

pump.”²⁰⁸ Further, although not expressly depicted in the figures by *Yi*, a POSITA would have understood that *Yi*’s pump comprises a crankshaft, which is annotated with a red line in the below figure of the pumps disclosed by *Yi*:



Ex. 1009 (*Yi*), Fig. 2 (annotated).

242. This understanding of *Yi* is consistent with the examiner’s rejection of Limitation 1[a] during prosecution, which was not contested by the applicant, where the examiner found that it is “inherent that crankshaft runs down axis of power end” of a pump as annotated.²⁰⁹ *Yi* therefore discloses this limitation.

²⁰⁸ Ex. 1010 (*Yi* Translation), [0010] (emphasis added).

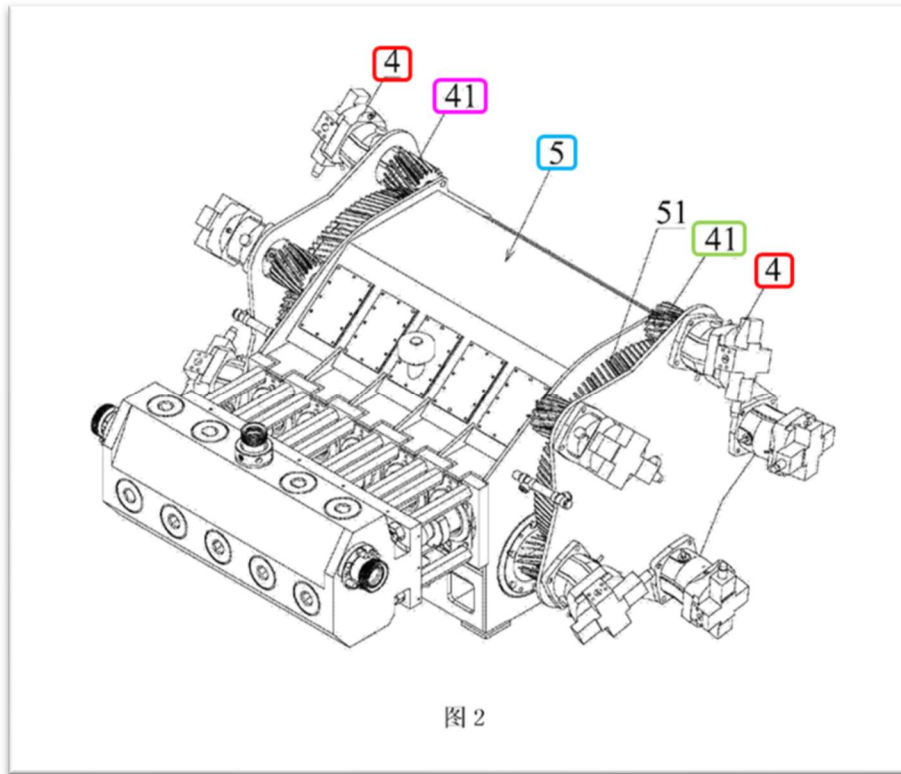
²⁰⁹ Ex. 1002 (533 File History), 140-145, 158-159.

3. **1[b]: “a plurality of motors positioned to power the multi-plunger pump; and”**

243. *Yi* discloses this limitation. *Yi* teaches that “the fracturing pump transmission system includes one or more engines, multiple oil pumps, *and multiple motors*. When there is one engine, the engine is used to drive multiple oil pumps. When there are multiple engines, each engine is used to drive at least one of the oil pumps. Each oil pump is connected to at least one of the motors, and *all the multiple motors are used to drive the fracturing pump*.”²¹⁰ *Yi* teaches that during operation “the multiple motors 4 [] rotate, the multiple motors 4 [annotated in red] drive the fracturing pump 5 [annotated in blue] to rotate.”²¹¹ Figure 2 of *Yi*, copied below, depicts this configuration:

²¹⁰ Ex. 1010 (*Yi* Translation) [0008].

²¹¹ Ex. 1010 (*Yi* Translation) [0046].



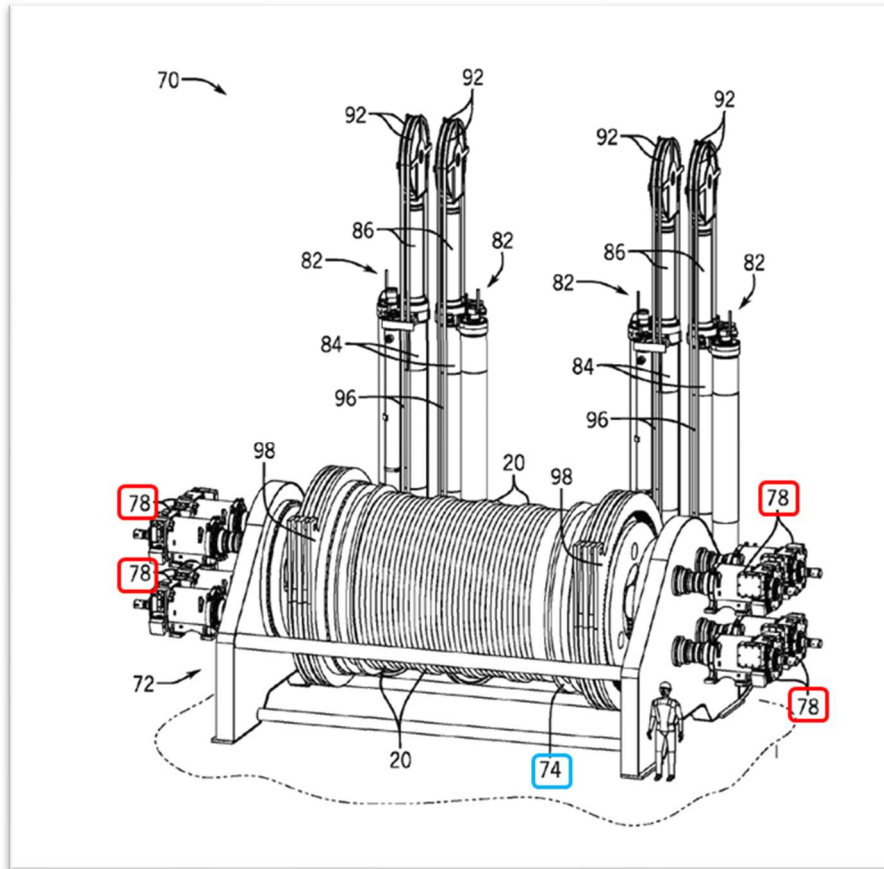
Ex. 1009 (Yi), Fig. 2.

244. *Yi* further discloses that the motors are connected through power input gears on both ends of the pump. *Yi* teaches “both ends of the crankshaft-type plunger pump, there are power input gears 5, and each motor 4 engages at least with the power input gears 51 at one end of the crankshaft-type plunger pump through a power output gear 41 [annotated in green].”²¹² Accordingly, the motors are positioned to provide power to the multi-plunger pump.

245. *Bergan* also teaches the use of a plurality of motors located axially with the shaft of the load (i.e. drum) and connected to the shaft via gearing systems. For

²¹² Ex. 1010 (*Yi* Translation) [0044].

example, when describing Fig. 3, *Bergan* discloses that “[m]otors 78 [annotated in red] can be operated to drive rotation of the drum 74 [annotated in blue] to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”²¹³



Ex. 1006 (*Bergan*) Fig. 3 (annotated)

²¹³ Ex. 1006 (*Bergan* [0030])

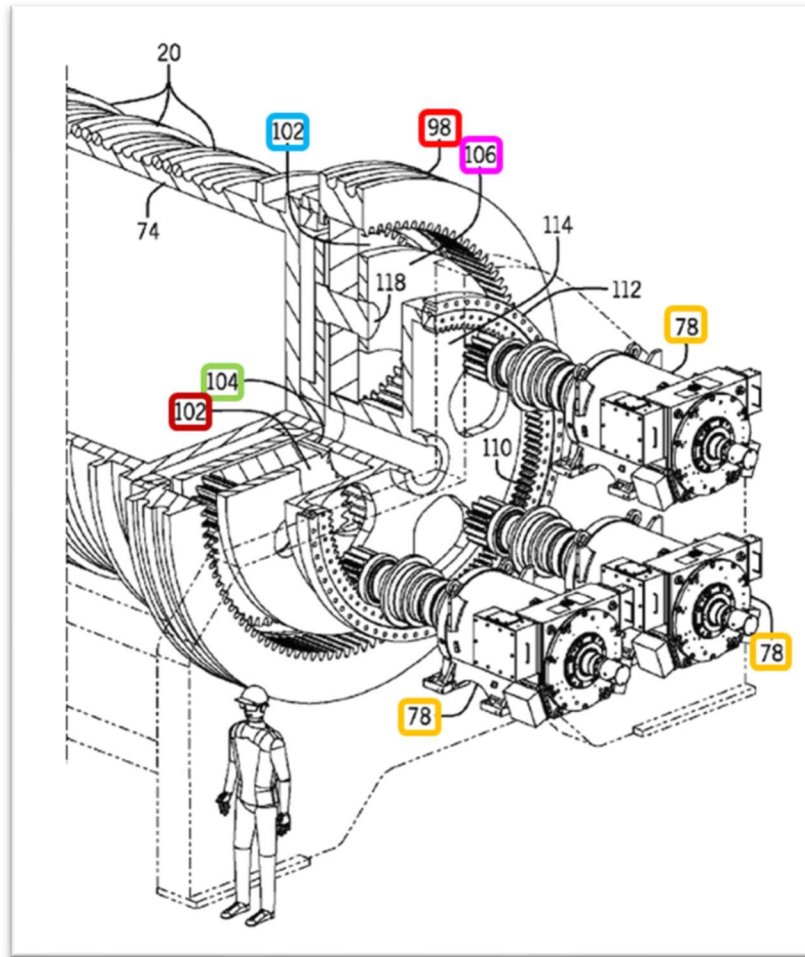
246. Accordingly, *Yi* and *Bergan*, alone or in combination, disclose limitation 1[b] and the combination of *Yi* and *Bergan* renders limitation 1[b] obvious.

4. 1[c]: “a planetary gear train positioned to translate power from the plurality of motors to the pump crankshaft of the multi-plunger hydraulic fracturing pump,”

247. The combination of *Yi* and *Bergan* renders this limitation obvious. *Bergan* discloses, with respect to Figures 4-6, a “planetary gear system” that includes “ring gear 98 [annotated in red below], planetary gears 102 [annotated in blue], and a sun gear 104 [annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in operation,” the rotation of which drives the rotation of the load.²¹⁴ *Bergan* further teaches that “the motors 78 [annotated in orange] rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 [annotated in dark red] are mounted on axles 118 coupled to the carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”²¹⁵ Figure 5 of *Bergan*, annotated below, depicts this configuration:

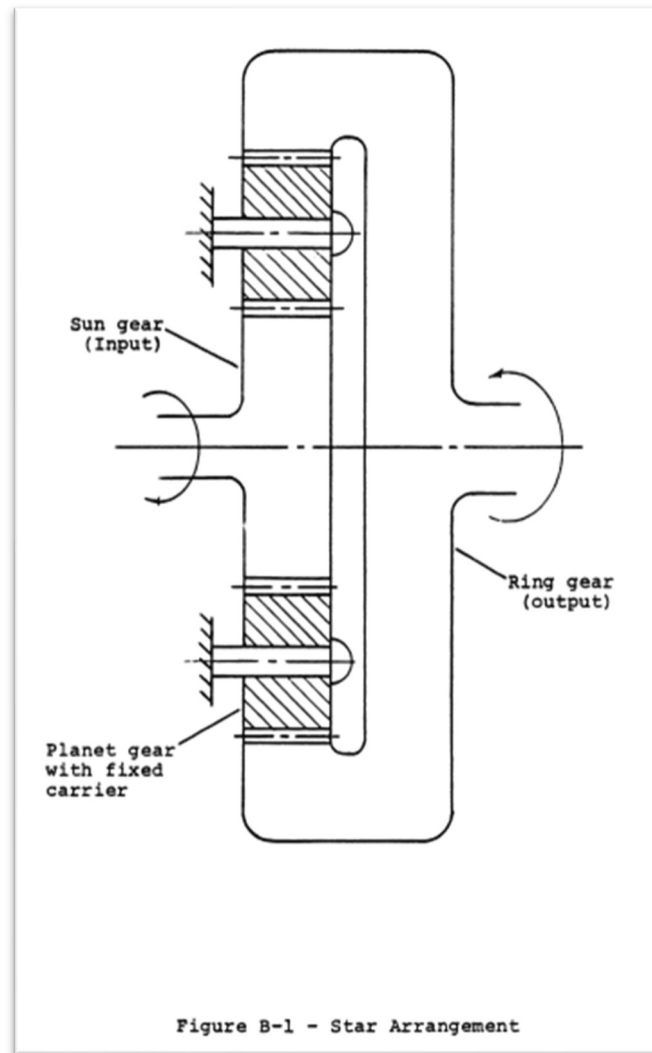
²¹⁴ Ex. 1006 (*Bergan*) [0032].

²¹⁵ Ex. 1006 (*Bergan*) [0032]; *see also, e.g.*, [0014], [0035], [0041], Claims 4-6, 10, 16-18.



EX1006, Fig. 5 (annotated)

248. *August* describes a well-known variation of the planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are coupled to both a fixed carrier and a ring gear, and the ring gear is driven by the rotation of the planetary gears to produce an output rotation. Figure B-1 of *August* depicts this configuration from a side-section view:



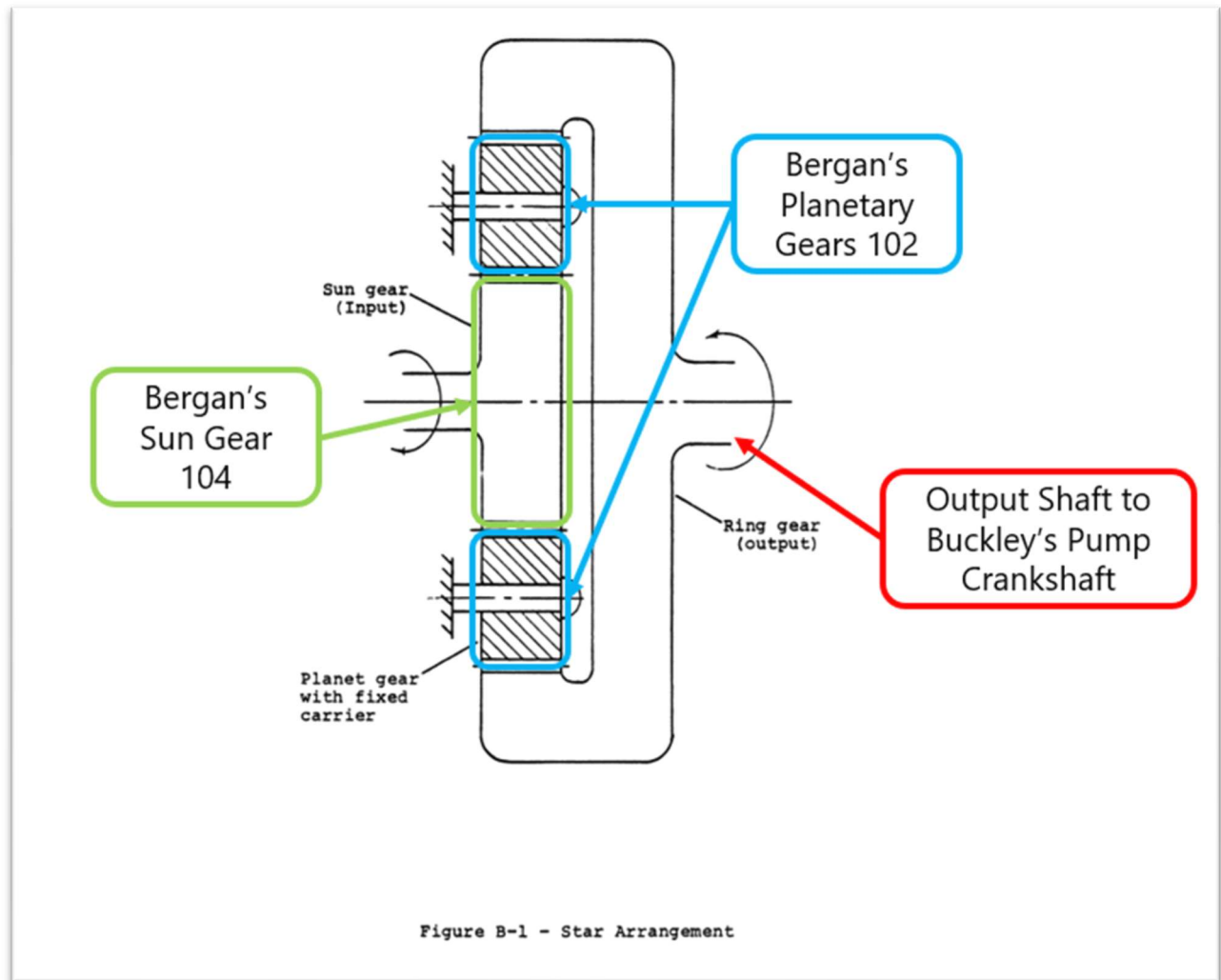
Ex. 1014 (August), 149 (Fig. B-1).

249. As discussed above, modifying the *Yi-Bergan* combination in view of *August*'s star arrangement would result in a well-known variation of a planetary gearing system wherein *Bergan*'s planetary gears 102 are coupled to a fixed carrier (as taught by *August*) and a ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan*'s carrier 106, would serve as the output

of the planetary gearing system to drive the pump crankshaft.²¹⁶ Annotated Figure B-1 of *August* below shows how *August*'s ring gear would interact with *Bergan*'s gearing (including sun gear 104, annotated in green, and planetary gears 102, annotated in blue) and output to *Buckley*'s pump crankshaft²¹⁷ (annotated in red) when combined:

²¹⁶ See Section XII.A.1 above.

²¹⁷ As I discuss in more detail below regarding Limitation 1[e], under the *Yi-Bergan-August-Morris-Joyner* combination, *August*'s ring gear outputs to *Yi*'s pump crankshaft via the universal joint-based coupling taught by the *Morris-Joyner* combination.



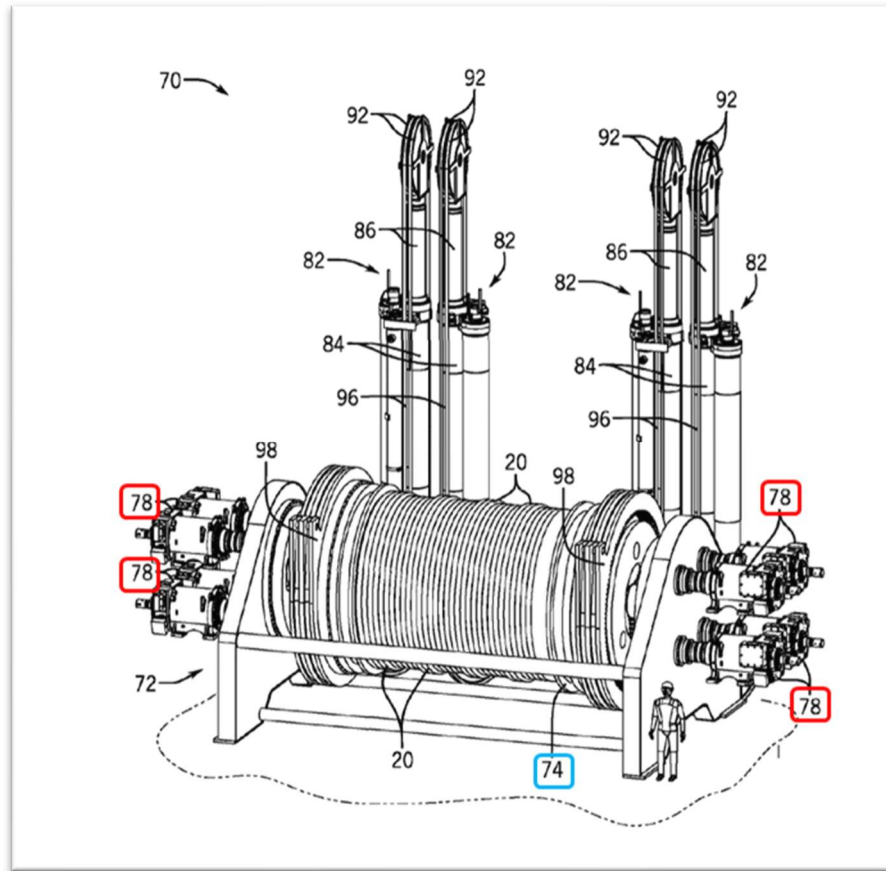
EX1014, Fig. B-1 (annotated).

250. Accordingly, the *Yi-Bergan-August* planetary gear train translates power from the plurality of motors to August's ring gear, which would be coupled to the crankshaft of *Buckley's* multi-plunger hydraulic fracturing pump in the combination. Thus, the *Yi-Bergan-August-Morris-Joyner* combination renders this limitation obvious.

5. 1[d]: “the planetary gear train comprising: a plurality of input pinion gears connected to the plurality of motors,”

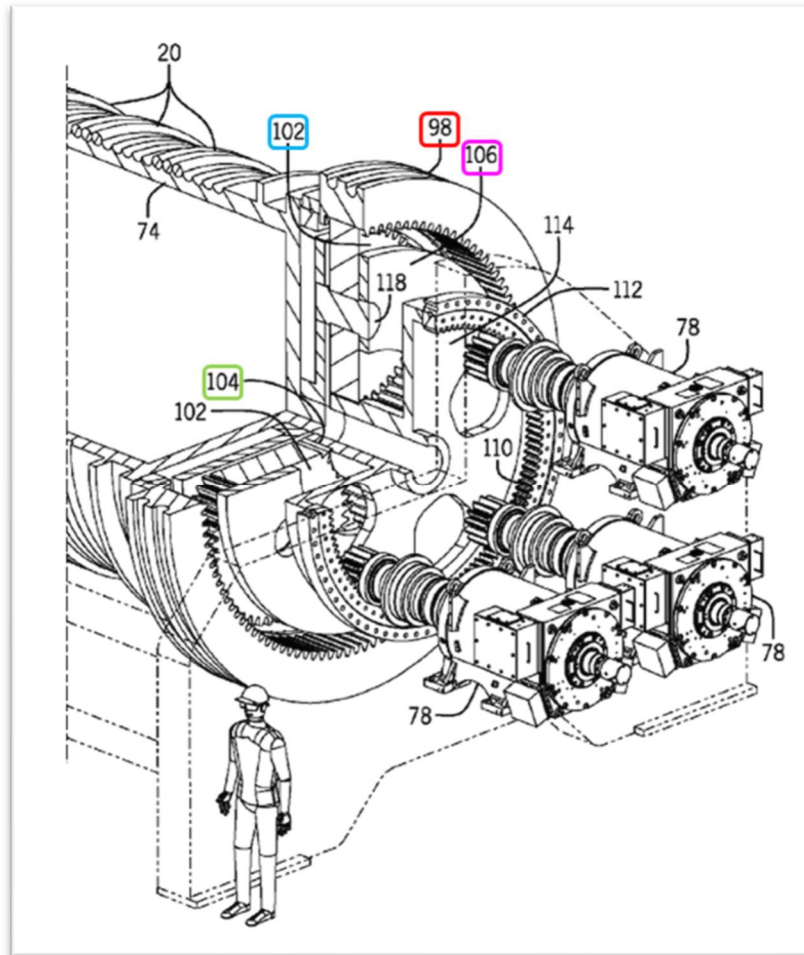
251. *Bergan* discloses this limitation. As discussed above, *Bergan* teaches the use of a plurality of motors located axially with the shaft of the load (i.e. drum) and connected to the shaft via gearing systems. For example, when describing Fig. 3, *Bergan* discloses “[m]otors 78 [annotated in red] can be operated to drive rotation of the drum 74 [annotated in blue] to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”²¹⁸

²¹⁸ Ex. 1006 (*Bergan* [0030])

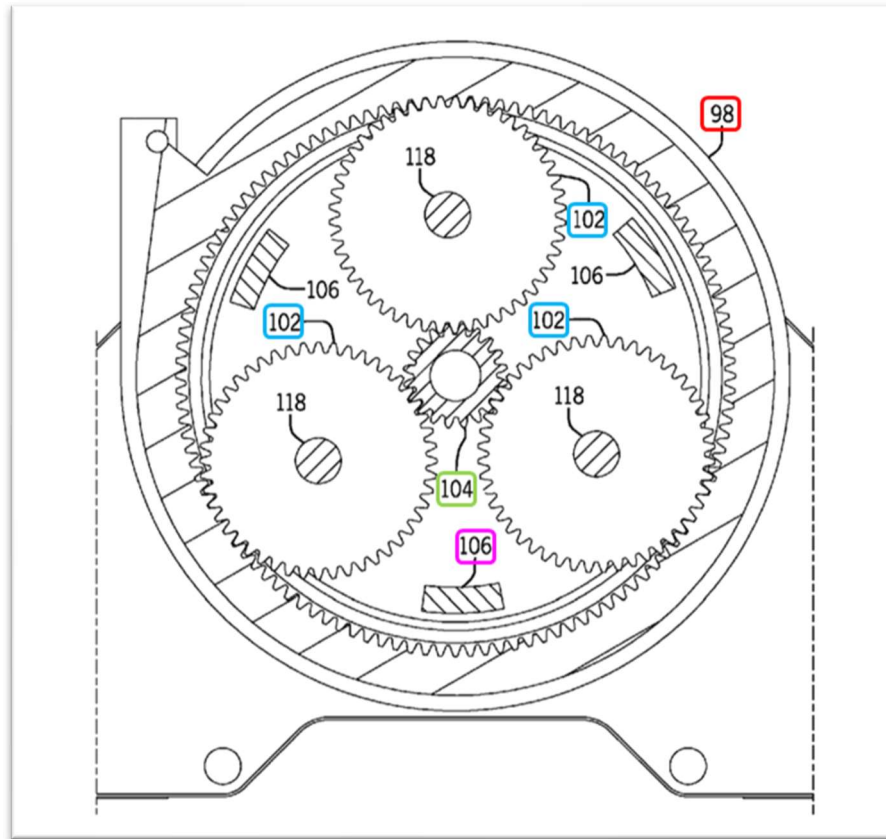
Ex. 1006 (*Bergan*) Fig. 3 (annotated)

252. *Bergan* further teaches the use of a planetary gear system to couple the motors to the shaft. *Bergan* discloses, “As generally shown in FIG. 4 and more specifically shown in FIGS. 5 and 6, the planetary gear system includes the ring gear 98 [annotated in red], planetary gears 102 [annotated in blue], and a sun gear 104 [annotated in green]. A carrier 106 [annotated in magenta] is coupled to rotate with the planetary gears 102 as they orbit the sun gear 104 in operation.”²¹⁹

²¹⁹ Ex. 1006 (*Bergan*) [0032].



Ex. 1006 (*Bergan*) Fig. 5 (annotated)



Ex. 1006 (*Bergan*) Fig. 6 (annotated)

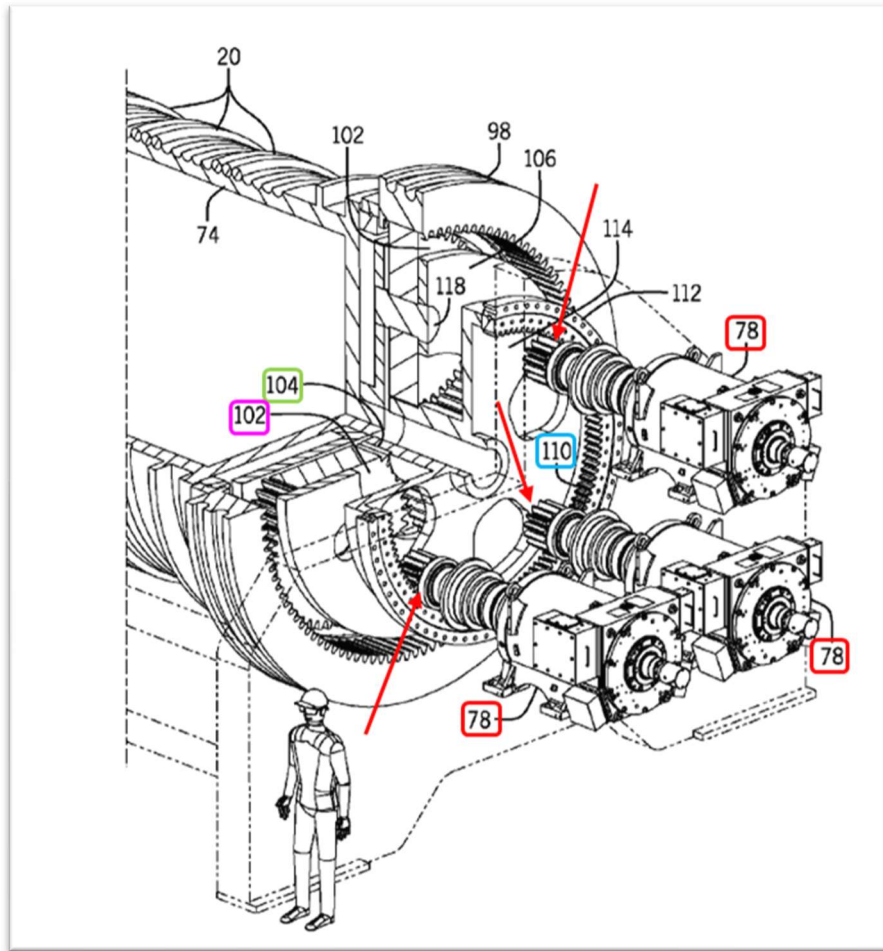
253. *Bergan* further discloses driving the planetary gear train with multiple motors. *Bergan* teaches “the motors 78 [annotated in red] are connected to drive rotation of a gear 110 [annotated in blue] of a slew bearing 112. The gear 110 is coupled to a sun wheel 114 having the sun gear 104 [annotated in green] such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110. The planetary gears 102 [annotated in magenta] are mounted on axles 118 coupled to the

carrier 106, which is coupled to drive the drum 74. This allows the orbit of the planetary gears 102 to drive rotation of both the carrier 106 and the drum 74.”²²⁰

254. Figure 5 shows a perspective view of *Bergan*’s gearing mechanism. Figure 5 further shows the motors 78 each rotationally coupled to an “input pinion” (not numbered, annotated with red arrows) allowing the motors to drive the gearing system. A “pinion” was known to be “a gear with a small number of teeth designed to mesh with a larger wheel or rack.”²²¹ The pinions annotated with red arrows mesh with the larger gear (wheel) 110.

²²⁰ Ex. 1006 (*Bergan*) [0032]; *see also, e.g.*, [0014], [0035], [0041], Claims 4-6, 10, 16-18.

²²¹ Ex. 1011.



Ex. 1006 (Bergan) Fig. 5 (annotated)

255. *Yi* also discloses using input pinion gears to connect the motors to the gear train. *Yi* teaches that during operation “the multiple motors 4 [] rotate, the multiple motors 4 [annotated in red] drive the fracturing pump 5 [annotated in blue] to rotate.”²²² Figure 2 of *Yi*, copied below, depicts this configuration:

²²² Ex. 1010 (*Yi* Translation) [0046].

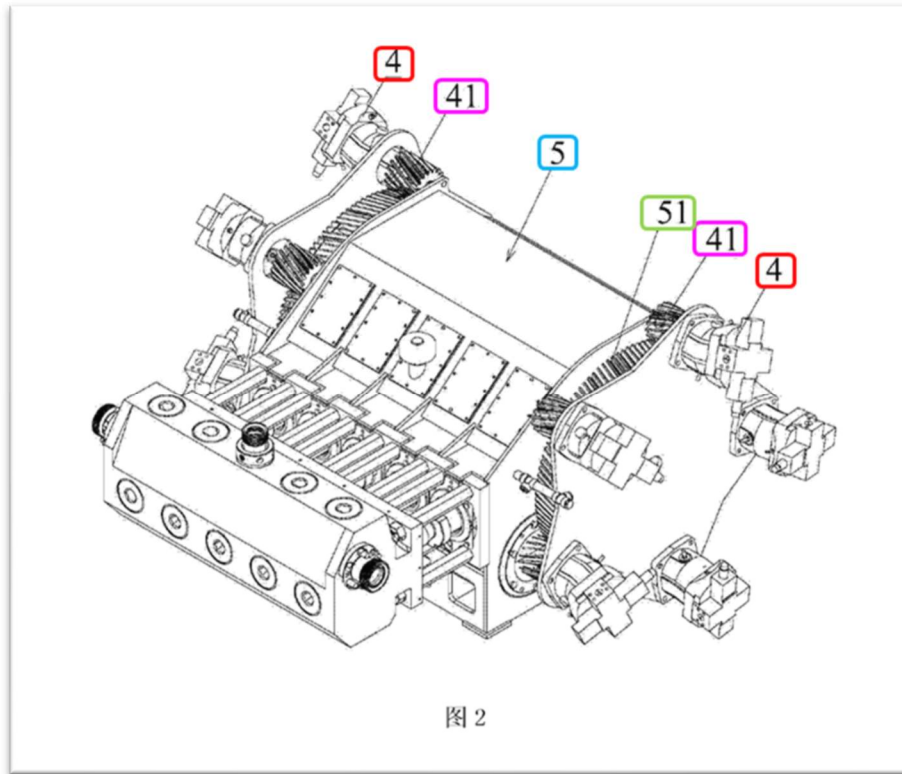


图 2

Ex. 1009 (Yi), Fig. 2.

256. *Yi* further discloses that the motors are connected through power input gears on both ends of the pump. *Yi* teaches “both ends of the crankshaft-type plunger pump, there are power input gears 51 [annotated in green], and each motor 4 [annotated in red] engages at least with the power input gears 51 at one end of the crankshaft-type plunger pump through a power output gear 41 [pinion, annotated in magenta].”²²³

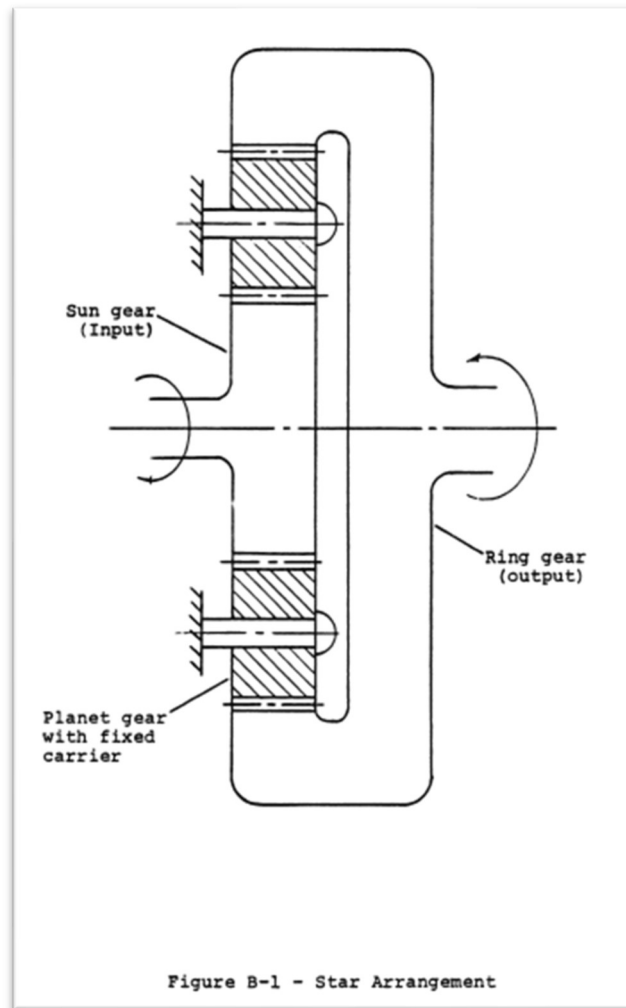
257. Accordingly, *Yi* and *Bergan*, alone or in combination, discloses a planetary gear train having a plurality of input pinion gears, each connected with a

²²³ Ex. 1010 (*Yi* Translation) [0044].

motor. Thus, *Bergan* discloses limitation 1[d] and the *Yi-Bergan-August-Morris-Joyner* combination renders limitation 1[d] obvious.

6. **1[e]: “and a final drive gear connected to the pump crankshaft of the multi-plunger hydraulic fracturing pump by a plurality of arms extending from the final drive gear.”**

258. First, *August*, in combination with the *Yi-Bergan* system, teaches “a final drive gear.” *August* describes a well-known variation of the planetary gearing configuration, referred to as a “star arrangement,” wherein the planetary gears are coupled to both a fixed carrier and a ring gear, and the ring gear is driven by the rotation of the planetary gears to produce an output rotation. Figure B-1 of *August* depicts this configuration from a side section view:



Ex. 1014 (August), 149 (Fig. B-1).

259. As discussed above, modifying the *Yi-Bergan* combination in view of *August's* star arrangement would result in a well-known variation of a planetary gearing system wherein *Bergan's* planetary gears 102 are coupled to a fixed carrier (as taught by *August*) and a ring gear (as taught by *August*), where the rotation of the ring gear, rather than the rotation of *Bergan's* carrier 106, would serve as the output

of the planetary gearing system to drive the pump crankshaft.²²⁴ Accordingly, a POSTIA would have recognized that *August*'s ring gear teaches a "final drive gear."

260. Second, the *Morris-Joyner* combination teaches combining two shafts via a plurality of arms. *Morris* discloses a hydraulic fracturing system wherein a "prime mover" is coupled to one or more pumps via "fixed couplings 1412," such as "flex couplings and/or universal joint-based coupling."²²⁵ *Morris* explains that the use of such couplings facilitates pumping operations by accounting for misalignment between the prime mover and the pumps that may arise from vibrations of the pump during operation.²²⁶

261. When the fixed coupling is implemented as a "universal joint-based coupling," as taught by *Morris*, a POSITA would have understood that the fixed coupling comprises "a plurality of arms." As explained by *Joyner* (Ex. 1016), universal joints are "are well known devices that provide a driving connection between two members that are adapted to rotate about non-aligned axes of rotation."²²⁷ Figure 1 of *Joyner* depicts the typical components of a universal joint, including a "yoke 11 including a sleeve portion 12 having a pair of opposed arms 13 [annotated in red] and 14 [annotated in blue] extending therefrom."²²⁸

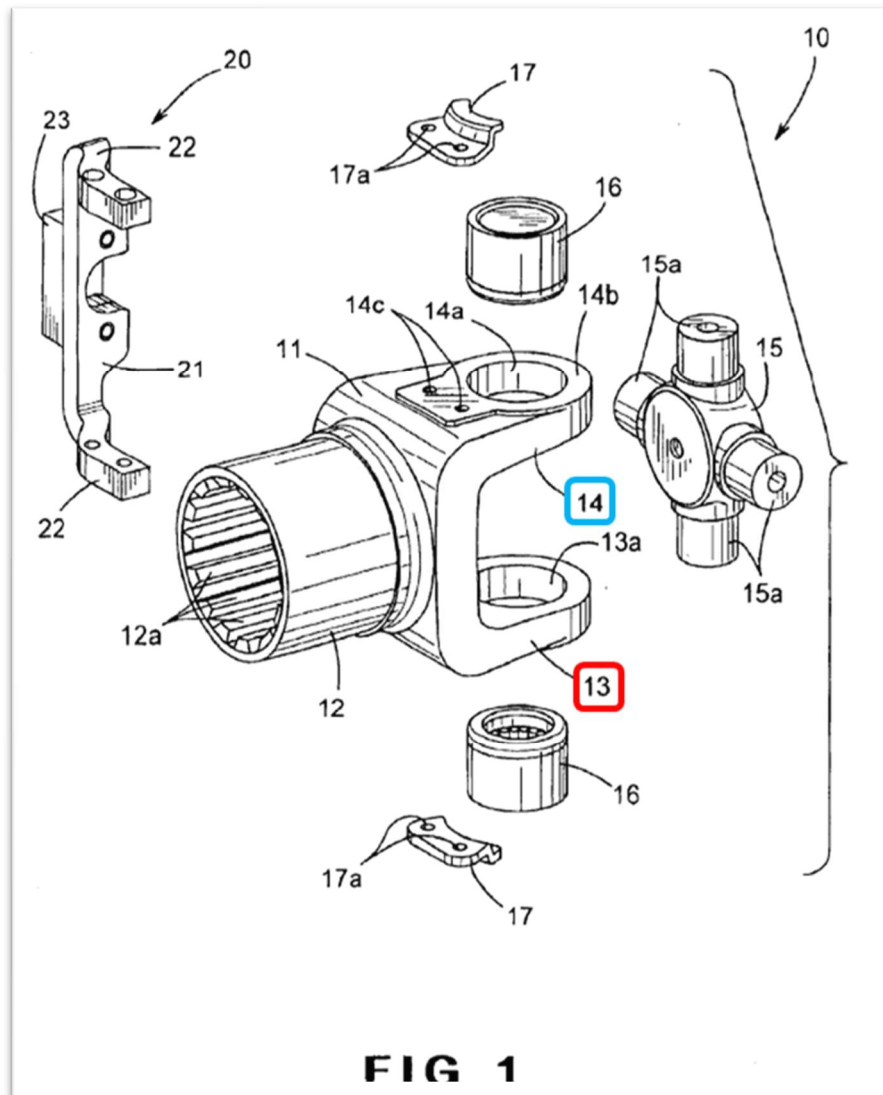
²²⁴ See Section XII.A.1 above.

²²⁵ Ex. 1015 (*Morris*), Abstract, [0094].

²²⁶ Ex. 1015 (*Morris*), Abstract, [0094].

²²⁷ Ex. 1016 (*Joyner*), 1:16-18.

²²⁸ Ex. 1016 (*Joyner*), 2:58-64.



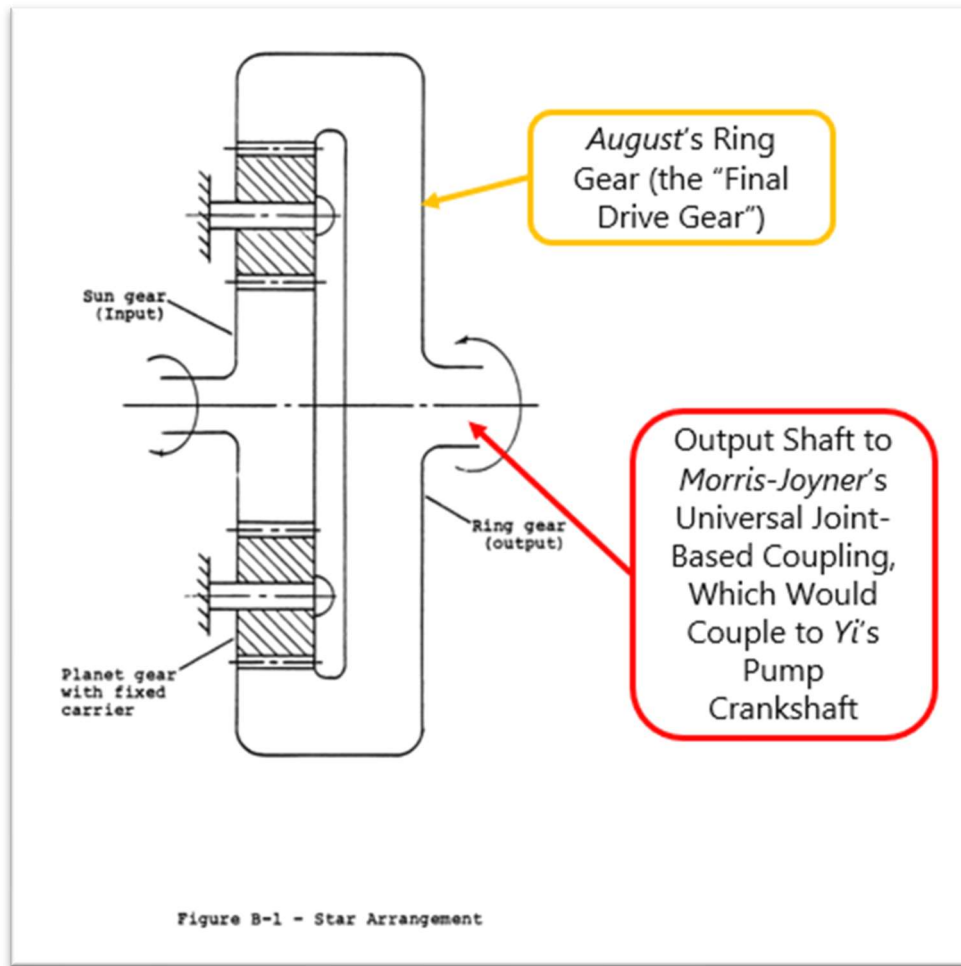
Ex. 1016 (Joyner), Fig. 1.

262. *Joyner* further explains that the sleeve portion 12 engages “with a drive shaft (not shown) or other member,” and that the arms of the yolk are coupled to opposite trunnions 15a of cross 15.²²⁹ A POSITA would have understood that a complete universal joint comprises a second yolk coupled to cross 15 (e.g., to the

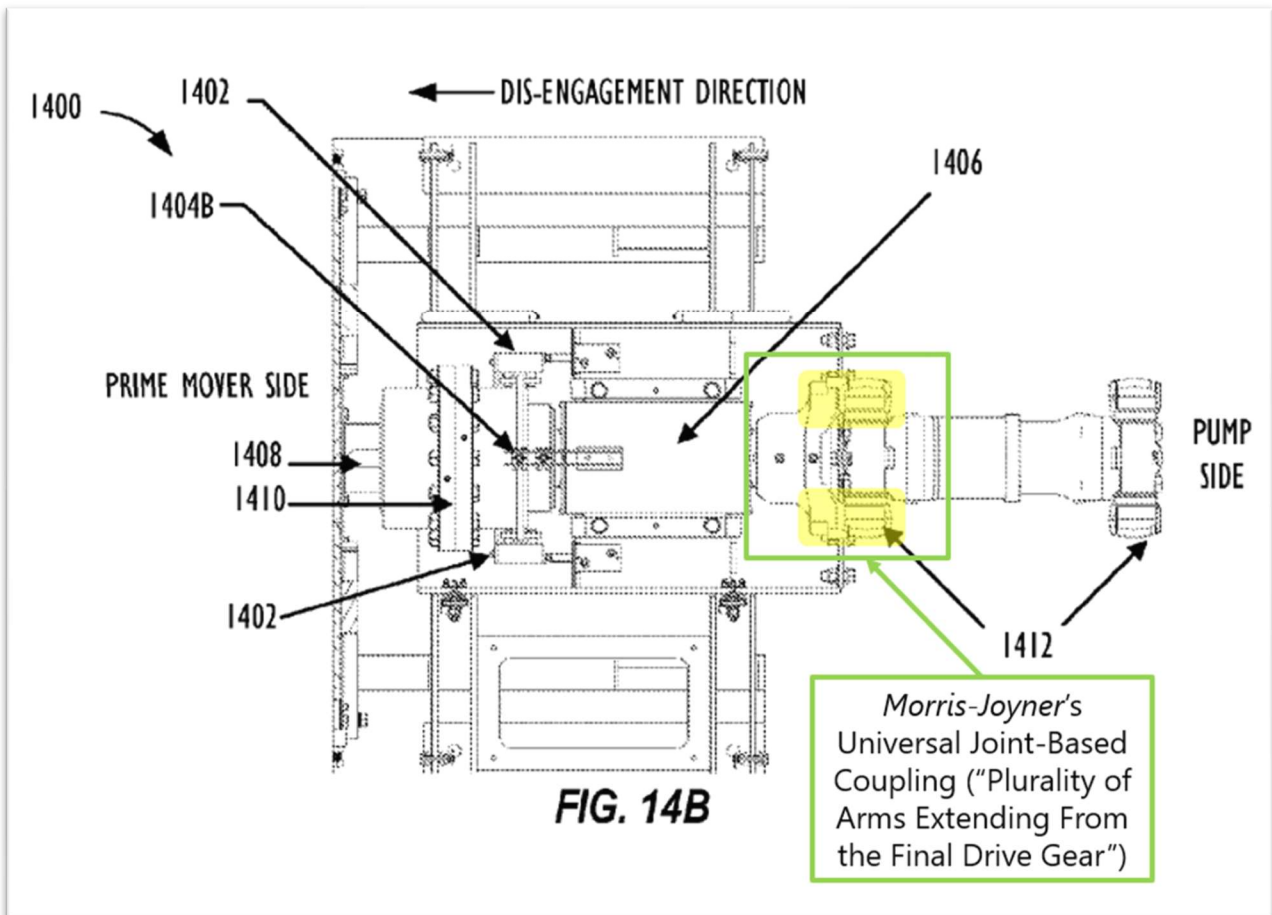
²²⁹ Ex. 1016 (Joyner), 2:64-3:1, 3:19-27.

horizontal trunnions 15a when the first yolk is coupled to the vertical trunnions 15a) such that two drive shafts would have been coupled by the universal joint.

263. When the *Yi-Bergan-August* pumping system is combined with the *Morris-Joyner* universal joint-based coupling, a POSITA would have understood that the output shaft of *August*'s ring gear (the "final drive gear") would have been coupled to the crankshaft of *Yi*'s pump (the "pump crankshaft of the multi-plunger hydraulic fracturing pump") via a universal joint that comprises multiple arms ("by a plurality of arms extending from the final drive gear"), as taught by the *Morris-Joyner* combination, to limit damage caused by misalignment between the ring gear's output shaft and the pump crankshaft, to limit damage caused by misalignment between the ring gear's output shaft and the pump crankshaft and to allow for easier repair / replacement of the pump and/or motor (as taught by *Morris*).



Ex. 1014 (*August*), Fig. B-1 (annotated).



Ex. 1015 (Morris), Fig. 14B (annotated, highlighting in yellow the arms of one yoke of the universal joint-based coupling).

264. Accordingly, the *Yi-Bergan-August-Morris-Joyner* combination renders obvious Limitation 1[e].

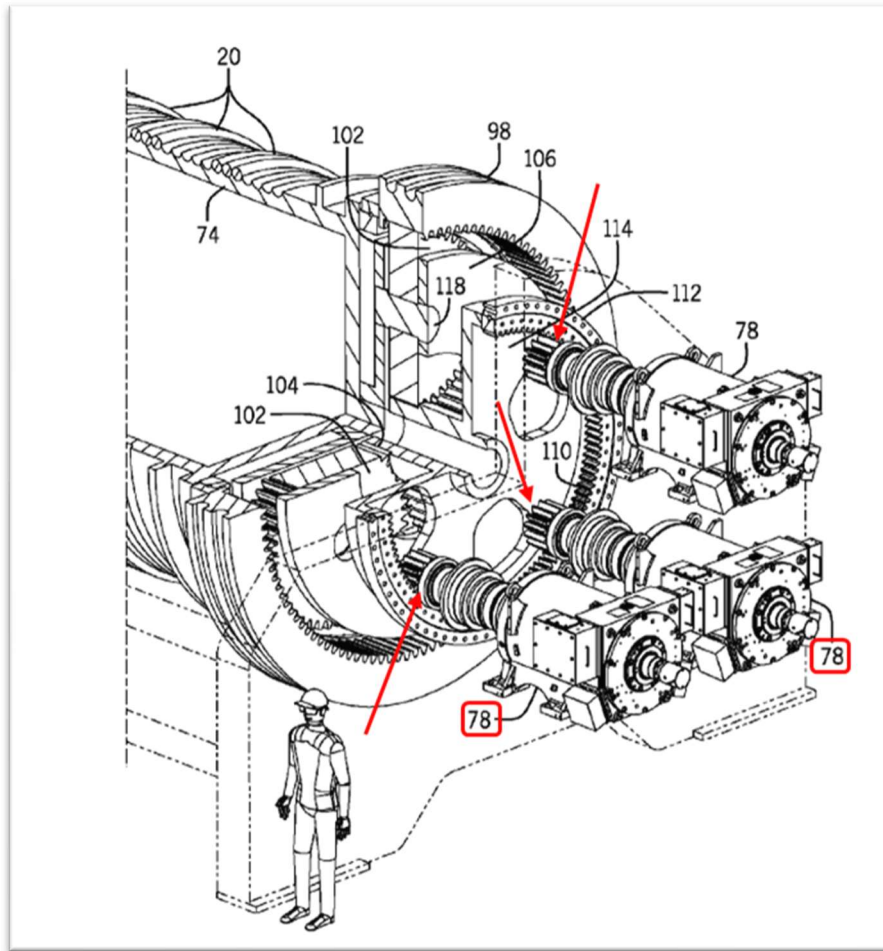
C. DEPENDENT CLAIM 2: “2. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS CONNECTED TO A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”

265. Dependent Claim 2 depends from Claim 1. In addition to the disclosures regarding Claim 1 disclosed above, both *Yi* and *Bergan*, alone or in combination, render the additional limitations of Claim 2.

266. *Bergan* teaches the use of electric motors. As discussed above regarding limitation 1[b], and incorporated herein by reference, *Bergan* teaches “motors 78” to drive the planetary gear system claimed. *Bergan* further discloses, for example, “[m]otors 78 can be operated to drive rotation of the drum 74 to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”²³⁰

267. And as discussed above with reference to Limitation 1[d], *Bergan* discloses that each motor is connected to the planetary gear system via a respective pinion (annotated with red arrows), as depicted in Figure 5 of *Bergan*:

²³⁰ Ex. 1006 (*Bergan*) [0030]



Ex. 1006 (Bergan), Fig. 5 (annotated)

268. *Yi* further discloses, or at least it would have been obvious, the use of a plurality of electric motors connected to input pinion gears to drive the fracturing pump. As discussed above regarding limitation 1[d], and incorporated herein by reference, *Yi* teaches the use of a plurality of motors connected to input pinions that are used to drive the fracturing pump. *Yi* also teaches “[a]dditionally, in specific implementation, there are various ways for multiple motors 4 to drive the fracturing pump 5, as long as the motors 4 can drive the fracturing pump 5 to rotate, which are

not limited in the embodiments of the invention,” which would have made it obvious to a POSITA that electric motors sized to “drive the fracturing pump 5 to rotate” would also have been used with the disclosures of *Yi*, as it was well known to use electric motors to drive fracturing pumps as discussed in Sections IX.F-G.²³¹

269. Thus, *Yi* alone, or in combination with *Bergan-August-Morris-Joyner* renders Claim 2 obvious.

D. DEPENDENT CLAIM 3: “3. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS THREE PLUNGERS.”

270. The ’533 Patent admits that multi-plunger hydraulic fracturing pumps that meet the limitations of Claim 3 were known in the art.²³² And as discussed above with reference to Limitation 1[a] incorporated herein by reference, a POSITA would have understood that the pump disclosed by *Yi* is a quintuplex (*i.e.*, five-plunger) pump, which has three plungers.²³³ *Yi* therefore discloses Claim 3.

E. DEPENDENT CLAIM 4: “4. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS THREE PLUNGERS.”

271. The ’533 Patent admits that multi-plunger hydraulic fracturing pumps that meet the limitations of Claim 4 were known in the art.²³⁴ And as discussed

²³¹ See Ex. 1010 (*Yi* Translation), [0044].

²³² Ex. 1001 (’533 Patent), 5:1-3.

²³³ See Section XI.B.2 above.

²³⁴ Ex. 1001 (’533 Patent), 5:1-3.

above with reference to Limitation 1[a] incorporated herein by reference, a POSITA would have understood that the pump disclosed by *Yi* is a quintuplex (*i.e.*, five-plunger) pump.²³⁵ *Yi* therefore discloses Claim 4.

F. INDEPENDENT CLAIM 10

272. As discussed in the following subsections, it is my opinion that the combination of *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 10 of the '533 Patent.

1. 10[p]: “10. A hydraulic fracturing method comprising:”

273. *Yi* discloses the preamble.²³⁶ *Yi* teaches that “[t]he invention relates to the technical field of fracturing trucks and discloses a fracturing pump transmission system and a fracturing truck.”²³⁷ Further, *Yi* describes “fracturing” to be “hydraulic fracturing for fracturing a subterranean formation”:

“Fracturing operations are one of the most important methods for modifying oil and gas reservoirs. For low-permeability oil and gas wells, fracturing is generally necessary to achieve stable production and increase output. A fracturing truck is the primary equipment used in fracturing operations. Its function is to inject high-pressure, large-volume fracturing fluid into the

²³⁵ See Section XI.B.2 above.

²³⁶ I understand that the preamble may not be limiting. I include analysis of the preamble out of an abundance of caution.

²³⁷ Ex. 1010 (*Yi* Translation) Abstract.

formation, causing it to crack open and injecting proppants (such as fracturing sand) into the fractures to enhance the permeability of the formation, increase the fluidity of oil and gas, and improve the recovery rate of oil and gas.”²³⁸

274. *Yi* describes the purpose of the invention as “provid[ing] a fracturing pump transmission system to effectively reduce the selection difficulty and cost of relevant components for the fracturing pump transmission system while also effectively improving the safety redundancy of the fracturing pump transmission system.”²³⁹ Thus, *Yi* discloses a technique for performing hydraulic fracturing, which involves “inject[ing] high-pressure, large-volume fracturing fluid into the formation, causing it to crack open,” using a multi-plunger pump.²⁴⁰

275. Accordingly, *Yi* discloses the preamble.

2. 10[a]: “by operation of a multi-plunger hydraulic fracturing pump of a hydraulic fracturing system, pumping fluid to a wellbore associated with a subterranean formation, the multiplunger hydraulic fracturing pump comprising a pump crankshaft;”

276. Except for being rewritten as a method claim, limitation 10[a] is essentially similar to limitation 1[a] and is rendered obvious by the combination of

²³⁸ Ex. 1010 (*Yi* Translation) [0002].

²³⁹ Ex. 1010 (*Yi* Translation) [0007].

²⁴⁰ Ex. 1010 (*Yi* Translation) [0002], [0010], Fig. 2.

Yi with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.B.2.

3. 10[b]: “powering the multi-plunger pump with a plurality of motors;”

277. Except for being rewritten as a method claim, limitation 10[b] is essentially similar to limitation 1[b] and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.B.3.

4. 10[c]: “translating power from the plurality of motors to the multi-plunger hydraulic fracturing pump through a planetary gear train,”

278. Except for being rewritten as a method claim, limitation 10[c] is essentially similar to limitation 1[c] and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.B.4.

5. 10[d]: “wherein translating power through the planetary gear train comprises translating power through: a plurality of input pinion gears that are driven by the plurality of motors; and”

279. Except for being rewritten as a method claim, limitation 10[d] is essentially similar to limitation 1[d] and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.B.5.

6. **10[e]: “a final drive gear that drives the pump crankshaft, wherein the final drive gear is connected to the pump crankshaft by a plurality of arms extending from the final drive gear.”**

280. Except for being rewritten as a method claim, limitation 10[e] is essentially similar to limitation 1[e] and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.B.6.

G. DEPENDENT CLAIM 11: “11. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS DRIVEN BY A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”

281. Except for being rewritten as a method claim, Claim 11 is essentially similar to Claim 2 and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.D..

H. DEPENDENT CLAIM 12

1. **The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has three plungers.**

282. Except for being rewritten as a method claim, Claim 12 is essentially similar to Claim 3 and is rendered obvious by the combination of *YI* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.E.

I. DEPENDENT CLAIM 13**1. The hydraulic fracturing method of claim 10, wherein the multi-plunger hydraulic fracturing pump has five plungers.**

283. Except for being rewritten as a method claim, Claim 13 is essentially similar to Claim 4 and is rendered obvious by the combination of *Yi* with *Bergan, August, Morris and Joyner* for the same reasons as those discussed above in Section XII.F

XIII. GROUND 2A: OBVIOUS OVER BUCKLEY IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER AND KARASSIK

284. It is my opinion that *Buckley* in view of *Bergan, August, Morris, Joyner, and Karassik* discloses, suggests, and renders obvious Claims 5, 6, 14, and 15 of the '533 Patent.

A. MOTIVATION TO COMBINE

285. The motivation to combine *Buckley, Bergan, August, Morris, and Joyner* is the same as that discussed above in Section XI.A and incorporated herein by reference. Nothing in *Karassik* teaches against the combination of *Buckley, Bergan, August, Morris, and Joyner*.

286. *Buckley* discloses a quintuplex (five-plunger) fracturing pump.²⁴¹ *Karassik* is a publication that describes fundamental pump theory and operations, including the use of one-, two-, three-, four-, five- six-, seven-, and nine-plunger

²⁴¹ See Ground 1A, Limitation 1[a] above.

pumps.²⁴² As discussed above in section IX.B, and confirmed by *Karassik*, “[u]nlike a centrifugal pump, a power pump [including a plunger pump] does not develop pressure; it only produces a flow of fluid. The downstream process or piping system produces a resistance to this flow, thereby generating pressure in the piping system and discharge portion of the pump.”²⁴³ Additionally, as discussed above in Section IX.B and also taught by *Karassik*, the flow rate of a plunger pump (at a given speed) is directly proportional to the number of plungers. For example, *Karassik* teaches that the ideal flowrate of a plunger pump is governed by

$$D = A \times m \times n \times s \times 6 \times 10^{-5}$$

Where

D = Displacement (volume flow rate, m³/h)

A = cross-sectional area of plunger or piston (mm²)

m = number of plungers or pistons

n = rpm of pump

s = stroke of pump (mm) (half the distance the plunger moves in on rev.)

287. *Karassik* further teaches the use of plunger pumps with up to 9 cylinders.

²⁴² Ex. 1017 (*Karassik*), pg. 3.11. (Table 7).

²⁴³ Ex. 1017 (*Karassik*), pg. 3.3.

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (C is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintaplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (*Karassik*) Table 8

Based on the equation above at a given speed (RPM) a nonuplex (9 plunger) pump would have 9 times the flow of a simplex (1 plunger) pump, 3 times the flow of a Triplex pump and 1.8 times the flow of a quintuplex pump.

288. Further, *Karassik* teaches that as the cylinder (plunger) count goes up, the variations in pressure are reduced. *Karassik* teaches that “the pulsating characteristics of the fluid flowing into and out of power pumps are significantly influenced by the number of plungers or pistons. Discharge flow pulsations are the most critical because of the high energy potential generated when the system resistance reacts with the flow to create pressure. Since the magnitude of the discharge pulsation is mostly affected by the number of cylinders, increasing the number of cylinders will reduce the flow pulsations.”²⁴⁴ As seen above the pulse variations (variations in flow) for a duplex pump, for example, range between -22%

²⁴⁴ Ex. 1017 pg. 3.10.

and +24% (46% total), and variations from a triplex pump range from -17% to +6% (23% total). In comparison, pulse variations for a nonuplex pump are only -2% to +1% (3% total). A POSITA would have known, based on the characteristics of a plunger pump described by *Karassik* that variations in flow lead to variations in pressure. Further, a POSITA would have known that pressure variations lead to noise, vibration and potential damage to the piping, valves and other equipment downstream of the pumps.

289. A POSITA would have been motivated to combine the teaches of *Karassik* with those of *Buckley* (and the combination of *Buckley* with the other references) to gain the additional flowrates, as well as reduced pulsations in the fluid, available from 7 and 9 plunger fluid pumps. A POSITA would have recognized that modifying *Buckley* to use seven plungers or nine plungers, as taught by *Karassik*, rather than five plungers would involve the simple substitution of one known element (a seven- or nine-plunger pump, as taught by *Karassik*) for another (*Buckley*'s five-plunger pump) to obtain the predictable result of performing fracturing operations with a seven-plunger or nine-plunger pump, and the associated increased flowrates and reduced pressure variations that come from using the higher plunger count pumps. Accordingly, a POSITA would have been motivated to combine *Buckley* with *Karassik* and would have a reasonable expectation of success when doing so.

B. DEPENDENT CLAIM 5: “THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS SEVEN PLUNGERS.”

290. As an initial matter, the ’533 Patent admits that multi-plunger hydraulic fracturing pumps were known in the art: “Multi-plunger hydraulic fracturing pumps, though known in the art, are typically limited to either triplex (three plungers) or quintuplex (five plungers) arrangements.”²⁴⁵ Since, according to the ’533 Patent, pumps are only “typically limited”, this at least implies that pumps with more plungers, including 7 plungers, were known. As discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Buckley* is a quintuplex (*i.e.*, five-plunger) pump.²⁴⁶

291. In addition to “quintuplex” pumps, *Karassik* discloses “septuplex” (seven-plunger) pumps.²⁴⁷

²⁴⁵ EX1001, 5:1-3.

²⁴⁶ See Ground 1A, Limitation 1[a] above.

²⁴⁷ See, *e.g.*, EX1017, 3.12 (Table 8, identifying “Septuplex” as the industry term for a seven-plunger pump).

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (C is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintaplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (Karassik) Table 8

292. A POSITA would have understood that *Buckley*'s quintuplex pump would have been substituted for a septuplex pump to gain the increased flowrates and reduced pressure variations, as these types and their characteristics were well-known alternatives for each other, as indicated by *Karassik*. Accordingly, Claim 5 is rendered obvious by the *Buckley-Karassik* combination in view of *Bergan*, *August*, *Morris*, and *Joyner*.

C. DEPENDENT CLAIM 6: "THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS NINE PLUNGERS."

293. As an initial matter, the '533 Patent admits that multi-plunger hydraulic fracturing pumps were known in the art: "Multi-plunger hydraulic fracturing pumps, though known in the art, are typically limited to either triplex (three plungers) or quintuplex (five plungers) arrangements."²⁴⁸ Since, according to the '533 Patent,

²⁴⁸ EX1001, 5:1-3.

pumps are only “typically limited”, this at least implies that pumps with more plungers, including 9 plungers, were known. As discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Buckley* is a quintuplex (*i.e.*, five-plunger) pump.²⁴⁹

294. In addition to “quintuplex” pumps, *Karassik* discloses “nonuplex” (nine-plunger) pumps.²⁵⁰

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (*C* is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintuplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (Karassik) Table 8

295. A POSITA would have understood that *Buckley*’s quintuplex pump would have been substituted for a nonuplex (nine plunger) pump, to gain the increased flowrates and reduced pressure variations, as these type pumps and their characteristics were well-known alternatives for each other, as indicated by

²⁴⁹ See Ground 1A, Limitation 1[a] above.

²⁵⁰ See, *e.g.*, EX1017, 3.11 (Table 7, identifying “Nonuplex” as the industry term for a nine-plunger pump).

Karassik. Accordingly, Claim 6 is rendered obvious by the *Buckley-Karassik* combination in view of *Bergan, August, Morris, and Joyner*.

D. DEPENDENT CLAIM 14: “THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS SEVEN PLUNGERS.”

296. Except for being rewritten as a method claim, Claim 14 is essentially similar to Claim 5 and is rendered obvious by the *Buckley-Karassik* combination in view of *Bergan, August, Morris, and Joyner* for the same reasons as those discussed above in Section XIII.B.

E. DEPENDENT CLAIM 15: “THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS NINE PLUNGERS.”

297. Except for being rewritten as a method claim, Claim 15 is essentially similar to Claim 6 and is rendered obvious by the *Buckley-Karassik* combination in view of *Bergan, August, Morris, and Joyner* for the same reasons as those discussed above in Section XIII.C.

XIV. GROUND 2B: OBVIOUS OVER *YI* IN VIEW OF *BERGAN, AUGUST, MORRIS, JOYNER* AND *KARASSIK*

298. It is my opinion that *Yi* in view of *Bergan, August, Morris, Joyner, and Karassik* discloses, suggests, and renders obvious Claims 5, 6, 14 & 15 of the '533 Patent.

A. MOTIVATION TO COMBINE

299. The motivation to combine *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that discussed above in Section XII.A and incorporated herein by reference. Nothing in *Karassik* teaches against the combination of *Yi*, *Bergan*, *August*, *Morris*, and *Joyner*.

300. *Yi* discloses a quintuplex (five-plunger) fracturing pump.²⁵¹ *Karassik* is a publication that describes fundamental pump theory and operations, including the use of one-, two-, three-, four-, five- six-, seven-, and nine-plunger pumps.²⁵² As discussed above in section IX.B, and confirmed by *Karassik*, “[u]nlike a centrifugal pump, a power pump [including a plunger pump] does not develop pressure; it only produces a flow of fluid. The downstream process or piping system produces a resistance to this flow, thereby generating pressure in the piping system and discharge portion of the pump.”²⁵³ Additionally, as discussed above in Section IX.B, and also taught by *Karassik*, the flowrate of a plunger pump (at a given speed) is directly proportional to the number of plungers. For example, *Karassik* teaches that the ideal flowrate of a plunger pump is governed by

$$D = A \times m \times n \times s \times 6 \times 10^{-5}$$

where

²⁵¹ See Ground 1B, Limitation 1[a] above.

²⁵² Ex. 1017, 3.11. (Table 7).

²⁵³ Ex. 1017 (*Karassik*), pg. 3.3.

D = Displacement (volume flow rate, m^3/h)

A = cross-sectional area of plunger or piston (mm^2)

m = number of plungers or pistons

n = rpm of pump

s = stroke of pump (mm) (half the distance the plunger moves in on rev.)

301. *Karassik* further teaches the use of plunger pumps with up to 9 cylinders.

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (C is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintaplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (*Karassik*) Table 8

Based on the equation above at a given speed (RPM) a nonuplex (9 plunger) pump would have 9 times the flow of a simplex (1 plunger) pump, 3 times the flow of a Triplex pump and 1.8 times the flow of a quintuplex pump.

302. Further, *Karassik* teaches that as the cylinder (plunger) count goes up, the variations in pressure are reduced. *Karassik* teaches that “the pulsating characteristics of the fluid flowing into and out of power pumps are significantly

influenced by the number of plungers or pistons. Discharge flow pulsations are the most critical because of the high energy potential generated when the system resistance reacts with the flow to create pressure. Since the magnitude of the discharge pulsation is mostly affected by the number of cylinders, increasing the number of cylinders will reduce the flow pulsations.”²⁵⁴ As seen above the pulse variations (variations in flow) for a duplex pump, for example, range between -22% and +24% (46% total), and variations from a triplex pump range from -17% to +6% (23% total). In comparison, pulse variations for a nonuplex pump are only -2% to +1% (3% total). A POSITA would have known, based on the characteristics of a plunger pump described by *Karassik* that variations in flow lead to variations in pressure. Further, a POSITA would have known that pressure variations lead to noise, vibration and potential damage to the piping, valves and other equipment downstream of the pumps.

303. A POSITA would have recognized that modifying *Yi* to use seven plungers or nine plungers, as taught by *Karassik* to gain the additional flowrates, as well as reduced pulsations in the fluid, available from 7 and 9 plunger fluid pumps rather than five plungers would involve the simple substitution of one known element (a seven- or nine-plunger pump, as taught by *Karassik*) for another (*Yi*’s five-plunger pump) to obtain the predictable result of performing fracturing

²⁵⁴ Ex. 1017 pg. 3.10.

operations with a seven- or nine-plunger pump, and the associated increased flowrates and reduced pressure variations that come from using the higher plunger count pumps. Accordingly, a POSITA would have been motivated to combine *Yi* with *Karassik-Bergan-August-Morris-Joyner* and would have a reasonable expectation of success when doing so.

B. DEPENDENT CLAIM 5: “THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS SEVEN PLUNGERS.”

304. As an initial matter, the ’533 Patent admits that multi-plunger hydraulic fracturing pumps were known in the art: “Multi-plunger hydraulic fracturing pumps, though known in the art, are typically limited to either triplex (three plungers) or quintuplex (five plungers) arrangements.”²⁵⁵ According to the ’533 Patent, pumps are only “typically limited,” which at least implies that pumps with more plungers, including 7 plungers, were known. As discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Yi* is a quintuplex (*i.e.*, five-plunger) pump.²⁵⁶

305. In addition to “quintuplex” pumps, *Karassik* discloses “septuplex” (seven-plunger) pumps.²⁵⁷

²⁵⁵ EX1001, 5:1-3.

²⁵⁶ See Ground 1B, Limitation 1[a] above.

²⁵⁷ See, e.g., EX1017, 3.11 (Table 7, identifying “Septuplex” as the industry term for a seven-plunger pump).

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (C is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintaplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (Karassik) Table 8

306. A POSITA would have understood that *Buckley's* quintuplex pump would have been substituted for a septuplex pump to gain the increased flowrates and reduced pressure variations, as these types of pumps and their characteristics were well-known alternatives for each other, as indicated by *Karassik*. Accordingly, Claim 5 is rendered obvious by the *Yi-Karassik* combination in view of *Bergan*, *August*, *Morris*, and *Joyner*.

C. DEPENDENT CLAIM 6: “THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS NINE PLUNGERS.”

307. As an initial matter, the '533 Patent admits that multi-plunger hydraulic fracturing pumps were known in the art: “Multi-plunger hydraulic fracturing pumps, though known in the art, are typically limited to either triplex (three plungers) or quintuplex (five plungers) arrangements.”²⁵⁸ Since, according to the '533 Patent,

²⁵⁸ EX1001, 5:1-3.

pumps are only “typically limited”, this at least implies that pumps with more plungers, including 9 plungers, were known. Further, as discussed above with reference to Limitation 1[a], a POSITA would have understood that the pump disclosed by *Yi* is a quintuplex (*i.e.*, five-plunger) pump.²⁵⁹

308. In addition to “quintuplex” pumps, *Karassik* discloses “nonuplex” (nine-plunger) pumps.²⁶⁰

TABLE 8 The effect of the number of plungers on variations in capacity from the mean (*C* is approx. 6:1)

Type	Number of Plungers	% Above Mean	% Below Mean	Total %	Plunger Phase
Duplex	2	24	22	46	180 deg.
Triplex	3	6	17	23	120 deg.
Quadruplex	4	11	22	33	90 deg.
Quintuplex	5	2	5	7	72 deg.
Sextuplex	6	5	9	14	60 deg.
Septuplex	7	1	3	4	51.5 deg.
Nonuplex	9	1	2	3	40 deg.

Ex. 1017 (Karassik) Table 8

309. A POSITA would have understood that *Buckley*’s quintuplex pump would have been substituted for a nonuplex pump, to gain the increased flowrates and reduced pressure variations, as these types of pumps and their characteristics were well-known alternatives for each other, as indicated by *Karassik*. Accordingly,

²⁵⁹ See Ground 1B, Limitation 1[a] above.

²⁶⁰ See, *e.g.*, EX1017, 3.11 (Table 7, identifying “Nonuplex” as the industry term for a nine-plunger pump).

Claim 6 is rendered obvious by the *Yi-Karassik* combination in view of *Bergan*, *August*, *Morris*, and *Joyner*.

D. DEPENDENT CLAIM 14: “THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS SEVEN PLUNGERS.”

310. Except for being rewritten as a method claim, Claim 14 is essentially similar to Claim 5 and is rendered obvious by the *Yi-Karassik* combination in view of *Bergan*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XIII.B.

E. DEPENDENT CLAIM 15: “THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP HAS NINE PLUNGERS.”

311. Except for being rewritten as a method claim, Claim 15 is essentially similar to Claim 6 and is rendered obvious by the *Yi-Karassik* combination in view of *Bergan*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XIII.C

XV. GROUND 3A: OBVIOUS OVER BUCKLEY IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, AND PAYNE

312. It is my opinion that *Buckley* in view of *Bergan*, *August*, *Morris*, *Joyner*, and *Payne* discloses, suggests, and renders obvious Claims 7 & 16 of the '533 Patent.

A. MOTIVATION TO COMBINE

313. The motivation to combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that discussed above in Section XI.A and incorporated herein by reference. Nothing in *Payne* teaches against the combination of *Buckley* and *Bergan*, *August*, *Morris*, and *Joyner*. A POSITA would have been motivated to combine the teachings of *Buckley* (and the rest of the combined references) with those of *Payne* in order to take advantage of the speed control benefits of *Payne*'s AC motors and VFDs used to control the speed and torque of the electric motors.

314. Initially, both *Buckley* and *Payne* teach the use of electric motors to drive hydraulic fracturing pumps. *Buckley* teaches “[t]he electric drive pump system is configured to provide a plurality of individual motors in selective configurations that work together to provide power to a power end. The motors are arranged around a gearbox which is used to convert the rotary motion of the electric motors into linear motion for operation of the plungers in the fluid ends.”²⁶¹ *Payne* describes “[a]

²⁶¹ Ex. 1004 (*Buckley*) [0009]; see also Ex. 1005 (*Buckley* Provisional) p. 4 (“Referring now to Figures 1 and 2 in the drawings, a side view of a schematic of a power end in communication with a plurality of electric motors and a representative perspective view is illustrated. The power end includes a pump that is used to operate one or more fluid ends. [] This system includes a series of electric motors of sufficient number needed to give the required output to operate the one or more fluid ends. The precise number is dependent upon design constraints and engineering parameters. It is understood that more than one may be used. In Figure 1,[sic. Figure 2] a total of 10 are shown or implied, with 5 being located on either side of the power end.”)

system for stimulating oil or gas production from a well bore includes a hydraulic fracturing pump unit having one or more hydraulic fracturing pumps driven by one or more electrical fracturing motors.”²⁶²

315. *Buckley* contains an express motivation to combine. *Buckley* discloses that “system of the present application may permit the motors 11 to run at various speeds or power outputs,”²⁶³ but provides little to no detail on *how* to construct a system that permits motors to run at various speeds or power outputs. A POSITA would have understood that standard industrial motors (AC induction motors or AC synchronous motors) operate at a fixed speed based on the construction of the motor and the frequency of power supplied to them.²⁶⁴ Although *Buckley* provides little detail on how to run the motors at various speeds or power outputs, *Payne* fills those gaps, and a POSITA would have been motivated to apply the teachings of *Payne* in order to develop a system to allow motors to operate at various speeds and power outputs.

316. *Payne* discloses “a variable frequency drive controlling the electrical fracturing motors.”²⁶⁵ *Payne* further discloses that the VFD is used to control speed

²⁶² Ex. 1008 (*Payne*) Abstract

²⁶³ Ex. 1004 (*Buckley*) [0058]; *see also* Ex. 1005 (*Buckley* Provisional) pg 6 “It is understood that the system of the present application may permit the motors to be run at various speeds or power outputs.”

²⁶⁴ See Section IX.F

²⁶⁵ Ex. 1008 (*Payne*) Abstract

of the pump (i.e. accelerate or decelerate pump rotational speeds). As an example, *Payne* teaches the use of a “distributed programmable automation controller (PAC) on each hydraulic fracturing unit.”²⁶⁶ *Payne* further teaches that “[t]he PAC relays the speed set point from the operator at the HMI to a variable frequency drive. The VFD provides ac current which turns the mechanically coupled motor and fracturing pump.”²⁶⁷ As described above in Section IX.E, controlling speed of motor(s), along with controlling torque, are the primary functions of a VFD.²⁶⁸

317. *Payne* teaches the advantages of using AC motors (i.e. induction or synchronous) and controlling speed with a VFD, particularly in “applications where the operating environment may be wet, corrosive or explosive.”²⁶⁹ A POSITA would have understood that a fracturing pump system operates by pumping water, and operates outdoors, both environments that may be wet. Further, oftentimes produced water which has a high saline content is used for the fracturing process, along with chemicals such as PH reducers (Acid) which are corrosive. Because of the nature of the formation, which is intended to recover hydrocarbons, the environment around a fracturing pump may be explosive.

²⁶⁶ Ex.1008 (*Payne*) [0039].

²⁶⁷ Ex. 1008 (*Payne*) [0039]. An HMI is a human machine interface.

²⁶⁸ As power is a function of the speed and torque of the motor, controlling speed and torque also allows the drive to control power output.

²⁶⁹ Ex. 1008 (*Payne*) [0011].

318. Payne discloses “AC motors are better suited for applications where the load varies greatly and light loads may be encountered for prolonged periods.” These advantages occur because of the construction of AC motors vs. DC motors. *Payne* teaches “DC motor commutators and brushes may wear rapidly under this condition. [load varying greatly].”²⁷⁰ Further, Payne discloses that “AC motors offer lower cost operation for higher power applications. In addition, AC motors are generally smaller, lighter, more commonly available, and less expensive than equivalent DC motors. AC motors require virtually no maintenance and are preferred for applications where reliability is critical.”²⁷¹ In addition to the lower cost of AC motors themselves, *Payne* discloses that, as of at least 2016 “VFD drive technology used with AC motors has advanced significantly in recent times to become more compact, reliable and cost effective. DC drives had a cost advantage for a number of years, but that has changed with the development of new power electronics like IGBTs (Insulated-gate bipolar transistors).”²⁷² A POSITA would have been motivated to apply the teachings of *Payne* to use AC motors, along with a VFD to control speed, to take advantage of the reliability, lower maintenance and cost savings of such a system over another type system, such as one that uses DC motors. The combination of AC motors and VFDs into the system of *Buckley-Bergan-*

²⁷⁰ Ex. 1008 (*Payne*) [0011].

²⁷¹ Ex. 1998 (*Payne*) [0010].

²⁷² Ex. 1008 (*Payne*) [0011].

August-Morris-Joyner would yield predictable results – the ability to control speed at a lower cost and more reliably than using DC motors.

319. A POSITA would have had a reasonable expectation of success in applying the teachings of *Payne* regarding using an AC motor and controlling speed with a variable frequency drive. Both AC motors and VFDs were well-known, established technologies.²⁷³ Further, both AC motors and VFDs were subject to industry standards before the time of the '533 application. Further, adding the teachings of *Payne* to fill in the gaps in *Buckley's* teaching is simply combining prior art elements (AC motors and VFDs along with the multi-motor pump system of *Buckley, Bergan, August, Morris, and Joyner*) according to known methods (controlling speed/torque of an AC motor with a VFD) to yield predictable results (control of the plurality of motors in *Buckley, Bergan, August, Morris, and Joyner*). Further still, such a combination uses a known technique (AC motors and VFDs) to improve similar devices (electric motor-driven pump compared with *Payne's* electric motor-driven pump) in the same way (VFD to control speed/torque of the motors in the *Buckley, Bergan, August, Morris, and Joyner* system).

²⁷³ See, e.g., Sections IX.E, F above.

B. DEPENDENT CLAIM 7: “7. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, FURTHER COMPRISING A VARIABLE FREQUENCY DRIVE (VFD) ASSOCIATED WITH THE PLURALITY OF MOTORS AND CONFIGURED TO CONTROL A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

320. Dependent Claim 7 depends from Claim 1. In addition to the disclosures regarding Claim 1 disclosed above, the combination of *Buckley, Bergan, August, Morris, Joyner* and *Payne* renders Claim 7 obvious.

321. *Payne* describes “[a] system for stimulating oil or gas production from a well bore includes a hydraulic fracturing pump unit having one or more hydraulic fracturing pumps driven by one or more electrical fracturing motors.”²⁷⁴ *Payne* additionally teaches that AC motors “offers lower cost operation for higher power applications. In addition, AC motors are generally smaller, lighter, more commonly available, and less expensive than equivalent DC motors. AC motors require virtually no maintenance and are preferred for applications where reliability is critical.”²⁷⁵

322. *Payne* further discloses “a variable frequency drive controlling the electrical fracturing motors.”²⁷⁶ *Payne* further discloses that the VFD is used to control speed of the pump (i.e. accelerate or decelerate pump rotational speeds). As

²⁷⁴ Ex. 1008 (*Payne*) Abstract

²⁷⁵ Ex. 1008 (*Payne*) [0010]

²⁷⁶ Ex. 1008 (*Payne*) Abstract. See also [0011], [0014], [0015], [0017], [0039], [0047] – [0048], [0053] – [0056].

an example, *Payne* teaches the use of a “distributed programmable automation controller (PAC) on each hydraulic fracturing unit.”²⁷⁷ *Payne* further teaches that “[t]he PAC relays the speed set point from the operator at the HMI to a variable frequency drive. The VFD provides AC current, which turns the mechanically coupled motor and fracturing pump.”²⁷⁸ A POSITA would have understood that this teaches that the VFD is “connected to the plurality of motors to control the speeds of the plurality of motors,” which, as described above in Section IX.E, is needed to perform one of the primary functions of a VFD (i.e., controlling speed and torque of AC motor(s)). A POSITA would have understood that by “turn[ing] the mechanically coupled motor and fracturing pump” in response to receiving a “speed set point” from an operator, *Payne*’s VFD controls the rotational speed of the electric motors (and, as a result, the fracturing pump driven by the electric motors) to the operator-selected speed.

323. Accordingly, *Payne* discloses the limitations of Claim 7 and the combination of *Buckley* and *Payne* in view of *Bergan*, *August*, *Morris*, and *Joyner*, renders Claim 7 obvious.

²⁷⁷ Ex.1008 (*Payne*) [0039]

²⁷⁸ Ex. 1008 (*Payne*) [0039]. An HMI is a human machine interface.

C. DEPENDENT CLAIM 16: “16. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, COMPRISING, BY OPERATION OF A VARIABLE FREQUENCY DRIVE (VFD), CONTROLLING A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

324. Except for being rewritten as a method claim, Claim 16 is essentially similar to Claim 7 and is rendered obvious by the combination of *Buckley* and *Payne* in view of *Bergan*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XV.B.

XVI. GROUND 3B: OBVIOUS OVER YI IN VIEW OF IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, AND PAYNE

325. It is my opinion that *Yi*, in view of *Bergan*, *August*, *Morris*, *Joyner*, and *Payne*, discloses, suggests, and renders obvious Claims 2, 7, 11 & 16 of the '533 Patent.

A. MOTIVATION TO COMBINE

326. The motivation to combine *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that disclosed above in Section XII.A above and incorporated herein by reference. Nothing in *Payne* teaches away from the combination of *Yi*, *Bergan*, *August*, *Morris*, and *Joyner*.

327. A POSITA would have been motivated to combine the teachings of *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* with those of *Payne* in order to take advantage of the speed control benefits of *Payne*'s AC motors and VFDs to control the speed and torque of the electric motors to replace the hydraulic motors of *Yi*. *Bergan*

already discloses using electric motors as one of the plurality of motors disclosed by both *Yi* and *Bergan*. For example, *Bergan* teaches “motors 78” to drive the planetary gear system claimed. *Bergan* further discloses, for example, “[m]otors 78 can be operated to drive rotation of the drum 74 to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”²⁷⁹

328. *Yi* also discloses using a plurality of motors to operate a single rotating load. Further, *Yi*’s teaching that “each engine 1 is used to drive at least one oil pump 2 for supplying pressurized oil to a plurality of motors 4” would have been recognized by a POSITA as disclosing a hydraulic motor. *Yi* also teaches that “there are various ways for multiple motors 4 to drive the fracturing pump, as long as the motor 4 can drive the fracturing pump 5 to rotate, which are not limited in the embodiments of the invention,” which would have made it obvious to a POSITA that electric motors sized to “drive the fracturing pump 5 to rotate” would also have been used with the disclosures of *Yi*.

329. Further, *Payne* describes the advantages of using AC electric motors in place of mechanical systems, such as the diesel-driven hydraulic motor of *Yi*. *Payne* discloses that “[d]iesel engines have been used as the primary driving mechanism for fracturing pumps in the past. Using diesel engines, however, has serious

²⁷⁹ Ex. 1006 (*Bergan*) [0030]

disadvantages, including the relative inefficiency of the internal combustion engine and the fact that its operation is costly. In addition, off-road diesel engines of the types used for hydraulic fracturing are noisy while pumping, limiting the areas in which they may be used. Also, diesel engines have many moving parts and require continuous monitoring, maintenance, and diagnostics. Ancillary Subsystems are typically driven hydraulically in traditional diesel-driven systems, which also contribute to other operational problems.”²⁸⁰

330. As an alternative, *Payne* teaches the use of electric motors for hydraulic fracturing operations. *Payne* teaches “[i]n view of the above deficiencies [of mechanical systems], electrical motors for hydraulic fracturing operations potentially offer an attractive alternative. Electrical motors are lighter, have fewer moving parts, and can more easily be transported. Further, the control of electrical motors provides many advantages over traditional diesel-driven, variable gear ratio powertrains, for example, through more precise, continuous speed control.”²⁸¹ Further still, *Payne* teaches benefits of using electrical motors not only on the fracturing pumps, but to replace the hydraulically driven ancillary systems. *Payne* teaches that “the use of electrical motors obviates the need for supplying diesel fuel to more traditional fracturing pumps, and reduces the footprint of the site, and its

²⁸⁰ Ex. 1008 (*Payne*) [0008].

²⁸¹ Ex. 1008 (*Payne*) [0009].

environmental impact. Other advantages of electrical motors include, but are not limited to, the ability to independently control and operate ancillary Sub Systems.”²⁸² A POSITA would have been motivated to implement the teachings of *Payne* to gain the benefits of electric motors, such as reduced footprint, reduced environmental impact and avoiding the expense of supplying diesel fuel to the site.

331. In addition to teaching the benefits of using electric motors to power the fracturing site, *Payne* teaches the benefits of using AC motors with variable frequency drives (VFDs). *Payne* teaches the advantages of using AC motors (i.e. induction or synchronous) and controlling speed with a VFD, particularly in “applications where the operating environment may be wet, corrosive or explosive.”²⁸³ A POSITA would have understood that a fracturing pump system operates by pumping water, and operates outdoors, both environments that may be wet. Further, oftentimes produced water which has a high saline content is used for the fracturing process, along with chemicals such as PH reducers (Acid) which are corrosive. Because of the nature of the formation, which is intended to recover hydrocarbons, the environment around a fracturing pump may be explosive.

332. *Payne* discloses “AC motors are better suited for applications where the load varies greatly and light loads may be encountered for prolonged periods.” These

²⁸² Ex. 1008 (*Payne*) [0009].

²⁸³ Ex. 1008 (*Payne*) [0011].

advantages occur because of the construction of AC motors vs. DC motors. *Payne* teaches “DC motor commutators and brushes may wear rapidly under this condition. [load varying greatly].”²⁸⁴ Further, *Payne* discloses that “AC motors offer lower cost operation for higher power applications. In addition, AC motors are generally smaller, lighter, more commonly available, and less expensive than equivalent DC motors. AC motors require virtually no maintenance and are preferred for applications where reliability is critical.”²⁸⁵ In addition to the lower cost of AC motors themselves, *Payne* discloses that, as of at least 2016 “VFD drive technology used with AC motors has advanced significantly in recent times to become more compact, reliable and cost effective. DC drives had a cost advantage for a number of years, but that has changed with the development of new power electronics like IGBTs (Insulated-gate bipolar transistors).”²⁸⁶ A POSITA would have been motivated to apply the teachings of *Payne* to use AC motors, along with a VFD to control speed, to take advantage of the reliability, lower maintenance and cost savings of such a system over another type system, such as one that uses DC motors. The combination of AC motors and VFDs into the system of *Yi/Rosman* would yield predictable results – the ability to control speed at a lower cost and more reliably than using DC motors.

²⁸⁴ Ex. 1008 (*Payne*) [0011].

²⁸⁵ Ex. 1998 (*Payne*) [0010].

²⁸⁶ Ex. 1008 (*Payne*) [0011].

333. A POSITA would have had a reasonable expectation of success in applying the teachings of *Payne* regarding using an AC motor and controlling speed with a variable frequency drive. Both AC motors and VFDs were well known, established technologies.²⁸⁷ Further, Both AC motors and VFDs were subject to industry standards before the time of the '533 application. Further, adding the teachings of *Payne* to *Yi, Bergan, August, Morris, and Joyner's* teaching of multiple motor driven loads teaching is simply combining prior art elements (AC motors and VFDs along with the multi-motor pump system of *Yi, Bergan, August, Morris, and Joyner*) according to known methods (controlling speed/torque of an AC motor with a VFD) to yield predictable results (control of the plurality of motors in *Yi, Bergan, August, Morris, and Joyner*). Further still, such a combination is using a known technique (AC motors and VFDs) to improve similar devices (*Yi, Bergan, August, Morris, and Joyner's* hydraulic motor driven pump compared with *Payne's* electric motor driven pump) in the same way (VFD to control speed/torque of the motors in the *Yi, Bergan, August, Morris, and Joyner* system).

²⁸⁷ See, e.g., Sections IX.E, F above.

B. DEPENDENT CLAIM 2: “2. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS CONNECTED TO A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”

334. *Yi* teaches that “there are various ways for multiple motors 4 to drive the fracturing pump 5, as long as the motors 4 can drive the fracturing pump 5 to rotate, which are not limited in the embodiments of the invention.”²⁸⁸ A POSITA would have understood that this suggests the use of any type of motor for powering the fracking pump, including electric motors which were well-known to have such an application.²⁸⁹ *Bergan* teaches that “motors 78” drive the planetary gear system claimed. Further, *Bergan* teaches that “[m]otors 78 can be operated to drive rotation of the drum 74 to reel in or reel out the hoisting lines 20 to raise and lower an attached load 30. Any suitable motors 78 could be used. The motors 78 can include electric motors, for example.”²⁹⁰ In the alternative, a POSITA would have understood that combining with *Payne* discloses using electric motors to power fracturing pumps, including *Yi*’s fracturing pump, to gain the benefits of using AC electric motors, as discussed above in Section XVI.A regarding the motivation to combine *Payne* with

²⁸⁸ Ex. 1010 (*Yi* translation) [0044].

²⁸⁹ See, e.g., Ex. 1013 at 47, explaining that “the majority of pumps are driven by electric motors,” and Ex. 1008 (generally describing the use of electric motors to drive fracturing pumps).

²⁹⁰ Ex. 1006 (*Bergan*) [0030]

the other references.²⁹¹ As discussed above in section XII.C and incorporated herein by reference, both *Yi* and *Bergan* teach the use of pinions connected to the output of the motor. Accordingly, Claim 2 is rendered obvious by *Yi* and *Bergan*, and, in the alternative, the *Yi*, *Bergan*, *Payne* combination in view of *August*, *Morris* and *Joyner*.

C. DEPENDENT CLAIM 7: “7. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, FURTHER COMPRISING A VARIABLE FREQUENCY DRIVE (VFD) ASSOCIATED WITH THE PLURALITY OF MOTORS AND CONFIGURED TO CONTROL A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

335. Dependent Claim 7 depends from Claim 1. In addition to the disclosures regarding Claim 1 disclosed above, the combination of *Yi*, *Bergan*, *August*, *Morris*, *Joyner* and *Payne* renders Claim 7 obvious.

336. *Payne* describes “[a] system for stimulating oil or gas production from a well bore includes a hydraulic fracturing pump unit having one or more hydraulic fracturing pumps driven by one or more electrical fracturing motors.”²⁹² *Payne* further discloses “a variable frequency drive controlling the electrical fracturing motors”.²⁹³ *Payne* further discloses that the VFD is used to control speed of the pump (i.e. accelerate or decelerate pump rotational speeds. As an example, *Payne* teaches the use of a “distributed programmable automation controller (PAC) on each

²⁹¹ See Section XVI.A above.

²⁹² Ex. 1008 (*Payne*) Abstract

²⁹³ Ex. 1008 (*Payne*) Abstract

hydraulic fracturing unit.”²⁹⁴ *Payne* further teaches that “[t]he PAC relays the speed set point from the operator at the HMI to a variable frequency drive. The VFD provides ac current which turns the mechanically couple motor and fracturing pump.”²⁹⁵ A POSITA would have understood that this teaches that the VFD is “connected to the plurality of motors to control the speeds of the plurality of motors,” which, as described above in Section IX.F, is needed to perform one of the primary functions of a VFD (i.e., controlling speed of and torque of AC motor(s)). Further, a POSITA would have understood that by “turn[ing] the mechanically coupled motor and fracturing pump” in response to receiving a “speed set point” from an operator, *Payne*’s VFD accelerates (or decelerates) the electric motors (and, as a result, the fracturing pump driven by the electric motors) to the operator-selected speed.

337. Accordingly, *Payne* discloses the limitations of Claim 7 and the combination of *Yi*, *Bergan*, and *Payne* in view of *August*, *Morris*, and *Joyner* renders Claim 7 obvious.

²⁹⁴ Ex.1008 (*Payne*) [0039]

²⁹⁵ Ex. 1008 (*Payne*) [0039]. An HMI is a human machine interface.

D. DEPENDENT CLAIM 11: “11. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN THE PLURALITY OF MOTORS COMPRISES A PLURALITY OF ELECTRIC MOTORS, AND EACH OF THE PLURALITY OF INPUT PINION GEARS IS DRIVEN BY A RESPECTIVE ONE OF THE PLURALITY OF ELECTRIC MOTORS.”

338. Except for being rewritten as a method claim, Claim 11 is essentially similar to Claim 2 and is rendered obvious by the combination of *Yi, Bergan*, and *Payne* in view of *August, Morris*, and *Joyner* for the same reasons as those discussed above in Section XVI.B.

E. DEPENDENT CLAIM 16: “16. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, COMPRISING, BY OPERATION OF A VARIABLE FREQUENCY DRIVE (VFD), CONTROLLING A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

339. Except for being rewritten as a method claim, Claim 16 is essentially similar to Claim 7 and is rendered obvious by the combination of *Yi, Bergan*, and *Payne* in view of *August, Morris*, and *Joyner* for the same reasons as those discussed above in Section XVI.C.

XVII. GROUND 4A: OBVIOUS OVER *BUCKLEY* IN VIEW OF *BERGAN, AUGUST, MORRIS, JOYNER, AND ROSMAN*

340. It is my opinion that *Buckley*, in view of *Bergan, August, Morris, Joyner*, and *Rosman*, discloses, suggests, and renders obvious Claims 8, 9, 17, 18, and 22 of the '533 Patent.

A. MOTIVATION TO COMBINE

341. The motivation to combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that discussed above in Section XI.A and incorporated herein by reference. A POSITA would have been motivated to further combine *Buckley* and *Bergan* with *Rosman*. Nothing in *Rosman* teaches away from the combination of *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner*.

342. As discussed above with reference to Limitation 1[d] in Ground 1A, *Bergan* discloses a planetary gear system wherein input pinion gears (annotated with red arrows below) mesh with gear 110, as depicted in Figure 5:

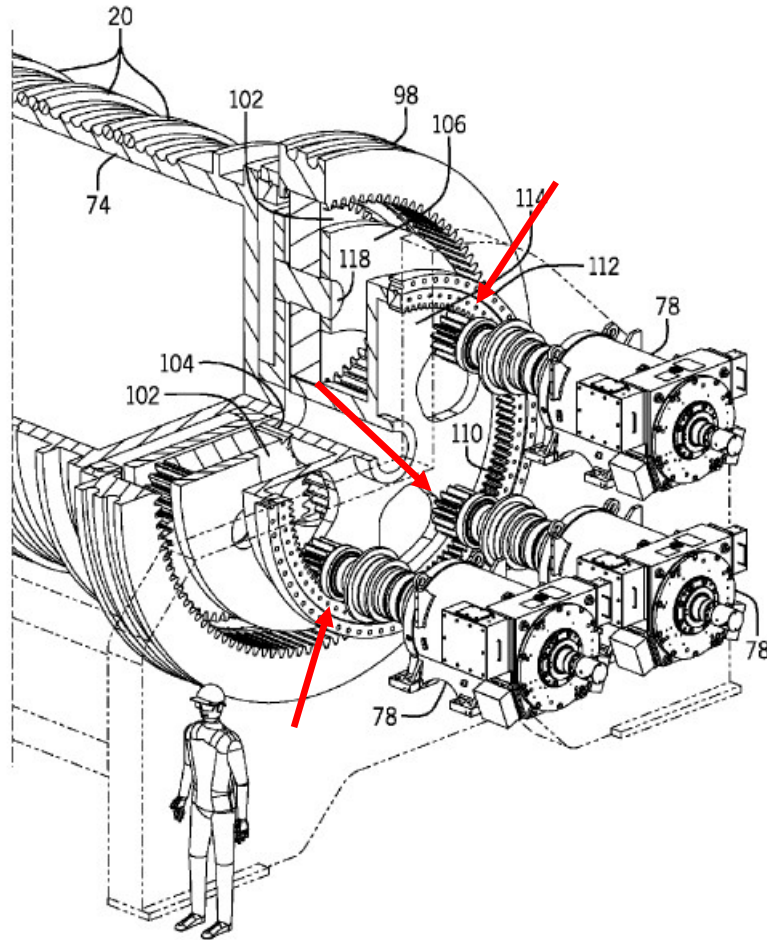
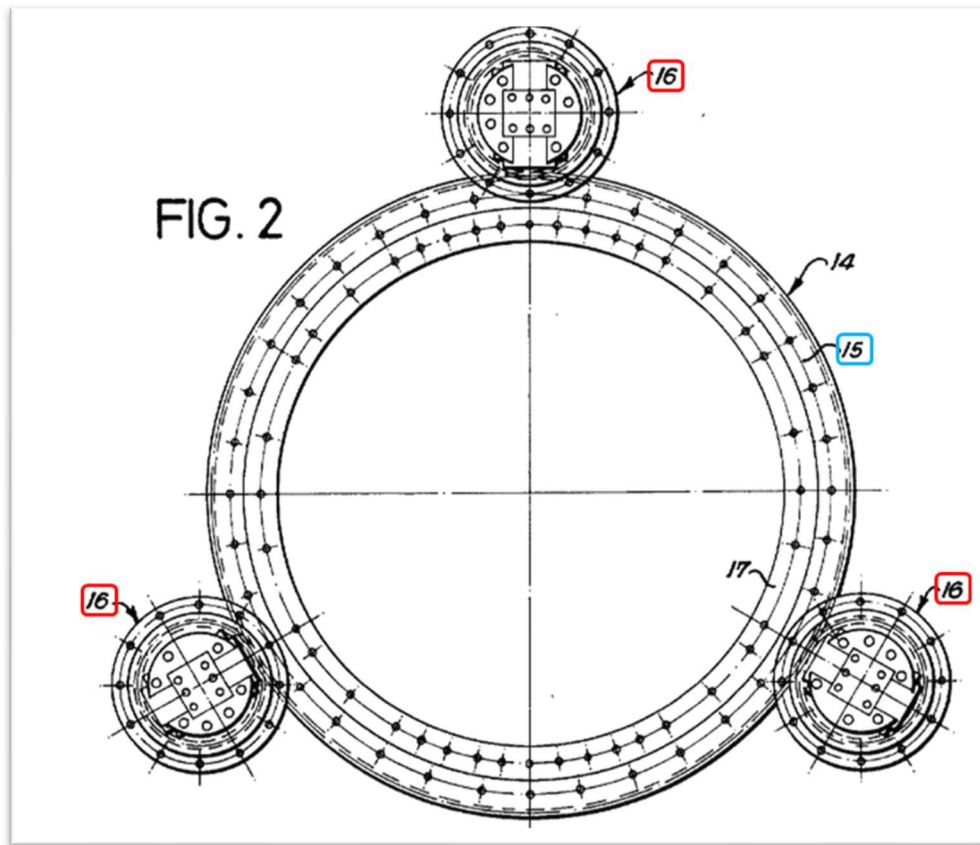


FIG. 5

Ex. 1006 (Bergan), Fig. 5 (annotated).

343. *Rosman* also discloses a gearing configuration wherein input pinion gears mesh with the external teeth of another gear to couple multiple motors to a load, as depicted in Figure 2 below:

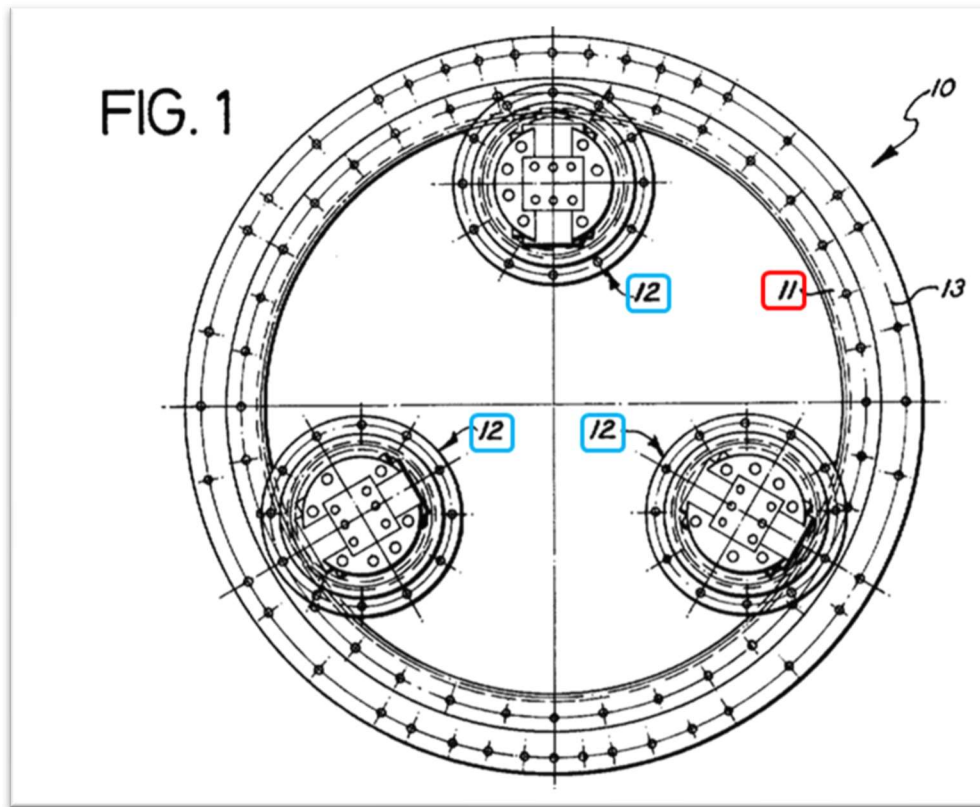


Ex. 1007 (Rosman), Fig. 2 (annotated)

344. *Rosman* explains that “outer annular member 15 [annotated in red] carr[ies] first engagement means,” which are “gear teeth disposed along the entire outer circumferential surface of ring member 15” that couple with gear teeth of pinion gears coupled to motors 16 [annotated in blue].²⁹⁶ *Rosman* also teaches an embodiment in which outer annular member 15 has gear teeth disposed around the “inner circumferential surface” like Bergan, as shown in Fig. 1.²⁹⁷

²⁹⁶ Ex. 1007 (Rosman), 4:18-34

²⁹⁷ Ex. 1007 (*Rosman*), 4:4-6, 6:65 – 67.



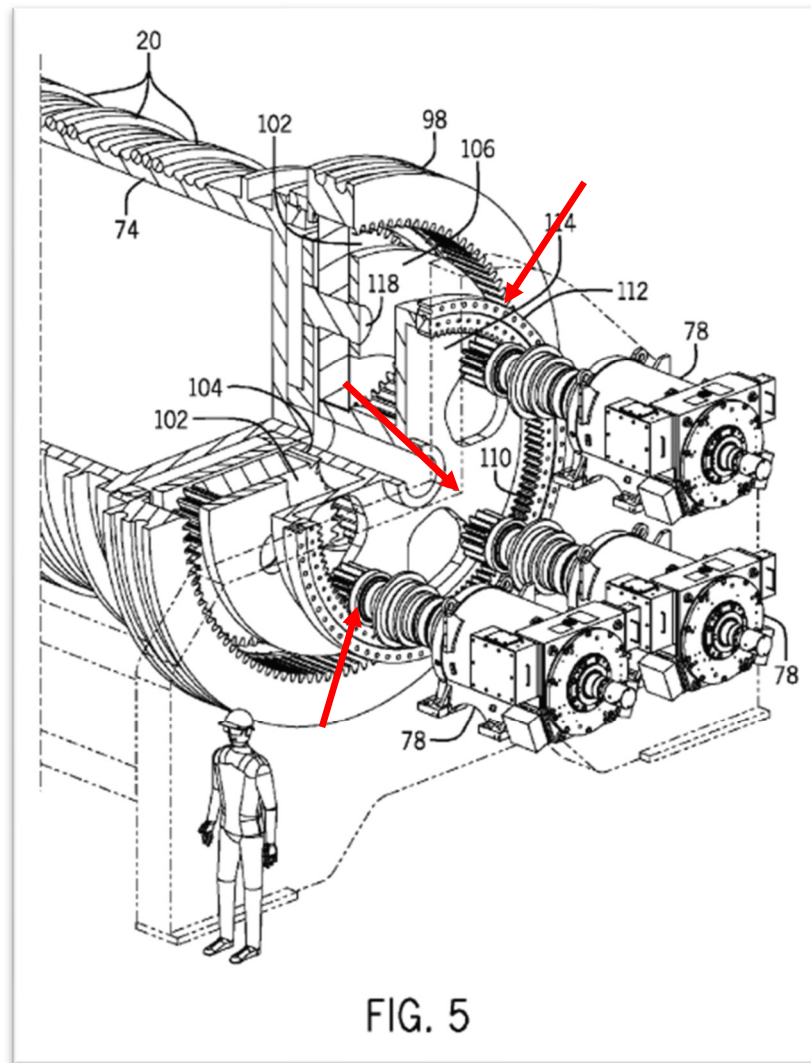
Ex. 1007 (*Rosman*), Fig. 1 (annotated)

345. By disclosing both arrangements, *Rosman* teaches that the use of both inner and outer gear teeth on the main gear are reasonably equivalent and depend simply on the choices of the designer. A POSITA would have motivated to combine *Rosman*'s ring member 15 with *Bergan*'s planetary gearing configuration such that *Bergan*'s input pinions are coupled to *Rosman*'s ring member 15 using either inner or outer gear teeth. Such a modification would involve a simple substitution of one known element (*Rosman*'s ring member 15) for another (*Bergan*'s gear 110) to obtain the predictable result of coupling *Bergan*'s input pinions to *Bergan*'s planetary gear system. Accordingly, a POSITA would have been motivated to

combine *Bergan* and *Rosman* and would have had a reasonable expectation of success in doing so.

**B. CLAIM 8: “8. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1,
WHEREIN THE PLANETARY GEAR TRAIN COMPRISES A MAIN GEAR THAT
CONTACTS EACH OF THE PLURALITY OF INPUT PINION GEARS, WHEREIN
THE MAIN GEAR COMPRISES EXTERNAL GEAR TEETH THAT MATE WITH
EXTERNAL GEAR TEETH OF THE PLURALITY OF INPUT PINION GEARS.”**

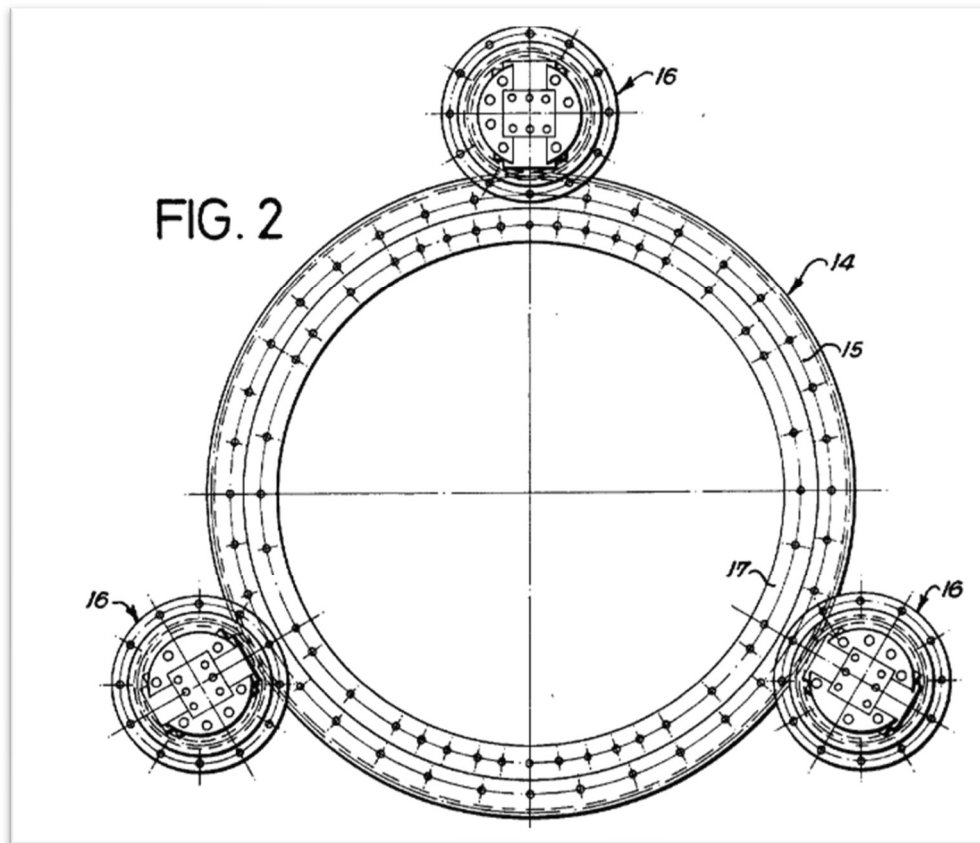
346. As discussed above with reference to Limitation 1[d] in Ground 1A, *Bergan* discloses a planetary gear system wherein input pinion gears (annotated with red arrows below) mesh with gear 110, as depicted in Figure 5:



Ex. 1006 (Bergan), Fig. 5 (annotated).

347. As depicted, however, gear 110 comprises internal gear teeth that mesh with the external gear teeth of the pinion gears.

348. *Rosman* discloses a gearing configuration wherein input pinion gears mesh with the external teeth of another gear to couple multiple motors to a load, as depicted in Figure 2 below:



Ex. 1007 (Rosman), Fig. 2.

349. *Rosman* explains that “outer annular member 15 [annotated in red] carr[ies] first engagement means,” which are “gear teeth disposed along the entire outer circumferential surface of ring member 15.”²⁹⁸ *Rosman* further discloses a “second engagement means constitute a pinion having gear teeth and disposed on each drive motor 16 [annotated in blue].”²⁹⁹ *Rosman* further describes that the first

²⁹⁸ Ex. 1007 (Rosman), 4:18-34.

²⁹⁹ Ex. 1007 (*Rosman*), 4:30 – 31.

and second sets of teeth engage with each other and “rotation of rotatably mounted ring member 15 is effected upon activation of the drive motors 16.”³⁰⁰

350. As discussed above, combining this gearing configuration with *Bergan*’s planetary gearing system would involve a simple substitution of *Rosman*’s ring member 15 for *Bergan*’s gear 110, such that *Bergan*’s input pinion gears couple with the external teeth of ring member 15 and otherwise drive *Bergan*’s planetary gearing system as taught by *Bergan*.³⁰¹

351. Accordingly, the *Bergan-Rosman* combination in view of *Buckley, August, Morris, and Joyner* renders Claim 8 obvious.

C. CLAIM 9

352. It is my opinion that the *Buckley-Bergan-August-Morris-Joyner-Rosman* combination renders Claim 9 obvious. As discussed below, *Bergan* and *Rosman* disclose each and every limitation of Claim 9, and thus Claim 9 would have been obvious to a POSITA based on the combined teachings of *Buckley, Bergan, August, Morris, Joyner* and *Rosman*.

³⁰⁰ Ex. 1007 (*Rosman*), 4:32 – 34.

³⁰¹ See Section XVII.A above.

1. 9[a]: “The hydraulic fracturing system of claim 8, wherein the planetary gear train comprises: a sun gear connected to the main gear by a shaft extending from the main gear; and”

353. *Bergan* discloses that its gear 110 is coupled to a sun wheel 114 having the sun gear 104 such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110.³⁰² Figure 5 of *Bergan*, annotated below, shows the gear 110 (annotated in red) and sun gear 104 (annotated in green) via a shaft (not labeled, annotated in blue) extending from the sun wheel 114 (which is coupled to gear 110, annotated in magenta):

³⁰² Ex. 1006 (Rosman), [0032].

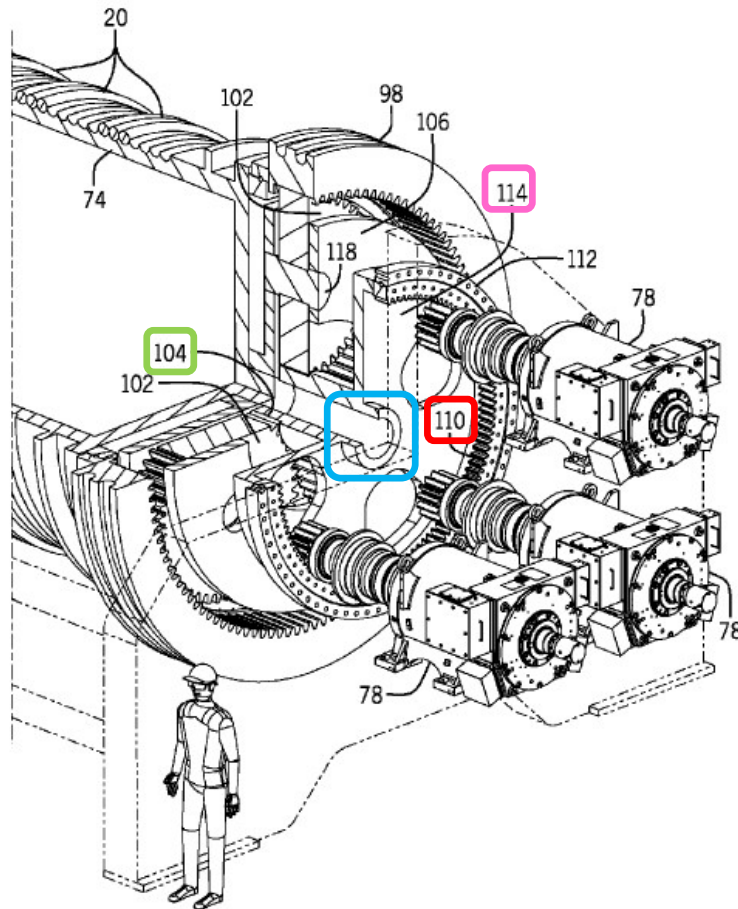
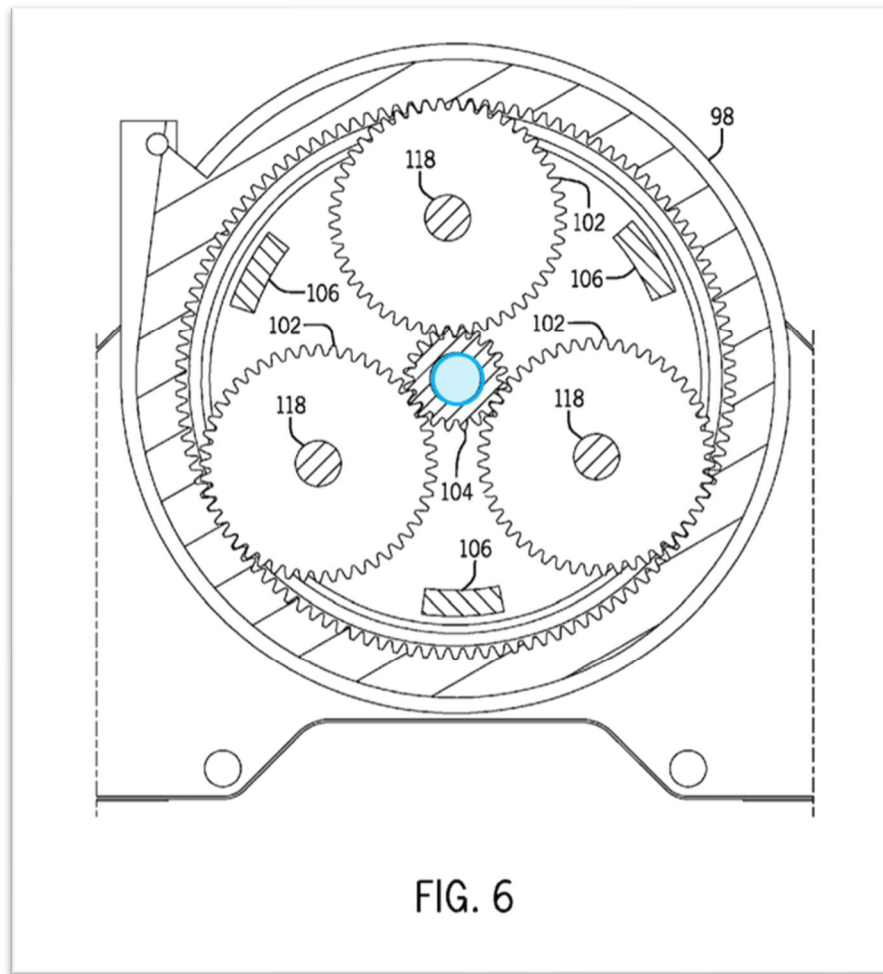


FIG. 5

EX1006, Fig. 5 (annotated).

354. Similarly, Figure 6 depicts the shaft connecting these components (annotated in blue):

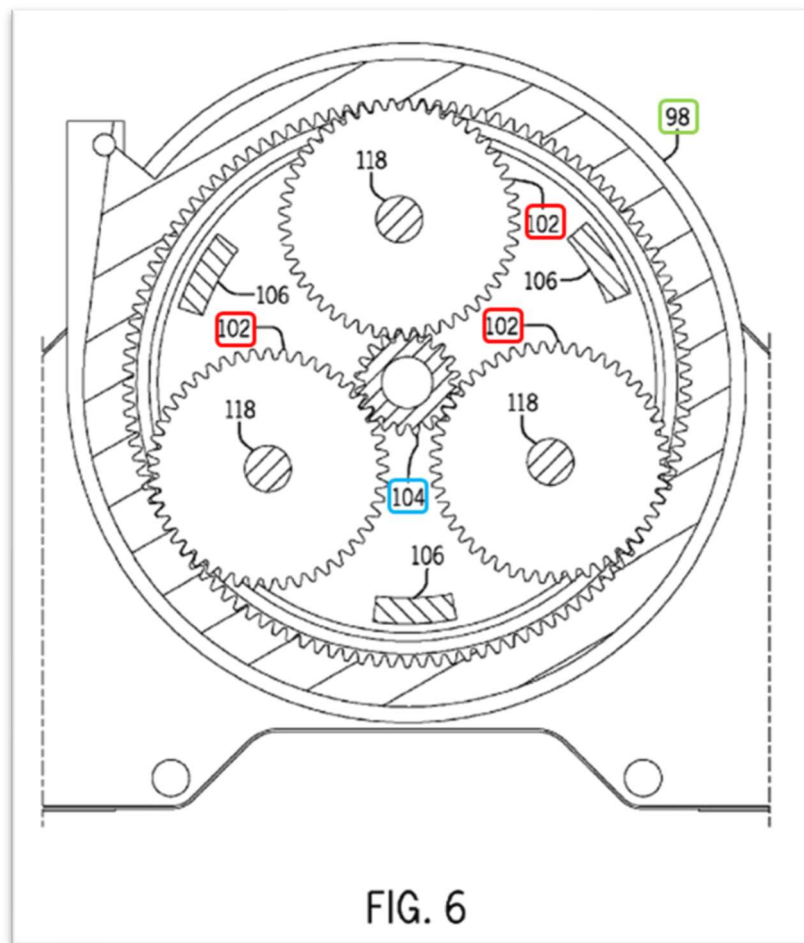


EX1006, Fig. 6 (annotated)

355. When *Bergan*'s gear 110 is substituted with *Rosman*'s ring member 15, as discussed above with reference to Claim 8, a POSITA would have understood that ring member 15 (the "main gear") would have been connected to sun gear 104 via the shaft to sun wheel 114 with which ring member 15 is coupled. Accordingly, Limitation 9[a] is rendered obvious by the *Bergan-Rosman* combination in view of *Buckley, August, Morris, and Joyner*.

2. 9[b]: “a plurality of planetary gears that each contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.”

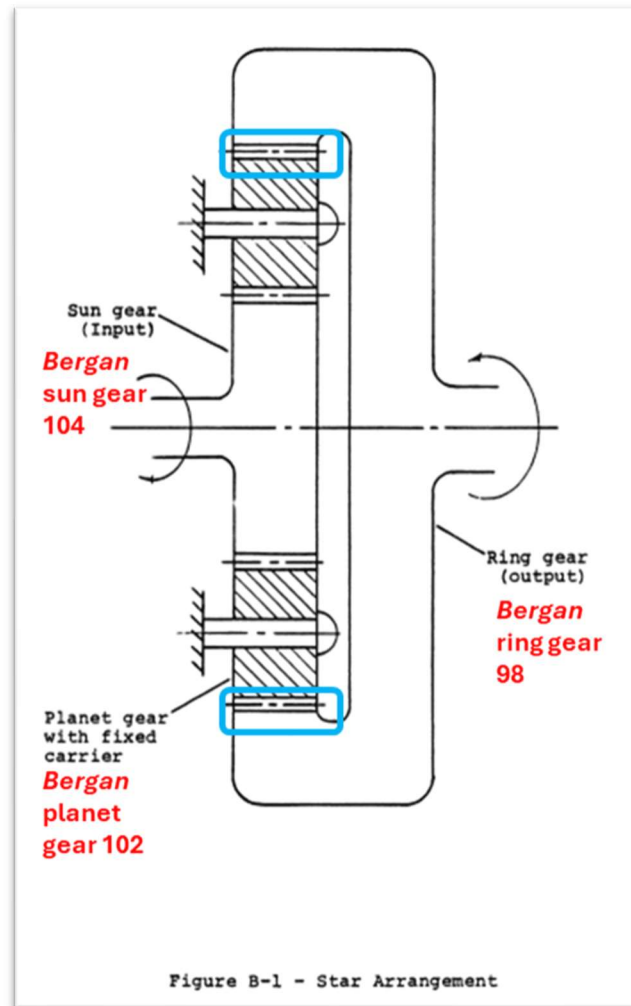
356. *Bergan* discloses a plurality of planetary gears 102 (annotated in red) that comprise external gear teeth that mate with the external gear teeth of sun gear 104 (annotated in blue), and also mate with the internal gear teeth of the ring gear 98 (annotated in green), as shown by Figure 6 of *Bergan*:



EX1006, Fig. 6

357. Further, as discussed above with reference to Limitation 1[e], adding *August* to the combination teaches that *Bergan*'s planetary gears 102 are held fixed and *Bergan*'s ring gear 98 is allowed to rotate and become the "final drive gear" and produces the output rotation for driving *Buckley*'s fracturing pump crankshaft.³⁰³ Figure B-1 of *August*, annotated in blue below, shows the points where the internal teeth of *August*'s ring gear ("final drive gear", analogous to *Bergan*'s ring gear 98) would mesh with the external teeth of *Bergan*'s planetary gears 102:

³⁰³ See Section XI.B.6 above.



EX1014, 149 (annotated).

358. Accordingly, Limitation 9[b] is rendered obvious by the *Buckley-Bergan-August* combination in view of *Morris, Joyner, and Rosman*.

D. DEPENDENT CLAIM 17: “17. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN TRANSLATING POWER THROUGH THE PLANETARY GEAR TRAIN COMPRISES TRANSLATING POWER THROUGH A MAIN GEAR THAT CONTACTS EACH OF THE PLURALITY OF INPUT PINION GEARS, WHEREIN THE MAIN GEAR COMPRISES EXTERNAL GEAR TEETH THAT MATE WITH EXTERNAL GEAR TEETH OF THE PLURALITY OF INPUT PINION GEARS.”

359. Except for being rewritten as a method claim, Claim 17 is essentially similar to Claim 8 and is rendered obvious by the combination of *Bergan-Rosman* combination in view of *Buckley, August, Morris, and Joyner* for the same reasons as those discussed above in Section XVII.B.

E. DEPENDENT CLAIM 18

360. It is my opinion that the *Buckley-Bergan-August-Morris-Joyner-Rosman* combination renders Claim 18 obvious. As discussed in the subsections below, *Buckley, Bergan, August, Morris, Joyner* and *Rosman* disclose each and every limitation of Claim 18, and thus Claim 18 would have been obvious to a POSITA based on the combined teachings of *Buckley, Bergan, August, Morris, Joyner* and *Rosman*.

1. 18[a]: “The hydraulic fracturing method of claim 17, wherein translating power through the planetary gear train comprises translating power through: a sun gear connected to the main gear by a shaft extending from the main gear; and”

361. Except for being rewritten as a method claim, Limitation 18[a] is essentially similar to Limitation 9[] and is rendered obvious by the *Bergan-Rosman*

combination in view of *Buckley, August, Morris, and Joyner* for the same reasons as those discussed above in Section XVII.C.1.

2. **18[b]: “a plurality of planetary gears that contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.”**

362. Except for being rewritten as a method claim, Limitation 18[b] is essentially similar to Limitation 9[b] and is rendered obvious by the combination of *Buckley-Bergan-August* combination in view of *Morris, Joyner, and Rosman* for the same reasons as those discussed above in Section XVII.C.2.

F. CLAIM 22

363. It is my opinion that the *Buckley-Bergan-August-Morris-Joyner-Rosman* combination renders Claim 22 obvious. As discussed in the subsections below, *Buckley, Bergan, August, Morris, Joyner* and *Rosman* disclose each and every limitation of Claim 22, and thus Claim 22 would have been obvious to a POSITA based on the combined teachings of *Buckley, Bergan, August, Morris, Joyner* and *Rosman*.

1. 22[p]: A hydraulic fracturing system for fracturing a subterranean formation, the hydraulic fracturing system comprising:

364. Limitation 22[p] is essentially similar to Limitation 1[p] and is disclosed by *Buckley* for the same reasons as those discussed above in Section XI.B.1.

2. 22[a]: a plurality of electric motors;

365. Limitation 22[a] is essentially similar to Limitation 1[b] and is disclosed by *Buckley* for the same reasons as those discussed above in Section XI.B.3.

3. 22[b]: a planetary gear train connected to the plurality of electric motors, the planetary gear train comprising:

366. Limitation 22[b] is essentially similar to Limitation 1[c] and is rendered obvious by the combination of *Buckley*, *Bergan*, and *August* for the same reasons as those discussed above in Section XI.B.4.

4. 22[c]: a plurality of input pinion gears, each driven by a respective one of the plurality of electric motors;

367. Limitation 22[c] is essentially similar to Limitation 1[d] and is rendered obvious by the combination of *Buckley* and *Bergan* for the same reasons as those discussed above in Section XI.B.5.

5. **22[d]: a main gear driven by the plurality of input pinion gears, the main gear comprising external gear teeth that mate with external gear teeth of the plurality of input pinion gears;**

368. Limitation 22[d] is essentially similar to Claim 8 and is rendered obvious by the combination of *Bergan* and *Rosman* for the same reasons as those discussed above in Section XVII.B.

6. **22[e]: a sun gear driven by the main gear and connected to the main gear by a shaft;**

369. Limitation 22[e] is essentially similar to Limitation 9[a] and is rendered obvious by the combination of *Bergan* and *Rosman* for the same reasons as those discussed above in Section XVII.C.1.

7. **22[f]: planetary gears driven by the sun gear, the planetary gears each comprising external gear teeth that mate with external gear teeth of the sun gear; and**

370. Limitation 22[f] is essentially similar to Limitation 9[b] and is rendered obvious by the combination of *Buckley*, *Bergan*, and *August* for the same reasons as those discussed above in Section XVII.C.2.

8. **22[g]: a final drive gear driven by the planetary gears, the final drive gear comprising internal gear teeth that mate with the external gear teeth of the planetary gears; and**

371. Limitation 22[g] is essentially similar to Limitations 1[e] and 9[b] and is rendered obvious by the combination of *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Sections XI.B.6 and XVII.C.2.

9. 22[h]: a multi-plunger hydraulic fracturing pump that pumps fluid to a wellbore and comprises a pump crankshaft that is driven by the final drive gear of the planetary gear train, the final drive gear connected to the pump crankshaft by a plurality of arms extending from the final drive gear.

372. Limitation 22[h] is essentially similar to Limitations 1[a] and 1[e] and is rendered obvious by the combination of *Buckley, Bergan, August, Morris*, and *Joyner* or the same reasons as those discussed above in Sections XI.B.2 and XI.B.6.

XVIII. GROUND 4B: OBVIOUS OVER YI IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, AND ROSMAN

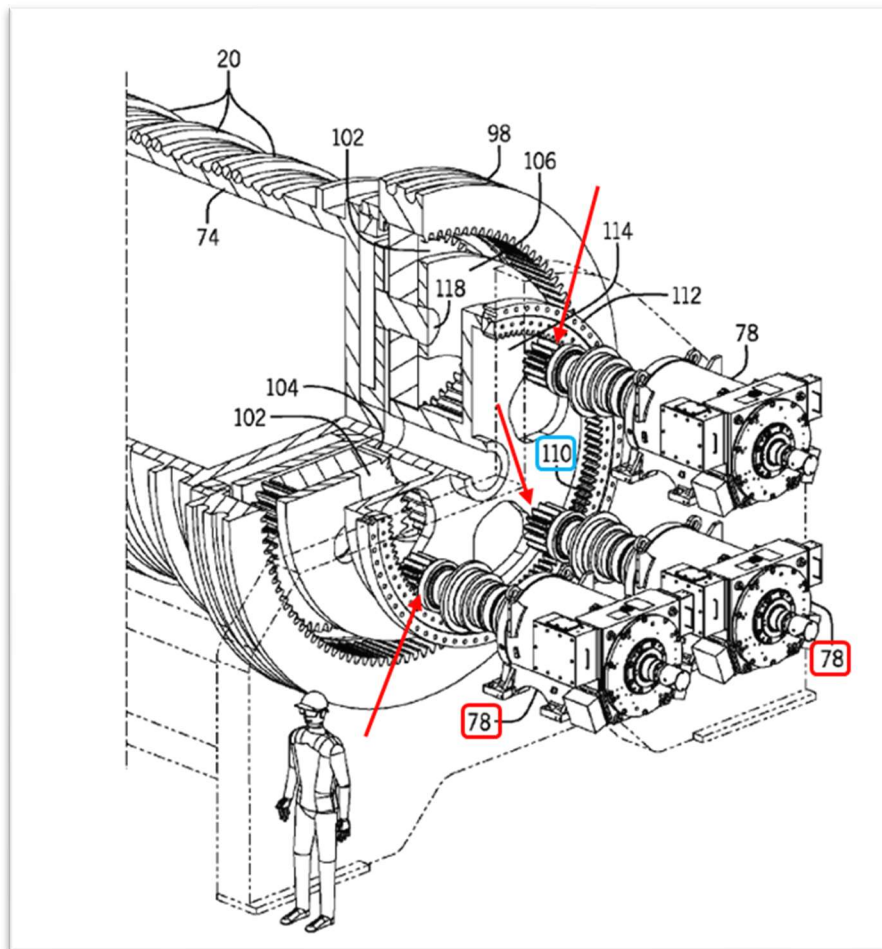
373. It is my opinion that *Yi* in view of *Bergan, August, Morris, Joyner*, and *Rosman* discloses, suggests, and renders obvious Claims 8, 9, 17, and 18 of the '533 Patent.

A. MOTIVATION TO COMBINE

374. The motivation to combine *Yi, Bergan, August, Morris*, and *Joyner* is the same as that discussed above in Sections XII.A and incorporated herein by reference. The motivation to combine *Bergan* and *Rosman* is the same as that discussed above in Section XVII.A and incorporated herein by reference. For these same reasons, a POSITA would have been motivated to further combine *Yi* and *Bergan* with *Rosman* and would have reasonably expected success in doing so (because combining *Rosman*'s ring member 15 to the *Yi-Bergan* combination's planetary gearing configuration is a simple substitution of elements to known methods to yield predictable results).

B. DEPENDENT CLAIM 8: “8. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 1, WHEREIN THE PLANETARY GEAR TRAIN COMPRISES A MAIN GEAR THAT CONTACTS EACH OF THE PLURALITY OF INPUT PINION GEARS, WHEREIN THE MAIN GEAR COMPRISES EXTERNAL GEAR TEETH THAT MATE WITH EXTERNAL GEAR TEETH OF THE PLURALITY OF INPUT PINION GEARS.”

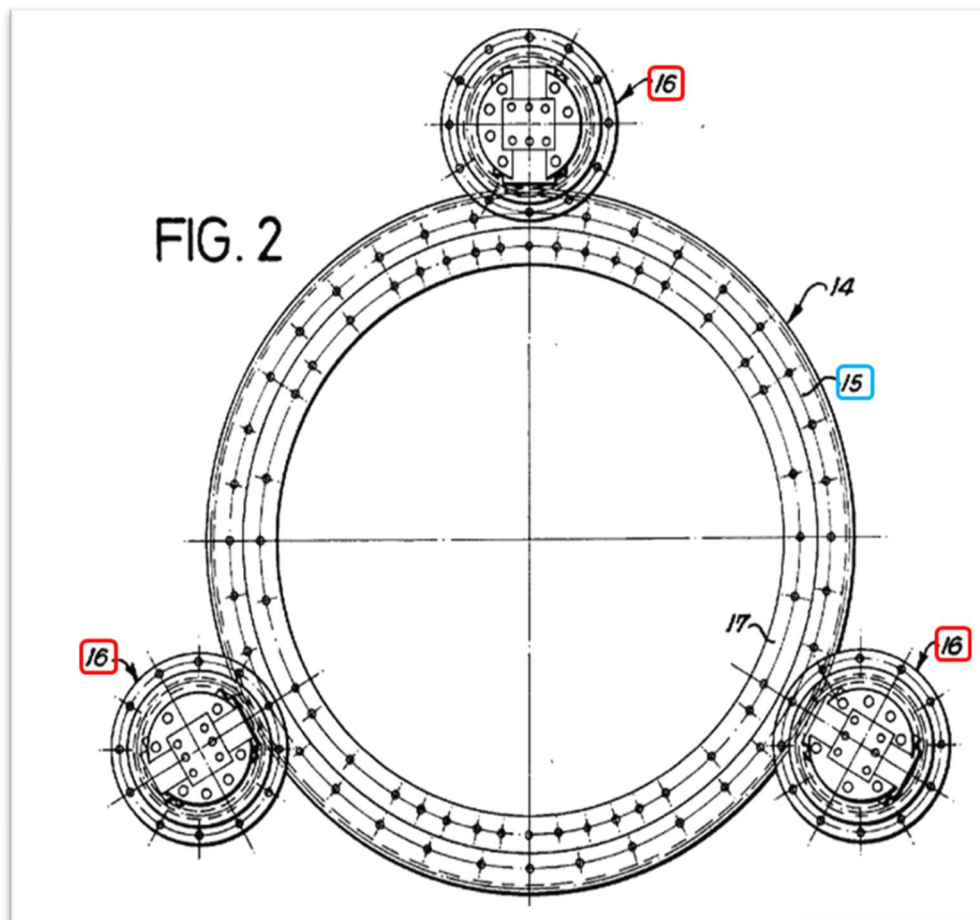
375. As discussed above with reference to Limitation 1[d] in Ground 1B, *Bergan* discloses a planetary gear system wherein input pinion gears (annotated with red arrows below) mesh with gear 110 [annotated in blue], as depicted in Figure 5:



Ex. 1006 (Bergan), Fig. 5 (annotated)

376. As depicted, however, gear 110 comprises internal gear teeth that mesh with the external gear teeth of the pinion gears.

377. *Rosman* discloses a gearing configuration wherein input pinion gears mesh with external teeth of another gear to couple multiple motors to a load, as depicted in Figure 2 below:



Ex. 1007 (Rosman), Fig. 2.

378. *Rosman* explains that “outer annular member 15 [annotated in red] carr[ies] first engagement means,” which are “gear teeth disposed along the entire

outer circumferential surface of ring member 15.”³⁰⁴ *Rosman* further discloses a “second engagement means constitute a pinion having gear teeth and disposed on each drive motor 16.”³⁰⁵ *Rosman* further describes that the first and second sets of teeth engage with each other and “rotation of rotatably mounted ring member 15 is effected upon activation of the drive motors 16.”³⁰⁶

379. As discussed above, combining this gearing configuration with *Bergan*’s planetary gearing system would involve a simple substitution of *Rosman*’s ring member 15 for *Bergan*’s gear 110, such that *Bergan*’s input pinion gears couple with the external teeth of ring member 15 and otherwise drive *Bergan*’s planetary gearing system as taught by *Bergan*.³⁰⁷

380. Accordingly, the *Bergan-Rosman* combination in view of *Yi*, *August*, *Morris*, and *Joyner* renders Claim 8 obvious.

C. CLAIM 9

381. It is my opinion that the *Yi-Bergan-August-Morris-Joyner-Rosman* combination renders Claim 9 obvious. As discussed below, *Bergan* and *Rosman* disclose each and every limitation of Claim 9, and thus Claim 9 would have been

³⁰⁴ Ex. 1007 (*Rosman*), 4:18-34.

³⁰⁵ Ex. 1007 (*Rosman*), 4:30 – 31.

³⁰⁶ Ex. 1007 (*Rosman*), 4:32 – 34.

³⁰⁷ See Section XVII.A above.

obvious to a POSITA based on the combined teachings of *Yi*, *Bergan*, *August*, *Morris*, *Joyner* and *Rosman*.

1. 9[a]: “The hydraulic fracturing system of claim 8, wherein the planetary gear train comprises: a sun gear connected to the main gear by a shaft extending from the main gear; and”

382. *Bergan* discloses that its gear 110 is coupled to a sun wheel 114 having the sun gear 104 such that the motors 78 rotate the sun gear 104 via the wheel 114 and the gear 110.³⁰⁸ Figure 5 of *Bergan*, annotated below, shows the gear 110 (annotated in red) and sun gear 104 (annotated in green) via a shaft (not labeled, annotated in blue) extending from the sun wheel 114 (which is coupled to gear 110, annotated in magenta):

³⁰⁸ Ex. 1006 (Rosman), [0032].

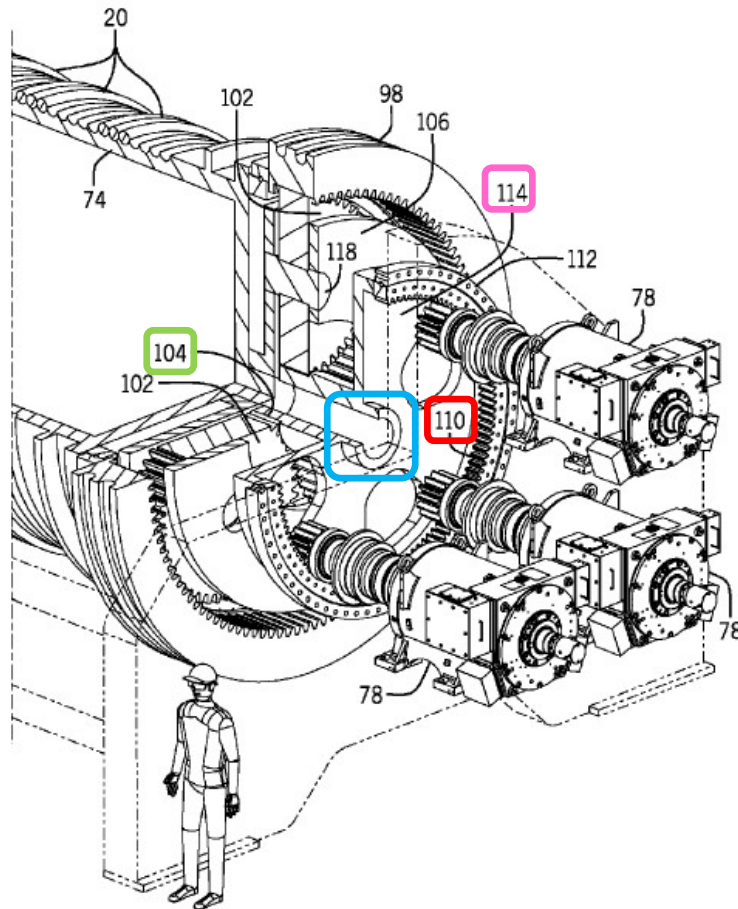
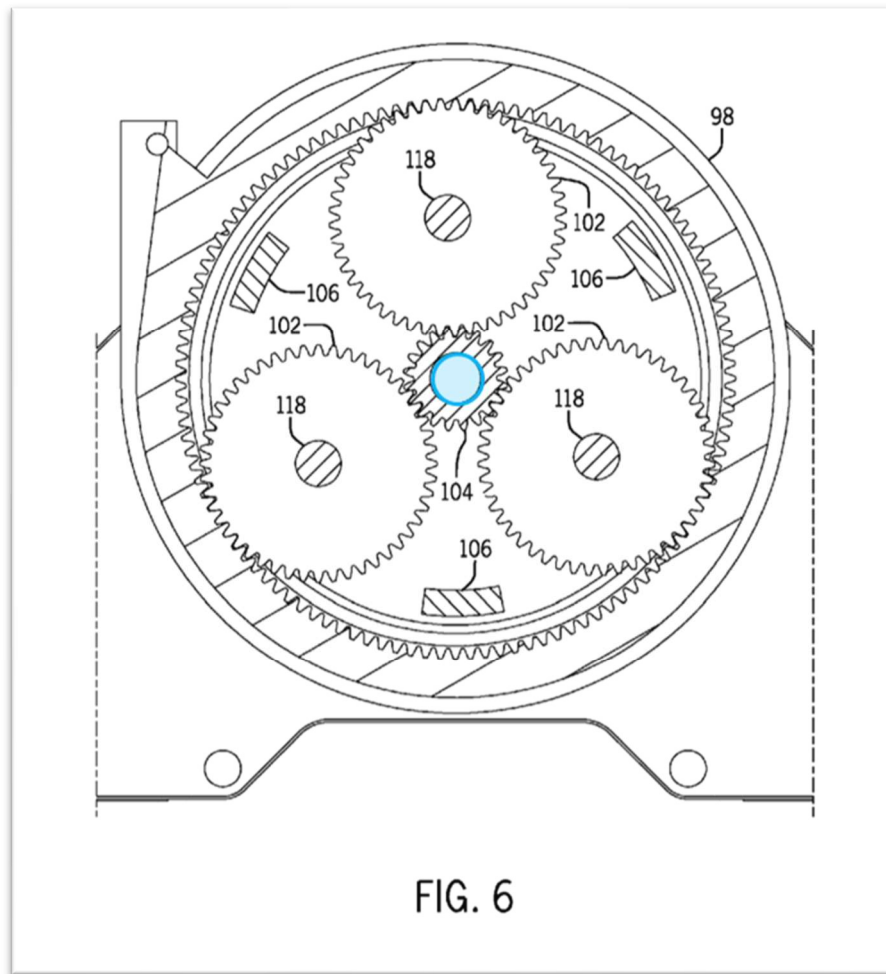


FIG. 5

EX1006, Fig. 5 (annotated).

383. Similarly, Figure 6 depicts the shaft connecting these components (annotated in blue):

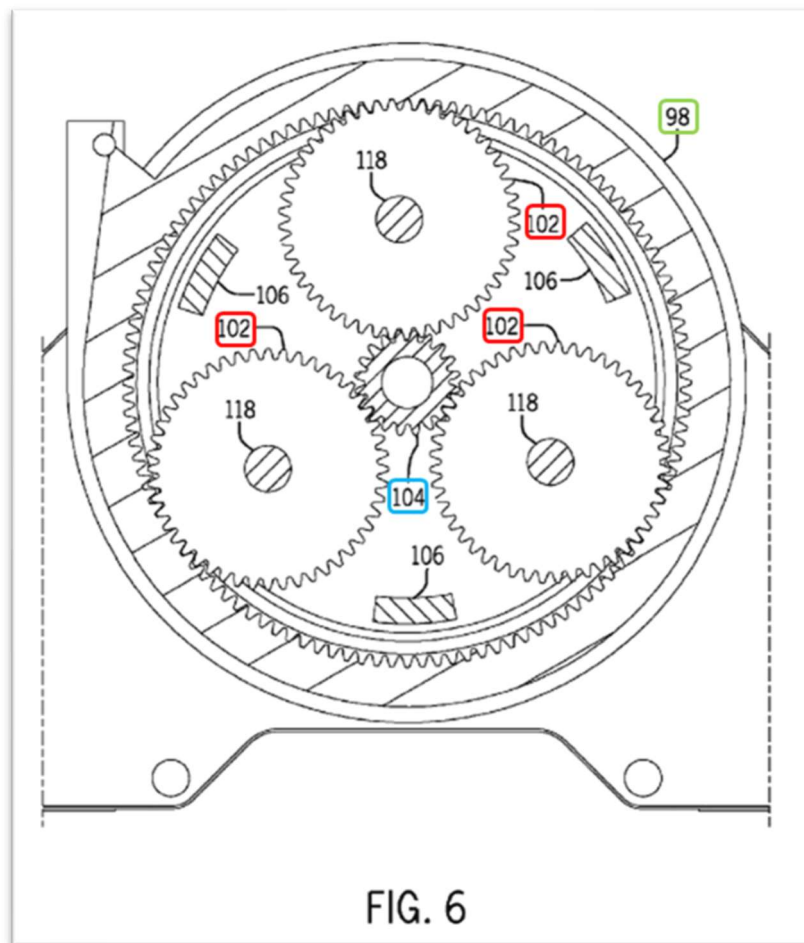


EX1006, Fig. 6 (annotated)

384. When *Bergan*'s gear 110 is substituted with *Rosman*'s ring member 15, as discussed above with reference to Claim 8, a POSITA would have understood that ring member 15 (the "main gear") would have been connected to sun gear 104 via the shaft to sun wheel 114 with which ring member 15 is coupled. Accordingly, Limitation 9[a] is rendered obvious by the *Bergan-Rosman* combination in view of *Yi, August, Morris, and Joyner*.

2. 9[b]: “a plurality of planetary gears that each contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.”

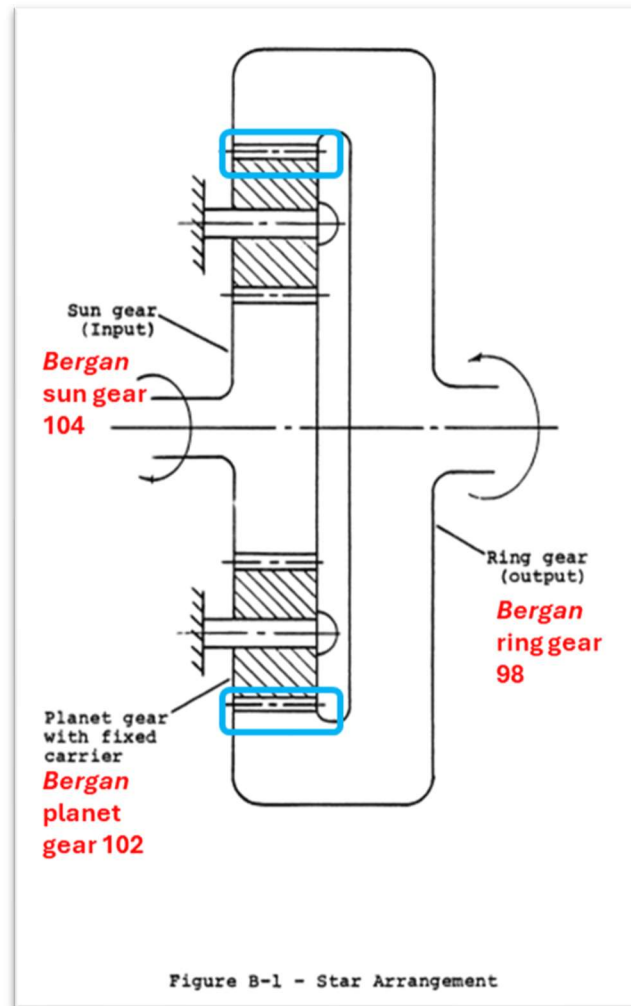
385. *Bergan* discloses a plurality of planetary gears 102 (annotated in red) that comprise external gear teeth that mate with external gear teeth of sun gear 104 (annotated in blue), and also mate with the internal gear teeth of the ring gear 98 (annotated in green), as shown by Figure 6 of *Bergan*:



EX1006, Fig. 6

386. Further, as discussed above with reference to Limitation 1[e], adding *August* to the combination teaches that *Bergan*'s planetary gears 102 are held fixed and *Bergan*'s ring gear 98 is allowed to rotate and become the "final drive gear" and produces the output rotation for driving *Buckley*'s fracturing pump crankshaft.³⁰⁹ Figure B-1 of *August*, annotated in blue below, shows the points where the internal teeth of *August*'s ring gear ("final drive gear", analogous to *Bergan*'s ring gear 98) mesh with the external teeth of *Bergan*'s planetary gears 102:

³⁰⁹ See Section XI.B.6 above.



EX1014, 149 (annotated).

387. Accordingly, Limitation 9[b] is rendered obvious by the *Yi-Bergan-August* combination in view of *Morris, Joyner, and Rosman*.

D. DEPENDENT CLAIM 17: “17. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, WHEREIN TRANSLATING POWER THROUGH THE PLANETARY GEAR TRAIN COMPRISES TRANSLATING POWER THROUGH A MAIN GEAR THAT CONTACTS EACH OF THE PLURALITY OF INPUT PINION GEARS, WHEREIN THE MAIN GEAR COMPRISES EXTERNAL GEAR TEETH THAT MATE WITH EXTERNAL GEAR TEETH OF THE PLURALITY OF INPUT PINION GEARS.”

388. Except for being rewritten as a method claim, Claim 17 is essentially similar to Claim 8 and is rendered obvious by the *Bergan-Rosman* combination in view of *Yi, August, Morris*, and *Joyner* for the same reasons as those discussed above in Section XVIII.B.

E. DEPENDENT CLAIM 18

389. It is my opinion that the *Yi-Bergan-August-Morris-Joyner-Rosman* combination renders Claim 18 obvious. As discussed in the subsections below, *Bergan* and *Rosman* disclose each and every limitation of Claim 18, and thus Claim 18 would have been obvious to a POSITA based on the combined teachings of *Yi, Bergan, August, Morris, Joyner* and *Rosman*.

1. 18[a]: “The hydraulic fracturing method of claim 17, wherein translating power through the planetary gear train comprises translating power through: a sun gear connected to the main gear by a shaft extending from the main gear; and”

390. Except for being rewritten as a method claim, Limitation 18[a] is essentially similar to Limitation 9[a] and is rendered obvious by *Bergan-Rosman* combination in view of *Yi, August, Morris*, and *Joyner* for the same reasons as those discussed above in Section XVIII.C.1.

2. 18[b]: “a plurality of planetary gears that contact the sun gear and the final drive gear, wherein each of the plurality of planetary gears comprises external gear teeth that mate with external gear teeth of the sun gear and with internal gear teeth of the final drive gear.”

391. Except for being rewritten as a method claim, Limitation 18[b] is essentially similar to Limitation 9[b] and is rendered obvious by the *Yi-Bergan-August* combination in view of *Morris*, *Joyner*, and *Rosman* for the same reasons as those discussed above in Section XVIII.C.2.

XIX. GROUND 5A: OBVIOUS OVER BUCKLEY IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, AND IN FURTHER VIEW OF THE KNOWLEDGE OF A POSITA AND, IN THE ALTERNATIVE, JELASKA

392. It is my opinion that *Buckley* in view of *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 19 of the '533 Patent in view of the knowledge of a POSITA and, in the alternative, *Jelaska*.

A. MOTIVATION TO COMBINE

393. The motivation to combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that discussed above in Sections XI.A and incorporated herein by reference. A POSITA would have been motivated to further combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* with *Jelaska*. Nothing in *Jelaska* teaches against the combination of *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner*. As discussed above in Ground 1A, the *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* combination teaches a multi-plunger pump powered by multiple electric motors via a planetary

gearing configuration. A POSITA would have searched for other references to better understand details of gearing configurations that are not described in *Buckley*, *Bergan*, and/or *August*. One such reference is *Jelaska*, which is a well-known publication that provides granular details about gearing configurations that would have been invaluable to a POSITA looking to apply the teachings of *Bergan* and *August* to a practical system. In particular, *Jelaska*'s description of transmission ratio and its effect on the speed of a driven component would aid a POSITA's design of a gearing configuration when implementing the *Bergan-August* combination's planetary gearing configuration to result in a particular pump speed.³¹⁰

394. Further, combining *Jelaska*'s teachings regarding transmission ratio to the *Buckley-Bergan-August* combination's pumping configuration is merely combining prior art elements (designing a transmission system to produce a desired output speed and the planetary gearset of the *Bergan-August* combination) to known methods (the *Bergan-August* combination's modified planetary gearset) to yield predictable results (producing a desired pump speed as the output of the planetary gearset). Accordingly, a POSITA would have been motivated to combine *Jelaska*'s teachings of fundamental gearing system operations with the *Buckley-Bergan-August* combination's pumping configuration and would have reasonably expected success in doing so.

³¹⁰ See Ex. 1012 (*Jelaska*), 3.

B. DEPENDENT CLAIM 19: “19. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, COMPRISING LIMITING A MAXIMUM PUMP SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP, WHEREIN THE MAXIMUM PUMP SPEED IS LIMITED BY A SELECTION OF A GEAR RATIO OF THE PLANETARY GEAR TRAIN AND A SPEED AT WHICH THE PLURALITY OF MOTORS OPERATE.”

395. As discussed above in Section IX.D, it was well known long before the ’533 Patent that the speed of the drive (i.e. motors) and the gear ratio of the gear train dictate the speed of the driven mechanism (i.e. pump) according to the equation

$$i = \frac{n_1}{n_2} = \frac{\omega_1}{\omega_2},$$

Where i is the gear ratio, n_1 is the driving shaft speed, n_2 is the driven shaft speed, ω_1 is the angular speed of the driving shaft, and ω_2 is the angular speed of the driven shaft.³¹¹ This was known to the ancient Greeks and is a well-understood fundamental of gear train operation and would have been included in the general knowledge of a POSITA. Indeed, the fact that the gear ratio and the driving speed dictate the speed of the driven shaft (i.e. pump) would have been known to anyone who has ridden a multi-speed bicycle with gears or anyone who has operated a manual transmission. To “limit a maximum pump speed associated with the multi-plunger pump” a POSITA would simply choose the maximum speed of the pump desired and coordinate the speed of *Buckley*’s motors with the gear ratio of the *Bergan-August* combination’s modified planetary gear train (which operates as the transmission that

³¹¹ Ex. 1012 (Jelaska), pg. 3.

links *Buckley*'s motors with its drive pump) so that the maximum speed of *Buckley*'s pump is not exceeded. The output speed of a gear train is predictable based on the input *Buckley*, *Bergan*, and *August*, in view of the general knowledge of a POSITA, *Morris*, and *Joyner* renders this limitation obvious. In the alternative, this limitation is rendered obvious by the *Buckley-Bergan-August* combination in view of *Jelaska*, *Morris*, and *Joyner* for the same reasons just discussed.

**XX. GROUND 5B: OBVIOUS OVER YI IN VIEW OF BERGAN
FURTHER IN VIEW OF AUGUST, MORRIS, JOYNER, PAYNE
AND THE KNOWLEDGE OF A POSITA AND, IN THE
ALTERNATIVE, JELASKA**

396. It is my opinion that *Yi* in view of *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 19 of the '533 Patent in view of the knowledge of a POSITA and, in the alternative, *Jelaska*.

A. MOTIVATION TO COMBINE

397. The motivation to combine *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* is the same as that discussed above in Sections XII.A and incorporated herein by reference. A POSITA would have been motivated to further combine *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* with *Jelaska*. As discussed above, the *Yi-Bergan-August-Morris-Joyner* combination teaches a multi-plunger pump powered by multiple motors via a planetary gearing configuration. A POSITA would have searched for other references to better understand details of gearing configurations that are not described in *Yi* and/or *Bergan*. One such reference is *Jelaska*, which is

a well-known publication that provides granular details about gearing configurations that would have been invaluable to a POSITA looking to apply the teachings of *Bergan* to a practical system. In particular, *Jelaska*'s description of transmission ratio and its effect on the speed of a driven component would aid a POSITA's design of a gearing configuration when implementing *Bergan*'s planetary gearing configuration to result in a particular pump speed.³¹²

398. Further, combining *Jelaska*'s teachings regarding transmission ratio to the *Yi-Bergan-August-Morris-Joyner* combination's pumping configuration is merely combining prior art elements (designing a transmission system to produce a desired output speed and the planetary gearset of *Bergan*) to known methods (*Bergan*'s planetary gearset) to yield predictable results (producing a desired pump speed as the output of the planetary gearset). Accordingly, a POSITA would have been motivated to combine *Jelaska*'s teachings of fundamental gearing system operations with the *Yi-Bergan-August-Morris-Joyner* combination's pumping configuration and would have reasonably expected success in doing so.

³¹² See Ex. 1012 (*Jelaska*), 3.

B. DEPENDENT CLAIM 19: “19. THE HYDRAULIC FRACTURING METHOD OF CLAIM 10, COMPRISING LIMITING A MAXIMUM PUMP SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP, WHEREIN THE MAXIMUM PUMP SPEED IS LIMITED BY A SELECTION OF A GEAR RATIO OF THE PLANETARY GEAR TRAIN AND A SPEED AT WHICH THE PLURALITY OF MOTORS OPERATE.”

399. As discussed above in Section IX.D, it was well known long before the ’533 Patent that the speed of the drive (i.e. motors) and the gear ratio of the gear train dictate the speed of the driven mechanism (i.e. pump) according to the equation

$$i = \frac{n_1}{n_2} = \frac{\omega_1}{\omega_2},$$

Where i is the gear ratio, n_1 is the driving shaft speed, n_2 is the driven shaft speed, ω_1 is the angular speed of the driving shaft, and ω_2 is the angular speed of the driven shaft.³¹³ This was known to the ancient Greeks and is a well-understood fundamental of gear train operation and would have been included in the general knowledge of a POSITA. Indeed, the fact that the gear ratio and the driving speed dictate the speed of the driven shaft (i.e. pump) would have been known to anyone who has ridden a multi-speed bicycle with gears or anyone who has operated a manual transmission. To “limit a maximum pump speed associated with the multi-plunger pump” a POSITA would simply choose the maximum speed of the pump desired and coordinate the speed of *Yi*’s motors with the gear ratio of *Bergan*’s planetary gear train (which operates as the transmission that links *Yi*’s motors with its drive pump)

³¹³ Ex. 1012 (Jelaska), pg. 3.

so that the maximum speed of *Yi*'s pump is not exceeded. The output speed of a gear train is predictable based on the input speed of the motor and the gear ratio of the drive train. Accordingly, the *Yi-Bergan-August* combination in view of the knowledge of a POSITA, *Morris*, and *Joyner* renders this limitation obvious. In the alternative, this limitation is rendered obvious by the *Yi-Bergan-August* combination in view of *Jelaksa*, *Morris*, and *Joyner* for the same reasons just discussed as *Jelaska* teaches basic gearing mechanism.

XXI. GROUND 6A: OBVIOUS OVER BUCKLEY, BERGAN, AUGUST, MORRIS, AND JOYNER IN VIEW OF THE KNOWLEDGE OF A POSITA AND, IN THE ALTERNATIVE, JELASKA AND TUTTEROW

400. It is my opinion that *Buckley* in view of *Bergan*, *August*, *Morris*, and *Joyner* discloses, suggests, and renders obvious Claim 19 of the '533 Patent in view of the knowledge of a POSITA and, in the alternative, *Jelaska* and *Tutterow*.

A. MOTIVATION TO COMBINE

401. The motivation to combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* and *Jelaska* is the same as that discussed above in Sections XI.A and XIX.A and incorporated herein by reference. Nothing in *Tutterow* teaches against the combination of *Buckley*, *Bergan*, *August*, *Morris*, *Joyner*, and *Jelaska*. A POSITA would have been motivated to combine the teachings of *Tutterow* with those of *Buckley*, *Bergan*, *August*, *Morris*, *Joyner* and *Jelaska* as *Tutterow* is intended as "a

comprehensive guide on variable speed pumps, motors and drives.”³¹⁴ *Tutterow* is a well-known publication that contains “sections on pumps, systems, motors, variable speed drives and control methods, which start with the basic principles, but progress to more advanced and detailed concepts.”³¹⁵ Further, *Tutterow* “concentrates on electronic variable frequency drives because they have the greatest benefits, including wide ranging applications, versatile control, energy saving and ease of retrofitting.”³¹⁶

402. As discussed above regarding Ground 1, Claim 1, *Buckley* teaches the use of a plurality of motors to provide power to the multi-plunger hydraulic fracturing pump. *Buckley* further teaches that the “system of the present application may permit the motors 11 to run at various speeds or power outputs.”³¹⁷ A POSITA would have understood this to be analogous to the teachings of *Tutterow* regarding “variable speed pumps, motors and drives” used in pumping. Additionally, *Tutterow* contains basic descriptions of the operation of pumps, including plunger pumps, that would have been invaluable to a POSITA looking to apply the teachings of *Buckley* to a practical system. Accordingly, the operation of the pumps of *Buckley* would

³¹⁴ Ex. 1013 (*Tutterow*) pg 1.

³¹⁵ Ex. 1013 (*Tutterow*) pg 2.

³¹⁶ Ex. 1013 (*Tutterow*) pg. 3.

³¹⁷ Ex. 1004 (*Buckley*) [0058]; *see also* Ex. 1005 (*Buckley* Provisional) pg 6 “It is understood that the system of the present application may permit the motors to be run at various speeds or power outputs.”

have already had the characteristics described by *Tutterow*, such as the risk of cavitation. *Tutterow* simply describes how the pumps operate, how cavitation occurs, and how and why to avoid it. A POSITA would have been motivated to avoid the “negative effects” of cavitation, as taught by *Tutterow*, to avoid the long-term damage or inefficiencies of pumping that cavitation creates.

403. A POSITA would have had a reasonable expectation of success in applying the teachings of *Tutterow* regarding avoiding cavitation of plunger pumps by controlling speed as such teachings were basic to the operation of positive displacement pumps, including plunger pumps. Such a combination is merely combining prior art elements (limiting pump operation speed to avoid cavitation and the pump of *Buckley, Bergan, August, Morris, Joyner and Jelaska* to known methods (the pump of *Buckley, Bergan, August, Morris, Joyner and Jelaska*) to yield predictable results (avoiding the negative effects of cavitation on the pumping system).

B. DEPENDENT CLAIM 20: “20. THE HYDRAULIC FRACTURING METHOD OF CLAIM 19, WHEREIN THE MAXIMUM PUMP SPEED CORRELATES WITH A CRITICAL PLUNGER SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

404. The combination of *Buckley, Bergan, August, Morris, Joyner*, along with the general knowledge of a POSITA, renders Claim 20 obvious. The specification of the '533 Patent refers to the critical speed as a speed that avoids cavitation. For example, the '533 Patent teaches that “by operating transmissions

such that pumps are maintained at or below critical pump speeds, such formation of vacuum bubbles and resulting pump cavitation and damage may be avoided.”³¹⁸ Accordingly, I understand “a critical plunger speed of the multi-plunger hydraulic fracturing pump,” as claimed, to be the maximum speed a pump can run without cavitation, given a particular system configuration. No other definition of “critical plunger speed” is provided in the specification.

405. As described above in Section IX.C, it was known to avoid cavitation in pumping systems, for example, to avoid negative effects of cavitation such as erosion.³¹⁹ The ’533 Patent admits that this was known.³²⁰ As further discussed in Section IX.C, it was also well known that it is an inherent property of positive displacement pumps (e.g. plunger pumps) that, for a given pump system, operation above a certain speed (i.e. critical plunger speed) creates cavitation and that the maximum speed of such pumps is therefore commonly limited to avoid cavitation.³²¹

³¹⁸ Ex. 1001 2:22-25.

³¹⁹ See, e.g., Ex. 1013 (*Tutterow*), 20.

³²⁰ See, e.g., Ex. 1001 2:10-20.

³²¹ See, e.g., Ex. 1013 (*Tutterow*), 30 (“The cavities [cylinders] on a positive displacement pump open and close as the pump operates and the liquid must flow quickly enough at the pump suction to fill the cavities completely with liquid. If the cavities do not fill with liquid, there will be a void, and apparent cavitation, resulting in a loss of both flow and pressure performance. ***If the speed is increased, this filling process becomes more problematical, limiting the maximum speed.***”) (emphasis added)).

406. Accordingly, operating a pump speed below the speed required to create cavitation, which a POSITA would have understood to be a “critical speed” of the pump, would have been obvious based on the general knowledge of a POSITA. Accordingly, *Buckley* in view of the knowledge of a POSITA, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 20 obvious. In the alternative, *Buckley* in view of *Jelaska*, *Tutterow*, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 20 obvious for the same reasons just provided as the references provide information on the basics of gearing mechanisms and plunger pumps respectively.

C. DEPENDENT CLAIM 21: “21. THE HYDRAULIC FRACTURING METHOD OF CLAIM 19, WHEREIN THE MAXIMUM PUMP SPEED IS 5% OVER A CRITICAL PLUNGER SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

407. The combination of *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner*, along with the general knowledge of a POSITA, or in the alternative *Jelaska* and *Tutterow* render Claim 21 obvious. Claim 5 simply claims operating the pump speed at a speed higher than the speed at which cavitation begins. The specification of the ’533 Patent itself teaches that operating the pump at speeds that allow for cavitation was not only known, but “commonly” performed. For example, the ’533 Patent discloses “A heightened speed of operation creates low pressure within the pumps, creating vacuum bubbles. As the pump plungers retract, the vacuum bubbles implode, causing damage (cavitation) to the pump and engine systems. Although the risks of operating the pumps at too great of speeds may be known, concerns about

lowered pump rates and lost efficiency resulting from maintaining slower transmission speeds *commonly lead to disregard of the risks as an unavoidable consequence of maintaining pump efficiency.*”³²²

408. The ’533 Patent claims no new benefit from operating the motor above the cavitation speed other than “to achieve a desired pump rate”, as even the specification of the ’533 Patent admits was “commonly” practiced before the ’533 Patent. Indeed, the ’533 Patent specification does not exclusively teach the 5% limit but instead teaches that “any other acceptable range [of speed above the cavitation speed].”³²³ Accordingly, even the specification of the ’533 Patent teaches that there is no inventive concept involved in operating at 5% above the cavitation speed.

409. Further, operating a pump above the speed at which cavitation begins is a type of risk-reward engineering decision that is made every day in industrial processes, including pumping. As described in Section IX.C, cavitation in a pumping system leads to problems such as erosion of the pump's internal components, noise and vibration, and loss of pumping pressure (head). While these are undesirable impacts of cavitation and should be avoided, a POSITA would also understand that small amounts of cavitation would affect the life and efficiency of the pump but

³²² Ex. 1001 2:10-20 emphasis added; see also Ex. 1001, 1:43-55, 1:62-2:4.

³²³ See Ex. 1001 6:10-21.

would not immediately stop the pumping process.³²⁴ Accordingly, there is a risk to operating with the pump cavitating (loss of life and pumping pressure), but also a reward (increased flow rate). The decision to operate in a region where cavitation occurs, particularly relatively low amounts of cavitation, is a tradeoff between the risks and the rewards. Operating to gain the benefits of higher flowrate while accepting a small reduction in the life of components or pumping pressure was well known, as the '533 Patent itself discloses, “Although the risks of operating the pumps at too great of speeds may be known, concerns about lowered pump rates and lost efficiency resulting from maintaining slower transmission speeds commonly lead to disregard of the risks as an unavoidable consequence of maintaining pump efficiency.”³²⁵

410. Accordingly, *Buckley* in view of the knowledge of a POSITA, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 21 obvious. In the alternative, *Buckley* in view *Jelaska*, *Tutterow*, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 21 obvious, as the references provide information on the basics of gearing mechanisms and plunger pumps respectively.

³²⁴ Ex. 1013 (*Tutterow*), pg. 20 (explaining that “total loss of pump-developed head occurs” only in “extreme cases” of cavitation).

³²⁵ Ex. 1001 2:15-20.

XXII. GROUND 6B: OBVIOUS OVER *YI* IN VIEW OF BERGAN, AUGUST, MORRIS, AND JOYNER IN VIEW OF THE KNOWLEDGE OF A POSITA AND, IN THE ALTERNATIVE, JELASKA AND TUTTEROW

411. It is my opinion that *Yi* in view of *Bergan*, *Rosman August*, *Morris*, and *Joyner*, discloses, suggests, and renders obvious Claim 14 of the '533 Patent in view of the knowledge of a POSITA and, in the alternative, *Jelaska* and *Tutterow*.

A. MOTIVATION TO COMBINE

412. The motivation to combine *Yi*, *Bergan*, *August*, *Morris*, *Joyner*, and *Jelaska* is the same as that discussed above in Sections XII.A and XX.A and incorporated herein by reference. Nothing in *Tutterow* teaches against the combination of *Yi*, *Bergan*, *August*, *Morris*, *Joyner*, and *Jelaska*. A POSITA would have been motivated to combine the teachings of *Tutterow* with those of *Yi*, *Bergan*, *August*, *Morris*, *Joyner*, and *Jelaska* as *Tutterow* is intended as “a comprehensive guide on variable speed pumps, motors and drives.”³²⁶ *Tutterow* is a well-known publication that contains “sections pumps, systems, motors, variable speed drives and control methods, which start with the basic principles, but progress to more advanced and detailed concepts.”³²⁷ Further, *Tutterow* “concentrates on electronic

³²⁶ Ex. 1013 (*Tutterow*) pg 1.

³²⁷ Ex. 1013 (*Tutterow*) pg 2.

variable frequency drives because they have the greatest benefits, including wide ranging applications, versatile control, energy saving and ease of retrofitting.”³²⁸

413. *Yi* teaches the use of a plurality of motors to provide power to the multi-plunger hydraulic fracturing pump. *Yi* further teaches “control over the speed and output power of the fracturing pump.”³²⁹ A POSITA would have understood this to be analogous to the teachings of *Tutterow* regarding “variable speed pumps, motors and drives” used in pumping. Additionally, *Tutterow* contains basic descriptions of the operation of pumps, including plunger pumps, that would have been invaluable to a POSITA looking to apply the teachings of *Yi* to a practical system. Accordingly, the operation of the pumps of *Yi* would have already had the characteristics described by *Tutterow*, such as the risk of cavitation. *Tutterow* simply describes how the pumps operate, how cavitation occurs, and how and why to avoid it. A POSITA would have been motivated to avoid the “negative effects” of cavitation, as taught by *Tutterow*, to avoid the long-term damage or inefficiencies of pumping that cavitation creates.

414. A POSITA would have had a reasonable expectation of success in applying the teachings of *Tutterow* regarding avoiding cavitation of plunger pumps by controlling speed as such teachings were basic to the operation of positive displacement pumps, including plunger pumps. Such a combination is merely

³²⁸ Ex. 1013 (*Tutterow*) pg. 3.

³²⁹ Ex. 1010 (*Yi* Translation), [0019].

combining prior art elements (limiting pump operation speed to avoid cavitation) to known methods (the pump of *Yi, Bergan, August, Morris, Joyner, and Jelaska*) to yield predictable results (avoiding the negative effects of cavitation on the pumping system).

B. DEPENDENT CLAIM 20: “20. THE HYDRAULIC FRACTURING METHOD OF CLAIM 19, WHEREIN THE MAXIMUM PUMP SPEED CORRELATES WITH A CRITICAL PLUNGER SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

415. The combination of *Yi, Bergan, August, Morris, and Joyner*, along with the general knowledge of a POSITA, and in the alternative *Tutterow* and *Jelaska*, renders Claim 20 obvious. The specification of the '533 Patent refers to the critical speed as a speed that avoids cavitation. For example, the '533 Patent teaches “by operating transmissions such that pumps are maintained at or below critical pump speeds, such formation of vacuum bubbles and resulting pump cavitation and damage may be avoided.”³³⁰ Accordingly, I understand “a critical plunger speed associated with the multi-plunger hydraulic fracturing pump”, as claimed, to be the maximum speed a pump can run without cavitation, given a particular system configurations. No other definition of “critical plunger speed” is provided in the specification.

³³⁰ Ex. 1001 2:22-25.

416. As described above in Section IX.C, it was known to avoid cavitation in pumping systems, for example, to avoid negative effects of cavitation such as erosion.³³¹ The '533 Patent admits that this was known.³³² As further discussed in Section IX.C, it was also well known that it is an inherent property of positive displacement pumps (e.g. plunger pumps) that, for a given pump system, operation above a certain speed (i.e. critical plunger speed) creates cavitation.³³³

417. Accordingly, operating a pump speed below the speed required to create cavitation, which a POSITA would have understood to be a “critical speed” of the pump, would have been obvious based on the general knowledge of a POSITA. Accordingly, *Yi* in view of the knowledge of a POSITA, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 20 obvious. In the alternative, *Yi* in view of *Jelaska*, *Tutterow*, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 20 obvious for the same reasons just provided, as the references provide information on the basics of gearing mechanisms and plunger pumps respectively.

³³¹ See, e.g., Ex. 1013 (*Tutterow*), 20.

³³² See, e.g., Ex. 1001 2:10-20.

³³³ See, e.g., Ex. 1013 (*Tutterow*), 30 (“The cavities [cylinders] on a positive displacement pump open and close as the pump operates and the liquid must flow quickly enough at the pump suction to fill the cavities completely with liquid. If the cavities do not fill with liquid, there will be a void, and apparent cavitation, resulting in a loss of both flow and pressure performance. ***If the speed is increased, this filling process becomes more problematical, limiting the maximum speed.***”) (emphasis added)).

C. DEPENDENT CLAIM 21: “21. THE HYDRAULIC FRACTURING METHOD OF CLAIM 19, WHEREIN THE MAXIMUM PUMP SPEED IS 5% OVER A CRITICAL PLUNGER SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

418. The combination of *Yi* and *Bergan*, along with the general knowledge of a POSITA, render Claim 5 obvious. Claim 5 simply claims operating the pump speed at a speed higher than the speed at which cavitation begins. The specification of the '533 Patent itself teaches that operating the pump at speeds that allow for cavitation was not only known, but “commonly” performed. For example, the '533 Patent discloses “A heightened speed of operation creates low pressure within the pumps, creating vacuum bubbles. As the pump plungers retract, the vacuum bubbles implode, causing damage (cavitation) to the pump and engine systems. Although the risks of operating the pumps at too great of speeds may be known, concerns about lowered pump rates and lost efficiency resulting from maintaining slower transmission speeds *commonly lead to disregard of the risks as an unavoidable consequence of maintaining pump efficiency.*”³³⁴

419. The '533 Patent claims no new benefit from operating the motor above the cavitation speed other than “to achieve a desired pump rate”, as even the specification of the '533 Patent admits was “commonly” practiced before the '533 Patent. Indeed, the '533 Patent specification does not exclusively teach the 5% limit

³³⁴ Ex. 1001 2:10-20 emphasis added; see also Ex. 1001, 1:43-55, 1:62-2:4.

but instead teaches that “any other acceptable range [of speed above the cavitation speed].”³³⁵ Accordingly, even the specification of the ’533 Patent teaches that there is no inventive concept involved in operating at 5% above the cavitation speed.

420. Further, operating a pump above the speed at which cavitation begins is a type of risk-reward engineering decision that is made every day in industrial processes, including pumping. As described in Section IX.C, cavitation in a pumping system leads to problems such as erosion of the pump's internal components, noise and vibration, and loss of pumping pressure (head). While these are undesirable impacts of cavitation and should be avoided, a POSITA would also understand that small amounts of cavitation would affect the life and efficiency of the pump but would not immediately stop the pumping process.³³⁶ Accordingly, there is a risk to operating with the pump cavitating (loss of life and pumping pressure), but also a reward (increased flow rate). The decision to operate in a region where cavitation occurs, particularly relatively low amounts of cavitation, is a tradeoff between the risks and the rewards. Operating to gain the benefits of higher flowrate while accepting a small reduction in the life of components or pumping pressure was well known, as the ’533 Patent itself discloses, “Although the risks of operating the pumps at too great of speeds may be known, concerns about lowered pump rates and

³³⁵ See Ex. 1001 6:10-21.

³³⁶ Ex. 1013 (*Tutterow*), pg. 20 (explaining that “total loss of pump-developed head occurs” only in “extreme cases” of cavitation).

lost efficiency resulting from maintaining slower transmission speeds commonly lead to disregard of the risks as an unavoidable consequence of maintaining pump efficiency.”³³⁷

421. Accordingly, *Yi* in view of the knowledge of a POSITA, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 21 obvious. In the alternative, *Yi* in view of *Jelaska*, *Tutterow*, *Bergan*, *August*, *Morris*, and *Joyner* renders Claim 21 obvious.

XXIII. GROUND 7A: OBVIOUS OVER BUCKLEY IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, ROSMAN, AND PAYNE

422. It is my opinion that *Buckley* in view of *Bergan*, *August*, *Morris*, *Joyner*, *Rosman*, and *Payne* discloses, suggests, and renders obvious Claim 23 of the ’533 Patent.

A. MOTIVATION TO COMBINE

423. The motivations to combine *Buckley*, *Bergan*, *August*, *Morris*, and *Joyner* are the same as those discussed above in Section XI.A and incorporated herein by reference. The motivations to add *Rosman* to the *Buckley-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XV.A. Further, the motivations to combine *Payne* with the *Buckley-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVII.A. Nothing in *Payne* or *Rosman* teaches against the combinations. Therefore, a

³³⁷ Ex. 1001 2:15-20.

POSITA would have been motivated to combine *Buckley, Bergan, August, Morris, Joyner, Rosman* and *Payne* for the same reasons as those discussed above in Sections XI.A, XV.A, and XVII.A, and incorporated herein by reference.

B. DEPENDENT CLAIM 23: “23. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 22, FURTHER COMPRISING A VARIABLE FREQUENCY DRIVE (VFD) ASSOCIATED WITH THE PLURALITY OF MOTORS AND CONFIGURED TO CONTROL A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

424. Except for depending from Claim 22, the limitations of Claim 23 are identical to Claim 7 and are rendered obvious by the combination of *Buckley* and *Payne* in view of *Bergan, August, Morris, Joyner*, and *Rosman* for the same reasons as those disclosed in Section XV.B above.

XXIV. GROUND 7B: OBVIOUS OVER YI IN VIEW OF BERGAN, AUGUST, MORRIS, JOYNER, ROSMAN, AND PAYNE

425. The motivations to combine *Yi, Bergan, August, Morris, and Joyner* are the same as those discussed above in Section XII.A and incorporated herein by reference. The motivations to add *Rosman* to the *Yi-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVI.A. Further, the motivations to combine *Payne* with the *Yi-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVIII.A. Nothing in *Payne* or *Rosman* teaches against the combinations. Therefore, a POSITA would have been motivated to combine *Yi, Bergan, August, Morris, Joyner, Rosman* and

Payne for the same reasons as those discussed above in Sections XII.A, XVI.A, and XVIII.A, and incorporated herein by reference.

A. INDEPENDENT CLAIM 22

1. 22[p]: A hydraulic fracturing system for fracturing a subterranean formation, the hydraulic fracturing system comprising:

426. Limitation 22[p] is essentially similar to Limitation 1[p] and is disclosed by *Yi* for the same reasons as those discussed above in Section XII.B.1.

2. 22[a]: a plurality of electric motors;

427. Limitation 22[a] is essentially similar to Claim 2 and is rendered obvious by is rendered obvious by *Yi* and, in the alternative, the *Yi-Bergan-Payne* combination in view of *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XVI.B.

3. 22[b]: a planetary gear train connected to the plurality of electric motors, the planetary gear train comprising:

428. Limitation 22[b] is essentially similar to Limitation 1[c] and Claim 2 and is rendered obvious *Yi* and, in the alternative, the *Yi-Bergan-Payne* combination in view of *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Sections XII.B.4 and XVI.B.

4. **22[c]: a plurality of input pinion gears, each driven by a respective one of the plurality of electric motors;**

429. Limitation 22[c] is essentially similar to Limitation 1[d] and Claim 2 and is rendered obvious by *Yi* and, in the alternative, the *Yi-Bergan-Payne* combination in view of *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Sections XII.B.5 and XVI.B.

5. **22[d]: a main gear driven by the plurality of input pinion gears, the main gear comprising external gear teeth that mate with external gear teeth of the plurality of input pinion gears;**

430. Limitation 22[d] is essentially similar to Claim 8 and is rendered obvious by the *Bergan-Rosman* combination in view of *Yi*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XVIII.B.

6. **22[e]: a sun gear driven by the main gear and connected to the main gear by a shaft;**

431. Limitation 22[e] is essentially similar to Limitation 9[a] and is rendered obvious by the *Bergan-Rosman* combination in view of *Yi*, *August*, *Morris*, and *Joyner* for the same reasons as those discussed above in Section XVIII.C.1.

7. **22[f]: planetary gears driven by the sun gear, the planetary gears each comprising external gear teeth that mate with external gear teeth of the sun gear; and**

432. Limitation 22[f] is essentially similar to Limitation 9[b] and is rendered obvious by the *Yi-Bergan-August* combination in view of *Morris*, *Joyner*, and *Rosman* for the same reasons as those discussed above in Section XVIII.C.2.

8. 22[g]: a final drive gear driven by the planetary gears, the final drive gear comprising internal gear teeth that mate with the external gear teeth of the planetary gears; and

433. Limitation 22[g] is essentially similar to Limitations 1[e] and 9[b] and is rendered obvious by the combination of *Yi, Bergan, August, Morris, and Joyner* in view of *Rosman* for the same reasons as those discussed above in Sections XII.B.6 and XVIII.C.2.

9. 22[h]: a multi-plunger hydraulic fracturing pump that pumps fluid to a wellbore and comprises a pump crankshaft that is driven by the final drive gear of the planetary gear train, the final drive gear connected to the pump crankshaft by a plurality of arms extending from the final drive gear.

434. Limitation 22[h] is essentially similar to Limitations 1[a] and 1[e] and is rendered obvious by the combination of *Yi, Bergan, August, Morris, and Joyner* for the same reasons as those discussed above in Sections XII.B.2 and XII.B.6

B. DEPENDENT CLAIM 23: “23. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 22, FURTHER COMPRISING A VARIABLE FREQUENCY DRIVE (VFD) ASSOCIATED WITH THE PLURALITY OF MOTORS AND CONFIGURED TO CONTROL A PUMP ROTATIONAL SPEED OF THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP.”

435. Except for depending from Claim 22, the limitations of Claim 23 are identical to Claim 7 and are rendered obvious by the *Yi-Bergan-Payne* combination in view of *August, Morris, and Joyner* for the same reasons as those disclosed in Section XVI.C above.

XXV. GROUND 8A: OBVIOUS OVER *BUCKLEY* IN VIEW OF BERGAN, AUGUST, JOYNER, MORRIS, ROSMAN, PAYNE, AND KARASSIK

436. It is my opinion that *Buckley* in view of *Bergan, August, Joyner, Morris, Rosman, Payne, and Karassik* discloses, suggests, and renders Claims 24 and 25 of the '533 Patent obvious.

A. MOTIVATION TO COMBINE

437. The motivations to combine *Buckley, Bergan, August, Morris, and Joyner* are the same as those discussed above in Section XI.A and incorporated herein by reference. The motivations to add *Rosman* to the *Buckley-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XV.A. Further, the motivations to combine *Payne* with the *Buckley-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVII.A. Nothing in *Payne* or *Rosman* teaches against the combinations. The motivations for adding *Karassik* to the *Buckley-Bergan-August-Morris-Joyner-Payne* combination are the same as those discussed above in Section XIII.A. Nothing in *Payne* or *Karassik* teaches against the combination. Therefore, a POSITA would have been motivated to combine *Buckley, Bergan, August, Morris, Joyner, Rosman, Payne* and *Karassik* for the same reasons as those discussed above in Sections XI.A, XIII.A, XV.A, and XVII.A, and incorporated herein by reference.

B. DEPENDENT CLAIM 24: “24. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 23, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP COMPRISES SEVEN PLUNGERS.”

438. Except for depending from Claim 23 and being rewritten as a method claim, Claim 24 is essentially similar to Claim 5 and is rendered obvious by the combination of *Buckley* and *Karassik* for the same reasons as those discussed above in Section XIII.B.

C. DEPENDENT CLAIM 25: “25. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 23, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP COMPRISES NINE PLUNGERS.”

439. Except for depending from Claim 23 and being rewritten as a method claim, Claim 25 is essentially similar to Claim 6 and is rendered obvious by the combination of *Buckley* and *Karassik* for the same reasons as those discussed above in Section XIII.C.

XXVI. GROUND 8B: OBVIOUS OVER YI IN VIEW OF BERGAN AND FURTHER IN VIEW OF THE KNOWLEDGE OF A POSITA AND, IN THE ALTERNATIVE, JELASKA, TUTTEROW, AND NESBITT

440. It is my opinion that *Yi* in view of *Bergan*, *August*, *Joyner*, *Morris*, *Rosman*, *Payne*, and *Karassik* discloses, suggests, and renders obvious Claims 24 and 25 of the '533 Patent.

A. MOTIVATION TO COMBINE

441. The motivations to combine *Yi*, *Bergan*, *August*, *Morris*, and *Joyner* are the same as those discussed above in Section XII.A and incorporated herein by

reference. The motivations to add *Rosman* to the *Yi-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVI.A. Further, the motivations to combine *Payne* with the *Yi-Bergan-August-Morris-Joyner* combination are the same as those discussed above in Section XVIII.A. Nothing in *Payne* or *Rosman* teaches against the combinations. The motivations to add *Karassik* to the *Buckley-Bergan-August-Morris-Joyner-Payne* combination are the same as those discussed above in Section XIV.A. Nothing in *Payne* or *Karassik* teaches against the combination. Therefore, a POSITA would have been motivated to combine *Buckley, Bergan, August, Morris, Joyner, Rosman, Payne* and *Karassik* for the same reasons as those discussed above in Sections XII.A, XIV.A, XVI.A, and XVIII.A, and incorporated herein by reference.

B. DEPENDENT CLAIM 24: “24. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 23, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP COMPRISES SEVEN PLUNGERS.”

442. Except for depending from Claim 23 and being rewritten as a method claim, Claim 24 is essentially similar to Claim 5 and is rendered obvious by the combination of *Yi* and *Karassik* for the same reasons as those discussed above in Section XIV.B.

C. DEPENDENT CLAIM 25: “25. THE HYDRAULIC FRACTURING SYSTEM OF CLAIM 23, WHEREIN THE MULTI-PLUNGER HYDRAULIC FRACTURING PUMP COMPRISES NINE PLUNGERS.”

443. Except for depending from Claim 23 and being rewritten as a method claim, Claim 25 is essentially similar to Claim 6 and is rendered obvious by the combination of *Yi* and *Karassik* for the same reasons as those discussed above in Section XIV.C.

XXVII. SECONDARY CONSIDERATIONS

444. I am not aware of any evidence of secondary considerations that would support a finding of nonobviousness of the '533 Patent. Should the Patent Owner put forth any alleged evidence of secondary considerations, I reserve the right to consider such evidence, to consider whether any such evidence has a nexus to any claims of the '533 Patent, and to update my analysis.

XXVIII. CONCLUSION

445. All statements made herein of my own knowledge are true, and all statements made on information and belief are believed to be true. I further understand that willful false statements and the like are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code. I declare under penalty of perjury that the foregoing is true and correct.

Executed on November 1, 2024.



Dr. Robert A. Durham

Appendix A

Dr. ROBERT A DURHAM, PhD, FIEEE

Resume
Specialization
Honors & Awards
Publications

Dr ROBERT A DURHAM, PhD, FIEEE

Robert A Durham is the Principal of D² Tech Solutions, a technology related firm concentrating on Mechanical and Electrical systems and energy conversions. He also serves as a Principal Scientist of THEWAY LABs, Tulsa, OK, an engineering and energy consulting firm that provides design and failure analysis of facilities and system installations.

Dr. Durham's work experience is broad and encompasses all areas of the energy industry. Dr. Durham spent 11 years with AEP/CSW, at the time the country's largest utility, in electrical engineering positions in the power generation and transmission planning departments. He then accepted a position as Manager of Electric Infrastructure for New Dominion, LLC., a major independent energy producer in Oklahoma. Dr. Durham then moved on to hold the position of Vice President of Engineering and Project Management for EDG Power Group, an Engineering Procurement and Construction company specializing in design and construction of small to medium size power generating facilities. Dr. Durham left EDG Power Group to accept his current positions. Dr. Durham has been accepted as an expert and offered testimony in several jurisdictions.

Dr. Durham's extensive client list includes the development of a broad spectrum of forensic, electrical and facilities projects for many companies. He has also taught University offered courses in electrical engineering review for board licensure. He has published five books, six magazine articles and over 40 other technical papers and articles. Dr. Durham's extensive work on standards and electrical systems has resulted in his elevation to Fellow of the IEEE, the highest grade of recognition in the electrical technology industry.

Dr. Durham received the B.S. in electrical engineering from the University of Tulsa in 1992 and the M.E. in Technology Management from The University of Tulsa in 1997. Tulsa, OK. In 2004, Dr. Durham received a PhD in Engineering Management from Kennedy Western University.

Degrees Earned

BSEE, with Honors, The University of Tulsa
Master of Engineering, The University of Tulsa
PhD , Kennedy Western University

Area of Specialization

lightning & grounding
failure analysis & forensic engineering
electrical power systems & safety
power generation
utility industry competition
economics & management
petroleum & chemical industry
electrical / mechanical energy conversion

Registration

Professional Engineer - Oklahoma
Professional Engineer – Texas
Professional Engineer – California
Professional Engineer – New Hampshire (Inactive)
Professional Engineer – Kansas
Professional Engineer – North Carolina (Inactive)
Professional Engineer – Missouri
Professional Engineer – Arkansas
Professional Engineer – Virginia (Inactive)
Professional Engineer – Illinois (Inactive)
Electrical Contractor - Oklahoma

Work History

D² Tech Solutions, Inc. 2002 - 2022
Principal

THEWAY Corp. 2004 - 2022
Principal Scientist

EDG Power Group, Inc. 2002 - 2004
Vice President Engineering & Project Management

New Dominion, LLC 2000 - 2002
Mgr Electric Infrastructure

Central & Southwest, Inc 1989 - 2000
Electrical Engineer

Professional Memberships

Fellow	Institute of Electrical and Electronic Engineers
Diplomate	American College of Forensic Examiners, International
Member	National Association of Fire Investigators
Voting Member	National Fire Protection Institute, Electrical Section
Executive Member	Petroleum and Chemical Industry Committee, IEEE
Diplomate,	
Past Board Member	American Board of Forensic Engineering and Technology
Member	IEEE Standards Association
Past Chair	Production Subcommittee, IEEE IAS/PCIC
CFC	American College of Forensic Examiners
Member	International Association of Arson Investigators
CFEI, CVFEI	National Association of Fire Investigators
Past Chair	Tulsa Section IEEE
Chair	IEEE RP1017.1 Working Group
Chair	IEEE RP1017.2 Working Group
Chair	IEEE RP1017.3 Working Group
Chair	IEEE RP1017.4 Working Group
Past Chair	IEEE PCIC Standards Subcommittee
Secretary	IEEE Petroleum and Chemical Industry Committee

Honors and Awards

Fellow of the IEEE

For contributions to submersible electrical equipment analysis and multi-point ground method in hazardous petroleum and chemical environments.

Honor Societies

Tau Beta Pi, national engineering honors
Eta Kappa Nu, national electrical engineering honors

Dr. Durham's publications have often successfully competed for outstanding paper awards from journals of the Institute of Electrical and Electronic Engineers (PCIC and IAS). This is an

international competitive peer review and evaluation of papers that provide a significant contribution to the advancement and understanding of electrical applications.

IEEE Industry Applications Society, New Orleans, LA: Prize Article for “Data Quality and Grounding: Considerations in a Mixed Use Facility”

PCIC, Cincinnati, OH: Prize Paper for “Grounding and Bonding Conductors: Solid, Stranded, Bare or Insulated”

PCIC, New Orleans, LA: Prize paper for "Industrial Design Application for Power Distribution over Extra-Long Distances"

PCIC, Philadelphia, PA: Prize paper for "Paradigm Shifts and Impact on Engineers and Industry"

Transactions on Industry Applications, Orlando, FL: Prize Paper for "Lightning, Grounding, and Protection for Control Systems”.

PCIC, Denver, CO: Prize Paper for “Grounding System Design for Isolated Locations and Plant Systems”

PCIC, St. Louis, MO: First place for "Lightning, Grounding, and Protection for Distributed Control and Communications Systems: A Retrofit".

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