UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT TRIAL AND APPEAL BOARD

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HALLIBURTON ENERGY SERVICES, INC.

Petitioner

v.

U.S. WELL SERVICES, LLC

Patent Owner

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Case No. 2023-00558
Patent No. 11,136,870

# DECLARATION OF DR. ROBERT DURHAM

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# I. INTRODUCTION

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. 11,136,870, which I may abbreviate as "the '870 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 '870 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.

# II. EXPERIENCE AND QUALIFICATIONS

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 electrification of 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 Challenged Patent, which I describe below in Section VII ("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) and completion operations for nearly twenty years. In addition to being responsible for interfacing with drilling and fracturing operations with regards to electrical needs as an employee of New Dominion, LLC, I have been further educated about drilling, fracturing and operations as I have consulted and investigated incidents on multiple well drilling, fracturing and completion pad sites over my engineering consulting engagements.

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 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, and establishing policies and procedures commensurate with OSHA requirements at all locations, including requirement for oil and gas sites.

14. 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.

15. 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 Challenged Patent at issue here and have been an expert in this field since before the Challenged 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 '870 Patent at the time of its filing.

## III. TASK SUMMARY AND MATERIALS REVIEWED

16. 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 to 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).

## IV. LIST OF EXHIBITS

17. 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. 11,136,870 by Joel Broussard *et al.* entitled "System for Pumping Hydraulic Fracturing Fluid using Electric Pumps" (the "'870 Patent") |
| 1002 | Declaration of Dr. Robert Durham |
| 1003 | File History for U.S. Patent No. 11,136,870 |
| 1004 | File History for U.S. Patent No. 9,410,410 |
| 1005 | U.S. Patent Publication No. 2012/0255734, Coli, *et al.*, "Mobile, modular, electrically powered system for use in fracturing underground formations," ("*Coli*") filed on April 6, 2012 and published on October 11, 2012. |
| 1006 | Toshiba International Corporation, "G7 Adjustable Speed Drive Operation Manual," Document No. 51546-009 (March 2005) ("*Toshiba Manual*"), available at: https://web.archive.org/web/20101207173900/http://www.toshiba.com/ind/data/tag_files/GX7%20Operation%20Manual_3886.pdf |
| 1007 | Declaration of Nathaniel E. Frank-White, custodian of records for Internet Archive regarding *Toshiba Manual* (May 27, 2022) |
| 1008 | U.S. Patent Publication No. 2011/0241590, Horikoshi, *et al.*, "Motor driving apparatus having fault diagnostic function," ("*Horikoshi*") filed on February 11, 2011 and published on October 6, 2011. |
| 1009 | U.S. Patent Publication No. 2010/0312415, Loucks, "Electrical Device Cooling Efficiency Monitoring," ("*Loucks*") filed on June 4, 2009 and published on December 9, 2010. |

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| 1010 | U.S. Patent Publication No. 2011/0197988, Vliet, *et al.*, "Fuel Delivery System and Method," ("*Vliet*") filed on February 16, 2011 and published on August 18, 2011. |
| 1011 | Gardner Denver, Inc., Well Servicing Pump, Model GD-2500Q, Quintuplex, Operating and Service Manual, 300FWF996 Revision C, ("*Gardner*") published in April 2005, Tulsa, OK, USA. |
| 1012 | Declaration of Duncan Hall, custodian of records for Internet Archive regarding *Gardner* (June 7, 2021) |
| 1013 | U.S. Patent No. 8,997,904, Cryer *et al*., "System and method of powering a hydraulic pump," ("*Cryer*") filed on July 5, 2012 and issued on April 7, 2015. |
| 1014 | U.S. Patent Publication No. 2013/0306322, Sanborn *et al*., "System and process for extracting oil and gas by hydraulic fracturing," ("*Sanborn*") filed on December 7, 2012 and published on November 21, 2013. |
| 1015 | K. Vidal, Memorandum regarding Interim Procedure for Discretionary Denials in AIA Post-Grant Proceedings with Parallel District Court Litigation (June 21, 2022) |
| 1016 | Donald G. Fink, STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS, 13th ed. (McGraw-Hill, New York: 1993), ISBN: 0-07-020984-7 ("Fink") |
| 1017 | National Electrical Manufacturers Association (NEMA) Standards Publication ICS 61800-4-2004, *Adjustable Speed Electrical Power Drive Systems, Part 4: General Requirements—Rating Specifications for a.c. Power Drive Systems above 1000 V a.c. and Not Exceeding 35 kV* (National Electrical Manufacturers Association: 2004) ("ICS-61800-4") |
| 1018 | Mark's Standard Handbook for Mechanical Engineers, Eleventh Edition, McGraw-Hill Companies, New York, 2007. |
| 1019 | "Root Cause Failure Analysis for AC Induction motors in the Petroleum and Chemical Industry," Austin H. Bonnet, Industry Applications Society 57th Annual Petroleum and Chemical Industry Conference, 2010. |

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| 1020 | European Patent Specification 1,900,973, Salvaire *et al*., "Method of performing hydraulic fracturing and fracturing pump system," ("*Salvaire*") filed on September 9, 2006 and issued on June 23, 2010. |
| 1021 | D. Roethemeyer and D. Yankaskas, "Evolution of motor and variable frequency drive technology," in *ACEEE Summer Study Proceedings on Energy Efficiency in Industry*, 1995, pp. 541-552. |
| 1022 | U.S. Patent No. 3,186,222, P.W. Martin, "Well Signaling System" ("*Martin*") filed on July 28, 1960,", and issued on June 1, 1965. |
| 1023 | U.S. Patent No. 3,075,136, D.V. Jones, "Variable Pulse Width Parallel Inverters," ("*Jones*") filed on August 31, 1961, and issued on January 22, 1963. |
| 1024 | U.S. Patent No. 3,262,036, C.D. Clarke *et al*., "Means for Smoothly Varying the Speed of a Star-Connected Polyphase Induction Motor," ("*Clarke*") filed on September 19, 1962, and issued on July 19, 1966. |
| 1025 | W. Shepherd and J. Stanway, "Unbalanced Voltage Control of 3-Phase Loads by the Triggering of Silicon Controlled Rectifiers," *IEEE Transactions on Industry and General Applications*, vol. IGA-1, no. 3, pp. 206-216, 1965, doi: 10.1109/TIGA.1965.4180543 ("*Shepherd*"). |
| 1026 | H. N. Hickok, "Adjustable Speed---A Tool for Saving Energy Losses in Pumps, Fans, Blowers, and Compressors," *IEEE Transactions on Industry Applications*, vol. IA-21, no. 1, pp. 124-136, 1985, doi: 10.1109/TIA.1985.349672. |
| 1027 | F. A. DeWinter and B. J. Kedrosky, "The application of a 3500 HP variable frequency drive for pipeline pump control," *Record of Conference Papers., Industrial Applications Society 35th Annual Petroleum and Chemical Industry Conference*, Dallas, TX, USA, 1988, pp. 133-138, doi: 10.1109/PCICON.1988.22429. |
| 1028 | M. Perrin, G. Kohn, S. Mugford, and G. Seggewiss, "Induction motors, reciprocating compressors and variable frequency drives," in *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 ("*Perrin*"). |

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| 1029 | B. Lockley, B. Wood, R. Paes, and F. DeWinter, "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 2006, pp. 1-10, doi: 10.1109/PCICON.2006.359687 ("*Lockley*"). |
| 1030 | U.S. Patent No. 2,533,001, E. Eberhard., "Flip-Flop Counter Circuit," ("*Eberhard*") filed on April 30, 1949 and issued on December 5, 1950. |
| 1031 | C. M. Chang, "An N-P-N high power fast germanium core driver transistor," *1957 International Electron Devices Meeting*, Washington, DC, USA, 1957, pp. 114-114, doi: 10.1109/IEDM.1957.187057 ("*Chang*"). |
| 1032 | F. B. Golden, "Liquid Cooling of Power Thyristors," in *IEEE Transactions on Industry Applications*, vol. IA-8, no. 5, pp. 601-606, Sept. 1972, doi: 10.1109/TIA.1972.349789 ("*Golden*"). |
| 1033 | A. H. Iversen and S. Whitaker, "A uniform temperature, ultra high heat flux liquid cooled, power semiconductor package," *Conference Record of the IEEE Industry Applications Society Annual Meeting,*, San Diego, CA, USA, 1989, pp. 1340-1347 vol.2, doi: 10.1109/IAS.1989.96817 ("*Iverson and Whitaker*"). |
| 1034 | Hilbert, C., S. Sommerfeldt, O. Gupta, and D. J. Herrell. 1990. "High performance air cooled heat sinks for integrated circuits," *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, 13: 1022-31 ("*Hilbert et al.*"). |
| 1035 | Hefner, A. R. 1992. "A dynamic electro-thermal model for the IGBT." In *Conference Record of the 1992 IEEE Industry Applications Society Annual Meeting*, 1094-104 vol.1 ("*Hefner*"). |
| 1036 | Jim Bentein, "Drying Out," *Oilweek* vol. 64 no. 3 (Mar. 2013). |
| 1037 | TM2500+™ Mobile Gas Turbine Generator Fact Sheet, GE Power & Water (June 25, 2014), available at: https://web.archive.org/web/20140625063653/https://www.ge-distributedpower.com/ |

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| 1038 | Declaration of Nathaniel E. Frank-White, custodian of records for Internet Archive regarding Ex. 1037 (June 21, 2022) |
| 1039 | ASME Landmark "America's First Power Generating Gas Turbine," available at: https://www.asme.org/wwwasmeorg/media/resourcefiles/aboutasme/who%20we%20are/engineering%20history/landmarks/100-belle-isle-gas-turbine.pdf (last accessed on Feb. 6, 2023) |
| 1040 | "GTS Admiral W.M. Callaghan," U.S. Department of Transportation, Maritime Administration, available at: https://maritime.dot.gov/multimedia/gts-admiral-wm-callaghan (last accessed on Feb. 6, 2023) |
| 1041 | GE TM2500+ Aeroderivative Mobile Gas Turbine Brochure (July 17, 2014), available at: https://web.archive.org/web/20140717215045/https://www.ge-distributedpower.com/component/cck/?task=download&file=seb_media_document&id=13183 |
| 1042 | Turbomachinery Systems For Oil and Gas Applications, Solar Turbines Caterpillar Company (November 2, 2006), available at: https://web.archive.org/web/20061102043710/http://mysolar.cat.com/cda/files/127587/7/bo&g.pdf |
| 1043 | Oil and Gas Industry Packages, Generator Sets, Solar Turbines: A Caterpillar Company (March 18, 2006), available at: https://web.archive.org/web/20060318215809/http://mysolar.cat.com/cda/layout?m=36056&x=7 |
| 1044 | Fast and Easy Installation for Mobile Power, Solar Mobile Turbomachinery, Solar Turbines: A Caterpillar Company, available at: https://www.solarturbines.com/en_US/solutions/oil-and-gas/solar-mobile-turbomachinery.html (last accessed on Feb. 6, 2023) |
| 1045 | Toshiba Low Voltage Adjustable Speed Drives, Integrated Power Services, available at: https://www.ipsrpd.com/toshiba-drives.html#:~:text=Toshiba%20International%20Corporation%20entered%20the%20North%20American%20adjustable,requirements%20for%20virtually |

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| | %20any%20industry%2C%20application%2C%20and%20environment (last accessed on Feb. 6, 2023) |
| 1046 | Oil & Gas, Toshiba International Corporation, available at: https://www.toshiba.com/tic/oil-gas#:~:text=Toshiba%27s%20oil%20and%20gas%20product%20offerings%20are%20packaged,environments%20while%20improving%20process%20control%20and%20system%20efficiency (last accessed on Feb. 6, 2023) |
| 1047 | GX7 Low Voltage Severe Duty Specialty, Toshiba (Nov. 23, 2012), available at: https://web.archive.org/web/20101123025808/http://www.toshiba.com/ind/product_display.jsp?id1=7&id2=601 |
| 1048 | IPR2021-01033, Paper 41 (P.T.A.B. Jan. 4, 2023) Final Written Decision concerning U.S. Patent No. 8,789,601 |
| 1049 | U.S. Patent No. 8,789,601, Broussard *et al*., "System for Pumping Hydraulic Fracturing Fluid Using Electric Pumps," filed on February 26, 2014 and issued on July 29, 2014. |
| 1050 | Declaration of Robert Schaaf from *U.S. Well Services, LLC v. Tops Well Services, LLC et al.*, No. 3:19-cv-00237, Dkt. 72-9 (S.D. Tex. Apr. 24, 2020) |
| 1051 | Deposition Transcript of Robert Schaaf taken in IPR2021-01033 (July 1, 2022) |
| 1052 | Deposition Transcript of Robert Schaaf taken in IPR2021-01032, -01034, -01036, -01038 (June 29, 2022) |
| 1053 | *Halliburton Energy Services, Inc., et al. v. U.S. Well Services, LLC*, No. 6:22-cv-00906-ADA-DTG, Dkt. 50 (Feb. 8, 2023) (Joint Motion to Extend Scheduling Deadlines) |

Other than Ex. 1003, Ex. 1004, and Ex. 1006, all citations to exhibits reference original page numbers found in the underlying document, and all emphases are added.

## V. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE

18. After reviewing the materials identified in the List of Exhibits, I have concluded that each of the Challenged Claims of the '870 Patent would have been obvious to a person of ordinary skill in the art, based on the following grounds.

| Ground | '870 Claims | Basis for Challenge |
|---|---|---|
| 1 | 1-16 | Obvious over *Coli* in view of *Toshiba Manual* |
| 2 | 1-6 | Obvious over *Coli* in view of *Horikoshi* |
| 3 | 7-16 | Obvious over *Coli* in view of *Loucks* |
| 4A | 12 and 13 | Obvious over *Coli* in view of *Toshiba Manual* and *Vliet* |
| 4B | 12 and 13 | Obvious over *Coli* in view of *Loucks* and *Vliet* |
| 5A | 14 and 15 | Obvious over *Coli* in view of *Toshiba Manual* and *Gardner* |
| 5B | 14 and 15 | Obvious over *Coli* in view of *Loucks* and *Gardner* |

## VI. LEGAL STANDARDS

### A. LEVEL OF ORDINARY SKILL IN THE ART

19. 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.

20. I have been instructed by counsel that the person of ordinary skill in the art 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

21. 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.

22. 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.

23. 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.

24. 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.

25. 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.

26. 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. OBVIOUSNESS

27. 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).

28. 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.

29. 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.

30. 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.

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

32. 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.

33. 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.

### D. PRIORITY DATE

34. 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.

35. 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.

36. 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.

37. 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.

## VII. OVERVIEW OF THE CHALLENGED PATENT

38. I have reviewed U.S. Patent No. 11,136,870 ("the '870 Patent"), which is entitled "System for Pumping Hydraulic Fracturing Fluid Using Electric Pumps."

Ex. 1001. I understand that the '870 Patent was filed on June 28, 2019, and that it was issued on October 5, 2021. The '870 Patent is a continuation of U.S. Patent 10,337,308, filed on July 5, 2016, which is a continuation of U.S. Patent 9,410,410, filed on November 16, 2012. Accordingly, the '870 Patent claims priority to November 16, 2012.

### A. THE SUBJECT MATTER OF THE CHALLENGED PATENT

39. For many years, the upstream oil & gas industry has been moving away from diesel power and towards the use of electric power. There are numerous reasons for this shift, including (1) environmental, air quality, noise, and safety concerns arising from the use of a large number of diesel engines around the wellsite; (2) the extensive physical footprint required by traditional diesel engines; and (3) the occasionally limited availability of diesel fuel in sufficient quantities. *See, e.g.*, Ex. 1014, [0006–0007], [0042]; Ex. 1013, 1:43–2:7, 4:24-67. Historically, one of the primary uses of diesel-powered engines at a wellsite was the pumps used for hydraulic fracturing. Thus, it was not surprising when the shift to electric power led to the introduction of electric fracturing pumps—i.e., pumps powered by an electric motor—as a replacement for these diesel pumps. This process began at least as early as September 2008. *See, e.g.*, Ex. 1013; *see also* Ex. 1020, [0023]-[0024].

40. The '870 Patent acknowledges the well-understood "problems associated with diesel pumps" and re-states what was already known in the art—i.e., the

problems associated with diesel pumps can be overcome by "using pumps powered by electric motors." Ex. 1001, 1:52–54; 1:25–26. In particular, the '870 Patent is directed to "pumping fracturing fluid into an oil or gas well using pumps powered by electric motors." Ex. 1001 at 1:23–26. The electric motor driven pumps are intended to replace typical "large diesel powered pumps" that must be moved on "heavy duty trailers," "require a relatively high level of expensive maintenance," and are associated with high operating costs due to the price of diesel fuel. Ex. 1001, 1:41-51.

41. The '870 Patent describes a hydraulic fracturing operation that includes "a plurality of pumps 10 mounted to pump vehicles 12." Ex. 1001, 3:40. The '870 Patent further states that "the pumps 10 are powered by electric motors 14, which can also be mounted to the pump vehicles 12." Ex. 1001, 3:42-44. The pumps 10 deliver fracturing fluid to a wellbore through a missile 18 positioned between the pumps 10 and a wellhead. Ex. 1001, 3:48-50.

42. As demonstrated herein, all features of the Challenged Claims, including the design considerations and purported advantages described in the '870 Patent, were well known at the time the application leading to the '870 Patent was filed.

### B. PROSECUTION HISTORY

43. The application leading to the '870 Patent—U.S. Patent App. No. 16/456,777—was filed June 28, 2019. Ex. 1003, 237 *et seq*. The application included

one independent claim, claim 1. Ex. 1003, 266. Prior to any substantive response by the Examiner, the Applicant filed a preliminary amendment cancelling claim one and adding claims 2–21, of which claims 2, 6, and 10 were independent claims. Ex. 1003, 167 *et seq.* Those independent claims respectively correspond to independent claims 1, 4, and 7 of the '870 Patent. *See* Ex. 1001.

44. The Patent Office issued a Non-Final Office Action on November 23, 2020, rejecting claims 6, 10, 12, 19, and 20 under pre-AIA 35 U.S.C. § 102(b) as being anticipated by Shampine et al., U.S. 7,845,413. Ex. 1003, 87 *et seq.* In addition, the Patent Office rejected claims 2–4, 5–8, 10–17, and 20 under pre-AIA § 102(e) as being anticipated by Cryer et al., U.S. 8,997,904. Ex. 1003, 90–91. The Patent Office rejected claims 2–3 and 5–21 on the ground of nonstatutory double patenting as being unpatentable over claims 1–3, 5, 8–9, 11–12, 16, and 18 of U.S. Patent No. 8,789,601, and claims 1, 3–6, 8–9, 11, 13-14, and 19–21 of U.S. Patent No. 9,410,410. Ex. 1003, 92–94. The Examiner, however, found that then-pending dependent claims 3, 9, and 18 "would be allowable if rewritten in independent form including all of the base claim and any intervening claims." Ex. 1003, 94. Then-pending claim 3 recited: "a variable frequency drive connected to the electric motor to control the speed of the motor, wherein the variable frequency drive frequently performs electric motor diagnostics to prevent damage to the one or more electric motors." Then-pending claim 9 recited: "controlling the speed of the motor using a

variable frequency drive, wherein the variable frequency drive frequently performs electric motor diagnostics to prevent damage to the electric motor." Then-pending claim 18 recited: "wherein the variable frequency drive has one or more power semiconductor heat sinks having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat."

45. In response, the Applicant submitted terminal disclaimers to overcome the double patenting rejections. Ex. 1003, 72–75. The Applicant amended independent claims 2, 6, and 10 to recite the features previously recited in claims 3, 9, and 18, which the Examiner previously indicated were allowable. Ex. 1003, 81 *et seq*. The Examiner issued a Notice of Allowance on June 30, 2021. Ex. 1003, 18.

46. Based on the above, the point of purported novelty of independent claims 1, 4, and 7 of the '870 Patent lies in the variable frequency drive utilizing diagnostics and sensors to prevent damage to the motor. Such variable frequency drives, however, were well know at the time of the claimed inventions of the '870 Patent.

47. The '870 patent is a continuation of U.S. Patent Application No. 15/202,085, that issued as U.S. Patent No. 10,337,308 (the "'308 patent"), which is a continuation of U.S. Patent Application No. 13/679,689, that issued as U.S. Patent No. 9,410,410 (the "'410 patent").

48. The application leading to the '410 Patent was filed November 16, 2012. Ex. 1004, 298. The application included twenty claims, of which claims 1, 8, and 18

were independent. Ex. 1004, 320–322. Those independent claims respectively correspond to independent claims 1, 10, and 19 of the '410 Patent.

49. The Patent Office issued Office Actions on December 3, 2014, March 16, 2015, and August 3, 2015, and in each rejected all claims as being unpatentable under 35 U.S.C. § 103. Ex. 1004, 188, 229, 255. In response to each, Patent Owner amended the claims. Ex. 1004, 240, 218, 204, 127. The Examiner issued a Notice of Allowance on April 6, 2016, and noted that the prior art failed to disclose or suggest a "hydraulic fracturing system incorporating the variable frequency drive performing diagnostics for the electrical motors," and thus failed to render the claims obvious. Ex. 1004, 111, 117.

50. Based on the above, the point of purported novelty of independent claims 1, 10 and 19 of the '410 Patent lies in the diagnostic capabilities of the variable frequency drives within the system. Variable frequency drives and these diagnostic capabilities, however, were well known at the time the '410 Patent was filed (along with all of the other features of all Challenged Claims). Every feature of the Challenged Claims is disclosed in the prior art.

### C. COMPARISON OF ASSERTED REFERENCES TO PRIOR ART DISCUSSED DURING PROSECUTION

51. I have been asked to review the examination history of the '870 Patent, and to compare the prior art grounds presented herein to those considered in

rejections by the Examiner during the examination of the ’870 Patent. As I describe below, my opinion is that the Grounds of invalidity considered herein are not cumulative of the prior art considered by the Examiner during examination.

52. **Primary reference:** I have relied on *Coli* as a base (or primary) reference. *Coli* is listed on the face of the ’870 Patent and was substantively considered by the Examiner during the prosecution of a parent application (U.S. Patent Application No. 15/202,085, which issued as U.S. Patent No. 10,337,308). However, *Coli* was not discussed in any office actions or responses during the prosecution of the ’870 Patent.

53. **Secondary reference:** I have relied upon several additional references (secondary references) that are used in combination with the primary reference. These references were not considered during prosecution of the ’870 Patent, and are not cited on the cover of the ’870 Patent. The claim limitations of the ’870 patent, to the extent not disclosed by the primary reference, are disclosed in the secondary references, and a POSITA would have been motivated to combine the primary reference with the secondary references in the manners in which I discuss below.

## D. THE CHALLENGED CLAIMS OF THE ’870 PATENT

54. The Challenged Claims of the ’870 Patent, which are Claims 1-16, are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

| Claim Element | Claim Language from '870 Patent |
|---|---|
| 1(pre) | 1. A system for hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the system comprising: |
| 1(a) | a trailer for attachment to a truck; |
| 1(b) | two or more pumps attached to the trailer and fluidly connected to the well, the pumps configured to pump fluid into the wellbore; |
| 1(c) | one or more electric motors attached to the pumps to drive the pumps, the electric motors attached to the trailer; and |
| 1(d) | a variable frequency drive connected the electric motor to control the speed of the motor, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the one or more electric motors. |
| 2 | 2. The system of claim 1, further comprising: a skid to which at least one of the pumps and the one or more electric motors are attached. |
| 3 | 3. The system of claim 1, further comprising: a natural gas powered generator for connection to the electric motor that provides electric power to the electric motor. |
| 4(pre) | 4. A method of hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the method comprising: |
| 4(a) | pumping fluid into the wellbore using hydraulic fracturing pumps; |
| 4(b) | powering the hydraulic fracturing pumps using an electric motor; and |
| 4(c) | controlling the speed of the motor using a variable frequency drive, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the electric motor. |

| Claim Element | Claim Language from '870 Patent |
|---|---|
| 5 | 5. The method of claim 4, further comprising: powering the electric motor using a generator. |
| 6 | 6. The method of claim 5, further comprising: powering the generator using natural gas. |
| 7(pre) | 7. A system for hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the system comprising: |
| 7(a) | a pump fluidly connected to the well; and |
| 7(b) | an electric motor to power the pump; |
| 7(c) | the pump configured to pump fluid into the wellbore; and |
| 7(d) | a variable frequency drive connected to the electric motor to control the speed of the motor and having one or more power semiconductor heat sinks having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat. |
| 8 | 8. The system of claim 7, wherein the electric pump is mounted on a vehicle and can be ported from one well to another. |
| 9 | 9. The system of claim 7, further comprising: a generator electrically connected to the electric motor to provide electric power to the motor. |
| 10 | 10. The system of claim 9, wherein the generator is fueled by natural gas. |
| 11 | 11. The system of claim 9, wherein the generator is a turbine generator. |
| 12 | 12. The system of claim 9, wherein the pump, electric motor and generator are mounted on a vehicle, and can be ported from one well to another. |

| Claim Element | Claim Language from '870 Patent |
|---|---|
| 13 | 13. The system of claim 12, wherein the vehicle is a truck having at least five axles. |
| 14 | 14. The system of claim 7, wherein the pump is a triplex or quinteplex pump rated at about 2250 hydraulic horsepower or more. |
| 15 | 15. The system of claim 7, wherein the electric motor has a maximum continuous power output of about 1750 brake horsepower or more. |
| 16 | 16. The system of claim 7, wherein the electric motor has a maximum continuous torque of about 8750 lb-ft or more. |

## VIII. TECHNOLOGY BACKGROUND AND STATE OF THE ART

55. In the subsections below, I describe some of the basic principles of engineering that would be used, or at least considered for use, in the field of electrification of oil and gas operations, and particularly in the field of electrification of hydraulic fracturing operations. The principles discussed in the subsections below would have been well-known to a POSITA in the 2012 timeframe, and long before.

### A. ADJUSTABLE SPEED DRIVES / VARIABLE FREQUENCY DRIVES

56. 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.

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

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

Ex. 1016 (Fink) p. 20-85. Exhibit 1016 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:

> 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.

Ex. 1008 (*Horikoshi*), [0004].

58. Accordingly, I understand that VFDs are a class of motor driving apparatus that takes incoming alternating current (AC) 3-phase power (at least for motors over 10 Hp), converts it to direct current (DC) power, and then converts it back to AC power for delivery to the motor. 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.

59. One of the more common ASD topologies, particularly for larger motors is a "pulse-width modulated (PWM)" drive topology. PWM drives have several advantages over other drive topologies including "high line-side power factor (near unity)," and the "distortion seen by the electrical network is . . . reduced." Additionally, "high dynamic performance can also be realized. Full torque can be maintained and controlled throughout the speed range – even at zero speed." Ex. 1016 (Fink) p. 20–89.

60. 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: $P = \tau \cdot \omega$. 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.

61. 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." Ex. 1021 at p. 543.

62. By 1960, SCRs were being used in oil and gas operations, albeit on a relatively small scale, as evidenced by "*Martin*," U.S. Patent No. 3,186,222, which was filed on July 28, 1960. Ex 1022.

63. By at least August 1961, pulse width modulated (PWM) drives were being used for motor drives. D.V. Jones (General Electric) developed "Variable Pulse Width Parallel Inverters," and a patent application on August 31, 1961, which issued as United States Patent No. 3,075,136 on January 22, 1963. Ex. 1023. *Jones* states that "by 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" Ex. 1023, at1:20–30.

64. By 1962, a "Means for Smoothly Varying the Speed of a Star-Connected Polyphase [3 phase] Induction Motor" had been developed. *See* Ex 1024.

65. 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." Ex. 1025, Introduction. 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. These devices were

"large, bulky and expensive" and had "marginal acceptance" throughout industry as a whole. Ex. 1021, at p. 543. However, "certain industries like petro/chem and textile" showed larger acceptance, largely because of the very large motors used in those industries. Ex. 1021, at p. 543.

66. 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. In the 1980s, because large drives were "large, bulky and expensive," they were applied first to large motors, such as those in the petrochemical industry, utility industry and the textile industry, where the amount of savings could justify the expense and space of ASD installation. Ex. 1026.

67. Between 1985 and 1989, bipolar PWM technology had been developed, and drives became "smaller [and] more economical" which lead to "a greater acceptance among users." Ex. 1021 at p. 544. In this time frame as well, Insulated Gate Bipolar Transistors (IGBTs) were in use and "smaller drive packages with micro drives for smaller hp motors" had gained "[a] much larger acceptance. Micro drives have actually become commodities." Ex. 1021 at 544. 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, computers have come down to the point where a small, handheld device contains "more computing power than NASA" during the Apollo missions.

68. By at least 1988, very large VFDs 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. Ex 1027. In this peer-reviewed publication, DeWinter discusses the expansion of a Canadian 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).” Ex 1027, Abstract at 1019. DeWinter states that “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.” Ex. 1027, at 1020. According to DeWinter, the installation would cost $CD800,000 in 1986 dollars, but would generate approximately $CD129,000 in overall operating cost savings in the first year alone. Ex. 1027, at p. 1019.

69. It is around this time that I gained my first exposure to large 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. Ex. 1021, at 543. However, the operational cost savings for these large motors more than justified the capital investment. Although industrial ASDs were first applied to very large, several thousand horsepower motors, where the cost savings would justify their installation, those in industry hoped ASDs would be cheap enough to justify their installation on small motors.

70. As my career progressed, I continued to design and oversee installation of increasingly small ASDs for various applications including in power generation, petrochemical, and commercial environments. ASD technology has progressed to the point that even small, integer horsepower motors in residential applications, such as HVAC blowers and pool pumps, have come to be controlled by ASDs.

71. By at least 1997, "the use of variable frequency drives (VFD) [had become] increasingly popular with induction motor driven gas compressors." Ex 1028, Abstract. To the motor and drive system, there is no significant difference between driving a reciprocating compressor or a reciprocating pump. *Perrin* describes applications of VFDs (ASDs) on 1500–3000 Hp installations. Ex 1028, at 3.

72. As discussed above, large drives were manufactured and marketed by large, well known electric equipment companies, such as General Electric and ABB, well before 2012. Other companies active in the marketplace for large drives include Toshiba, Rockwell Automation and Schneider Electric.

73. By the early 2000s, installations of large ASDs in petroleum and chemical operations became so ubiquitous that industry recognized a need for standardization. This need led to the development of IEEE 1566, titled *Standard for Performance of Adjustable Speed Drives Rated 375 kW and Larger*. This standard was sponsored by the Standards Subcommittee of the Petroleum and Chemical Industry Committee

(PCIC) of the IEEE. In my role as Chair of the standards Subcommittee of PCIC, I was responsible for maintenance, update, and oversight of IEEE 1566. IEEE 1566 continues in force today.

74. *Lockley*, published in 2006, states that "[w]ork started in 2000 on an IEEE standard for large ASDs . . . [and] the standard was approved in 2005 and published in 2006." Ex. 1029, at p. 2. Thus, by 2006, large ASD installations had become so pervasive—particularly in the petroleum and chemical industries—that the drives themselves had become standardized.

## B. ELECTRIC MOTOR DIAGNOSTICS TO PREVENT DAMAGE TO THE ELECTRIC MOTOR

75. Electric motor diagnostics is a function that is inherent in PWM ASDs (VFDs) that control both the torque and the speed of the motor. Ex. 1016 (Fink) p. 20-89. It was also routine for ASDs to control the output to be within the motor operating limits.

### a. NEMA ICS-61800-4 (Ex. 1017) corroborates general engineering knowledge regarding ASDs/VFDs

76. As another example of general engineering knowledge, standards governing construction of ASD/VFDs specify the types of electric motor diagnostics to perform to prevent damage to the electric motor. For example, NEMA ICS 61800-4 ("61800-4") is a manufacturing standard for adjustable speed drives published in

2004. Ex. 1017 (NEMA ICS-61800-4). Exhibit 1017 contains true and correct copies of pages from NEMA ICS-61800-4.

77. NEMA is the National Electrical Manufacturer's Association. NEMA was founded in the 1920s and is an ANSI-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.

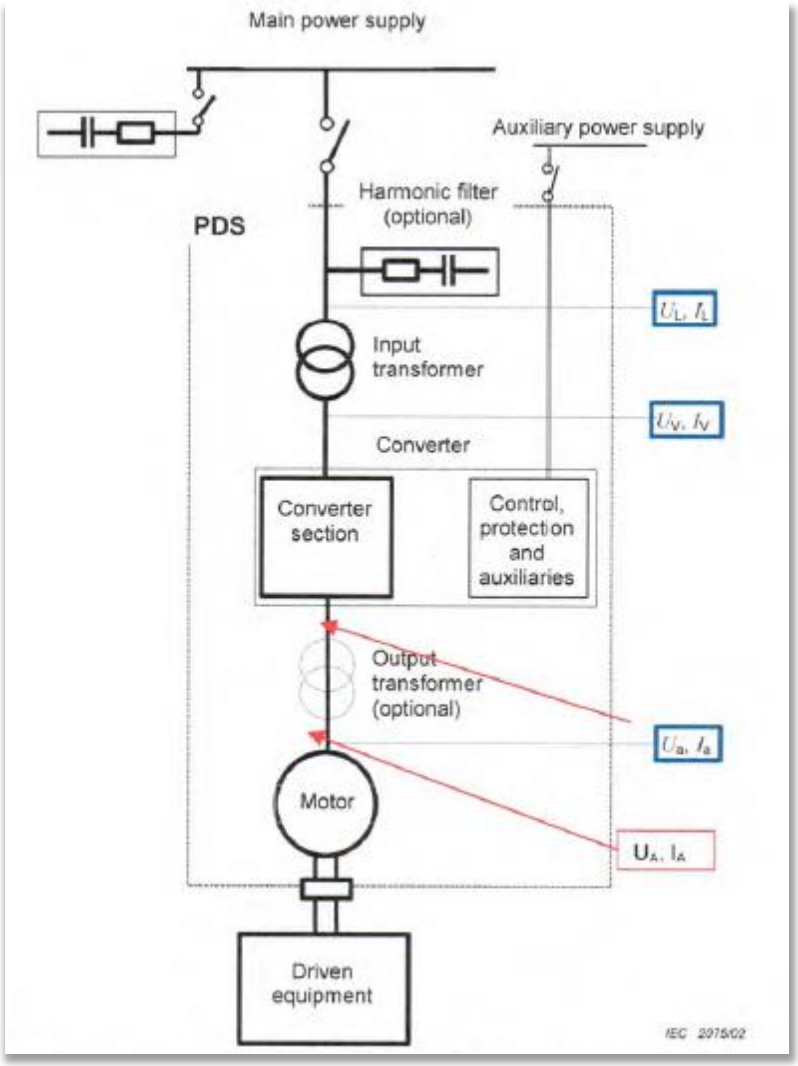
78. One group of standards developed by NEMA are the Industrial Control and Systems ("ICS") family of standards. The ICS standards provide practical general information concerning ratings, construction, testing, performance and manufacture of industrial control and systems equipment and terminal blocks. One of the NEMA ICS Standards is NEMA ICS 61800-4 *Adjustable Speed Electrical Power Drive Systems Part 4: General Requirements – Rating Specifications for a.c. Power Drive Systems above 1000 V a.c. and Not Exceeding 35kV.* Ex. 1017 (ICS-61800-4) (published in 2004). ICS 61800-4 reflects general engineering knowledge of power drive systems, including ASDs/VFDs, known over a decade before the priority date of the '870 Patent.

79. Clause 1.1 of 61800-4 discusses the "Scope and Object" of the standard and contains the following language:

> This standard gives the characteristics of the converters, their topologies and their relationship with the complete a.c. drive system. It also states their performance requirements with respect to ratings, normal operating conditions, overload conditions, surge withstand capabilities, stability, protection, a.c. line earthing, topologies and testing. Furthermore, it deals with application guidelines, such as control strategies, torsion analysis, recommendations for earthing and drive system component integration.

Ex. 1017 (ICS-61800-4) p. 1 (§1.1). Thus ICS-61800-4 is a repository of knowledge and manufacturing requirements of a.c. power drive systems (PDS).

80. NEMA ICS defines a PDS: System with a voltage above 1kV (see figure 1) is an interconnected combination of equipment which provides a means of adjusting the speed of a mechanical load coupled to a motor." Ex. 1017 (ICS-61800-4) p. 6 (§3.1.1). Figure 1 further describes the PDS, with annotations in the original.




Ex. 1017 (ICS-61800-4) p. 7 (§3.1.1) (coloring in original). A POSITA would have understood ICS-61800-4 to describe adjustable speed drives (ASDs or VFDs) and requirements of such drives. It should also be noted that this figure shows switchgear (in the form of circuit breakers and fuses), and a transformer between the switchgear and the motor, both of which are common components of an ASD system.

81. Section 3 of 61800-4 defines the output parameters of the drive that are required for operation of the drive / motor system. The "load envelope" is defined in Section 3.4.1 as stated below.

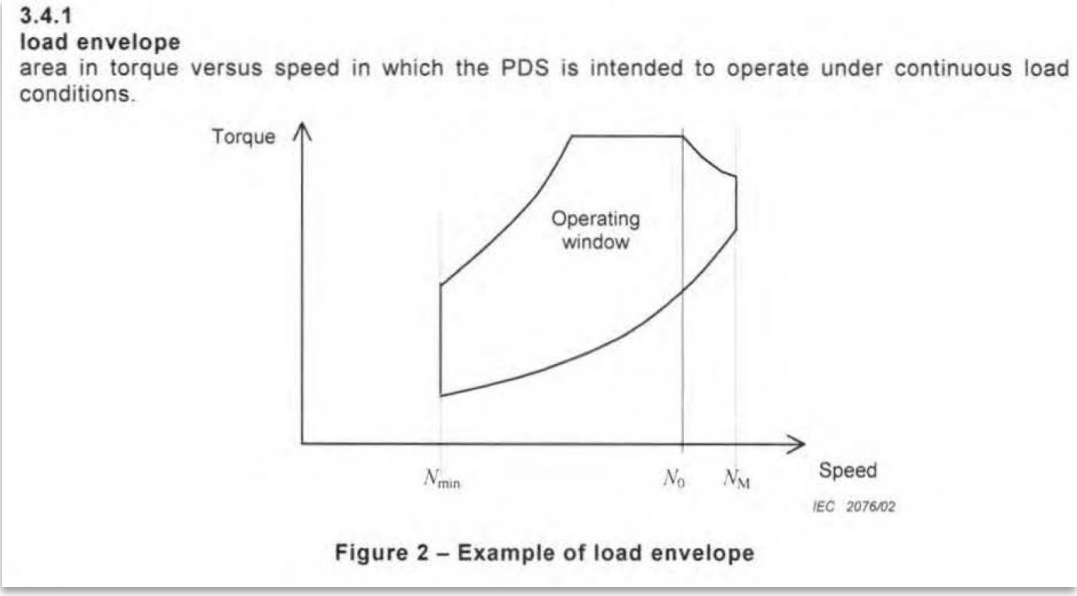



**Figure 2 – Example of load envelope**

Ex. 1017(NEMA ICS 61800-4) p. 15.

82. One set of requirements for an ASD are "PDS Integration Requirements," outlined in Section 9 of ICS-61800-4. One requirement is for the ASD to perform motor protection through diagnostics. These include diagnosing and protecting against power source irregularities (e.g., voltage surges, over and under voltage, phase reversal, voltage unbalance), overcurrent conditions (e.g., fault currents, ground currents, and internal faults), overloads, overtemperature, motor overspeed, excessive vibration, lost lubrication, and others. Ex. 1017 (ICS-61800-4) p. 73-74

(§9.5-§9.6). ICS-61800-4 summarizes such motor protection and diagnostic steps in Table 8.

**Table 8 – PDS protection functions**

| Line-side supply | Alarm | Trip | Remark |
|---|---|---|---|
| Outage, phase loss | X | X | |
| Line overvoltages | X | X | |
| Line under-voltages | X | X | |
| Line voltage unbalance | X | X | |
| **Line feeder** | **Alarm** | **Trip** | **Remark** |
| Over-current | | X | |
| Overload | X | X | |
| **Transformer** | **Alarm** | **Trip** | **Remark** |
| Gas relay (Buchholz) | X | X | oil-type only |
| Over-temperature | X | X | |
| Loss of cooling media | X | X | |
| Low oil level | X | | oil-type only |

| Converter | Alarm | Trip | Remark |
|---|---|---|---|
| Overcurrent | X | X | commutation failure, short circuit, etc. |
| Overload | X | (X) | thermal |
| Overvoltage | X | X | |
| Ground fault | X | (X) | |
| Loss of cooling | X | (X) | |
| Over-temperature | X | (X) | |
| Loss of auxiliary supply | X | X | |
| Loss of communication to process control | X | (X) | |
| Loss of speed feedback | X | | |

| Motor | Alarm | Trip | Remark |
|---|---|---|---|
| Motor over/under-voltage | X | X | |
| Motor overcurrent | X | X | |
| Overload | X | (X) | thermal |
| Over-speed | X | X | |
| Winding over-temperature | X | X | |
| Bearing over-temperature | X | X | |
| High vibrations | X | X | |
| Loss of cooling | X | (X) | |
| Loss of lubrication | X | X | |

NOTE 1 Vibration protection functions can be taken care of by the driven equipment supplier.

NOTE 2 (X): conditionally applied.

NOTE 3 The impedance of the supply network at the IPC (see 5.1.1.2), and the input impedances of the PDS (see 8.2.3) shall be considered.

Ex. 1017 (ICS-61800-4) p. 75 (Table 8). Thus, ICS-61800-4 reflects the general engineering knowledge that a purpose of an ASD/VFD would be to conduct motor diagnostics in order to protect a motor from such conditions as over/under voltage, overcurrent (e.g., ground fault or short circuit), overload, overspeed, and others.

### b. ***Horikoshi*** **(Ex. 1008) corroborates general engineering knowledge regarding ASDs/VFDs**

83. Another example of the general engineering knowledge of VFDs performing motor diagnostics is provided by *Horikoshi*. Ex. 1008. *Horikoshi* is a publication of a United States patent application, U.S. Patent Publication No. 2011/0241590A1. *Horikoshi* is entitled, "Motor Driving Apparatus Having Fault Diagnostic Function." *Horikoshi* was filed February 11, 2011 (claiming priority to a foreign application filed March 31, 2010) and published October 6, 2011. Each of these dates is before the earliest possible priority date of all Challenged Claims of the '870 Patent.

84. *Horikoshi* is directed to the configuration and use of a "motor driving apparatus having a fault diagnostic function." Ex. 1008, [0002]. Specifically, *Horikoshi* is directed to a variable frequency drive that is "capable of detecting during operation a ground fault and a phase-to-phase short circuit by distinguishing one from the other." Ex. 1008, [0011]; *see* [0012]. *Horikoshi* explains that a variable-frequency drive in the form of an AC/DC/AC power converter "is known." Ex. 1008, [0002]. A POSITA would have understood that one aspect of a motor that needs diagnostics is the potential problem of damage to the motors due to shorting or grounding.

85. *Horikoshi* teaches the use of a "motor driving apparatus" that includes an "AC/DC converter 18 [that] converts three-phase AC power" into DC power, and an associated "DC/AC converter 10 [that] converts the DC power...into frequency variable three-phase AC power for output." Ex. 1008, [0027]. The apparatus further includes "[c]urrent sensors" to detect current output from the DC/AC converter 10 to an electric motor." Ex. 1008. The current sensors may be used to detect "overcurrent" associated with "the insulation resistance of the motor" connected to the drive apparatus. Ex. 1008, ¶[0004], ¶[0006]. The "overcurrent" can be caused by a "ground fault or a phase-to-phase short circuit." Ex. 1008. Thus, *Horikoshi* discloses a variable frequency drive with diagnostic capabilities that performs the

diagnostics to identify ground or short circuit conditions and prevent any subsequent damage to the motor.

86. *Horikoshi* teaches a system that monitors and performs fault diagnostic functions "during operation." In fact, *Horikoshi* describes the system monitoring a fault that occurs momentarily, in operation on only part of a cycle and then clears. Figure 2 and Figure 4 of *Horikoshi* show these momentary faults as a portion of a single cycle of an AC signal. At 60 Hz (most North American Utility AC Power), and even if the output frequency was as low as 0.1 Hz, the time required for completion of a single cycle of the AC output signal would be 10 Seconds.

### C. POWER SEMICONDUCTOR HEAT SINKS

87. It has long been known that power semiconductor devices generate substantial heat that must be dissipated (i.e., the devices must be cooled) in order to prevent damage to the devices. This is particularly true for semiconductor devices used in power applications. Even for the earliest semiconductor devices—namely, transistors—it was generally understood that heatsinks were needed. In fact, in most applications (for example, those described herein), the author simply assumed that the user knew that a heat sink would be necessary.

88. In April 1949, E. Eberhard filed a patent application titled "Flip-Flop Counter Circuit," which issued under the same name as United States Patent No. 2,533,001 on December 5, 1950. Ex. 1030. *Eberhard* refers to "a three-electrode

semiconductor amplifier which has been termed a "transistor." Ex. 1030, at 1:33–35. In such amplifiers "a large portion of the power must be dissipated as heat." Ex. 1030, at 1:20–22.

89. As early as 1957, when discussing the development of an N-P-N Fast Germanium Core Driver Transistor, Chang referenced "the heat sink kept at room temperature." Ex. 1031 at 114.

90. As an additional example, in 1972, *Golden* wrote an article discussing the "heat-transfer problems associated with high-power thyristors," a type of semiconductor device. Ex. 1032 at 601. *Golden's* article discusses a method of analyzing "heat sinks used in high-power thyristor equipment" from the perspective of the user. Ex. 1032 at 601. *Golden* observes that "[a] vacuum exists concerning the establishment of a mathematical or graphical relationship for a given completed heat-sink design that would be useful to the heat-sink user—the solid-state equipment designer." Ex. 1032 at 601. *Golden* is directed toward liquid cooled heat sinks, as shown below in Figure 1.

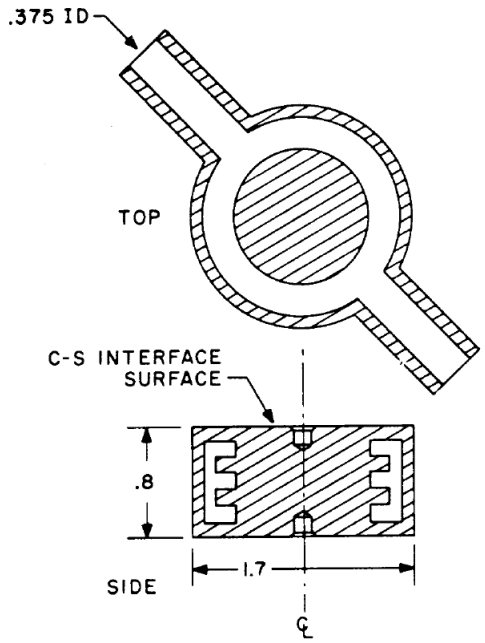



Fig. 1. Cross sections showing liquid passages of G6 heat sink.

Ex. 1032, Fig. 1.

91. *Golden* discusses the fact that the cooling effect of the heat sink has a relationship to the flow of coolant through the heat sink. By controlling flow, the amount of heat dissipation (cooling) of the heat sink can be controlled. This is exemplified in Fig. 4 below, which compares the cooling effect of the heat sink to the flow rate of water ($H_2O$).

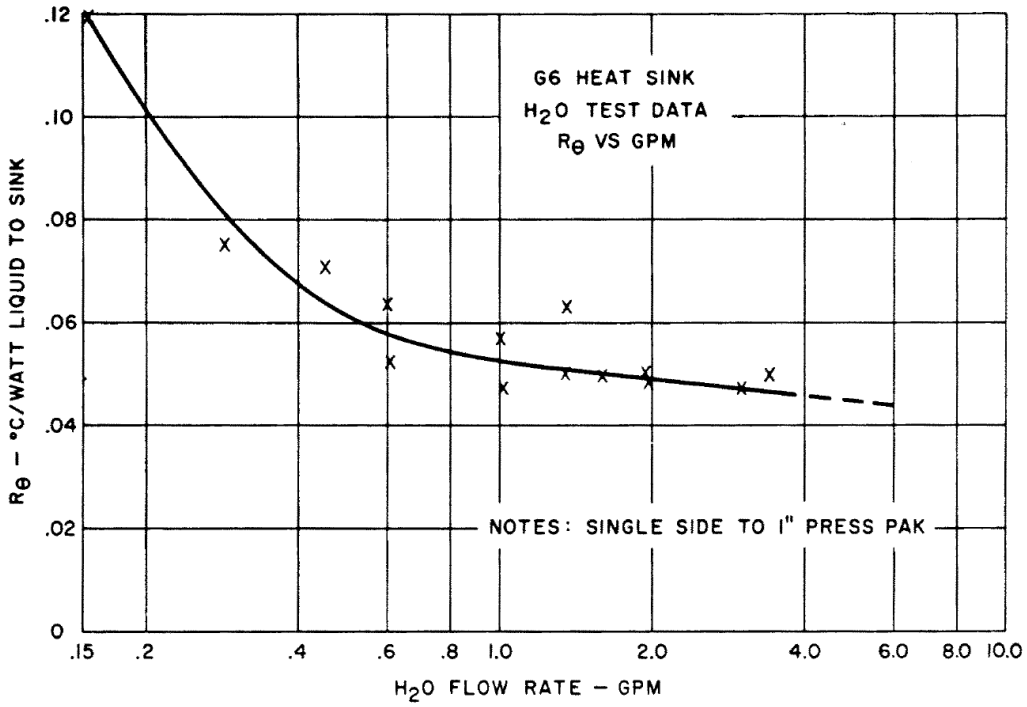



Fig. 4. Heat-sink thermal $R$ versus water flow rate.

Ex. 1032, Fig. 4. *Golden* then goes on to suggest that plots of heat dissipation versus fluid flow "be made available to the equipment designer together with charts that simplify the conversion of a given liquid low rate in gal/min and the liquid property, a Reynolds number based on the heat sink in question." Ex. 1032, at 604.

92. Liquid cooled heat sinks continued to be used for cooling of power semiconductors through the 1980s. In 1989, Arthur Iversen and Stephen Whitaker wrote a paper titled "A Uniform Temperature, Ultra High Heat Flux Liquid Cooled, Power Semi-Conductor Package," and directed to "[a] new type of heat exchange process is used for semiconductor heat sinks." Ex. 1033, at 1340. According to Iversen and Whitaker, "[t]he performance of high power devices such as diodes,

thyristors, GTO's, MOSFETs, etc. is often limited by the heat removal capabilities of the thermal package. . . . A common method for power device cooling is the use of high mechanical forces (up to 10 tons) to press the Disc Type package against the external heat sink." Ex. 1033, at 1340. The paper discusses "a novel packaging and cooling scheme" for high power devices. Ex. 1033, at 1340. This novel approach uses specific cooling liquids and curved surface heat sinks in order to improve the efficiency of the heat sink. *See generally* Ex. 1033.

93. As a POSITA would have understood from *Eberhard*, the original heat sinks were air cooled. Air cooled heat sinks continued to be used throughout the history of power electronic devices. *See generally* Ex. 1030. As an example, *Hilbert* teaches "High Performance Air Cooled Heat Sinks for Integrated Circuits." Ex. 1034. According to *Hilbert*, "[l]iquid cooling will generally be able to outperform air cooling. . . . However, air cooling is less expensive, more portable, and generally evokes less apprehension among users." Ex. 1034, at 1022. These air-cooled heat sinks comprise fans to "forc[e] the air to flow through the heat sink." Ex. 1034, at 1022. *Hilbert* monitored the internal temperature of the heat sink by use of a "type T (copper-constantan) thermocouple located inside a hole drilled into the solder interface between the chip and heat sink at the center of the heat sink base. . . . The thermocouples were connected to a Fluke 2285B data logger which scans all the inputs." Ex. 1034, at 1027. A Fluke 2285B data logger would have been recognized

by a POSITA as containing microprocessor(s) to monitor the internal temperature of the heat sink. My team has had a Fluke 2285B data logger in our lab since the 1990s.

94. It was also well-known to use heat sinks to cool Insulated Gate Bipolar Transistors (IGBTs), another form of power semiconductor. In 1992, Allen Hefner described an "Electro-Thermal model for the IGBT" by combining "a temperature-dependent IGBT electrical model with dynamic thermal models for the IGBT silicon chip, packages, and heat sinks." Ex. 1035, at 1094. *Hefner* describes a commercially available, off the shelf heat sink "the TTC1406 heatsink" used in his model. Ex. 1035, at 1094. Hefner, like Hilbert et al., discusses both "forced and natural convection heat transfer" from the heat sink. "Forced convection" is the result of using fans. Ex. 1035, at 1100.

95. These are only a few examples of the ubiquitous nature of heat sinks and power electronics. A POSITA would have recognized that the use of heat sinks and thermal sensors (such as thermocouples) to monitor and control forced cooling devices (pumps, fans, etc.) would help to maintain a safe temperature for the power electronics. Even an ordinary user of basic power semiconductor devices, such as a computer or mobile phone charger, recognizes that use of these devices generates heat which must be dissipated (allowed to cool) to prevent damage to the electronics, and that often, this heat is dissipated from the heat sinks using forced cooling methods such as fans.

## D. TURBINE GENERATORS ON FRACTURING SITES

96. A gas turbine generator (GTG) is a very well-known configuration for the production of electric energy from natural gas. As an initial matter, a generator is an electric machine that converts mechanical rotational energy into electric energy. According to Faraday's law of induction, a conductor moving inside a magnetic field generates a voltage. A generator creates voltage by rotating a coil of wires inside a magnetic field. The voltage generated is dependent on Faraday's Law:

$$Voltage = \frac{(N\Delta(BA))}{\Delta t}$$

N is the number of turns in the coil, B is the average magnetic field, A is the area of the coil (perpendicular to the magnetic field), and t is time. The rotation of the coil changes the area of the coil that is perpendicular to the magnetic field as it rotates (ΔA), generating the voltage.

97. A gas turbine operates in the same manner as a jet engine on a commercial or military aircraft. In fact, a substantial portion of gas turbine generators in use today are derived from aircraft jet engines. A gas turbine draws in air and fuel into the front end of a compression stage, which increases the pressure (and reduces the volume) of the fuel/air mixture. The compressed fuel/air mixture is then ignited, causing it to heat up and expand. The hot gases then exit the turbine through the hot section, which has turbine blades that are rotated as the hot gas expands and

exhausts. The turbine blades are attached to a shaft, which provides rotating power for both the compressor and intake sections, as well as the connected generator.

98. The first gas turbine (GT) generator installation was at the Oklahoma Gas & Electric Bell Isle Generating Station. This gas turbine generator was manufactured by GE and had a capacity of 3,500 kW. Ex. 1039 at 5. The GTG used for the Bell Isle installation was derived from a portable, locomotive gas turbine, which was also used in "early aircraft gas turbine practice." Ex. 1039, at 3. In other words, it was an aeroderivative (derived from an airplane engine) gas turbine generator. The Belle Isle turbine generator was installed in July 1949 and stayed in operation until 1980. Ex. 1039, at 4, 6. Several other GE gas turbine generators, based on the same technology as the Bell Isle GT generator, were installed across the country in the next 30 years. Ex. 1039, at 3. From 1966 to 1976 (representing a span of only 10 years of that period), GE installed 1,429 of the GT generators across the U.S. Ex. 1039, at 3.

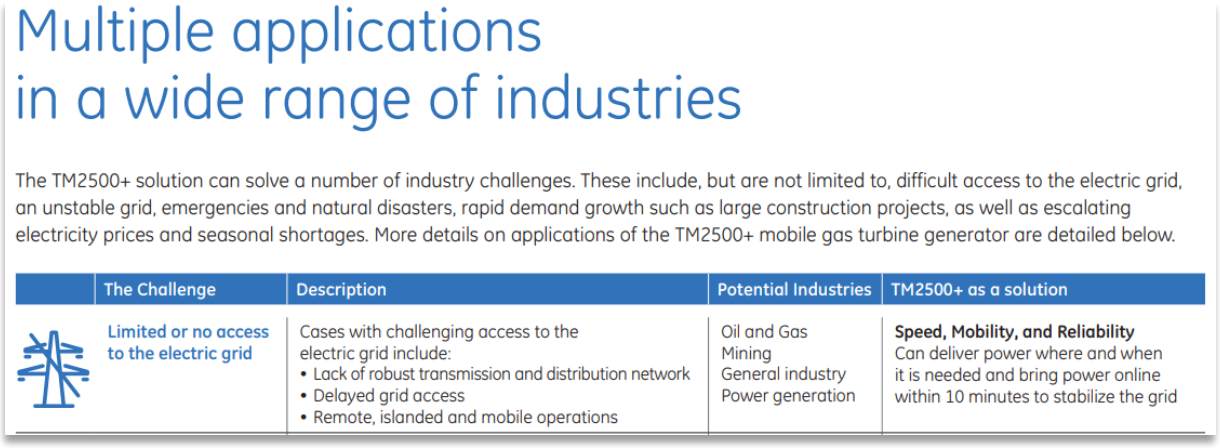
99. Another example of an early usage of a gas turbine was the Pratt & Whitney FT4 gas turbines used on the MTS *ADM Callaghan*. By 1969, these FT4 gas turbines "were replaced with the first production examples of the General Electric LM-2500 marine gas turbine. The LM-2500, a derivative of GE's CF-6 aerojet engine, has since become ubiquitous in U.S. Naval Service" Ex. 1040.

100. The LM-2500, offered by GE since at least 1969, is the land and marine (LM) version of the GE TM-2500 (Trailer-Mounted) gas turbine generator, which is also a CF-6 aeroderivative gas turbine generator. *See, e.g.*, Ex. 1037. I am very experienced with GE CF-6 aeroderivative gas turbine generator as I was chief electrical and control systems engineer for the installation of several GE LM-6000 CF-6 aeroderivative gas turbine generator systems in the early 2000s.

101. At least by July 17, 2014 (and likely much earlier in view of *Coli*, discussed below), General Electric advertised a suite of turbine generators for sale, including the TM2500+. *See* Ex. 1039; *see also* Ex. 1040. A picture of the TM2500+ from General Electric is shown below:

Ex. 1041.

102. Among the target applications for the TM2500+ turbine was generation of electricity for "Oil and Gas Mining" in areas with "Limited or no access to the electrical grid." Ex. 1041, at 2.



## Multiple applications in a wide range of industries

The TM2500+ solution can solve a number of industry challenges. These include, but are not limited to, difficult access to the electric grid, an unstable grid, emergencies and natural disasters, rapid demand growth such as large construction projects, as well as escalating electricity prices and seasonal shortages. More details on applications of the TM2500+ mobile gas turbine generator are detailed below.

| | The Challenge | Description | Potential Industries | TM2500+ as a solution |
|---|---|---|---|---|
| | Limited or no access to the electric grid | Cases with challenging access to the electric grid include:<br>• Lack of robust transmission and distribution network<br>• Delayed grid access<br>• Remote, islanded and mobile operations | Oil and Gas<br>Mining<br>General industry<br>Power generation | **Speed, Mobility, and Reliability**<br>Can deliver power where and when it is needed and bring power online within 10 minutes to stabilize the grid |

103. The use of gas turbine generators in oil and gas exploration and production operations, including fracking, was well known even before the 2014 date of the GE TM2500+ websites, and long before the priority dates of the Asserted Patent. As only one example, from 2000–2002, while employed as manager of electric infrastructure by New Dominion LLC, an exploration and production company, I investigated the use of SOLAR brand gas turbines to support drilling, exploration and production operations, including hydraulic fracturing, in central Oklahoma fields. *See, e.g.*, Ex. 1042. These fields, as is common in the E&P industry, were largely located in rural areas with very limited electrical infrastructure. The cost and time necessary for expansion of the electric infrastructure made exploration and production in some areas a very difficult

proposition. SOLAR gas turbine generators have been marketed to the oil and gas space since the 1960s. Back in 2006, SOLAR's offerings ranged from the 1,210 kW Saturn 20 to the 15MW Titan 130. Ex. 1043. "Solar Turbomachinery" was a specific remote single trailer generation design for the oil and gas industry that was introduced in 1987, and has sold over 2,000 units with more than 30 million total operating hours. Ex. 1044. The use of GTGs for oil and gas operations was well known by at least 2000, with many such uses including "mobile" or "trailer mounted" gas turbine generators, including those manufactured by Solar Turbine.

104. *Coli* was filed April 6, 2012, claiming priority to a provisional application filed on April 7, 2011. The Abstract of *Coli* states:

> The present invention provides a method and system for providing on-site electrical power to a fracturing operation, and an electrically powered fracturing system. Natural gas can be used to drive a turbine generator in the production of electrical power.

Ex. 1005, Abstract. *Coli* further states that "[a] turbine suitable for this purpose is a TM2500+ turbine generator sold by General Electric. Other generation packages could be supplied by Pratt & Whitney or Kawasaki for example. Multiple options are available for turbine power generation, depending on the amount of electricity required." Ex. 1005, [0044]. By March 2013, the technology was already deployed in the field and described in trade journals. According to Jim Bentein's article "Drying Out," published in the March 2013 volume of *Oilweek*:

> Calgary-based Evolution Well Services has developed a fracking system that relies not on diesel to fuel the massive pressure pumpers needed for big frac jobs but rather natural gas-fuelled [*sic*, fueled] electricity, offering the opportunity to eliminate diesel engines and their related emissions and help with manpower and maintenance issues.

Ex. 1036, at 24. Eldon Schelske was interviewed in the article and described that turbine generators were known technology. He explained that Evolution's "turbine can be powered with LNG or compressed natural gas [CNG], or it can use wellhead gas, which optimizes the benefits applicable to pad drilling operators, who might drill several weeks from a single location." Ex. 1036, at 25. He based the idea of using natural-gas fueled electric power from "system[s] for offshore oil and gas development." Ex. 1036, at 25. Schelske noted that the technology was already developed—he "didn't need to reinvent the wheel"—because he was able to deploy "GE's mobile TM2500 gas turbine to generate on-site power." Ex. 1036, at 25.

## IX. OVERVIEW OF THE PRIOR ART

### A. COLI (EX. 1005)

#### a. Status of Coli

105. *Coli* is a publication of a United States patent application, U.S. Patent Publication No. 2012/0255734. *Coli* is titled "Mobile, modular, electrically powered system for use in fracturing underground formations." *Coli* was filed on April 6, 2012 and published on October 11, 2012. Ex. 1005. *Coli* claims priority to Provisional Application No. 61/472,861, filed on April 7, 2011. The publication of

*Coli* as well as the claimed priority date of *Coli* thus predate the claimed priority date of the ’870 Patent.

106. A gas turbine operates in the same manner as a jet engine on a commercial or military aircraft. In fact, a substantial portion of gas turbine generators in use today are derived from aircraft jet engines. A gas turbine draws in air and fuel into the front end of a compression stage, which increases the pressure (and reduces the volume) of the fuel/air mixture. The compressed fuel/air mixture is then ignited, causing it to heat up and expand. The hot gases then exit the turbine through the hot section, which has turbine blades that are rotated as the hot gas expands and exhausts. The turbine blades are attached to a shaft, which provides rotating power for both the compressor and intake sections, as well as the connected generator.

**b. Overview of the Disclosure of Coli**

107. Like the ’870 Patent, *Coli* involves a “fracturing system” for “delivering fracturing fluid to a wellbore at a fracturing operation.” Ex. 1005, [0034]. And like the ’870 Patent, *Coli* discloses how the electrification of the fracturing operation can improve costs (Ex. 1005, [0075]), efficiency (Ex. 1005, [0077]), safety (Ex. 1005, [0066]), and environmental impact (Ex. 1005, [0080]). For example, *Coli* discloses the use of natural-gas powered turbines to generate electricity, which in turn powers electric motors for driving the pumps. Ex. 1005,

[0042]. The turbines may use natural gas that is collected on site thereby "obviating the need for a constant supply of diesel fuel to the site and reducing the site footprint and infrastructure required for the fracturing operation." Ex. 1005, [0036]; *see also* Ex. 1005, [0075]. Further, the smaller size and lighter weight of pumping modules with electric motors "allow[s] for placement of four pumps 22 in the same physical dimension (size and weight) as the spacing needed for a single pump in conventional diesel systems." Ex. 1005, [0049]. Thus, "the number of fracturing modules 20 placed on each trailer 10" is "maximized." *See* Ex. 1005, [0052].

108. *Coli* further discloses that "[t]he electric motor can be capable of operation in the range of up to 1500 rpms and up to 20,000 [ft-lbs][1] of torque." Ex. 1005, [0011]. The "[e]lectric motors [are] controlled via variable frequency

[1] The unit of torque is ft-lb, as recited in the claim. There appears to be a typographical error in *Coli* insofar as it expresses torque in ft/lbs. The proper units for torque (in the US customary system) is ft-lb. As an example, 5 ft-lb is equivalent to a force of 5 lb acting on an arm with a length of 1 ft. "Ft/lb" is a unit of mass density. As an example, 5 ft/lb would mean a rod (or other linear device) that has a mass of 0.2. lb/ft. It would take 5 feet of rod to reach a mass of 1 lb. Accordingly, I understand that "20,000 ft/lb" is a typographical error and should be read "20,000 ft-lb".

drive [and] are far safer and easier to control than conventional diesel powered equipment." Ex. 1005, [0066].

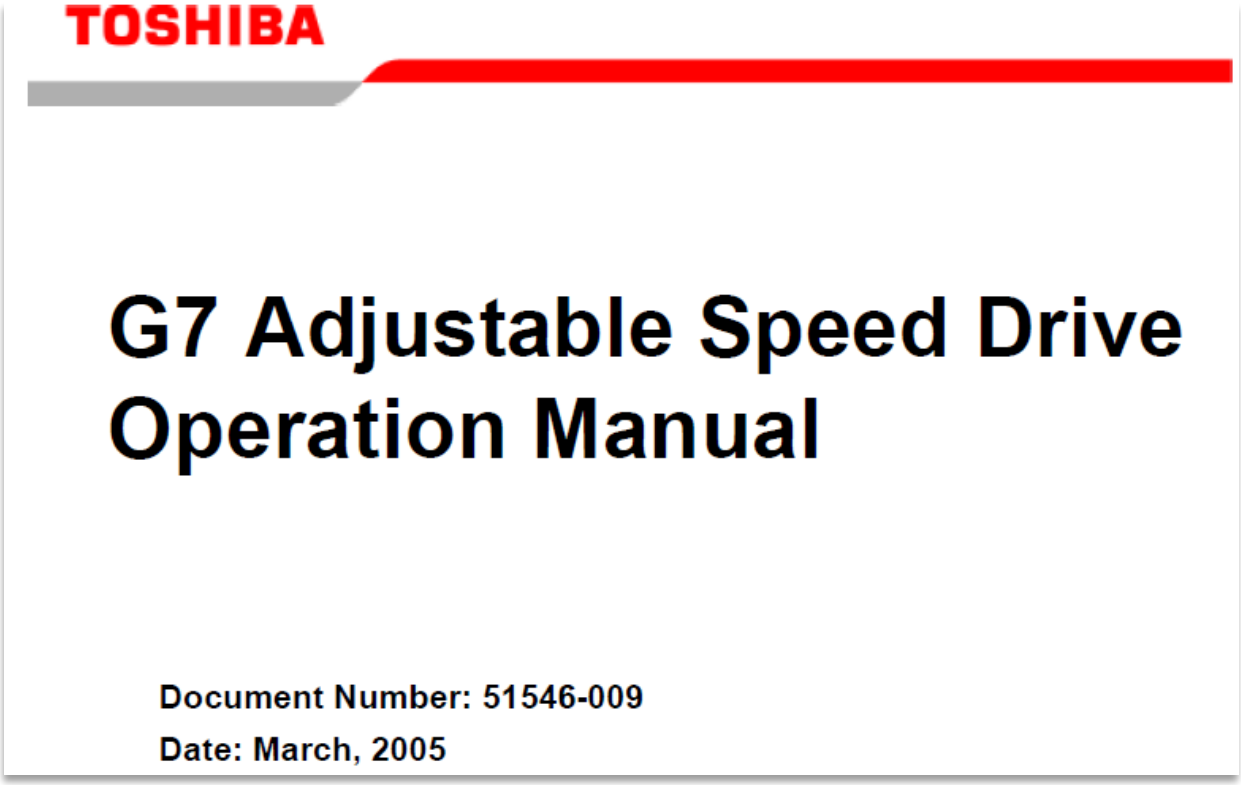
109. *Coli* expressly discloses that the pump is a triplex or quinteplex pump rated at about 2250 hydraulic horsepower or more. Specifically, *Coli* discloses "a quintiplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc.," which is a pump rated at 2500 horsepower or more. Ex. 1005, [0046]; [0049] ("[T]he present system can deliver a true 2500 hp directly to each pump 22 because pump 22 is directly coupled to electric motor 21."); [0050] ("fracturing module 20," which contains one or more pumps and electric motors, "is capable of operating at 2500 hp.").

110. Thus, in my opinion, a POSITA would have understood that *Coli* discloses an entire fracturing system, similar to the system described in the '870 Patent, that includes trailer-mounted electric pumps and motors, with associated variable frequency drives and natural-gas turbine generators.

## B. TOSHIBA MANUAL (EX. 1006)

### a. Status of Toshiba Manual

111. *Toshiba Manual* refers to "G7 Adjustable Speed Drive Operation Manual," Document No. 51546-009, published by Toshiba International Corporation **("Toshiba")** and with a copyright date on the cover of March 2005. A screenshot of the cover is shown below:


TOSHIBA

G7 Adjustable Speed Drive Operation Manual

Document Number: 51546-009
Date: March, 2005

Ex. 1006.

112. Toshiba has been a major manufacturer of electric motors and variable frequency drives and has been for decades before the Challenged Patents. Toshiba "entered the North American adjustable speed drives market in 1981 and has continued to grow the market with [its] products." Ex. 1045. Toshiba has actively marketed and participated in the Oil & Gas industry. "Toshiba's oil and gas product offerings are packages as a complete solution, increasing maximization of system uptime and mean time between failures…With extensive experience in oil and gas applications, including drilling, pumping, [and] production …, we understand your

specific applications and can provide highly reliable solutions to meet your needs." Ex. 1046.

113. Toshiba actively participated in industry organizations and activities, such as the Petroleum and Chemical Industry Committee (PCIC) of the IEEE. A POSITA would have been well aware of Toshiba's expertise and prevalence in the oil and gas market, particularly with motors and drives. A POSITA would have been motivated to look to Toshiba's products, manual, documentation and brochures for teachings on solutions to problems integrating motors and variable frequency drives.

114. One such offering was Toshiba's G7 line of drives, in particular the GX7 offering. "Toshiba's GX7 Series PWM adjustable speed drive is a severe duty drive built to handle all conventional applications in the industry, ranging from the simplest to the most complex…This drive maintains astoundingly tight control over both torque and speed with the industry's most user-friendly operator interface." Ex. 1047. *Toshiba Manual* contains information regarding operation and setup of the G7 family of drives, including the GX7. When a POSITA would access the Toshiba website to obtain the operations manual for the G7 family of drives, one would have found *Toshiba Manual*. As evidenced by the Declaration of the custodian from Internet Archive, *Toshiba Manual* was publicly accessible from the Toshiba website by at least December 7, 2010, corresponding to the date it was archived by the

WayBack Machine of Internet Archive. Ex. 1007 at 1, 25 (describing Ex. 1006, *Toshiba Manual*).

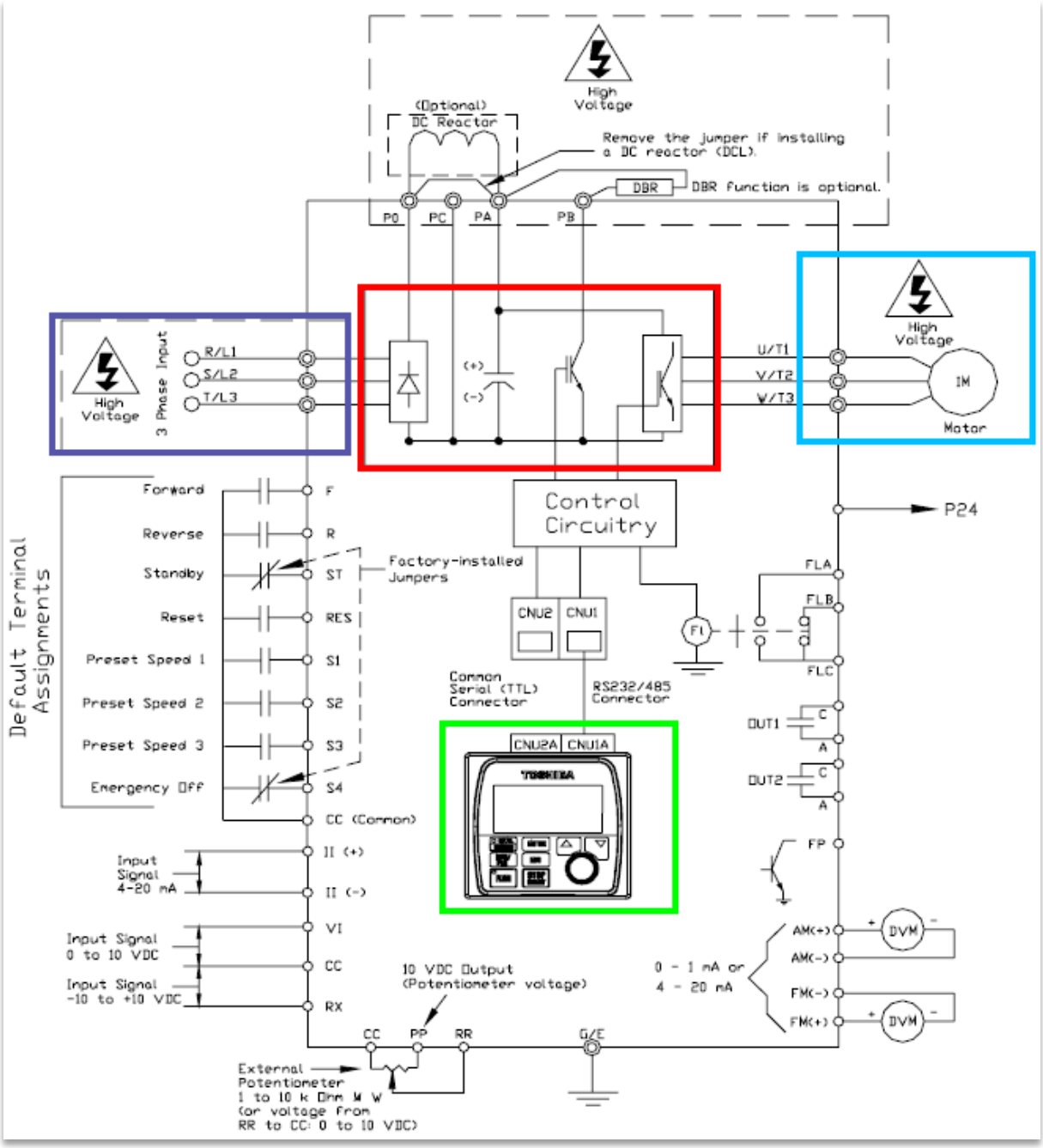
**b. Overview of the Disclosure of Toshiba Manual**

**i. *Variable Frequency Drive***

115. *Toshiba Manual* contains a description of a VFD. The title of *Toshiba Manual* is "G7 Adjustable Speed Drive Operation Manual." As discussed in Section VIII.A., "a Variable Frequency Drive (VFD) is another term for an Adjustable Speed Drive (ASD)." Further, *Toshiba Manual* describes that the VFD "uses a sinusoidal Pulse Width Modulation (PWM) control system. The output current waveform generated by the ASD approaches that of a perfect sine wave …." Ex. 1006 at 19. Insulated Gate Bipolar Transistors (IGBTs) are used for the power electronics in *Toshiba Manual.* Ex. 1006 at 145, 180, 183, 207, 209, 211.

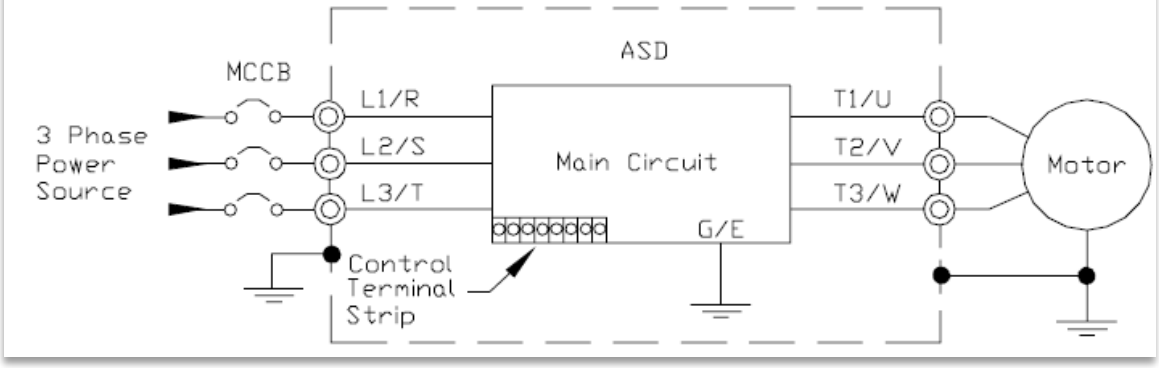
116. *Toshiba Manual* provides a schematic, showing the components of a quintessential VFD, including: "3 Phase Input" of electricity (purple box); an AC/DC/AC converter (including a rectifier circuit and inverter circuit) to convert fixed-frequency input AC electricity to DC and then to variable-frequency AC (red box); and output of that converted AC electricity to an electric motor (blue box). I described such components in Section VIII.A. Also shown is an Electronic Operator Interface ("EOI") (green box) that provides input to control circuitry for the VFD, as well as displaying the operational status of the VFD and associated equipment,

including the motor. Ex. 1006. at 36 (Fig. 18, "typical connection diagram") (annotated below).

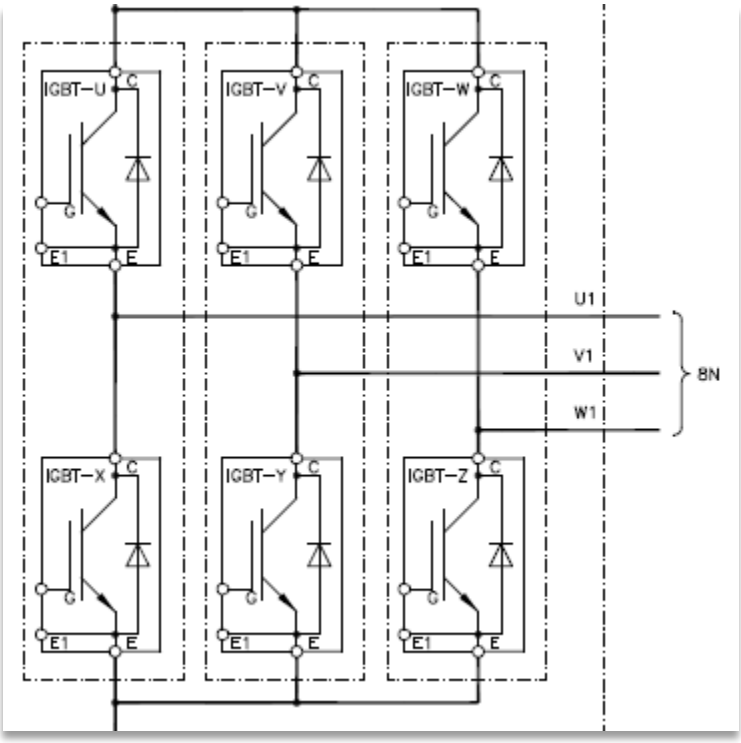


*Toshiba Manual* shows the inverter circuit using Insulated Gate Bipolar Transistors (IGBTs), the same type of inverter circuit shown in *Horikoshi*. *Toshiba Manual* also shows a figure for connecting the VFD (ASD) to the electric motor:

Figure 4. ASD/Motor connection diagram.




Ex. 1006 at 26. The Toshiba website published schematics of the power electronics to accompany *Toshiba Manual*, and they confirm the presence of an IGBT output converter using the same configuration as in *Horikoshi*.




Ex. 1007 (Internet Archive Declaration) p. 254. *Toshiba Manual* is directed toward the same ASD/VFD topology described in *Horikoshi.*

### ii. ***Performing Electric Motor Diagnostics***

117. *Toshiba Manual* discloses numerous examples of electric motor diagnostics. *Toshiba Manual* expressly discloses that the Electronic Operator Interface (EOI) (a touchscreen interface, shown in green above) "may be used to monitor system functions, input data into the system, or ***perform diagnostics***." Ex. 1006 at 43. The diagnostics includes a "fault screen" that "identifies the active Fault." Ex. 1006 at 182–186 (Table 12, containing a list of 5 pages of faults that are diagnosed). Examples of motor diagnostics used to protect the connected motor disclosed in *Toshiba Manual* include:

- Overload protection (Ex. 1006 at 19)
- Over-current protection (Ex. 1006 at 22)
- Electronic Thermal Protection (Ex. 1006 at 160)
- Overcurrent Stall Level (Ex. 1006 at 160)
- Motor 150% OL Time Limit (Ex. 1006 at 161)
- Short Circuit Test (Ex. 1006 at 162)
- Over-torque trip (Ex. 1006 at 163)
- Earth Fault Trip (Ex. 1006 at 166)

These diagnostic functions result in an alarm or trip condition on the ASD. *Toshiba Manual* describes alarms and trips:

> If a user setting or an ASD parameter has been exceeded, or if a data transfer function produces an unexpected result, a condition that is referred to as a **Fault** is incurred.
>
> An **Alarm** is an indication that a **Fault** is imminent if existing operating conditions continue unchanged. …
>
> In the event that the condition that caused the Alarm does not return to its normal operating level within a specified time, the ASD Faults and a Trip is incurred (Fault and Trip are sometimes used interchangeably). A Trip is a safety feature, and is the result of a Fault, that disables the ASD system in the event that a subsystem of the ASD is malfunctioning, or one or more of the variables listed below exceeds its normal range (time and/or magnitude).
>
> - Current,
> - Voltage,

- Speed,
- Temperature,
- Torque, or
- Load.

Ex. 1006, at 179.

118. As discussed above, certain diagnostic actions result in a trip. Table 12 from Ex. 1006 shows several trip conditions and possible causes. Included in this table as it relates to preventing damage to an electric motor are the following:

| Fault Screen Display | Possible Causes |
|---|---|
| Earth Fault | Ground Fault at the motor |
| Load Drooping | Load requirement is in excess of the capabilities of the motor |
| Motor Overload | Motor is locked<br>Load requirement exceeds ability of the motor<br>Continuous operation at low speed |
| Overcurrent During Acceleration | Accel time too short<br>Motor/machine jammed<br>Mechanical brake engaged while the ASD is running |
| Overcurrent During Deceleration | Motor / machine jammed<br>Mechanical brake engaged while the ASD is running |
| Overtorque | A torque requirement by the load in excess of the setting of the motor (specific settings) |
| U phase Short Circuit | Low impedance at the U lead of the ASD output (at the motor or in cable to motor) |
| V phase Short Circuit | Low impedance at the V lead of the ASD output (at the motor or in cable to motor) |
| W phase Short Circuit | Low impedance at the W lead of the ASD output (at the motor or in cable to motor) |

Ex. 1006, at 82–84 (Table 12).

119. The majority of the diagnostics that would result in a trip of the drive to protect the motor are conducted on a continuous basis as the motor is being run. Some diagnostics, such as the "Short Circuit Test," are specifically conducted "every run" or "every power up" (Ex. 1006, at 162), which meets the definition of frequently, as used in this proceeding.

### iii. *Thermal Monitoring Heat Sinks*

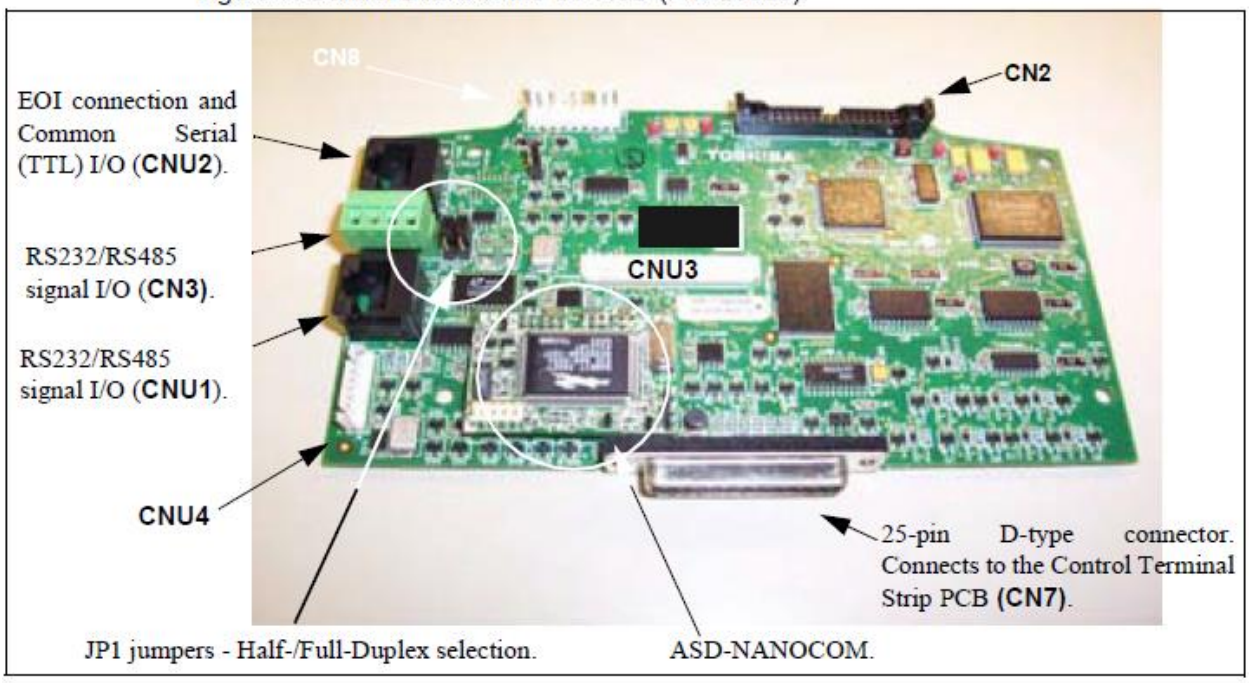
120. As discussed above, *Toshiba Manual* discloses a VFD with a rectifier circuit and an inverter circuit (AC-DC-AC converter) to convert fixed-frequency input electricity to DC and then to constant-frequency AC. Ex. 1006 at 36. The inverter and rectifiers are examples of "power semiconductors." *Toshiba Manual* discloses that the VFD contains heat sinks: "The heat sink and other components may become extremely hot to the touch." Ex. 1006, at 14; *see also* at Ex. 1006 at 204 ("cooling capacity of the heatsink").[2]

121. A POSITA would understand that an ASD, in particular an ASD that switches several thousand times a second such as a PWM drive, requires control and

[2] Photographs of the heat sinks are shown in the brochure accompanying the *Toshiba Manual*. The Heat sinks are located so as to dissipate heat "out-the-back" of the cabinet of the VFD, which also includes a "Long Life 1200 cfm Front-Removable Heatsink Fan." Ex. 1007, at p. 20.

processing by a microprocessor. Further such communication functions as "RS232/RS485" and "Modbus, Profibus, or DeviceNet" all require microprocessor control. Ex. 1006, at 33, 206. Several such microprocessors are contained on the control board of the ASD, as shown in the photograph below:

Figure 7. Control Board of the **G7 ASD** (P/N 56000).




Ex. 1006 at 32 (Figure 7).

122. The heat sink has thermal monitors that are monitored by the microprocessor of the ASD. For example, one of the alarms displayed on the EOI is "*OH" which refers to "Overheat," which is when the "ASD ambient temperature is excessive." Ex. 1006, at 2, 42–43, 180. The "Overheat" error can occur if the "ASD is operating at an elevated temperature," if the "Cooling fan vent is obstructed," or if the "Internal thermistor is disconnected." Ex. 1006 at 180; *see* Ex.

1006, at 185 (overheat); Ex. 1006, at 163 ("cooling fan control"). To detect an "elevated temperature," the Toshiba VFD is being monitored by temperature sensors. The temperature sensors include an "internal thermistor." Ex. 1006, at 180, 185. The temperature of the VFD is controlled by cooling fans blowing air over the heat sinks, and the cooling fans and temperature is controlled by a microprocessor. One of the settings in the CPU (microprocessor) is for "Cooling Fan Control," which can be set to "Automatic" or "Always on." Ex. 1006, at 163. In order for the CPU to control the cooling fans of the VFD in "automatic" mode, it would be necessary to have temperature data supplied to the microprocessor so it could determine when to turn the fans on (supply additional cooling) or off (conserve energy when not needed). A POSITA would further understand that in order to protect against overheat, the heatsink would necessarily have sensors which would report temperature data to the CPU (microprocessor). By performing a "protective function" of "heatsink overheat," *Toshiba Manual* is disclosing that the purpose of the heatsink, and the monitoring of the heat sink by temperature sensors connected to the CPU, is to prevent damage cause by excessive heat.

123. Further, "Overheat" is listed as an alarm popup on the EOI, which is controlled by, and provides control input to, the CPU. A POSITA would understand that the heatsink is the main heat dissipating device in the ASD cabinet. An overheat

condition would, therefore, be based on heatsink temperature as well as ambient temperature.

124. Based on the totality of the above description from the *Toshiba Manual*, as well as general engineering knowledge regarding the operation of ASDs, power semiconductors (IGBTs), heat sinks, CPUs and control interfaces, *Toshiba Manual* discloses a power semiconductor heatsink having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat.

### C. HORIKOSHI (EX. 1008)

#### a. Status of Horikoshi

125. *Horikoshi* is a publication of a United States patent application, U.S. Patent Publication No. 2011/0241590. *Horikoshi* is titled "Motor driving apparatus having fault diagnostic function." *Horikoshi* was filed on February 11, 2011 and published on October 6, 2011. Ex. 1008, 1. The publication of *Horikoshi* as well as the claimed priority date of *Horikoshi* predate the claimed priority date of the '870 Patent.

#### b. Overview of the Disclosure of *Horikoshi*

126. *Horikoshi* is directed to the configuration and use of a "motor driving apparatus having a fault diagnostic function." Ex. 1008, [0008]. Specifically, *Horikoshi* is directed to a variable frequency drive ("VFD") that is "capable of

detecting during operation a ground fault and a phase-to-phase short circuit." Ex. 1008, [0011], [0027].

127. *Horikoshi* teaches a method applicable to ASDs/VFDs as a motor driving apparatus that converts AC three phase power to DC and then coverts the DC power to AC for supply to a motor. Ex. 1008. POSITA would have no difficulty in understanding that *Horikoshi* describes an ASD (VFD).

128. Further, in my opinion, *Horikoshi* is in a field of art—variable frequency drives—that is highly relevant to the '870 Patent, which describes the use of variable frequency drives to control electric-motor driven pumps and a POSITA would have understood that *Horikoshi* addresses the potential problem of damage to the motors due to shorting or grounding.

129. *Horikoshi* teaches a system that monitors and performs fault diagnostic functions "during operation." Specifically, *Horikoshi* teaches the use of a "motor driving apparatus" that includes an "AC/DC converter 18 [that] converts three-phase AC power" into DC power, and an associated "DC/AC converter 10 [that] converts the DC power … into frequency variable three-phase AC power for output." *See generally* Ex. 1008; *see also* Ex. 1008, [0027]. The apparatus further includes "[c]urrent sensors" to detect current output from the DC/AC converter 10 to an electric motor. Ex. 1008, [0028]. The current sensors may be used to detect "overcurrent" associated with "the insulation resistance of the motor" connected to

the drive apparatus. Ex. 1008, [0004], [0006]. The "overcurrent" can be caused by a "ground fault or a phase-to-phase short circuit." Ex. 1008. Thus, in my opinion, a POSITA would have understood that *Horikoshi* discloses a variable frequency drive with diagnostic capabilities that performs the diagnostics to identify ground or short circuit conditions and prevent any subsequent damage to the motor.

### D. LOUCKS (EX. 1009)

#### a. Status of Loucks

130. *Loucks* is a publication of a United States patent application, U.S. Patent Publication No. 2010/0312415. *Loucks* is titled "Electrical Device Cooling Efficiency Monitoring." *Loucks* was filed on June 4, 2009 and published on Dec 9, 2010. Ex. 1009, 1. The publication date of *Loucks* thus predates the claimed priority date of the '870 Patent.

#### b. Overview of the Disclosure of Loucks

131. *Loucks* is directed toward a method of determining "cooling efficiency" for "a monitored electrical device" based on several factors. These factors comprise "input electrical power to the monitored electrical device and a temperature differential across the monitored electrical device. A monitored electrical device temperature and an ambient temperature proximate the monitored electrical device are determined to compute a temperature differential." Ex. 1009, [0005]

132. *Loucks* teaches that the cooling calculations are applied to various electrical equipment including "transformers, circuit breakers, uninterruptible power supplies (UPSs) or variable frequency drive." These pieces of electrical equipment are examples in which "a certain percentage of energy consumed is converted into heat." Ex. 1009, [0036]. *Loucks*' method "detects changes in cooling performance" in order to prevent "electrical equipment malfunction or accelerated degradation" and "equipment damage" due to "overheated equipment." Ex. 1009, [0004], [0018], [0003]. *Loucks* teaches that because "electrical or electronic equipment can malfunction due to over-temperature, detecting these [temperature] problems is important." This is particularly true "for a variable loaded system." *See* Ex. 1009, [0018]. If temperature problems are not detected in a timely manner, "equipment damage [may] occur[] in the time it takes to resolve the cooling problem." Ex. 1009, [0018]. Accordingly, in my opinion, a POSITA would have understood that *Loucks* teaches a method for preventing damage to electrical equipment due to overheat.

133. *Loucks*' method is performed using "[c]omputer-readable medium having computer-executable instructions for performing a cooling efficiency monitoring method." Ex 1009, Claim 1. This "cooling efficiency monitoring system 500" comprises "multiple temperature sensors" including "a power electronics heat sink temperature sensor 510." Ex 1009, [0063]; *see* Ex. 1009, Fig. 5. These sensors provide "data 716" which is collected by "computer 700" which comprises

"processor 702 [which] may be a variety of various processors including dual microprocessor or other multi-processor architectures." Ex. 1009, [0072]. *Louks* teaches that "the cooling efficiency logic 730 could be implemented in the processor 702." Ex. 1009, [0066].

### E. VLIET (EX. 1010)

#### a. Status of Vliet

134. *Vliet* is a publication of a United States patent application, U.S. Patent Publication No. 2011/0197988. *Vliet* is titled "Fuel Delivery System and Method." *Vliet* was filed on February 16, 2011 and published on August 18, 2011. *See* Ex. 1010, 1. The publication date and the claimed priority date of *Vliet* predate the claimed priority date of the '870 Patent.

#### b. Overview of the Disclosure of Vliet

135. *Vliet* discloses a "fuel delivery system for delivery of fuel to fuel tanks of equipment at a well site during fracturing" and acknowledges that "[f]or use at different well sites, the fuel delivery system should be portable and transportable to various well sites." Ex. 1010, [0014], [0003]. *Vliet* further discloses that the "pumps" and "electrical equipment" are on a trailer and "are supplied with power from a conventional generator or *generators* (not shown), *which may conveniently be mounted on the trailer*." Ex. 1010, [0027] (emphasis added).

136. *Vliet* further discloses that the "spatial orientation" of the components, including generators, is a matter of design choice for the manufacturer and will depend on space requirements." Ex. 1010, [0027].

137. Thus, in my opinion, a POSITA would have understood that *Vliet* discloses a system in which "the generator[s] are mounted on" the same trailer or truck on which the pumps and electrical equipment are mounted, "and can be ported from one well to another."

## F. GARDNER (EX. 1011)

### a. Status of Gardner

138. *Gardner* is an operating and service manual for Gardner Denver's GD-2500Q Quintuplex pump (300FWF996 Rev C) that was published in August 2005. Ex. 1011, 1. I also understand that per Internet Archives, *Gardner* was publicly available on the internet at least as of September 2012. The publication date of *Gardner* and its public availability date thus predate the claimed priority date of the '870 Patent.

**b. Overview of the Disclosure of Gardner**

139. *Gardner*'s "SWGS-2500"[3] pump is expressly cited in *Coli* as an example of a suitable "quintiplex or triplex plunger style pump" that can be coupled to an electric motor and used in a fracturing module. Ex. 1005, [0046]. A POSITA would have understood that the "SWGS-2500 quintuplex pump" disclosed by *Coli* refers to a Gardner Denver GD-2500Q pump end coupled with a Gardner Denver SGWS fluid end.

140. *Gardner* discloses that the GD-2500Q is a quintuplex pump with a "Stroke Length" of "8.0 inches," and a "plunger size" (diameter) of "3.75, 4, 4.5, 5, 5,5, 5.75, 6, 6.5, [or] 6.75" inches. Ex. 1011, at 14. In addition, *Gardner* discloses that the input power to the pump, which is the same as the output power of the electric motor coupled to the pump, is 2200 to 2500 bhp. Ex. 1011. *Gardner* also discloses that the pump is rated at 2500 bhp. Ex. 1011, at 20.

141. A POSITA would have understood that horsepower ratings for pumps can be provided either as an input or an output horsepower. Input horsepower (sometimes referred to as brake horsepower) is the amount of power that must be delivered to the shaft in order for the pump to operate according to the pressure/flow

[3] A POSITA would have understood that "SWGS-2500" mentioned in *Coli* is a typographical error, and it refers to "SGWS-2500"—i.e., Super Gardner Well Services-2500.

rate specified. Output horsepower (sometimes referred to as hydraulic horsepower) is the amount of power delivered to the fluid that is being pumped and is often specified as a pressure (PSI) and a flowrate (GPM). Power (horsepower) is directly proportional to the pressure * flowrate. A POSITA would have understood that, in English units, the following equation yields the hydraulic horsepower.

$$Hp\ (hydraulic) = \frac{pressure\ (psi)\ *\ flowrate\ (GPM)}{1714}$$

Ex. 1018 (Mark's Standard Handbook for Mechanical Engineers), 14-13, 14-14.

142. As shown below, *Gardner* provides input (brake) horsepower for GD-2500Q:

| 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. 1011, 14.

143. Based on this table and the equation above, a POSITA would have understood that the output (hydraulic) horsepower of GD-2500Q is as follows:

| | | Displacement at Pump RPM - Well Stimulation and Intermittent Application | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plunger Dia | Disp per Rev | 100 | | | 150 | | | 250 | | | 330 | | |
| in | Gal/rev | GPM | PSI | Output Power (Hp) | GPM | PSI | Output Power (Hp) | GPM | PSI | Output Power (Hp) | GPM | PSI | Output Power (Hp) |
| 3.75 | 1.91 | 191 | 17800 | 1984 | 287 | 13500 | 2261 | 478 | 8100 | 2259 | 631 | 6100 | 2246 |
| 4 | 2.17 | 217 | 15600 | 1975 | 326 | 11800 | 2244 | 544 | 7100 | 2253 | 718 | 5400 | 2262 |
| 4.5 | 2.75 | 275 | 12400 | 1989 | 413 | 9300 | 2241 | 688 | 5600 | 2248 | 908 | 4200 | 2225 |
| 5 | 3.4 | 340 | 1000 | 198 | 510 | 7600 | 2261 | 850 | 4500 | 2232 | 1121 | 3400 | 2224 |
| 5.5 | 4.11 | 411 | 8300 | 1990 | 617 | 6300 | 2268 | 1028 | 3800 | 2279 | 1357 | 2800 | 2217 |
| 5.75 | 4.49 | 449 | 7600 | 1991 | 674 | 5700 | 2241 | 1124 | 3400 | 2230 | 1483 | 2600 | 2250 |
| 6 | 4.89 | 489 | 6900 | 1969 | 734 | 5300 | 2270 | 1223 | 3200 | 2283 | 1615 | 2400 | 2261 |
| 6.5 | 5.74 | 574 | 5900 | 1976 | 861 | 4500 | 2261 | 1436 | 2700 | 2262 | 1895 | 2000 | 2211 |
| 6.75 | 6.19 | 619 | 5500 | 1986 | 929 | 4200 | 2276 | 1548 | 2500 | 2258 | 2044 | 1900 | 2266 |
| Input Power | | 2200 | | | 2500 | | | 2500 | | | 2500 | | |

144. A POSITA would have known that the output (hydraulic) horsepower rating of a pump corresponds to the maximum power that the pump can output using any given plunger diameter. Accordingly, a POSITA would have understood that *Gardner's* pump is rated <u>*about*</u> *2250 hydraulic horsepower or more.* For instance, with a 6-inch plunger diameter, the maximum output (hydraulic) horsepower of *Gardner's* pump is 2283 hp. Similarly, with a 4.5-inch plunger diameter, the maximum output (hydraulic) horsepower of Gardner's pump is 2248 hp. Accordingly, a POSITA would have understood that Gardner's pump is rated at about 2250 hydraulic horsepower.

145. A POSITA would have, therefore, understood that a pump that has a brake horsepower rating of 2500 is a "pump rated at about 2250 (hydraulic) horsepower or more," as recited in claim 14.

146. In addition, a POSITA would have understood that *Gardner* discloses a plunger-type quintuplex pump for fracturing operations that includes an 8-inch stroke, 4.5-inch diameter plungers, and is rated at about 2250 (hydraulic) horsepower or more. Relatedly, a POSITA would have understood an electric motor coupled to the Gardner pump would be equipped to provide a maximum continuous power output of more than 1750 horsepower.

## X. GROUND 1: CLAIMS 1-16 ARE OBVIOUS OVER COLI IN VIEW OF TOSHIBA MANUAL

147. It is my opinion that *Coli* in view of *Toshiba Manual* discloses and/or suggests all limitations of Claims 1-16, and thus renders those claims obvious.

### A. REASONS TO COMBINE COLI AND TOSHIBA MANUAL

148. *Coli* discloses how the electrification of a traditional fracturing operation can provide a number of benefits including improving costs (Ex. 1005, [0075]), efficiency (Ex. 1005, [0077]), safety (Ex. 1005, [0066]), and environmental impact (Ex. 1005, [0080]). 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." Ex. 1005, [0066].

149. *Coli* discloses the need for "variable frequency drives," which are used to "essentially 'tell' the motors what they are allowed to do." Ex. 1005, [0065]. *Coli* further discloses the necessity for monitoring VFD and motor operations. Ex. 1005,

[0066]. *Coli* explains that because "electric motors are controlled by variable frequency drives . . . the control software and variable frequency drives ["VFD"] calculate a maximum current available to the motors." Ex. 1005, [0065]. *Toshiba Manual* discloses further details about these features described by *Coli*. *See* Ex. 1006.

150. *Toshiba Manual*, entitled "G7 Adjustable Speed Drive Operation Manual," contains a description and details regarding the functionality, and schematics of a quintessential VFD. Ex. 1006. *Toshiba Manual* provides numerous examples of electric motor diagnostics, including overload protection, over-current protection, electronic thermal protection, overheat, overcurrent stall level, motor 150% OL time limit, short circuit test, over-torque trip, and earth fault trip. Ex. 1006 at 19, 22, 160, 161, 162, 163, 166, 180. The diagnostics further includes a "fault screen" that "identifies the active Fault." Ex. 1006 at 182-186 (Table 12). *Toshiba Manual* further discloses the use of alarms to indicate that "a Fault is imminent if existing operating conditions continue unchanged." Ex. 1006 at 179.

151. *Toshiba Manual* also discloses that its VFD includes a rectifier circuit and an inverter circuit (AC-DC-AC converter) to convert fixed-frequency input electricity to DC and then to constant-frequency AC. Ex. 1006 at 36. A POSITA would understand that the inverters and rectifiers are examples of power semiconductors. Specifically, *Toshiba Manual* discloses the use of insulated gate

bipolar transistors (IGBTs). Ex. 1006 at 36, 145, 180, 183, 207, 209, 211. *Toshiba Manual* further discloses that its VFD contains heat sinks, which "may become extremely hot to the touch." Ex. 1006 at 14. To detect an "elevated temperature" of the VFD, an "[i]nternal thermistor" (i.e., "thermal sensor") monitors the temperature. Ex. 1006 at 180, 184-185. *Toshiba Manual* further teaches the use of cooling fans in order to protect against "overheat," which is controlled by a CPU (i.e., a "microprocessor"). Ex. 1006 at 58, 163, 174, 185, 204.

**a. Motivation to Combine**

152. A POSITA would have been motivated to use a Toshiba VFD as the variable frequency drive in *Coli*, or to enhance the *Coli* VFD with the features taught by *Toshiba Manual*.

153. A POSITA would have been motivated to combine *Toshiba Manual* with *Coli* for *Toshiba Manual's* express disclosure of VFD control and monitoring of parameters of the electric motor in *Coli*, such as current, voltage, speed, temperature, torque, and load, and use the diagnostic functionality of *Toshiba Manual* (e.g., the alarms and fault trips) in order to prevent damage to the electric motor. Ex. 1006 at 179; *see* Ex. 1006 at 182-85 (Table 12, listing trips from diagnostics). The results of the combination would have been predictable and obvious to a POSITA.

154. Furthermore, a POSITA would have been motivated to combine *Toshiba Manual* with *Coli* to include the power semiconductor heat sinks having thermal sensors in order to prevent overheating of the IGBT power electronics. The results of the combination would have been predictable and obvious to a POSITA.

155. In my opinion, a POSITA would have been motivated to simply substitute the VFD of *Coli* for the VFD of *Toshiba Manual* that has the diagnostic functionality and temperature monitoring to prevent damage, without affecting the other functionalities of *Coli*.

156. Alternatively, a POSITA would have been motivated to enhance the VFD of *Coli* with the diagnostic and temperature monitoring/protection functionality of *Toshiba Manual* because such an improvement represents the mere application of a known technique (i.e., the fault detection and temperature monitoring/protection including heat sinks of *Toshiba Manual*) to predictably improve a similar system (i.e., the VFD of *Coli*) in the same way.

**b. Reasonable Expectation of Success**

157. A POSITA would have had a reasonable expectation of success in combining *Coli* with *Toshiba Manual* because VFD technology was well-known before the ’870 Patent. As one example, *Toshiba Manual* dates back to 2005 (*see* Ex. 1006) and expressly teaches basic features that a POSITA would have already implemented in *Coli*.

158. In my opinion, a POSITA would have had a reasonable expectation of success in of combining *Coli* and *Toshiba Manual* by substituting the VFD of *Coli* for the VFD of *Toshiba Manual* because the combination involves the simple substitution of one known element for another to obtain a predictable result. Alternatively, a POSITA would have had a reasonable expectation of success in enhancing the VFD of *Coli* with the diagnostic and temperature monitoring/protection functionality of *Toshiba Manual* because the combination involves a mere application of a known technique to predictably improve a similar system. The results of the combination would have been predictable and obvious to a POSITA.

## B. DISCLOSURE OF COLI IN VIEW OF TOSHIBA MANUAL

### a. Independent Claim 1

#### i. *Claim 1 (preamble): "A system for hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the system comprising:"*

159. To the extent the preamble is limiting, *Coli* discloses a "system for hydraulically fracturing an underground formation in an oil or gas well" through its description of a "system and method for hydraulic stimulation of underground hydrocarbon-bearing formations." Ex. 1005, [0009]. The "hydraulic stimulation" in *Coli* includes "fracturing operations" in which "pressurized fluid" is delivered to

a wellbore. Ex. 1005, [0006], [0013]. One wellbore described in *Coli* is a "single horizontal wellbore in a tight natural gas formation." Ex. 1005, [0006]. I further understand that the Board found a substantially similar preamble of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 20-21. Accordingly, *Coli* discloses the preamble.

**ii. *Claim 1(a): "a trailer for attachment to a truck;"***

160. *Coli* discloses a "fracturing operation [that] includes one or more trailers 10, each housing one or more fracturing modules 20." Ex. 1005, [0038]. *Coli* explains that while traditional fracturing infrastructure includes fluid pumps "housed on a dedicated truck and trailer configuration," *i.e.*, "[e]ach trailer 5 is attached to a truck 6," *Coli's* improved fracturing system "requires significantly less infrastructure" because each trailer 10 "does not need a *dedicated* truck 6." Ex. 1005, [0007], [0037], [0039] (emphasis added). Accordingly, a POSITA would have understood that each trailer 10 is "for attachment to a truck" when needed to be moved or transported. In my understanding, *Coli* discloses this limitation.

161. In my opinion, a POSITA would have understood that the use of trucks to transport trailers to and from oil and gas well sites has been well-known for decades long before the '870 Patent.

### iii. *Claim 1(b): "two or more pumps attached to the trailer and fluidly connected to the well, the pumps configured to pump fluid into the wellbore;"*

162. *Coli* discloses a "trailer 10 for housing one or more fracturing modules 20," where "[e]ach fracturing module 20 can include an electric motor 21 and a fluid pump 22 coupled thereto." Ex. 1005, [0040]. Fracturing modules 20 are "removably mounted to a trailer 10 to facilitate ease of replacement as necessary." *Id.*, [0040]. As shown below in Figure 3 of *Coli*, in one embodiment, "four electric motors 21 and pumps 22 are transported on a single trailer 10."

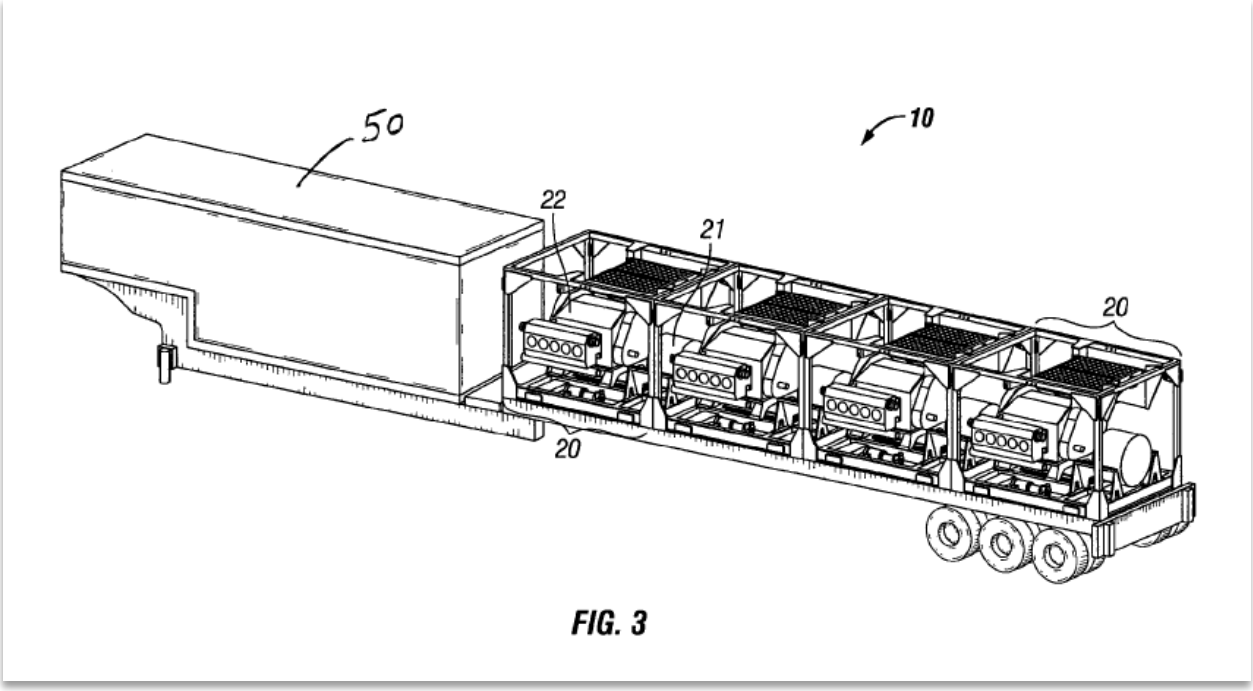



FIG. 3

*Id.*, Fig. 3. *Coli* teaches that the fracturing modules 20 (i.e., the electric motor 21 and fluid pump 22) "utilize electric power ... to pump the fracturing fluid directly to the wellbore." *Id.*, [0040]. I further understand that the Board found a substantially

similar claim element of the ’601 Patent to be disclosed by *Coli*. Ex. 1048 at 21-23. Accordingly, *Coli* discloses claim 1[b].

#### iv. *Claim 1(c): “one or more electric motors attached to the pumps to drive the pumps, the electric motors attached to the trailer;” and*

163. In my understanding, *Coli* discloses “one or more electric motors attached to pumps to drive the pumps” through its description of “one or more fracturing modules 20,” each containing an “electric motor 21” and a “pump 22” that “utilize electric power…to pump the fracturing fluid directly into the wellbore.” Ex. 1005, [0040].

164. *Coli* further discloses that the “one or more fracturing modules 20” are removably mounted to a trailer 10 (i.e., “the electric motors attached to the trailer”). Ex. 1005. A POSITA would, therefore, have understood *Coli* to disclose “electric motors attached to the pumps to drive the pumps” with the electric motors housed on a trailer. I understand that the Board found a substantially similar claim element of the ’601 Patent to be disclosed by *Coli*. Ex. 1048 at 21-23. Thus, *Coli* discloses this limitation.

**v. *Claim 1(d): "a variable frequency drive connected to the electric motor to control the speed of the motor, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the one or more electric motors."***

165. *Coli* discloses that "[t]ypically, each fracturing module 20 will be associated with a drive housing for controlling electric motor 21 and pumps 22, as well as an electrical transformer and drive unit 50." Ex. 1005, [0047]. *Coli* specifically teaches the use of a "variable speed motor" within the fracturing module 20, and further teaches that the electric motors used in the system are "controlled by variable frequency drives" that "essentially 'tell' the motors what they are allowed to do." Ex. 1005, [0011], [0065]. A POSITA would have understood these descriptions to disclose "a variable frequency drive connected to the electric motor to control the speed of the motor." I further understand that the Board found a substantially similar claim element of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 23-29.

166. As discussed above, *Toshiba Manual* likewise discloses an "Adjustable Speed Drive" or VFD used to control the speed of a motor. Ex. 1006 at 2. *Toshiba Manual* further discloses operating a VFD with the ability to "perform diagnostics." Ex. 1006 at 43. The diagnostics includes a "fault screen" that "identifies the active Fault." Ex. 1006 at 182–186 (Table 12, containing a list of 5 pages of faults that are diagnosed). *Toshiba Manual* further discloses a variable frequency drive that

performs electric motor diagnostics to prevent damage to the electric motor, including protecting against overload, overcurrent, overtorque, short circuit, and earth faults. *Toshiba Manual* further explains that its VFD controls a motor that, in turn, may power a pump. *See* Ex. 1006. at 13 ("[t]he output terminals of the ASD . . . must be connected to the motor that is to be controlled"); Ex. 1006 at 71 ((describing prevention of "motor overload trips when used on fans, blowers, pumps, and other centrifugal loads which require less torque at lower frequencies").

167. In my opinion, it would have been obvious to a POSITA to use the *Toshiba Manual* VFD as the VFD in *Coli* to provide additional diagnostic capability of the VFD and prevent the various types of damage disclosed in *Toshiba Manual* (i.e., a VFD "connected to the electric motor . . . wherein the [VFD] performs electric motor diagnostics to prevent damage to the one or more electric motors."). *See supra* Section X.A; Ex. 1001, 7:58-61.

168. Alternatively, it would have been obvious to a POSITA to enhance *Coli's* VFD with the diagnostic functionality expressly taught by *Toshiba Manual*.

**b. <u>Dependent Claims 2-3</u>**

**i. *Claim 2: "The system of claim 1, further comprising: a skid to which at least one of the pumps and the one or more electric motors are attached."***

169. *Coli* discloses that "pumping systems are typically mobilized on skids or tractor-trailers." Ex. 1005, [0005]; [0040]; [0082]. *Coli* further discloses a "trailer

10 for housing one or more fracturing modules 20," wherein "[t]railer 10 can also be a skid." Ex. 1005, [0040]. In addition, *Coli* discloses that "each fracturing module 20 will be associated with a drive housing for controlling electric motor 21 and pumps 22, as well as an electrical transformer and drive unit 50 (see FIG. 3)." Ex. 1005, [0047].

170. Accordingly, a POSITA would have understood that *Coli* teaches "a skid to which at least one of the electric pumps and the one or more electric motors, and the variable frequency drives are attached." Additionally, the configuration comprising one or more pumps and one or more motors attached to a skid would have been obvious to a POSITA in view of the disclosure.

**ii.** ***Claim 3: "The system of claim 1, further comprising: a natural gas powered generator for connection to the electric motor that provides electric power to the electric motor."***

171. *Coli* discloses "a plurality of generators" in the form of "[o]ne or more natural gas-powered turbine generators 30." Ex. 1005, [0038]. *Coli* teaches that the fracturing modules 20 (i.e., a "plurality of pumps" and associated electric motors) are "operatively associated" with and "receive electric power" from the turbine generators 30 (i.e., "a natural gas powered generator for connection to the electric motor that provides electric power to the electric motor"). Ex. 1005, [0040], [0009] ("each electric fracturing module comprising an electric motor and a coupled fluid pump, each electric motor operatively associated with the dedicated source of

electric power.") Further, *Coli* discloses "the dedicated power source is an on-site turbine generator…and generated electricity can be used to power the fracturing modules, blenders, and other on-site operations as necessary." Ex 1005, [0042].

172. *Coli* discloses using natural-gas powered turbine generators to generate electricity, and the electricity in turn powers electric motors. Ex. 1005, [0042]. I understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 30-31. Accordingly, *Coli* discloses the limitation of claim 3.

**c. <u>Independent Claim 4</u>**

**i. *Claim 4 (preamble): "A method of hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the method comprising:"***

173. *Coli* describes a "method of delivering fracturing fluid to a wellbore" in order to create fractures in the formation so as to create "a permeable membrane for hydrocarbon fluids and gases to flow through so they may be recovered" at the surface. Ex. 1005, [0009], [0035]. Thus, to the extent the preamble of claim 4 is limiting, *Coli* discloses the limitation found therein.

174. Otherwise, *Coli* discloses the preamble of claim 4 for the same reasons that *Coli* discloses the preamble of claim 1 as described above. *See supra* Section X.B.a.i.

### ii. *Claim 4(a): "pumping fluid into the wellbore using hydraulic fracturing pumps;"*

175. As discussed above with respect to claim 1[b], *Coli* discloses this claim limitation through its disclosure of fracturing modules 20 each including an electric motor 21 and pump 22, which "pump the fracturing fluid directly to the wellbore." Ex. 1005, [0040]. Accordingly, *Coli* discloses claim 4[a]. *See supra* Section X.B.a.iii.

### iii. *Claim 4(b): "powering the hydraulic fracturing pumps using an electric motor; and"*

176. Similar to claim 1[c] discussed above, *Coli* teaches "a medium low voltage AC permanent magnet electric motor 21 receives electric power from turbine generator 30, and is coupled directly to pump 22." Ex. 1005 [0052]; *see also id.*, [0040], [0046]; Figs. 4A, 4B. A POSITA would have understood that the electric motor powers the hydraulic fracturing pump. *See supra* Section X.B.a.iii.

### iv. *Claim 4(c): "controlling the speed of the motor using a variable frequency drive, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the electric motor."*

177. Claim 4[c] is similar in scope to claim 1[d] but stated in different words, and therefore, is disclosed by the combination of *Coli* and *Toshiba Manual* in the same way as described above. *See supra* Section X.B.a.v.

**d. Dependent Claims 5-6**

**i. *Claim 5: "The method of claim 4, further comprising: powering the electric motor using a generator."***

178. The scope of claim 5 is subsumed within claim 3, and therefore, is disclosed by *Coli* in the same way as described for claim 3 above. *See supra* Section X.B.b.ii.

**ii. *Claim 6: "The method of claim 5, further comprising: powering the generator using natural gas."***

179. The scope of claim 6 is subsumed within the scope of claim 3, and therefore, is disclosed by *Coli* in the same way as described above for claim 3. *See supra* Section X.B.b.ii.

**e. Independent Claim 7**

**i. *Claim 7 (preamble): "A system for hydraulically fracturing an underground formation in an oil or gas well to extract oil or gas from the formation, the oil or gas well having a wellbore that permits passage of fluid from the wellbore into the formation, the system comprising:"***

180. To the extent the preamble is limiting, the preamble of claim 7 is identical to the preamble of claim 1, and therefore, is disclosed by *Coli* in the same manner as described above. *See supra* Section X.B.a.i.

**ii. *Claim 7(a): "a pump fluidly connected to the well; and."***

181. As discussed with respect to claim 1[b], *Coli* discloses electric pumps 22 that "pump fluid directly to the wellbore." Ex. 1005, [0040]. A POSITA would

have understood that a wellbore is within a well, and therefore, by virtue of *Coli* teaching pumping fluid "directly to the wellbore," *Coli* also discloses pumping fluid to the well. *See supra* Section X.B.a.iii.

**iii. *Claim 7(b): "an electric motor to power the pump;"***

182. Claim 7[b] is subsumed within the subject matter of claim 4[b], and therefore, is disclosed by *Coli* in the same manner as described above. *See supra* Section X.B.c.iii.

**iv. *Claim 7(c): "the pump configured to pump fluid into the wellbore; and"***

183. Claim 7[c] is subsumed within the subject matter of claim 1[b], and is thus disclosed by *Coli* in the same manner as described above. *See supra* Section X.B.a.iii.

**v. *Claim 7(d): "a variable frequency drive connected to the electric motor to control the speed of the motor and having one or more power semiconductor heat sinks having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat."***

184. As discussed above with respect to claims 1 and 4, both *Coli* and *Toshiba Manual* disclose a VFD used to control the speed of an electric motor. *See supra* Sections X.B.a.v. and X.B.c.iv.

185. *Toshiba Manual* further discloses a VFD with a rectifier circuit and an inverter circuit (AC-DC-AC converter) comprised of IGBTs. Ex. 1006 at 36. A

POSITA would understand that a rectifier circuit and an inverter circuit (AC-DC-AC converter) are examples of "power semiconductors." *See supra* Sections IX.B.b and X.A.

186. *Toshiba Manual* teaches that the power semiconductors, including IGBTs, have heat sinks. Ex. 1006 at 14 (heat sink and other components may become extremely hot to the touch"); *see* Ex. 1006 at 204 ("cooling capacity of the heat sink"). The heat sinks have thermal sensors (e.g., thermistors) monitored by a microprocessor to prevent damage caused by excessive heat. Specifically, the heat sink has thermal monitors that are monitored by the microprocessor of the ASD. For example, one of the alarms displayed on the EOI is "*OH" which refers to "Overheat," which is when which is when the "ASD ambient temperature is excessive." Ex. 1006 at 2, 42–43, 180. The "Overheat" error can occur if the "ASD is operating at an elevated temperature," if the "Cooling fan vent is obstructed," or if the Internal thermistor is disconnected." Ex. 1006; *see* Ex. 1006 at 185 (overheat); Ex. 1006 at 163 ("cooling fan control"). Thus, to detect an "elevated temperature," the Toshiba VFD is monitored by temperature sensors. One of the settings in the CPU (microprocessor) is for "Cooling Fan Control," which can be set to "Automatic" or "Always on." Ex. 1006 at 163. In order for the CPU to control the cooling fans of the VFD in "automatic" mode, it would be necessary to have temperature data supplied to the microprocessor so it could determine when to turn

the fans on (supply additional cooling) or off (conserve energy when not needed). A POSITA would further understand that in order to protect against overheat, the heatsink would necessarily have sensors which would report to the CPU (microprocessor) temperature data. By performing a "protective function" of "heatsink overheat," *Toshiba Manual* is disclosing that the purpose of the heatsink, and the monitoring of the heat sink by temperature sensors connected to the CPU, is to prevent damage cause by excessive heat. In view of these disclosures of *Toshiba Manual*, it is my opinion that a POSITA would understand that *Toshiba Manual* discloses a VFD with power semiconductors having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat.

**f. <u>Dependent Claims 8-16</u>**

**i. *Claim 8: "The system of claim 7, wherein the electric pump is mounted on a vehicle, and can be ported from one well to another."***

187. *Coli* teaches "one or more fracturing modules," each including "an electric motor 21 and a fluid pump 22," and each removably mounted on a trailer 10 (i.e., the plurality of pumps are mounted on a trailer). Ex. 1005, [0040]. *Coli* further teaches that the "plurality of electric motors 21 and pumps 22 can be transported on a single trailer 10" (i.e., the pumps 22 are capable of being "ported from one well to another"). Ex. 1005, [0040]. A trailer, particularly one connected to a tractor (i.e., truck), is a type of vehicle.

188. A POSITA would have understood the teachings in *Coli* regarding the transportation of pumps on a trailer to disclose the transportation of pumps "from one well to another." Additionally, such a use would have been obvious to a POSITA in view of *Coli*. I further understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 32.

**ii.** ***Claim 9: "The system of claim 7, further comprising: a generator electrically connected to the electric motor to provide electric power to the motor."***

189. Claim 9 is subsumed within the subject matter of claim 3 and therefore, is disclosed by *Coli* in the same manner as described for claim 3. *See supra* Section X.B.b.ii.

**iii.** ***Claim 10: "The system of claim 9, wherein the generator is fueled by natural gas."***

190. Claim 10 is subsumed within the subject matter of claim 3 and therefore, is disclosed by *Coli* in the same manner as described for claim 3. *See supra* Section X.B.b.ii.

**iv.** ***Claim 11: "The system of claim 9, wherein the generator is a turbine generator."***

191. As discussed above regarding claim 3, *Coli* discloses "a plurality of generators" which can be "[o]ne or more natural gas-powered turbine generators 30." Ex. 1005, [0038]. Thus, *Coli* discloses claim 11. *See supra* Section X.B.b.ii.

### v. *Claim 12: "The system of claim 9, wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another."*

192. *Coli* teaches "one or more fracturing modules," each including "an electric motor 21 and a fluid pump 22," that are removably mounted on a trailer 10 (i.e., the plurality of electric motors and pumps are mounted on a trailer). Ex. 1005, [0040]. *Coli* further teaches that the "plurality of electric motors 21 and pumps 22 can be transported on a single trailer 10" (i.e., the electric motors and pumps are capable of being "ported from one well to another"). Ex. 1005. A POSITA would have understood the teachings in *Coli* regarding the transportation of electric motors and pumps on a trailer to disclose the transportation of electric motors and pumps "from one well to another." Additionally, such a use would have been obvious to a POSITA in view of *Coli*.

193. *Coli* further teaches that turbine generators 30, which power trailer-mounted fracturing modules, are intended to "replace the diesel prime movers" of the prior art. Ex. 1005, [0038] and [0040]. *Coli* discloses that "[m]ultiple options are available for turbine power generation," including "liquid fuels such as condensate" and "natural gas." Ex. 1005, [0044]. A POSITA would, therefore, have understood the teachings directed to the replacement of trailer-mounted diesel prime movers with the trailer-mounted fracturing module/turbine generators 30 to disclose

"generators are mounted on vehicles." Additionally, such a configuration would have been obvious to a POSITA in view of the disclosure.

194. *Coli* further teaches that the "plurality of electric motors 21 and pumps 22" of the fracturing modules powered by the turbine generators 30 "can be transported on a single trailer 10." Ex. 1005, [0040]. A POSITA would have understood the teachings in *Coli* regarding the transportation of electric motors and pumps on a trailer, along with the associated generators, to disclose the transportation of electric motors, pumps, and generators "from one well to another."

195. Further, *Coli* references a specific generator, "a TM2500+ turbine generator sold by General Electric" as "a turbine suitable" for use with the fracturing system of *Coli*. Ex. 1005, [0044]; Ex. 1037 (TM2500+ Fact Sheet); Ex. 1038 (authenticating Ex. 1037). A POSITA would have understood that a TM2500+ is the trailer mounted ("TM") version of the ubiquitous LM2500 (Land Marine) generator based on the GE CF6 aeroderivative turbine. *See supra* Section VIII.D.

196. The trailer-mounted generator configuration would have further been obvious to a POSITA in view of *Coli*'s express teachings of trailer-mounted electric motors and pumps, as it would have been likewise obvious to mount the associated generators on trailers to provide power to the trailer-mounted electric motors and pumps. Ex. 1005, [0040]. I further understand that the Board found a substantially

similar claim of the ’601 Patent to be disclosed by *Coli*. Ex. 1048 at 32-33. Accordingly, *Coli* at least renders obvious claim 12.

197. A POSITA would have understood the teachings in *Coli* regarding the trailer-mounted electric motors, pumps, and generators to disclose the transportation of electric motors and pumps “from one well to another.” Additionally, such a use would have been obvious to a POSITA in view of *Coli*, particularly in view of *Coli’s* stated portability goals. Ex. 1005, [0063]; Ex. 1048 at 32.

#### vi. *Claim 13: “The system of claim 12, wherein the vehicle is a truck having at least five axles.”*

198. Figure 3 of *Coli* clearly depicts a trailer 10 with three axles “for housing one or more fracturing modules,” wherein “[e]ach fracturing module” includes “an electric motor 21 and a fluid pump 22 coupled thereto.” Ex. 1005, [0040], Fig. 3.

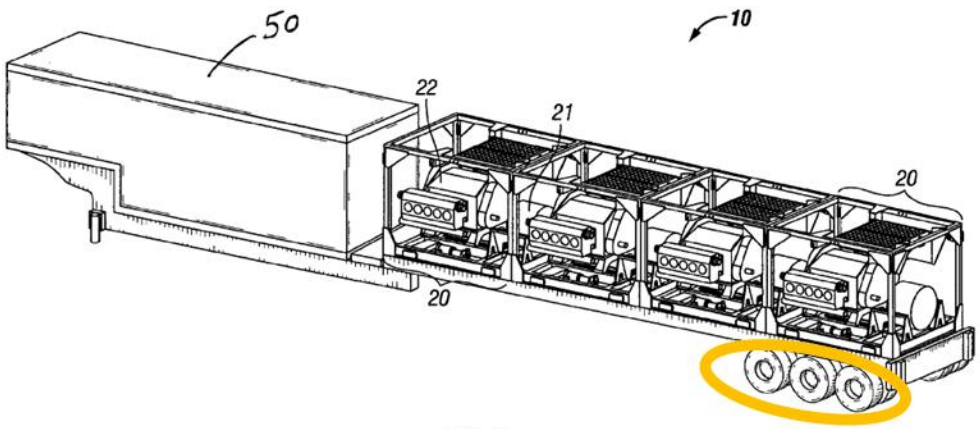



FIG. 3

Further, *Coli* discloses “[e]ach trailer 5 is attached to a truck 6.” Ex. 1005, [0037]; [0007]; [0039]; [0078]. A POSITA would have understood that any truck pulling the

trailer in *Coli* would have at least two axles. Accordingly, *Coli* discloses a vehicle that is truck-trailer configuration with a total of 5 axles.

199. Additionally, a "unitary" truck with five axles would have been obvious to a POSITA in view of this disclosure of a three axle semi-trailer intended to be attached to and pulled by a tractor (commonly referred to collectively as a "tractor-trailer truck," a "semi-trailer truck," and a "semi-truck") because a POSITA would have known that the semi-trailer portion could be permanently attached to the tractor portion of the truck instead of as a detachable trailer, as is done with many commercial trucks.

200. Furthermore, a POSITA would have understood that the number of axles used on a vehicle is a simple design choice, with the number of axles to use being determined based on the amount of load that is supported by the axles. I further understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 43. Accordingly, *Coli* discloses or at least renders obvious claim 13.

#### vii. *Claim 14: "The system of claim 7, wherein the pump is a triplex or quinteplex pump rated at about 2250 hydraulic horsepower or more."*

201. *Coli* discloses an electric motor that is "coupled to one or more electric pumps," and discloses that a "suitable pump" is a "quintuplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver,

Inc.," which is rated at 2500 bhp (brake horsepower). Ex. 1005, [0046]. *Coli* further discloses that while conventional diesel powered fluid pumps rated for 2250 horsepower typically only deliver about 1800 hp to the pumps, the electric motors of *Coli* "can deliver a true 2500 hp directly to each pump 22 because pump 22 is directly coupled to electric motor 21." Ex. 1005, [0049] (emphasis added). Because the motor of *Coli* delivers 2500 hp to the pump, a POSITA would have understood that the pump must be rated for at least that amount of delivered power. Thus, *Coli* discloses "wherein the pump is a triplex or a quinteplex pump rated at about 2250 horsepower or more."

202. Further, a POSITA would have known that the Gardner SWGS-2500 pump in *Coli* was rated at 2500 hp, as specified in *Garner*. Ex. 1011 at 14, 21. I further understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 43. Accordingly, *Coli* discloses or at least renders obvious claim 14.

#### viii. *Claim 15: "The system of claim 7, wherein the electric motor has a maximum continuous power output of about 1750 brake horsepower or more."*

203. *Coli* discloses that the motor "can deliver a true 2500 hp directly to each pump 22 because pump 22 is directly coupled to electric motor 21." Ex. 1005, [0049]. Accordingly, a POSITA at the time the '870 Patent was filed would have recognized that *Coli* discloses the "electric motor has a maximum continuous power

output of about 1750 horsepower or more." I further understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 41.

#### ix. *Claim 16: "The system of claim 7, wherein the electric motor has a maximum continuous torque of about 8750 lb-ft or more."*

204. *Coli* discloses that the "electric motor can be capable of operation in the range of up to 1500 rpms and up to 20,000 ft/lbs of torque."[4] Ex. 1005, [0011]. Accordingly, a POSITA at the time the '870 Patent was filed would have recognized that *Coli* discloses an "electric motor has a maximum continuous torque of about 8750 ft-lb or more." I further understand that the Board found a substantially similar claim of the '601 Patent to be disclosed by *Coli*. Ex. 1048 at 41-42.

## XI. GROUND 2: CLAIMS 1-6 ARE OBVIOUS OVER COLI IN VIEW OF HORIKOSHI

205. It is my opinion that *Coli* in view of *Horikoshi* discloses and/or suggests all limitations of Claims 1-6, and thus renders those claims obvious.

206. Specifically, *Horikoshi* in combination with *Coli* discloses "wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the [at least one] electric motor" as required by independent claims 1 and 4. All

[4] As explained above, the unit of torque is ft-lb, as recited in the claim. There appears to be a typo in *Coli* insofar as it expresses torque in ft/lbs, as opposed to ft-lbs.

other elements of claims 1-6 are disclosed or rendered obvious by *Coli* as explained in Ground 1. *See supra* Section X.B.a-d.

### A. REASONS TO COMBINE COLI AND HORIKOSHI

207. Standard Handbook for Electrical Engineers describes the basic function of an ASD as follows:

> In order to supply an adjustable frequency to an ac motor, the incoming constant-frequency voltage or current must first be 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 time I the cycle. This selected firing allows control of the resultant voltage or current.

Ex. 1016, 20-85.

208. Thus, I understand that variable frequency drives are a class of motor driving apparatus that takes incoming alternating current (AC) 3-phase power (at least for motors over 10 Hp), converts it to direct current (DC) power and then converts it back to AC power for delivery to the motor. 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. This matches the description of a "motor driving apparatus" disclosed in *Horikoshi*.

209. Further, at least in some applications, it may be beneficial to distinguish between a ground fault or phase-to-phase short circuit. This is particularly true when troubleshooting or making repair decisions. For example, a peer reviewed article, entitled "Root Cause Failure Analysis for AC Induction motors in the Petroleum and Chemical Industry," authored by Austin Bonnet—one of the premier experts on motors and motor analysis in the petroleum and chemical industry—describes the benefits in gathering information about the failure mode of the motor including in Table 5 where distinguishment is made between "Turn to Turn, Phase to Phase, [and] Phase to Ground failure modes." Ex. 1019, 3-5; 13 (". . .time should be spent collecting valuable information that will assist in a root cause failure analysis.") Accordingly, I understand that the type of failure, whether "phase-to-phase" or "ground fault" is valuable during the repair and troubleshooting of the failure of the motor.

210. Moving from the background to the specific combination at hand, as discussed above, *Coli* teaches the benefits of replacing traditional diesel powered fracturing operations with electric-powered operations, including improving costs (Ex. 1005, [0075]), efficiency (Ex. 1005., [0077]), safety (Ex. 1005, [0066]), and environmental impact (Ex. 1005, [0080]). *Coli* also discloses the need for "variable

frequency drives," which are used to "essentially 'tell' the motors what they are allowed to do" and explains the safety benefit of "[e]lectric motors controlled via variable frequency drive are far safer and easier to control than conventional diesel powered equipment." Ex. 1005, [0066]. *Coli* explains that because "electric motors are controlled by variable frequency drives . . . the control software and variable frequency drives ["VFD"] calculate a maximum current available to the motors." Ex. 1005, [0065]. And in the event the actual current exceeds the maximum current calculated by the VFD, *Horikoshi* provides an "apparatus that can reliably detect any overcurrent occurring in the DC/AC converter" of the VFD. Ex. 1008, [0004].

211. A POSITA would have understood that "overcurrent" is a potential source of damage to an electric motor, and detecting overcurrent associated with "a ground fault or a phase-to-phase short circuit" is a way to protect the electric motor from damage. A POSITA would have understood that excessive current (overcurrent) would cause damage to motors just as excessive voltage (overvoltage) or excessive temperature (overtemperature) would cause damage to motors. In fact, because heat generated is proportional to the square of the current (heat = $I^2Rt$), excessive current would directly lead to excessive temperature. A PSOITA would have understood that exceeding the rating of any physical parameter of the motor (such as overcurrent) would be a source of damage to the motor.

212. *Horikoshi* discloses several prior art techniques that provide a level of diagnostics and motor protection to a motor drive apparatus that "provides protection against ground faults by detecting the presence or absences of a ground fault before starting the operation by applying a ground-fault detecting control signal to the AC/DC converter." Ex. 1008, [0008], [0010]. Thus, *Horikoshi* discloses that at least as of 2011—the filing date of *Horikoshi*—prior art VFD diagnostic techniques were well-known.

213. *Horikoshi*, however, explains that in the prior art "no description is given of how a distinction is made between a ground fault and a phase-to-phase short circuit." Ex. 1008, [0008]. To rectify that deficiency, *Horikoshi* states its object as providing "a motor driving apparatus having a fault diagnostic function capable of detecting during operation a ground fault and a phase-to-phase short circuit by distinguishing one from the other." Ex. 1008, [0011].

214. Although *Coli* does not expressly disclose the diagnostic capabilities of its VFD, which was likely present in light of the well-known diagnostic function of VFDs (see Section VIII.A), in my opinion, it would have been obvious from *Horikoshi* that having the diagnostic capability of at least detecting a ground fault or a phase-to-phase short is desirable to prevent damage to the motors.

215. Notably, I understand that the Board has analyzed the combination of *Horikoshi* and *Coli* in its Final Written Decision in IPR2021-01033 (Paper 41)

("'601 FWD") relating to U.S. Patent No. 8,789,601 (the "'601 Patent"). Ex. 1048. The relevant claim language in the '601 Patent is substantially similar to that in the '870 Patent—indeed, if anything, the claim language in the '870 Patent is broader in scope in that it does not include the claim limitations "frequently" or "if they become grounded or shorted." Claim 1 of the '601 Patent provides, in pertinent part, as follows:

> at least one variable frequency drive connected to the electric motors to control the speed of the motors, the at least one variable frequency drive frequently performing electric motor diagnostics to prevent damage to the electric motors if they become grounded or shorted . . . .

Ex. 1049, at 9:9–13. Similarly, claim 1 of the '870 Patent states, in pertinent part, as follows:

> a variable frequency drive connected to the electric motor to control the speed of the motor, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the one or more electric motors.

Ex. 1001, at 7:58–61.

216. In its Final Written Decision for the '601 Patent, the Board found as follows:

> Horikoshi discloses "a motor driving apparatus having a fault diagnostic function" in the form of a unit that uses signals received from a zero phase current detector and current sensors to determine whether a detected overcurrent is a short or a ground fault. Horikoshi expressly teaches that it is desirable to detect and identify such sources of overcurrent and that it is known in the art to use fault detection to "provide[] protection against ground faults."

Ex. 1048 at 27 (internal citations omitted).

217. The Board found persuasive Petitioner's argument that "Horikoshi's detection and classification of an overcurrent condition is the performance of electric motor diagnostics as recited in the claims." *Id.* at 28. Further, the Board conclusively found that *Coli* and *Horikoshi* supported Petitioner's contention that it would have been obvious to combine *Coli* and *Horikoshi* to add the diagnostic functionality of *Horikoshi*'s driving apparatus to Coli's variable frequency drive, and that "Petitioner ha[d] set forth reasoning with rational underpinning explaining why it would have been obvious to combine the teachings of Coli and Horikoshi." *Id.* at 29.

**a. <u>Motivation to Combine</u>**

218. A POSITA would have been motivated to combine *Coli* with *Horikoshi* with a reasonable expectation of success. Specifically, a POSITA would have been motivated to simply substitute the VFD of *Coli* for the VFD of *Horikoshi* that has

the diagnostic functionality to detect a ground fault or a phase-to-phase short circuit, without affecting the other functionalities in *Coli*.

219. Alternatively, a POSITA would have understood that the VFD of *Coli* would be enhanced with the diagnostic functionality of *Horikoshi* because such an improvement represents the use of a known technique (i.e., the fault detection of *Horikoshi*) to predictably improve a similar system (i.e., the VFD of *Coli*) in the same way.

**b. Reasonable Expectation of Success**

220. A POSITA would have had a reasonable expectation of success in combining *Coli* and *Horikoshi* by substituting the VFD in *Coli* for the VFD of *Horikoshi* because the combination involves a simple substitution of one known element for another, and the results of this simple substitution would be predictable and obvious to a POSITA.

221. A POSITA would have had a reasonable expectation of success in enhancing the VFD in *Coli* with the diagnostic functionality of the VFD in *Horikoshi* because such an improvement would be predictable and obvious to a POSITA as it involves the use of a known technique to improve a similar system in the same way.

## B. DISCLOSURE OF COLI IN VIEW OF HORIKOSHI

### a. Independent Claim 1

#### i. *Claim 1(d): "a variable frequency drive connected to the electric motor to control the speed of the motor, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the one or more electric motors."*

222. As discussed above, *Coli* teaches the use of a "variable speed motor" within the fracturing module 20, and further teaches that the electric motors used in the system can be "controlled by variable frequency drives" that "essentially 'tell' the motors what they are allowed to do." Ex. 1005, [0011], [0065]. Further, *Coli* expressly teaches a VFD used to control the speed of an electric motor. Ex. 1005, [0047], [0049], [0059], Fig. 3; *see supra* Sections X.B.a.v and XI.A.

223. *Horikoshi* teaches the use of a "motor driving apparatus comprising an AC/DC converter for converting three-phase AC power supplied from a 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." Ex. 1008, [0012], [0027].

224. Consistent with the plain language of the claims (e.g., "a variable frequency drive connected to the electric motor to control the speed of the motor," as recited in claim 1 of the '870 Patent), in my opinion, a POSITA would have understood such a description of the "motor driving apparatus" to be quintessentially

that of a variable frequency drive that supplies "three-phase AC power" "to a motor" and thus controls its speed.

225. *Horikoshi* further teaches that the "motor driving apparatus [has] a fault diagnostic function." Ex. 1008, [0002]. Specifically, *Horikoshi* teaches that that the apparatus can include current sensors to "detect any overcurrent occurring in the DC/AC converter and can also identify whether the cause [of the overcurrent] is a ground fault or a phase-to-phase short circuit" *associated* with "insulation resistance of the motor" or the power source providing power to the apparatus." Ex. 1008, [0004], [0006]. In my opinion, a POSITA would have understood that "overcurrent" is a potential source of damage to an electric motor, and detecting overcurrent associated with "a ground fault or a phase-to-phase short circuit" is a way to protect the electric motor from damage.

226. Indeed, *Horikoshi* discloses that such an apparatus may "provide *protection* against ground faults by detecting the presence or absences of a ground fault *before starting the operation* by applying a ground-fault detecting control signal to the AC/DC converter." Ex. 1008, [0008]. Accordingly, a POSITA would have understood that *Horikoshi* discloses a variable frequency drive that "performs electric motor diagnostics to prevent damage to the at least one electric motor."

227. As discussed in Section XI.A, it would have been obvious to a POSITA to modify the system of *Coli* with the VFD of *Horikoshi* to create the variable

frequency drive with the required diagnostic functionality. Specifically, it would have been obvious to modify the VFD described in *Coli* to include the diagnostic functionality of *Horikoshi* at least because both references discuss or are directed to the control of electric motors using VFDs, and the incorporation of *Horikoshi's* diagnostic functionality would have been obvious to try and would have yielded predictable results.

228. Alternatively, a POSITA would have understood the "motor driving apparatus" in *Horikoshi* to be interchangeable with the "variable frequency drives" in *Coli* such that it would have been obvious to simply substitute the "motor driving apparatus" in *Horikoshi* for the "variable frequency drives" in *Coli* to take advantage of the overcurrent protection provided by *Horikoshi*.

**b. Independent Claim 4**

**i. *Claim 4(c): "controlling the speed of the motor using a variable frequency drive, wherein the variable frequency drive performs electric motor diagnostics to prevent damage to the electric motor."***

229. Claim 4[c] is similar in scope to claim 1[d] but stated in slightly different words, and therefore, is disclosed by the combination of *Coli* and *Horikoshi* in the same way as described above for claim 1.

## XII. GROUND 3: CLAIMS 7-16 ARE OBVIOUS OVER COLI IN VIEW OF LOUCKS

230. It is my opinion that the combination of *Coli* and *Loucks* discloses and/or suggests all limitations of claims 7-16, and thus renders those claims obvious.

231. Specifically, *Loucks* in combination with *Coli* discloses or renders obvious a variable frequency drive "having one or more power semiconductor heat sinks having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat" as required by independent claim 7. All other elements of claims 7-16 are disclosed or at least rendered obvious by *Coli* as described above in Ground 1. *See supra* Section X.B.e-f.

### A. REASONS TO COMBINE COLI AND LOUCKS

232. *Coli* discloses how the electrification of a traditional fracturing operation can provide a number of benefits including improving costs (Ex. 1005, [0075]), efficiency (Ex. 1005, [0077]), safety (Ex. 1005, [0066]), and environmental impact (Ex. 1005, [0080]). 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." Ex. 1005, [0066].

233. *Coli* discloses the need for "variable frequency drives," which are used to "essentially 'tell' the motors what they are allowed to do." Ex. 1005, [0065]. *Coli* further discloses the necessity for monitoring VFD and motor operations. Ex. 1005,

[0066]. *Coli* explains that because "electric motors are controlled by variable frequency drives . . . the control software and variable frequency drives ["VFD"] calculate a maximum current available to the motors." Ex. 1005, [0065]. *Loucks* provides details regarding protection of electrical equipment, including VFDs, from damage due to excessive temperatures. *See generally* Ex 1009.

234. *Loucks* teaches that its cooling efficiency calculation method is directly applicable to electrical equipment such as "transformers, circuit breakers, uninterruptible power supplies (UPSs) or variable frequency drives (VFDs)." Ex. 1009, [0036]. A POSITA would have been motivated to use the cooling efficiency calculation method of *Loucks* to "detect problems before temperatures [of electronic equipment] reach alarm limits." Ex. 1009, [0018]. This is important because "electrical or electronic equipment can malfunction due to overtemperature," a problem which is particularly exacerbated in "variably loaded systems." Ex. 1009, [0018]. As would have been well known to a POSITA, "cooling problems . . . can contribute to electrical equipment malfunction or accelerated degradation since overheated equipment does not operate as effectively as equipment operating at acceptable temperature limits." Ex. 1009, [0003]; *see also supra* Section VIII.C. *Loucks* further teaches a "cooling efficiency monitoring system" that comprises "[m]ultiple temperature sensors" including "a power electronics heat sink temperature sensor 510." *Id.*, [0063]. These sensors provide measured temperature

data to a computer 700, which includes a processor 702 and cooling efficiency logic 730, which in one example, is implemented in the processor 702. *Id.*, [0066]. The "processor 702 may be a variety of various processors including dual microprocessor other multi-processor architectures." Ex. 1009, [0072]. The cooling efficiency logic 730 computes a "temperature differential between the temperature of the monitored device and the ambient temperature, and uses that differential to calculate an "operating cooling efficiency indicator." *Id.*, [0008], [0068]-[0070]

**a. Motivation to Combine**

235. A POSITA would have been motivated to use *Loucks'* method and equipment—including the "heat sink temperature sensor 510" monitored by "computer 700," which includes a processor 702 and cooling efficiency logic 730—in order to protect against thermal degradation and damage to the VFD of *Coli*. This is particularly the case when it was well understood that power semiconductor components of a VFD require cooling to prevent damage caused by overheating, a problem addressed by the use of heat sinks long before the '870 Patent. *See supra* Section VIII. Particularly in view of *Loucks'* applications to VFDs, a POSITA would have been motivated to look to *Loucks'* heat sinks and temperature sensors and employ *Loucks'* cooling efficiency monitoring techniques to "detect problems" with *Coli's* VFD "before temperatures reach alarm limits" and to ensure that it does

not "malfunction" or suffer from "accelerated equipment degradation and early failure." Ex. 1009, [0018].

236. Further, Figures 4-6 of *Loucks* provides "examples of how sensors could be installed in typical enclosures containing a variety of heat producing electrical devices," including VFDs, and a POSITA would have understood how to install *Loucks'* heat sink and associated temperature sensors monitored by a microprocessor into *Coli's* VFD in view of these examples. Ex. 1009, [0061]; *see also* [0036]. As one example, Figure 5 of *Loucks* shows an enclosure 505 (e.g., for *Coli's* VFD) that includes a power electronics heat sink temperature sensor 510, a microprocessor temperature sensor 520, and an ambient temperature sensor 540. Ex. 1009, [0063]. It would have been routine and ordinary to a POSITA to install the various temperature sensors, associated microprocessor, and heat sink of *Loucks* into *Coli's* VFD, as these are basic and well-known components that have been known long before the '870 Patent. *Loucks* merely provides examples of one way to install such temperature sensors into an electrical device enclosure, and a POSITA a would have known how to install these well-known components into *Coli's* VFD enclosure.

237. Accordingly, a POSITA would have been motivated to incorporate the heat sink (and associated temperature sensors and temperature monitoring by a microprocessor) as taught in *Loucks* into the variable frequency drive described in

*Coli* to prevent damage caused by excessive heat, without affecting the other functionalities in *Coli*. Such a combination represents the application of a known technique (i.e., to incorporate the heat sink, temperature sensors, and temperature monitoring using a microprocessor of VFDs as taught in *Loucks*) to a known device (e.g., VFD of *Coli*) ready for improvement to yield predictable results (i.e., to protect against malfunction, equipment degradation, and early failure due to overheating). Such a combination likewise represents the use of a known technique (i.e., to incorporate the heat sink and associated temperature sensors and temperature monitoring by a microprocessor to prevent malfunction of variable frequency drives as taught in *Loucks*) to predictably improve a similar system (i.e., to protect *Coli*'s VFD from malfunction, degradation, and early failure due to excessive heat) in the same way (i.e., by providing heat sinks, temperature sensors, and temperature monitoring). The use of heat sinks and temperature sensors monitored by a microprocessor was well-known long before the '870 Patent, and a POSITA would have known how to incorporate these well-known heat sinks, temperature sensors, and a microprocessor into the VFD of *Coli* with a reasonable expectation of success.

**b. Reasonable Expectation of Success**

238. A POSITA would have a reasonable expectation of success in combining *Coli* with *Loucks* because VFD technology and protecting VFDs from damage caused by overheating was well known before the '870 patent. *See supra*

Section VIII. In my opinion, a POSITA would have a reasonable expectation of success in combining *Coli* and *Loucks* by adding the heat sink, temperature sensors, and processor (including microprocessor(s)) of *Loucks* into the VFD of *Coli* in order to detect cooling problems and prevent damage to the electrical and electronic equipment of *Coli*'s VFD from overheating. A POSITA would have had a reasonable expectation of success because such a combination is simply using a known technique to improve a similar system in the same way. Furthermore, a POSITA would have had a reasonable expectation of success because such a combination is nothing more than an application of a known technique to a known device ready for improvement to yield predictable results.

### B. DISCLOSURE OF COLI IN VIEW OF LOUCKS

#### a. Independent Claim 7

##### i. *Claims 7(d): "a variable frequency drive connected to the electric motor to control the speed of the motor and having one or more power semiconductor heat sinks having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat."*

239. Both *Coli* and *Loucks* are directed to the use of the "variable frequency drive (VFD)." *See supra* Sections IX.A.b and IX.D.b. A POSITA would have understood that VFDs (ASD) are used to control the speed of an electric motor, as this technology was well known decades before the '870 patent. A POSITA would also have understood that VFDs are comprised of "power semi-conductor devices"

and that these semi-conductor devices generate heat, which must be dissipated. The use of heat sinks to dissipate this heat was also well-known decades before the '870 Patent. *See supra* Section VIII.

240. *Loucks* further verifies that the power semiconductors have heat sinks. Ex. 1009, [0063] (monitoring of "power electronics heat sink temperature sensor 510"); Ex. 1009, [0003] ("monitoring…heat sinks or other areas of equipment"); Ex. 1009, [0030], [0031] ("efficiency of heat transfer (heat sink" and "heat sink efficiency"); Ex. 1009, [0063] (monitoring of "power electronics heat sink temperature sensor 510").

241. The heat sinks of *Loucks* have thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat. Specifically, the heat sink has thermal monitors that are monitored by the microprocessor of the ASD. *See* Ex. 1009, [0063] ("Multiple temperature sensors are utilized including . . . a power electronics heat sink temperature sensor 510 and a microprocessor temperature sensor 520"; *see also* Ex. 1009, [0072] ("describing an example configuration of the computer 700, the processor 702 may be a variety of various processors inducing dual microprocessor and other multi-processor architectures"); *and* Ex. 1009, Claim 1 ("Computer readable medium having computer-executable instruction stored thereon for performing a cooling efficiency monitoring method.").

242. A POSITA would further understand that in order to protect against overheat, the heatsink would have sensors which would report temperature data to the CPU (microprocessor). *Loucks* teaches that overheat (cooling problems) "can contribute to electrical equipment malfunction or accelerated degradation since overheated equipment does not operate as effectively as equipment operating at acceptable temperature limits." Ex. 1009, [0003]. *Loucks* additionally teaches "for a variably loaded system [such as a VFD], simply waiting for a high temperature limit to be reached may result in equipment damage that occurs in the time it takes to resolve the cooling problem." Ex. 1009, [0018]. In view of these disclosures of *Loucks,* it is my opinion that a POSITA would understand that the combination of *Coli* and *Loucks* discloses a VFD with power semiconductors having thermal sensors monitored by a microprocessor to prevent damage caused by excessive heat.

## XIII. GROUND 4A: CLAIMS 12 AND 13 ARE OBVIOUS OVER COLI IN VIEW TOSHIBA MANUAL AND VLIET

243. The combination of *Coli* in view of *Toshiba Manual* and *Vliet* discloses and/or suggests all limitations of claims 12 and 13, and thus renders those claims obvious.

244. To the extent Patent Owner argues *Coli* in view of *Toshiba Manual* does not sufficiently disclose or render obvious "wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another,"

this ground is presented as an alternative to Ground 1. All other elements of claims 12 and 13 are disclosed or rendered obvious by *Coli* in view of *Toshiba Manual* as explained above for Ground 1.

### A. REASONS TO COMBINE COLI WITH TOSHIBA MANUAL AND VLIET

245. As discussed above, *Coli* involves a "fracturing system" for "delivering fracturing fluid to a wellbore at a fracturing operation." Ex. 1005, [0034]. *Coli* discloses how the electrification of the fracturing operation can improve costs (Ex. 1005, [0075]), efficiency (Ex. 1005, [0077]), safety (Ex. 1005, [0066]), and environmental impact *(*Ex. 1005, [0080]). Regarding efficiency (including portability), *Coli* discloses "[e]ach electric motor 21 is paired to a pump 22 as a single fracturing module 20" that "can be removably mounted to trailer 10 to facilitate ease of replacement as necessary." Ex. 1005, [0040]. Further, as discussed in Section X.B.f.v, *Coli* at least suggests or renders obvious that generators may also be mounted on the same trailer as the pumps, motors, and related equipment.

246. Like *Coli*'s disclosure and/or suggestion of mounting generators, pumps, and motors on a trailer, *Vliet* discloses that "at a well site during fracturing" the "pumps" and "electrical equipment" are on a trailer and "are supplied with power from a conventional generator or generators (not shown), which may conveniently be mounted on the trailer." Ex. 1010, [0003], [0027]. *Vliet* further teaches that the

"spatial orientation" of the components, including generators, is a matter of design choice for the manufacturer and will depend on space requirements." Ex. 1010.

247. Accordingly, to the extent the Board determines that *Coli* does not expressly disclose or render obvious the mounting of a generator on a vehicle (i.e., trailer) with the pump and electric motor, a POSITA would have been motivated to modify *Coli* such that the generator in *Coli* is also mounted on the vehicle (i.e., trailer) with the pump and electric motor for portability. The results of the combination would have been predictable and obvious to a POSITA.

**a. Motivation to Combine and Reasonable Expectation of Success**

248. In addition to being motivated to combine *Coli* with *Toshiba Manual* as described in Section X.A of Ground 1, a POSITA would have been motivated to further combine *Coli* with *Vliet* with a reasonable expectation of success, because the combination represents nothing more than the use of the known technique of mounting generators on a trailer just as the pumps, motors, and related equipment of *Coli* are mounted to improve convenience, efficiency, and portability of *Coli*'s fracturing system.

249. Additionally, the teaching, suggestion, and motivation in *Vliet* (and in *Coli* itself) would have led a POSITA to modify the system of *Coli* to arrive at the claimed invention.

### B. DISCLOSURE OF COLI IN VIEW OF TOSHIBA MANUAL AND VLIET

#### a. Dependent Claims 12

##### i. *Claim 12: "The system of claim 9, wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another."*

250. *Vliet* discloses a "fuel delivery system for delivery of fuel to fuel tanks of equipment at a well site during fracturing" and acknowledges that "[f]or use at different well sites, the fuel delivery system should be portable and transportable to various well sites." Ex. 1010, [0014], [0003]. *Vliet* further discloses that the "pumps" and "electrical equipment" are mounted on a trailer and "are supplied with power from a conventional generator or generators (not shown), which may conveniently be mounted on the trailer." Ex. 1010, [0027]. A POSITA would, therefore, have understood these teachings directed to a system "wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another."

## XIV. GROUND 4B: CLAIMS 12 AND 13 ARE OBVIOUS OVER COLI IN VIEW OF LOUCKS AND VLIET

251. The combination of *Coli* in view of *Loucks* and *Vliet* discloses and/or suggests all limitations of claims 12 and 13, and thus renders those claims obvious. To the extent that Patent Owner argues that *Coli* in view of *Loucks* does not sufficiently disclose or render obvious "wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another,"

this ground is presented as an alternative to Ground 3. All other elements of claims 12 and 13 are disclosed or rendered obvious by *Coli* in view of *Loucks* as explained in Ground 1.

### A. REASONS TO COMBINE COLI WITH LOUCKS AND VLIET

252. In addition to being motivated to combine *Coli* with *Loucks* as explained in Section XII.A of Ground 3, a POSITA would have been motivated to further combine *Coli* and *Loucks* with *Vliet* with a reasonable expectation of success for the same reasons stated above in Section XIII for Ground 4A.

### B. DISCLOSURE OF COLI IN VIEW OF LOUCKS AND VLIET

#### i. *Claim 12: "The system of claim 9, wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another."*

253. To the extent that Patent Owner argues that the combination of *Coli* and *Loucks* does not render obvious the limitation "wherein the pump, electric motor, and generator are mounted on a vehicle, and can be ported from one well to another" as described in Ground 3, *Vliet* expressly discloses this limitation for the same reasons stated above in Section XII for Ground 4A.

## XV. GROUND 5A: CLAIMS 14 AND 15 ARE OBVIOUS OVER COLI IN VIEW OF TOSHIBA MANUAL AND GARDNER

254. The combination of *Coli* in view of *Toshiba Manual* and *Gardner*, either alone or in combination, discloses and/or suggests all limitations of claims 14 and 15, and thus renders those claims obvious. To the extent that Patent Owner

argues that *Coli* in view of *Toshiba Manual* does not sufficiently disclose "wherein the pump is a triplex or a quintuplex pump rated at about 2250 horsepower or more," this ground is presented as an alternative to Ground 1 for claims 14 and 15. All other elements of claims 14 and 15 are disclosed or rendered obvious by *Coli* in view of *Toshiba Manual* as explained above in Ground 1.

### A. REASONS TO COMBINE COLI WITH TOSHIBA MANUAL AND GARDNER

255. In addition to being motivated to combine *Coli* with *Toshiba Manual* as described in Section VIII.A.1 of Ground 1, a POSITA would have been motivated to further combine *Coli* and *Toshiba Manual* with *Gardner* with a reasonable expectation of success, because *Gardner* provides details of the pump disclosed in *Coli* that are not fully described in *Coli*.

256. Additionally, the teaching, suggestion, and motivation in *Gardner* (and *Coli* itself) would have led a POSITA to understand the details of the system of *Coli*. Specifically, *Coli* discloses the use of a "quintuplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc" for use in a fracturing operation. Ex. 1005, [0046]. The "SWGS-2500 quintuplex pump" disclosed by *Coli* refers to a Gardner Denver GD-2500Q pump end coupled with a Gardner Denver SGWS fluid end. *Gardner* discloses that the SWGS-2500 pump of *Coli*—i.e., GD-2500Q pump—is rated at 2500 bhp. Ex. 1011 at 14.

## B. DISCLOSURE OF COLI IN VIEW OF TOSHIBA MANUAL AND GARDNER

### a. Dependent Claim 14

#### i. *Claim 14: "The system of claim 7, wherein the pump is a triplex or quinteplex pump rated at about 2250 hydraulic horsepower or more."*

257. As described in Ground 1, the combination of *Coli* and *Toshiba Manual* discloses and/or suggests the limitation of claim 14. *See supra* Section X.B.f.vii. To the extent the Board determines that the combination of *Coli* and *Toshiba Manual* does not disclose or render obvious the limitation "wherein the pump is a triplex or a quintuplex pump rated at about 2250 horsepower or more," *Gardner* expressly discloses this limitation.

258. As discussed in Section X.B.f.vii, *Coli* discloses a motor "coupled to one or more electric pumps," and discloses that a suitable pump is a "quintuplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc.," which is rated at 2500 bhp (brake horsepower). Ex. 1005, [0046], [0049]. *Coli* further discloses that while conventional diesel powered fluid pumps rated for 2250 horsepower typically only deliver about 1800 hp to the pumps, the electric motors of *Coli* "can deliver a true 2500 hp directly to each pump 22 because pump 22 is directly coupled to electric motor 21." Ex. 1005, [0049]; [0050] ("fracturing module 20," which contains one or more pumps and electric motors, "is capable of operating at 2500 hp."). Because the motor of *Coli* delivers 2500 hp to

the pump, a POSITA would have understood that the pump must be rated for at least that amount of delivered power.

259. Furthermore, *Gardner* expressly discloses that the SWGS-2500 pump is rated at 2500 hp. Ex. 1011 at 14. A POSITA would have understood that *Coli* in view of *Gardner* at least renders obvious "wherein the pump is a triplex or a quinteplex pump rated at about 2250 horsepower or more."

## XVI. GROUND 5B: CLAIMS 14 AND 15 ARE OBVIOUS OVER COLI IN VIEW OF LOUCKS AND GARDNER

260. The combination of *Coli* in view of *Loucks* and *Gardner* discloses and/or suggests all limitations of claims 14 and 15, and thus renders those claims obvious. To the extent that Patent Owner argues that *Coli* in view of *Loucks* does not sufficiently disclose or render obvious "wherein the pump is a triplex or a quinteplex pump rated at about 2250 horsepower or more," this ground is presented as an alternative to Ground 3 for claims 14 and 15. All other elements of claims 14 and 15 are disclosed or rendered obvious by *Coli* in view of *Loucks* as explained in Ground 3.

### A. REASONS TO COMBINE COLI WITH LOUCKS AND GARDNER

261. In addition to being motivated to combine *Coli* with *Loucks* as explained in Section XII of Ground 3, a POSITA would have been motivated to

further combine *Coli* and *Loucks* with *Gardner* with a reasonable expectation of success for the same reasons stated above in Section XV for Ground 5A.

### B. DISCLOSURE OF COLI IN VIEW OF LOUCKS AND GARDNER

#### a. Dependent Claim 14

##### i. *Claim 14: "The system of claim 7, wherein the pump is a triplex or quinteplex pump rated at about 2250 hydraulic horsepower or more."*

262. As described in Ground 3, the combination of *Coli* and *Loucks* discloses and/or suggests the limitation of claim 14. To the extent the Board determines that the combination of *Coli* and *Loucks* does not disclose the limitation "wherein the pump is a triplex or a quintuplex pump rated at about 2250 horsepower or more," *Gardner* expressly discloses this limitation for the same reasons stated above in Section XV for Ground 5A.

## XVII. SECONDARY CONSIDERATIONS

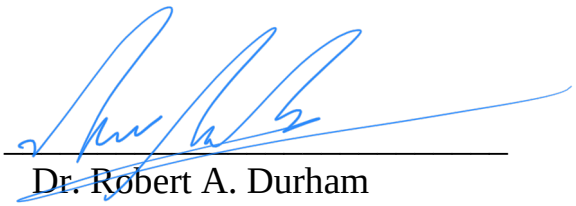
263. Should the Patent Owner put forth any alleged evidence of secondary considerations in this proceeding or the related Halliburton Litigation, I reserve the right to consider such evidence, to consider whether any such evidence has a nexus to any claims of the Challenged Patent, and to update my analysis.

## XVIII. CONCLUSION

264. 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 February 10, 2023.



Dr. Robert A. Durham

# APPENDIX A

# Dr. ROBERT A DURHAM, PhD, FIEEE

Resume
Specialization
Honors & Awards
Publications


HALLIBURTON EXHIBIT 1002
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 137

# Dr ROBERT A DURHAM, PhD, FIEEE

Robert A Durham is the Principal of $D^2$ 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.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**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**

$D^2$ Tech Solutions, Inc. 2002 - 2020
Principal

THEWAY Corp. 2004 - 2020
Principal Scientist

EDG Power Group, Inc. 2002 - 2004
Vice President Engineering & Project Management


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New Dominion, LLC 2000 - 2002
Mgr Electric Infrastructure

Central & Southwest, Inc 1989 - 2000
Electrical Engineer

**Professional Memberships**

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|---|---|
| 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 Working Group |
| Chair | IEEE RP1018 Working Group |
| Chair | IEEE RP1019 Working Group |
| Chair | IEEE PCIC Standards Subcommittee |

**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.


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IEEE Industry Applications Society, New Orleans, LA: Prize Article for "Data Quality and Grounding: Considerations in a Mixed Use Facility"

PCIC, Cincinnati, OK: 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".

**Publications**

Electrical Engineering in a Nutshell, Dr. Robert A Durham, Dr. Marcus O. Durham, ISBN 978-1466236795, 2011

Electrical Failure Analysis for Fire and Incident Investigations, Marcus O. Durham, Robert A. Durham, Rosemary Durham, Jason Coffin, ISBN 978-1463773472, 2011

Leadership and Success in Relationships and Communication, Marcus O. Durham and Robert A Durham, ISBN 978-1463758769, 2011

Leadership and Success in Organizations, Culture & Ethics: Group or Horizontal Interactions, Marcus O. Durham and Robert A Durham, ISBN 978-1466250338, 2011

Leadership and Success in Economics, Law & Technology: Society or External Influence, Marcus O. Durham and Robert A Durham, OK,ISBN 978-1466250461, 2011

How Should Generating Asset Acquisitions by Regulated, Vertically Integrated Utilities be Overseen in Today's Quasi-Regulated Electric Utility Environment? A Dissertation Presented to


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the Faculty of the School of Engineering Kennedy-Western University, KWU Press, Thousand Oaks, CA, 2004

R. A. Durham, M. O. Durham and T. W. Gillaspie, "Lightning Protection at Petrochemical Facilities - Part 2 Standards Requirements," *2021 IEEE Petroleum and Chemical Industry Committee Conference (PCIC)*, San Antonio, TX, 2021.

R. A. Durham, M. O. Durham and T. W. Gillaspie, "Petrochemical Facility Lightning Protection Primer: Part 1: History and Basic Science," in IEEE Industry Applications Magazine, vol. 27, no. 2, pp. 47-56, March-April 2021, doi: 10.1109/MIAS.2020.3024492.

R. A. Durham, S. J. Szczecinski and M. O. Durham, "Factors Impacting Selection of Grounding and Bonding Conductors," in *IEEE Transactions on Industry Applications*, vol. 56, no. 5, pp. 4652-4661, Sept.-Oct. 2020, doi: 10.1109/TIA.2020.3005637.

R. A. Durham, M. O. Durham and T. W. Gillaspie, "Lightning Protection at Petrochemical Facilities - Part 1 History and Background Science," *2019 IEEE Petroleum and Chemical Industry Committee Conference (PCIC)*, Vancouver, BC, Canada, 2019, pp. 205-214, doi: 10.1109/PCIC30934.2019.9074531.

R. A. Durham, S. J. Szczecinski and M. O. Durham, "Grounding and Bonding Conductors: Solid, Stranded, Bare or Insulated?: Copyright Material IEEE, Paper No. PCIC-2018-03," *2018 IEEE Petroleum and Chemical Industry Technical Conference (PCIC)*, Cincinnati, OH, USA, 2018, pp. 19-28, doi: 10.1109/PCIC31437.2018.9080442.

F. P. Feletto, R. Durham, E. Bortoni and J. Costa, "IMPROVENT OF MV CASCADED H BRIDGE INVERTER (CHBI) VFD AVAILABILITY FOR HIGH POWER ESP OIL WELLS," in *IEEE Transactions on Industry Applications*.
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F. Feletto, R. A. Durham, E. da Costa Bortoni and J. G. C. Costa, "Techniques to improve MV cascaded H bridge inverter (CHBI) VFDs availability applied to drive high power esp oil wells," *2017 Petroleum and Chemical Industry Technical Conference (PCIC)*, Calgary, AB, Canada, 2017, pp. 363-370.
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R. A. Durham, M. Azambuja, F. P. Feleto and M. O. Durham, "PD testing of motors for hostile environments," *2015 IEEE Petroleum and Chemical Industry Committee Conference (PCIC)*, Houston, TX, 2015, pp. 1-8.
doi: 10.1109/PCICON.2015.7435106
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Durham, Robert A.; Brinner, Thomas R., "Oilfield electric power distribution," Petroleum and Chemical Industry Technical Conference (PCIC), 2014 IEEE , vol., no., pp.429,442, 8-10 Sept. 2014 doi: 10.1109/PCICon.2014.6961908
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Durham, Robert; Durham, M.O. “What Does Grounding Have To Do with Fire & Injury”, Fire Protection vol 40 no 2, Fire Protection Association of Southern Africa, June 2014.

Durham, M.O.; Durham, R.A., "Does a Unified Energy Equation Contain the Higgs Field?," Access, IEEE , vol.1, no., pp.505,508, 2013
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Durham, R.A.; Durham, M.O.; , "Does Corrugated Tubing + Lightning = Catastrophic Failure?," *Industry Applications, IEEE Transactions on* , vol.48, no.4, pp.1243-1250, July-Aug. 2012
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Durham, R.A.; Durham, M.O.; , "Lightning, grounding, and protection for control and communications systems: Re-evaluated," *Petroleum and Chemical Industry Conference Europe Conference Proceedings (PCIC EUROPE), 2011* , vol., no., pp.1-11, 7-9 June 2011
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Durham, M.O.; Durham, R.A.; , "Lightning dangers on corrugated tubing carrying hydrocarbons," *Petroleum and Chemical Industry Conference (PCIC), 2010 Record of Conference Papers Industry Applications Society 57th Annual* , vol., no., pp.1-9, 20-22 Sept. 2010 doi: 10.1109/PCIC.2010.5666860
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Brinner, T.R.; Durham, R.A.; , "Transient voltage aspects of grounding," *Petroleum and Chemical Industry Technical Conference, 2008. PCIC 2008. 55th IEEE* , vol., no., pp.1-9, 22-24 Sept. 2008
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"Ignition or Shock, is Grounding the Culprit?", Marcus O Durham, Robert A Durham, Rosemary Durham, Jason A. Coffin, *Proceedings of 43rd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2010.

"Unraveling the Myths of Low Energy Ignition", Marcus O Durham, Robert A Durham, Curtis L. Ozment, Jason A. Coffin, *Proceedings of 42nd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2009.

"Lightning, Transient & High Frequency Impact on Material Such As Corrugated Tubing", Marcus O. Durham & Robert Durham, Proceedings of 41st Annual Frontiers in Power Conference, OSU, Stillwater, OK, October 2008.

"Lightning Damage an Act of God, or Act of Negligence?", Marcus O. Durham, Robert Durham, Randall Overton, Curtis Ozment, Proceedings of 40th Annual Frontiers in Power Conference, OSU, Stillwater, OK, October 2007.

"The Flat Earth Society Perception of Grounding", Marcus O. Durham & Robert Durham, Proceedings of 39th Annual Frontiers in Power Conference, OSU, Stillwater, OK, October 2006.

"The IEEE Standards Process, A Case Study", Marcus O. Durham & Robert Durham, *Proceedings of 38th Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2005.

"Engineering Management: A Course For Survival", Marcus O. Durham, Robert A. Durham, & Rosemary Durham, *American Society of Engineering Educators*, Pittsburg, KS 2004.

"Eleven Ground Systems and Connections", Marcus O. Durham & Robert Durham, *Proceedings of 37th Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2004.

"Engineering Management, An Oxymoron?", Marcus O. Durham, Robert Durham & Rosemary Durham, *Proceedings of 37th Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2004.

"Corrosion and Electrical Safety", Marcus O. Durham & Robert Durham, *Proceedings of 36th Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2003.

"Applications Engineers Don't Do Hairy Math", Marcus O. Durham, Robert A. Durham, and Karen D. Durham, *Proceedings of 35th Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2002.


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"Grounding Systems Interaction," Robert A. Durham and Marcus O. Durham, *Proceedings of 33rd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2000.

"A Cost Effective, Numeric Technique for Projecting Quality of Insulation and Impending Failures," Marcus O. Durham and Robert A. Durham, *Proceedings of 33rd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2000.

"An Engineering Selection for Size of Long Conductors Considering Factors in Addition to NEC," Marcus O. Durham and Robert A. Durham, *Proceedings of 33rd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 2000.

“Grounding Systems Interaction,” Robert A. Durham and Marcus O. Durham, *Proceedings of 32nd Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 1999.

“Can Electrical Insulation and Conductor Performance Be Predicted?” Marcus O. Durham and Robert A. Durham, *Proceedings of Production Operations Symposium*, SPE 52161, Oklahoma City, OK, March 1999

“Engineering Paradigms: Change, Opportunity and Benefit,” Robert A. Durham and Marcus O. Durham, *Proceedings of 31st Annual Frontiers in Power Conference*, OSU, Stillwater, OK, October 1998.

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